The Economic Value of Wi-Fi®: A global view (2021 – 2025)

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Telecom Advisory Services LLC (URL: www.teleadvs.com) is an international consulting firm registered in the state of New York (United States), with physical presence in New York, Madrid, Bogotá and Buenos Aires. Founded in 2006, the firm specializes in the development of business strategies and public policies for digital and telecommunications companies, governments, and international organizations. Its clients include leading companies in the digital and telecommunications sectors, as well as international organizations such as the International Telecommunication Union, the World Bank, the Inter-American Development Bank, the World Economic Forum, the UN Economic Commission for Latin America and the Caribbean, CAF Development Bank for Latin America, the GSMA Association, the CTIA, the National Cable TV Association (U.S.), GigaEurope, Wi-Fi Alliance, and the FTTH Council (Europe), as well as the governments of Argentina, Brazil, Colombia, Ecuador, Costa Rica, Germany, Mexico, Peru, and Saudi Arabia.

This study was commissioned by Wi-Fi Alliance® and conducted by Telecom Advisory Associates between August and December of 2020; the authors are solely responsible for its contents.

A summary of this economic study is available for review at www.valueofwifi.com.

This study is supplemented with details on the theoretical framework and methodologies for estimating the economic value of Wi-Fi, with sections for each country studied, beginning on page 83 of this document.

EXECUTIVE SUMMARY

In 2018, Telecom Advisory Services LLC (TAS) published a study assessing the worldwide economic value of Wi-Fi®.[1] The study's purpose was to measure Wi-Fi's economic surplus to consumers and producers, as well as Wi-Fi's direct net contribution to output (Gross Domestic Product, or GDP) and employment between 2018 and 2023. The result of that study estimated Wi-Fi's global economic value to be $1.96 trillion in 2018 and forecast that it would reach $3.47 trillion by 2023.[2]

Significant changes have taken place since 2018 in the Wi-Fi ecosystem, warranting a new study. First, in 2019, Wi-Fi equipment manufacturers began launching Wi-Fi 6 products for consumer and enterprise.[3] Wi-Fi 6 is the sixth generation of Wi-Fi, offering higher performance, lower latency, and faster data rates. Additionally, with the launch of Wi-Fi 6 and in anticipation of the recommendations presented at the 2023 World Radiocommunication Conference (WRC-23) of the International Telecommunication Union (ITU), regulators in many countries recognized the importance of unlicensed spectrum in driving Wi-Fi performance. In April 2020, the Federal Communications Commission (FCC) in the United States unanimously voted to open 1,200 megahertz of spectrum in 6 GHz available for unlicensed innovation, with a decision on low power unlicensed devices in the 6 GHz band pending final approval. In July 2020, the United Kingdom's Office of Communications (Ofcom) reached a decision to allocate the lower 6 GHz band for unlicensed use supporting Wi-Fi connectivity indoors with limited outdoor coverage. In October 2020, South Korea's Ministry of Science and ICT (MSIT) announced that it had approved the use of 1,200 megahertz of spectrum in the 6 GHz band for unlicensed use. In November 2020, Chile's regulator, Subtel, announced the release of the full 6 GHz band, while Costa Rica and Peru have completed their public consultation on allocation of the same band and the regulators of Mexico, Colombia, and Argentina, among others, have launched similar processes. The European Union and other European countries are also on track to release approximately 500 megahertz of the 6 GHz band to unlicensed use by early 2021, though it is possible that more spectrum could be allocated in future.

The combination of new technology and additional spectrum has enhanced the economic value of Wi-Fi since it was estimated in 2018. For example, assuming approval of Very Low Power devices operating in 6 GHz in all countries, this new category will enable the deployment of a new generation of Augmented Reality/Virtual Reality (AR/VR) solutions and unlock even wider deployment of Internet of Things (IoT) devices.

Conversely, the COVID-19 pandemic has resulted in a downward adjustment in the macroeconomic forecast. While before the pandemic the world economy was

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[1] Katz, R. and Callorda, F. (2018a). *The Economic value of Wi-Fi: A Global View (2018 and 2023)*. New York: Telecom Advisory Services. October.

[2] All currency numbers in the study are reported in U.S. dollars.

[3] Wi-Fi Alliance dubbed devices capable of 6 GHz band operation Wi-Fi 6E devices.

projected to grow at 2.90 percent for 2020, the International Monetary Fund now projects a contraction of 4.7 percent. This revised perspective has had an impact on the base upon which Wi-Fi economic value is projected. At the same time, the global pandemic has demonstrated how critical Wi-Fi technology is in building social and economic resilience:

- Free Wi-Fi in public sites provides Internet access to consumers that cannot purchase broadband service due to affordability;
- Residential Wi-Fi supports simultaneous access of multiple devices for distance learning, telecommuting, telemedicine, and information distribution at home;
- Prompted by isolation and confinement, consumers tend to rely more on wireless devices, with Wi-Fi being key to limiting wireless expenditures;
- Wi-Fi enabled Wireless Internet Service Providers (WISPs) offer Internet access for broadband in unserved[4] communities; and
- Wi-Fi technology enables digital transformation of businesses by supporting the virtualization of business processes, facilitating telecommuting.

To trace the projections of this update vis-à-vis the 2018-2023 study, we estimate Wi-Fi economic value for two scenarios:

(i) Baseline: addresses the growth of Wi-Fi value in the 2.4 GHz and 5 GHz unlicensed bands, as well as equipment in the Wi-Fi 4 and Wi-Fi 5 generations; and

(ii) Accelerated: considers the effect of adding 6 GHz spectrum band allocation and the release of new Wi-Fi 6 and Wi-Fi 6E equipment.[5]

Both scenarios reflect the changes in economic context. In addition, this report expands on the 2018 study, covering the following countries:

- North America: United States;
- Europe: United Kingdom and European Union;
- Asia Pacific: Australia, Japan, New Zealand, Singapore, and South Korea; and
- Latin America: Brazil, Colombia, and Mexico.

As in the 2018 study, country and regional estimates are extrapolated to generate a global value.

Wi-Fi total global economic value, including worldwide availability of Wi-Fi 6 devices operating in 6 GHz, to reach $4.9 T by 2025

According to the baseline scenario of this updated study, which includes Wi-Fi devices up through Wi-Fi 5 operating in the 2.4 and 5 GHz spectrum bands, Wi-Fi's total global economic value is $3,244.1 billion, forecasting to reach $4,348.2 billion in 2025. However, assuming a worldwide availability of Wi-Fi 6 devices operating in the 6 GHz spectrum, the total value in 2021 would

[4] Broadband unserved is defined as the population that cannot access fixed broadband service because of lack of service coverage.
[5] Wi-Fi 6E devices are Wi-Fi devices capable of operating in the 6 GHz band.

increase to $3,302.0 billion, or $3.3 trillion, reaching $4,875.7 billion, or 4.9 trillion, by 2025 (see Table A).

Table A. Global Wi-Fi Economic Value ($ billion)

	2021	2025
2018 Study	$2,840.7	$4,361.5[6]
2020 Study: Baseline Scenario	$3,244.1	$4,348.2
2020 Study: Wi-Fi 6 / 6 GHz	$57.9	$527.5
Total 2020 Study	$3,302.0	$4,875.7

Source: Telecom Advisory Services analysis

The 2021 estimate represents a 16 percent increase from the prior study, even considering the global coronavirus pandemic. Wi-Fi drives digital resilience and innovation, significantly outweighing the negative effects of COVID-19 on a global scale.

The countries with the highest Wi-Fi economic value creation (including the baseline and Wi-Fi 6/6 GHz scenarios) in 2021 are the United States ($995.0 billion), followed by Japan ($251.1 billion), Germany ($134.5 billion), Brazil ($105.2 billion), United Kingdom ($98.8 billion), South Korea ($89.3 billion), and France ($62.5 billion) (see Table B).

Table B. Wi-Fi Total Economic Value (Baseline and Wi-Fi 6 Scenarios)

	2021	2025
United States	$995.0	$1,580.1
United Kingdom	$98.8	$108.5
European Union*	$457.6	$637.2
Australia	$34.7	$41.7
Japan	$251.1	$324.9
South Korea	$89.3	$139.5
New Zealand	$6.7	$9.8
Singapore	$10.6	$12.4
Brazil	$105.2	$124.3
Mexico	$56.6	$117.5
Colombia	$18.9	$41.4
Total World (*)	$3,302.0	$4,875.7

(*) The estimates for the European Union include detailed analyses for France, Germany, Poland, and Spain.
(**) Including "Rest of the World" nations not estimated above
Source: Telecom Advisory Services analysis

The main drivers of economic value include:

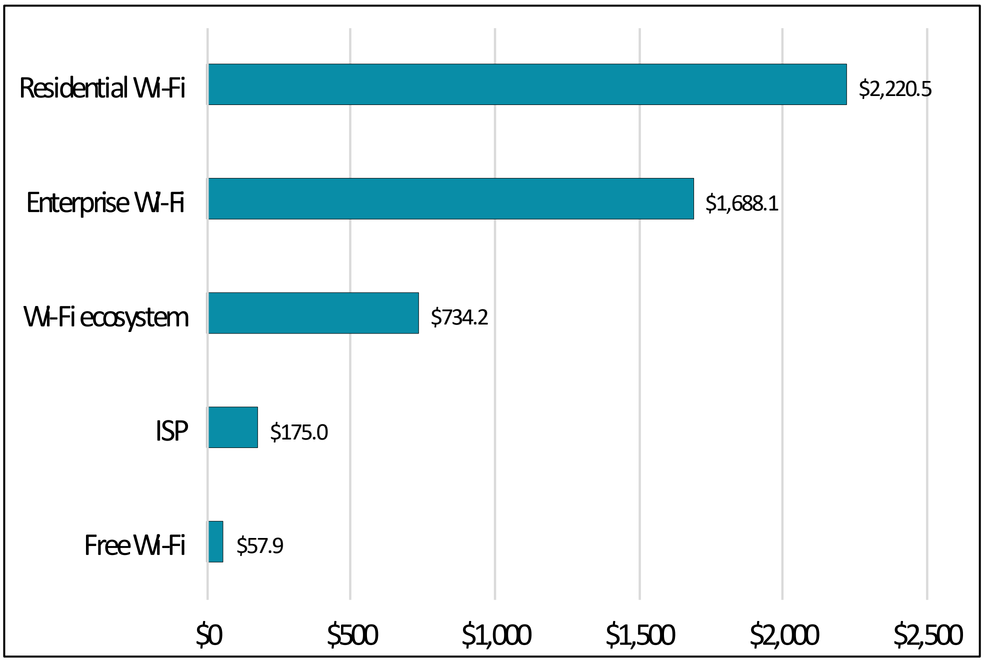
- Free Wi-Fi: benefit to consumers accessing Wi-Fi hotspots in public sites;
- Residential Wi-Fi: provision of Internet access and connectivity of devices at home;
- Enterprise Wi-Fi: use of Wi-Fi to support a significant portion of enterprise broadband traffic and productivity gains from Wi-Fi enabled IoT and AR/VR;

[6] While the 2018 study final estimate was for 2023, an extrapolation of the study's growth rate to 2025 would yield a value close to the baseline scenario of the current study. This would mean that the 2018 study was more conservative in the short run but fairly aligned with the current update in the long run.

- Internet Service Providers (ISPs): savings for cellular providers who rely on Wi-Fi re-routing and revenues of Wi-Fi commercial providers; and
- Margins of manufacturing and Wi-Fi ecosystem companies, including manufacturers of Wi-Fi devices and equipment, IoT networks and AR/VR solutions.

The most important sources of economic value in 2025 are residential Wi-Fi and enterprise Wi-Fi. That said, the Wi-Fi ecosystem also benefits from Wi-Fi in terms of the profits received by manufacturers of equipment (access points, controllers, routers, gateways, sensors, AR/VR devices, smart speakers, home security systems, and the like), while ISPs generate savings by relying on the technology to offload traffic from their networks. Finally, Wi-Fi also generates economic value through social contributions: the technology represents a useful application to bridge the digital divide in rural and isolated geographies, while also providing an important platform for free Internet access (see Graphic C).

Graphic C. Global Wi-Fi Economic Value (2025) (in $ billions)

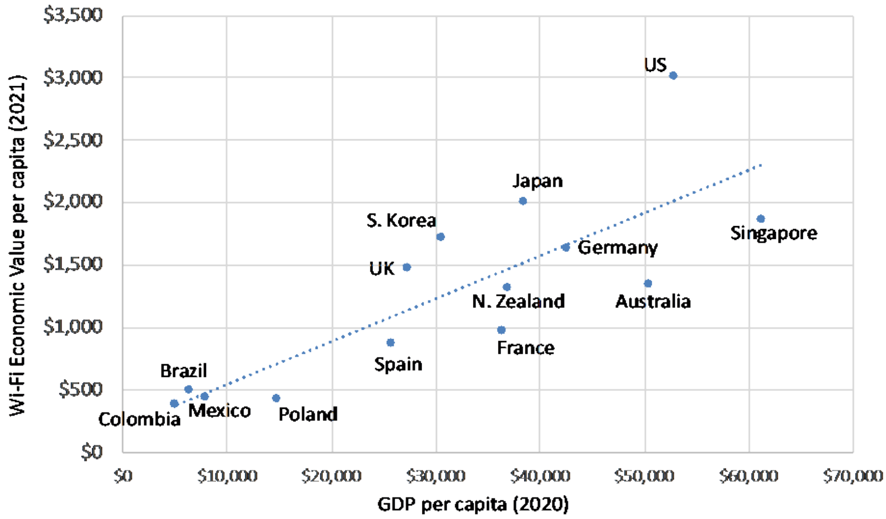


Source: Telecom Advisory Services analysis

The study also provides an estimate of Wi-Fi contribution to job creation by relying on Input / Output analysis. Global employment benefitting from Wi-Fi in 2021 amounts to 3.2 million jobs and is expected to reach 4.0 million jobs by 2025.

The addition of eight countries to the original list of nations studied in detail in the 2018 study is useful to draw some cross-national comparisons and insights. First, **a country's economic development is directly linked to the value of Wi-Fi.** Graphic D indicates that the higher the GDP per capita, the more important is the economic value of Wi-Fi per capita.

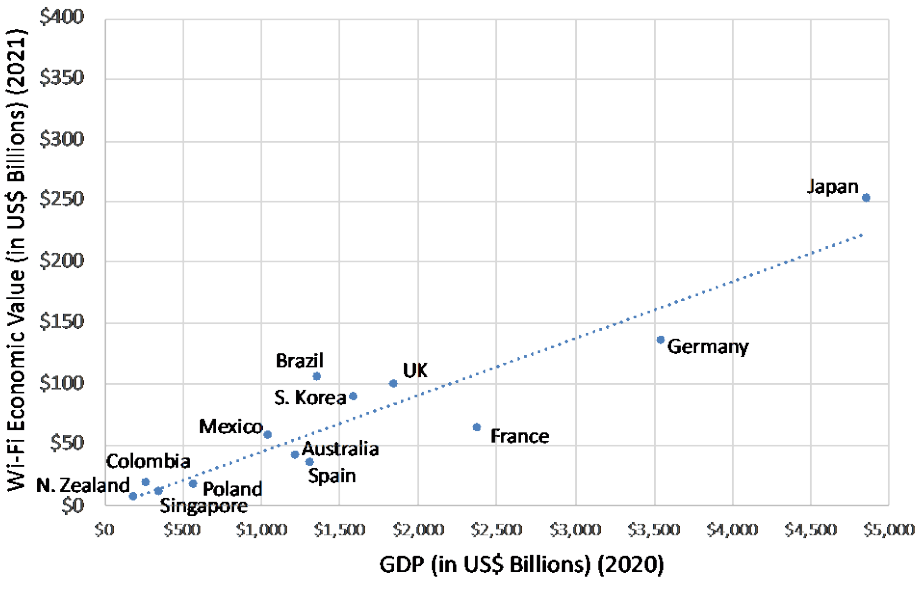
Graphic D. Economic Development and Wi-Fi Value (*)



(*) Including the baseline and Wi-Fi 6/6GHz scenarios)
Sources: International Monetary Fund; Telecom Advisory Services analysis

Second, while GDP per capita is associated with higher Wi-Fi economic value per capita, some developing countries display higher total Wi-Fi economic value than the size of their economy might predict (see Graphic E).

Graphic E. Size of the Economy and Total Wi-Fi Value (*)



Note: United States observation excluded to depict the difference among countries with lower aggregate value.
(*) Including the baseline and Wi-Fi 6/6GHz scenarios)
Sources: International Monetary Fund; Telecom Advisory Services analysis

As indicated in Graphic E, Brazil exhibits a higher total Wi-Fi economic value than some advanced economies such as the United Kingdom, France, and South Korea, while Mexico's Wi-Fi value is higher than Australia and Spain. In both cases the Wi-Fi value in developing nations exceeds that of some advanced economies. This is due to four factors:

- Emerging countries typically do not have fully developed cellular infrastructure (i.e. lower density of base stations), with average cellular speeds lagging significantly behind those of Wi-Fi. As a result, **the percentage gain in speed from routing traffic through Wi-Fi is greater in developing countries than in many advanced economies, and so is the implied economic impact**.

- Emerging nations have a larger digital divide (unserved and underserved[7] population) than advanced economies. As a result, **a higher number of households and economic units benefit from free Wi-Fi and Wireless ISPs in developing countries than in industrialized ones.**

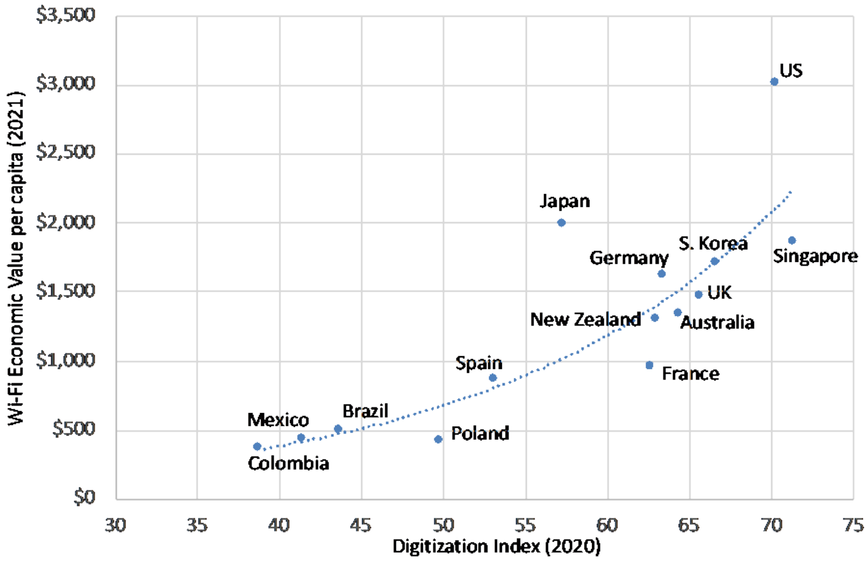
- Cellular prices in developing countries are much higher in relative terms than in developed nations. The simple average of the most economic cellular data plan for the three Latin American countries included in this study (Brazil, Mexico and Colombia) is $2.3 per gigabyte (GB) in 2020, while in Europe it is $0.76 and Asia-Pacific $0.94 This considerably increases the economic value of routing residential and business traffic through Wi-Fi.

- To calculate the advantage Wi-Fi 6 and 6 GHz bring, we made assumptions based on spectrum allocation levels actually being considered in those markets. For instance, some country estimates are based on 1200 megahertz (United States, South Korea, Mexico, Colombia, Australia, New Zealand, Japan, Singapore and Brazil), while others are based on 500 MHz (Germany, France, United Kingdom, Spain, and Poland).

Third, a country's level of digitization[8] is exponentially related to the economic value of Wi-Fi. In other words, **the digital transformation of the economy increases the value of Wi-Fi in a non-linear fashion** (see graphic F).

[7] Broadband underserved is defined as the population that has access to broadband service but at a significant low level of service quality (i.e. slow download speeds, very high latency).
[8] Digitization is measured through a composite index based on 64 indicators grouped in six pillars: digital infrastructure, connectivity, household digitization, digital economy, digitization of the state, and factors of digital production. See Katz, R. and Callorda, F. (2018b).

Graphic F. Digitization and Wi-Fi Value



Source: Telecom Advisory Services analysis

Based on this evidence, **Wi-Fi technology should be recognized as one of the dominant economic engines of the digital economy**. Governments around the world should develop incentives to stimulate the social and economic benefits of Wi-Fi. This includes assigning enough spectrum to avoid congestion, encouraging the private sector to create new applications using Wi-Fi, and relying on the technology to address the digital divide barrier.

I. INTRODUCTION: IMPETUS TO UPDATE THE 2018 ECONOMIC VALUE STUDY

The study of the economic value of Wi-Fi and unlicensed spectrum has been an area of research since 2012.[9] In 2018, the authors of the present study published a report assessing, for the first time on a global basis, the economic value of Wi-Fi.[10] The study's purpose was to measure Wi-Fi's economic value, both to consumers and producers[11], as well as its direct net contribution to output (Gross Domestic Product, or GDP) and employment between 2018 and 2023. The study covered, in detail, an analysis of the United States, United Kingdom, France, Germany, Japan, and South Korea, and also extrapolated Wi-Fi's global value. Based on data available through 2017, we estimated the economic value in 2018 for the six countries studied to be $930.8 billion, reaching $1,654.6 billion by 2023.

Significant changes have taken place since 2018 in the Wi-Fi ecosystem that warrant a new study. They comprise: (i) the launch of Wi-Fi 6, a new generation of high performance Wi-Fi devices, (ii) new allocations of unlicensed spectrum for Wi-Fi use, and (iii) the consequent development of new sources of value, such as increasing deployment of IoT and growing adoption of AR/VR solutions. Additionally, the new economic context triggered by the COVID-19 pandemic represents a macro-economic variable influencing the final estimate. Each of these four factors will be reviewed in turn.

I.1. Wi-Fi 6, a new generation

Starting in 2019, Wi-Fi equipment manufacturers started launching a sixth generation of devices offering higher performance, lower latency, and faster data rates. Categorized as Wi-Fi 6, the sixth generation of Wi-Fi equipment adopted the 802.11ax standard, offering a base speed of 1.2 Gbps, and up to 4.8 Gbps under a quad-stream configuration.

Following the release of the Wi-Fi 6 standard, a new generation of devices is being introduced that can operate in the 6 GHz spectrum band, as opposed to exclusively

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[9] Among the original studies, we can count Thanki, R. (2009). *The economic value generated by current and future allocations of unlicensed spectrum*. Perspective Associates; Milgrom, P., Levin, J., & Eilat, A. (2011). *The case for unlicensed spectrum*. Stanford Institute for Economic Policy Research Discussion Paper No. 10-036; Cooper, M. (2011). *The consumer benefits of expanding shared use of unlicensed radio spectrum: Liberating Long-Term Spectrum Policy from Short-Term Thinking* . Washington D.C.: Consumer Federation of America; Katz, R. (2014). *Assessment of the economic value of unlicensed spectrum in the United States.* New York: Telecom Advisory Services; Katz, R. (2014). *Assessment of the future economic value of unlicensed spectrum in the United States.* New York: Telecom Advisory Services; Katz, R. (2018). *A 2017 assessment of the current and future economic value of unlicensed spectrum*. Washington, DC: Wi-Fi Forward; Katz, R. (2020). *Assessing the economic value of unlicensed use in the 5.9 GHz and 6 GHz bands*. Washington, DC: Wi-Fi Forward.

[10] Katz, R. and Callorda, F. (2018a). *The Economic value of Wi-Fi: A Global View (2018 and 2023)*. New York: Telecom Advisory Services. October.

[11] Producers are defined as enterprises benefitting from Wi-Fi to reduce their telecommunications spending, companies delivering products and services in the Wi-Fi ecosystem, and Internet Service Providers that reduce their infrastructure costs by relying on Wi-Fi access points.

in the traditional 2.4 GHz and 5 GHz bands, and, consequently, take advantage of several 160 MHz channels. This additional spectrum addresses the congestion developing in the traditional bands by providing more contiguous spectrum blocks. The release of Wi-Fi 6E equipment is occurring simultaneously with the allocation of 6 GHz spectrum for unlicensed use that is currently occurring in many countries around the world.

I.2. New spectrum allocations for Wi-Fi use

With the launch of Wi-Fi 6, regulators in many countries have recognized the importance of unlicensed spectrum in driving the performance of Wi-Fi. In April 2020, the Federal Communications Commission (FCC) in the United States allowed low power unlicensed devices to operate in the 6 GHz band, although the authorization for Very Low Power devices (VLP) has not been approved as of yet. In addition to the FCC decision, other countries have also allocated spectrum for Wi-Fi use. In Asia, South Korea's Ministry of Science and ICT (MSIT) issued a proposed "amendment of technical standards" in June 2020 for releasing the entire 6 GHz band for Wi-Fi indoor operation by the end of 2020, while outdoor use will follow in 2022.[12] Similar consultations are underway in Central European Countries with regard to the allocation of the 6 GHz band, while Ofcom in the United Kingdom already reached a decision for Great Britain in July 2020. Rather than releasing the entire band, the European approach considers only the lower 500 MHz part of the band. In Latin America, the allocation of the 6 GHz spectrum for unlicensed use is accelerating. In November 2020, Chile's regulator, Subtel, announced the release of the full 6 GHz band. In December 2020, the Brazilian telecommunications regulator opened a public consultation to release the entire 6 GHz band (that is to say allocate 1,200 MHz). Similarly, telecommunications regulators in Mexico, Peru, Costa Rica, Argentina, and Colombia have launched public consultations for the evaluation of the 6 GHz band allocation options.

I.3. New sources of economic value

Triggered by the allocation of new Wi-Fi spectrum and the release of Wi-Fi 6 and Wi-Fi 6E devices, other sources have been confirmed as important drivers for future value growth. The creation of the Low Power Indoor device categories, as implied by the decision of the United States regulator, will drive the development of additional sources of economic value. The 6 GHz band (jointly with the pre-existing unlicensed spectrum) will allow support for much wider channels in spectrum bands. Additionally, the increase in Wi-Fi speed and capacity will lead to a broader scale IoT deployment. While IoT roll-out has been proceeding for a number of years, large scale deployment has suffered from the risk of congestion. The additional unlicensed spectrum will mitigate congestion and, therefore, provide a boost to the growth of IoT. Finally, the creation of a Very Low Power device category will enable the deployment of a new generation of AR/VR solutions. Virtual Reality (VR) is already used within a wide array of areas, ranging from the gaming industry and entertainment, to training and simulation, including training in the medical field.

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[12] Yonhap (2020). "Unlicensed frequency band to boost Wi-Fi speed, smart factory penetration: ministry", *The Korea Herald*, (June, 27).

Other areas of application include education and culture, sports, live broadcasting, real estate, advertising, architecture, and arts. Augmented Reality (AR) has an almost limitless range of uses in a wide variety of areas, be it commerce, technical applications, work processes, or education. AR and VR can serve both consumers and professional users in the private and public sectors.

I.4. The new economic context resulting from COVID-19

In addition to changes in the Wi-Fi ecosystem, the global economy has undergone an unexpected disruption. The COVID-19 pandemic has triggered a worldwide downward adjustment in the economic forecast (see Table I-1).

Table I-1. Selected Countries: Downward adjustment in GDP growth

		Pre-COVID 2020 Growth	Post-COVID 2020 Growth
Countries	Brazil	2.40	-5.80
	France	1.40	-9.80
	Germany	1.70	-6.00
	Japan	0.40	-5.30
	Mexico	1.90	-9.00
	Spain	1.90	-12.80
	United Kingdom	1.40	-9.80
	United States	1.90	-4.30
Regions	Latin America and the Caribbean	2.30	-8.10
	Emerging and Developing Asia	6.20	-1.70
	World Growth Based on Market Exchange Rates	2.90	-4.70

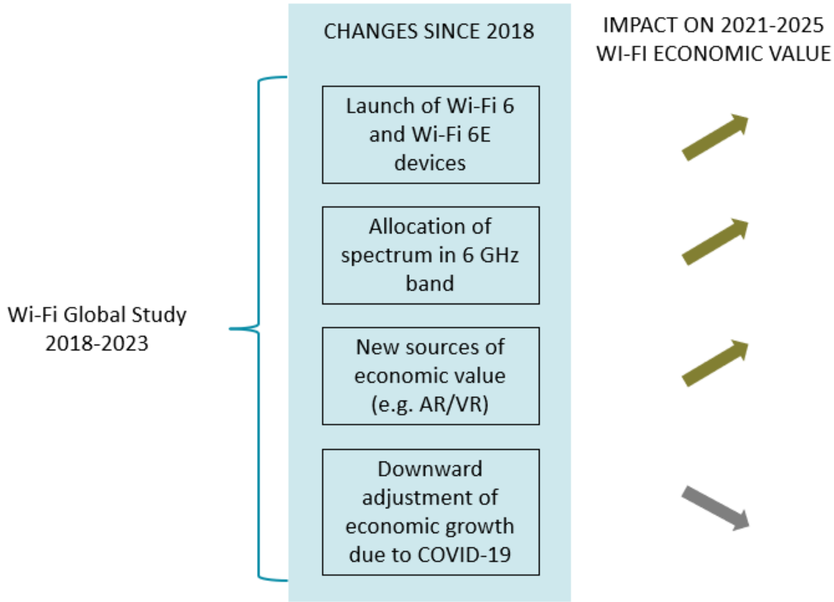
Source: International Monetary Fund

As indicated in Table I-1, the outlook for economic growth has declined from an average growth of 2.90 percent to -4.70 percent. This change results in a downward adjustment on the economic baseline from which the contribution of Wi-Fi is estimated. That said, COVID-19 has put into perspective Wi-Fi's critical contribution to connecting households, as well as supporting telecommuting and distance learning.

I.5. A compilation of changes since 2018 affecting Wi-Fi economic value

A combination of changes and enhancements in the Wi-Fi landscape, as well as the changes triggered by the coronavirus pandemic have had an impact on our 2018 study. The launch of Wi-Fi 6, the allocation of additional unlicensed spectrum, and new sources of value have increased Wi-Fi aggregate economic contribution. Meanwhile, the recession triggered by COVID-19 has had a downward impact on the macroeconomic base from which the value of Wi-Fi is measured. The combined effects of these changes are depicted in figure I-1.

Figure I-1. Changes in Wi-Fi Economic Value Since the 2018 study



Source: Telecom Advisory Services

The following report presents an assessment of economic value and growth between 2021 and 2025 for selected countries. In order to compare the changes that have taken place in the original study and consider the upside represented by Wi-Fi 6 and the allocation of the 6 GHz band for unlicensed use, the assessment differentiates between two scenarios (a baseline and one attributed to Wi-Fi 6 and 6 GHz). Chapter II presents the theoretical concepts and methodologies that frame the analysis. Chapters III and on present the results of the analysis for each market. Detailed explanation of the methodologies and models used to calculate the economic value by source are available in "Theoretical Framework, Methodologies and Detailed Country Assessments for The Economic Value of Wi-Fi: A Global View (2021-2025)" starting on page 83 of this document.

II. THEORETICAL FRAMEWORK AND METHODOLOGIES FOR ESTIMATING THE ECONOMIC VALUE OF WI-FI

II.1. Theoretical framework

Wi-Fi is what economists call a factor of production (or enabling resource) that yields economic value by complementing wireline and cellular technologies, enabling the development of alternative products and services that expand consumer choice, support the creation of innovative business models, and expand access to communications. The following chapter begins by defining the intrinsic value of Wi-Fi, both as a complementary technology that is part of the telecommunications ecosystem, enhancing the performance of networks and providing a platform for developing innovative applications. Following this, we put forward the concept of economic value, calculated as gains to consumer and producer surplus, a contribution to GDP, and job creation. Having formalized these sources of value, we then move to categorize the five economic agents that benefit from them: (i) individual consumers benefitting from access to free Wi-Fi service, (ii) consumer residences, (iii) enterprises, (iv) Internet Service Providers, and (v) manufacturers of communications equipment and consumer electronics. This categorization provides the framework to defining starting spectrum allocation assumptions and methodologies.

The intrinsic value of Wi-Fi

Considered as a factor of production, a complementary technology is a resource that, due to its intrinsic strengths, compensates for the limitations of another resource. For example, Wi-Fi can enhance the effectiveness of devices, such as smartphones, which use licensed spectrum. Wi-Fi access points can enhance the value of cellular networks by allowing wireless devices to switch to Wi-Fi hotspots, thereby reducing the cost of broadband access and increasing the access speed rate. Consumers accessing the Internet within the reach of a Wi-Fi access point can reduce their access costs by turning off their cellular service. They can also gain additional access speed as the transfer rate of Wi-Fi sites is generally faster than that offered by current cellular technology—even 4G LTE at current loads.[13] Likewise, many wireless operators reduce their capital spending by complementing their cellular networks with carrier-grade Wi-Fi access points, which are considerably less expensive than cellular network equipment with similar capacity.[14] In addition to reducing capital expenditures, wireless carriers can offer fast access to service without a base station congestion challenge.

In addition to complementing cellular networks, Wi-Fi can provide the required environment to enable the development and introduction of innovations such as Wi-

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[13] For example, in 2020 the average mobile connection speed in the United States is estimated at 25.51 Mbps while the average Wi-Fi speed from a mobile device is 69.6 Mbps (Source: data interpolated from Cisco's Annual Internet Report Highlights Tool 2018-2023). Naturally, we can expect that speed gap to diminish with the progress of 5G deployments.

[14] The CAPEX savings resulting from Wi-Fi offloading for a cellular carrier in 1.5 million population cities is approximately 30 percent (Source: LCC Wireless).

Fi-enabled tablets, wireless security systems and household appliances, thereby providing consumers with a larger set of choices. By limiting transmission power and relying on spectrum with low propagation, Wi-Fi avoids interference, rendering irrelevant any barriers to innovation caused by the need to use licensed spectrum. In fact, some of the most important technological innovations in communications are intimately linked to Wi-Fi for gaining access. Numerous products and services, such as the multi-AP/mesh networking systems and smart speakers launched in the past ten years were developed leveraging Wi-Fi. By providing consumers with service choices in addition to those offered through cellular services, Wi-Fi also supports the development of innovative business models. Firms developing new applications that rely on Wi-Fi do not need approval from cellular operators, do not incur time-to-market penalties, and do not face financial disincentives derived from costly revenue splits with cellular service providers.

In addition to innovative applications, technologies relying on unlicensed spectrum used by Wi-Fi can help address the digital gap in broadband coverage. A large portion of the population that has not adopted the Internet around the world is located in rural and isolated areas. Many of them can gain access to broadband services provided by Wireless Internet Service Providers (WISPs), which typically operate through Wi-Fi. In addition, further developments in the areas of spectrum sensing, dynamic spectrum access, and geo-location techniques can improve the quality of Wi-Fi.

The derived value of Wi-Fi

There is a significant amount of research-based evidence that Wi-Fi technology has very high social and economic value. Prior research agrees that, contrary to licensed bands where economic value could equate to whatever is paid at auction, the economic value of unlicensed spectrum, such as Wi-Fi, needs to be measured based on the concept of economic surplus.[15]

The concept of economic surplus is based on the difference between the value of units consumed and produced up to the equilibrium price and quantity, allowing for the estimation of consumer surplus and producer surplus.[16] Consumer surplus measures the total amount consumers would be willing to pay to have the service, compared to what they actually pay. Producer surplus measures the analogous quantity for producers, which is essentially the economic profit they earn from

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[15] Thanki, R. (2009). *The economic value generated by current and future allocations of unlicensed spectrum*. London: Perspective Associates; Thanki, R. (2012). *The Economic Significance of License-Exempt Spectrum to the Future of the Internet.* London; Perspective Associates; Milgrom, P., Levin, J., and Eilat, A. (2011). *The case for unlicensed spectrum*. Stanford Institute for Economic Policy Research Discussion Paper No. 10-036; Katz, R. ibid.

[16] Following Alston (1990), we acknowledge that this approach ignores effects of changes in other product and factor markets; for example, Wi-Fi also increases the economic value of technologies operating in licensed bands (Alston, J.M. and Wohlgenant, M.K. (1990). "Measuring Research Benefits Using Linear Elasticity Equilibrium Displacement Models". John D. Mullen and Julian M. Alston, *The Returns to Australian Wool Industry from Investment in R&D*, Sydney, Australia: New South Wales Department of Agriculture and Fisheries, Division of Rural and Resource Economics).

providing the service. Consumer and producer surplus together yield an economic surplus. Adding GDP contribution results in a total economic value estimate.

Consistent with the concept presented above, this study measures the economic value of Wi-Fi by focusing first on the economic surplus generated after its adoption.[17] The underlying assumption is that Wi-Fi generates a shift both in the demand and supply curves, resulting from changes in how services are produced, as well as the corresponding willingness-to-pay for such services. On the supply side, the approach measures changes in the value of inputs in the production of wireless communications. The most obvious example is, as mentioned above, whether Wi-Fi represents a positive contribution to wireless carriers' capital expenditures (CAPEX) and operating expenses (OPEX) insofar as they can control their spending, while meeting demand for increased wireless traffic. From an economic theory standpoint, the telecommunications industry can then increase its output, yielding a marginal benefit exceeding the marginal cost. This results in a shift in the supply curve by a modification in the production costs. The shift in the supply curve yields a new equilibrium price and quantity. Additionally, since the demand curve is derived from the utility function[18], the consumer benefits from stable Wi-Fi prices, yielding an increase in the willingness-to-pay, and consequently a shift in the demand curve. Under these conditions, total economic value is now represented by both changes in the consumer and producer surplus.

To quantify the incremental surplus derived from Wi-Fi adoption, we need to itemize all the effects linked to this technology. In addition, we complement the concept of economic surplus with an assessment of the direct contribution of the technologies and applications relying on Wi-Fi, such as Wi-Fi service providers, to national GDP. By including the GDP contribution measurement, we follow Greenstein et al. (2010) and prior research literature measuring the economic gains of new goods.[19] We focus on consumer and producer surplus, but also consider the new economic growth enabled by Wi-Fi. In measuring the direct contribution to GDP, we strictly consider the revenues added "above and beyond" what would have occurred had the Wi-Fi spectrum been licensed. After quantifying Wi-Fi's contribution to GDP, the impact on job creation can also be ascertained not only within the telecommunications industry but also in terms of the spillovers through the rest of the economy.

Source of value and economic agents that create value through Wi-Fi

The economic value of Wi-Fi is generated from multiple sources of value, including the capability to deliver traffic at faster speed than other networking technologies,

[17] See a similar approach used by Mensah and Wohlgenant (2010) to estimate the economic surplus of adoption of soybean technology (Mensah, E., and Wohlgenant, M. (2010). "A market impact analysis of Soybean Technology Adoption", *Research in Business and Economics Journal*).

[18] A utility function measures the consumer preference for a service beyond the explicit monetary value paid for it.

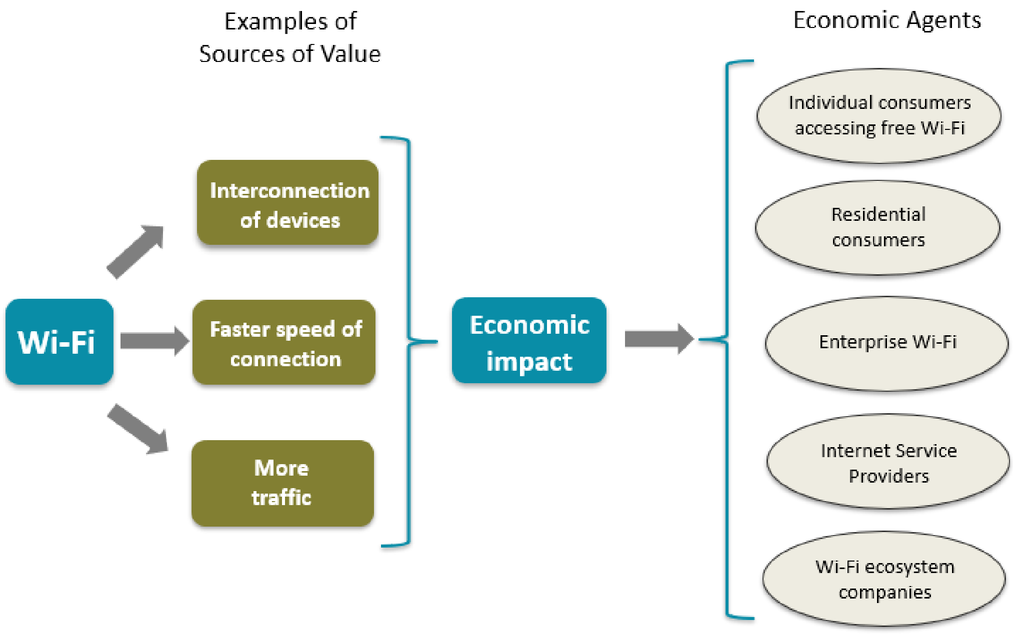
[19] Greenstein, S. and McDevitt, R. (2009). *The broadband bonus: accounting for broadband Internet's impact on U.S. GDP.* National Bureau of Economic Research Working Paper 14758. Cambridge, MA.

provide Internet access, and interconnect devices. These sources of economic value are then channeled into economic gains for five economic agents:

- Individual consumers accessing free Wi-Fi sites;
- Residential consumers;
- Enterprises;
- Internet service Providers (ISPs); and
- Companies that provide Wi-Fi products and services or manufacture products enabled by Wi-Fi (members of the Wi-Fi ecosystem).

For each economic agent, the above-mentioned sources of value translate into cost savings, productivity gains, and expanded economic activity (see Figure II-1).

Figure II-1. Sources and agents of economic value of Wi-Fi



Source: Telecom Advisory Services

In terms of the detailed effects:

- **Free Wi-Fi:** The providers of free Wi-Fi service (i.e. coffee shops, retailers, municipalities) allow consumers to connect to the Internet without paying for access, creating a benefit measured as consumer surplus.[20] The consumer surplus measures the difference between the user's willingness-to-pay and the price paid for the service (which in this case equals to zero). For example, if a consumer accesses the Internet at a public hotspot for free, surplus would equate to the monetary value he or she would be willing to pay to a cellular carrier for gaining similar access.[21] Additionally, free Wi-Fi hotspots could

[20] This category does not include providers of paid Wi-Fi access such as those operating in airports or hotels; this type of agent is included in the Internet Systems Providers category below.
[21] The introduction of what are called "unlimited" wireless plans does not invalidate this point since all of them include some explicit caps, such as speed throttling.

also provide Internet access to those consumers that lack broadband service, thereby partially bridging the "digital divide". While less important in advanced economies, this effect could be critical to increasing broadband adoption in developing countries, and hence, the impact on GDP.[22]

- **Residential Wi-Fi:** As calculated in our 2018 study**,** residential Wi-Fi also drives consumer surplus. Routers installed in home dwellings provide Internet access for devices that lack a wired port (i.e. tablets, smartphones, netbooks), allowing consumers to avoid the investment in Ethernet wiring. Wi-Fi routers also support easy networking between devices (printers, storage devices, computers), allow for sharing and streaming media content (sound systems, home theaters, etc.), represent a network hub to handle home automation, and may interface with a smart grid. Additional surplus is generated as a Wi-Fi connection as last mile of fixed broadband is typically faster than that of a cellular network.[23] Finally, consumer surplus is generated if the willingness-to-pay (as a measure of benefit) exceeds the price paid for purchasing residential Wi-Fi devices and equipment. All these benefits can be aggregated in terms of the residential consumer surplus. Wi-Fi is also an appropriate technology to offer residential Internet access in rural and isolated areas. Since the technology allows for increasing broadband penetration without the need for more trenching and wiring, it becomes a key factor in driving service coverage and, consequently, GDP growth. This could have multiple positive effects, such as job creation, enhancing the productivity of rural businesses, and increasing access to public services.[24]

- **Enterprise Wi-Fi:** Wi-Fi in office buildings and on campuses allows for voice and data communications without incurring the cost of "capped" connectivity and avoids the limited in-building coverage of cellular networks, as well as the cost of enterprise wiring. Additionally, Wi-Fi supports communication between enterprises and their customers (i.e. customer/client access in financial services, employee/guest connections in the hospitality industry), while also improving internal production efficiencies (product/inventory tracking, remote control equipment, and POS ordering in the retail industry). This equates to a producer surplus, composed of the cost savings enjoyed by enterprises that rely on Wi-Fi technology, rather than wideband cellular service. In addition, Wi-Fi allows faster access to the Internet than cellular networks do. These faster speeds have a positive contribution to the economy in terms of increased overall productivity, efficiency, and innovation. Finally, Wi-Fi technology facilitates the expansion of Internet of Things (IoT) platforms and Augmented Reality

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[22] See Katz, R. and Callorda, F. (2020). *How broadband, digitization and ICT regulation impact the global economy*. Geneva: International Telecommunications Union. Retrieved from: http://handle.itu.int/11.1002/pub/81377c7f-en

[23] This effect is particularly important in 3G and 4G networks but could also be relevant in relation to indoor reception.

[24] Katz, R. and Beltran, F. (2015). *Socio-economic impact of alternative spectrum assignment approaches.* Presentation to the International Telecommunications Society Regional Conference, Los Angeles, CA.

and Virtual Reality (AR/VR) applications. Those developments generate productivity spillovers on the economy, thereby contributing to the growth of GDP.

- **Internet Service Providers (ISPs):** Due to the explosive growth in data traffic, wireless carriers operating in licensed bands deploy Wi-Fi access points to reduce both capital and operating expenses and reduce congestion challenges. Since ISPs monetize the Wi-Fi access they provide, the producer surplus measures the difference in capital and operating expenses for the traffic that is off-loaded. This model is critical to understanding Wi-Fi's contribution to 5G deployment. Wi-Fi allows service providers to launch paid Internet access in public places (such as venues, stadiums, airports, airlines, hotels, etc.). These access points generate new revenues that would not exist if Wi-Fi were not available. Similarly, Wireless Internet Service Providers (WISPs) rely on Wi-Fi to offer broadband connectivity in areas typically not served by wireline carriers, yielding additional revenues to be accounted for as part of the GDP.

- **Wi-Fi ecosystem**: Locally manufactured Wi-Fi devices generate revenues. The difference between the market price of these Wi-Fi enabled devices and the cost to manufacture them represents the manufacturer's profit margin (producer surplus). Such products include home networking devices, Wi-Fi enabled wireless speakers, routers, and security systems on the consumer side, and access points and controllers on the enterprise side. Similarly, as Wi-Fi facilitates the expansion of IoT, developing firms within the IoT ecosystem (hardware, software, and services), generate a producer surplus. Similarly, the economic effect of AR/VR is driven in part by an ecosystem that includes firms ranging from software development to hardware production and applications development. The profit margins of firms involved in this endeavor represent a producer surplus.

II.2. Assumptions made regarding the regulatory context of spectrum use for Wi-Fi

The economic value of Wi-Fi is contingent upon the amount of spectrum available for use. This study was conducted in a regulatory context where the use of unlicensed spectrum is in a state of transition. In general terms, Wi-Fi is currently allowed to operate in two spectrum bands: 2.4 GHz and 5 GHz. The explosive growth in Wi-Fi traffic has stretched the capacity of existing bands. In light of this, the International Telecommunication Union (ITU) is considering some recommendations on the assignment of the 6 GHz band (5925-7125 megahertz) to be submitted at the 2023 World Radiocommunication Conference (WRC-23), which could potentially address part of the congestion. At the same time, national regulatory agencies are already making decisions about the use of the 6 GHz band. However, regulatory decisions are not consistent: some countries, such as China, support the use of the entire 6 GHz for 5G licensed use, while others, such as the United States, are proposing its full use for unlicensed applications (i.e. Wi-Fi). In addition, other nations are limiting the band use for unlicensed use to the bottom

500 megahertz part of the 6 GHz. The point at 6425 MHz is being considered as how the WRC-23 splits the band.

The process to decide the use of the 6 GHz band at the national level is still ongoing for most countries: at the publication of this report, only the United Kingdom, Chile and South Korea had finalized their decision (see detail below). In this context, the analysis of the economic value of Wi-Fi has to consider two interrelated methodological issues:

- Differentiate between estimates of economic value for the current (2.4 GHz and 5 GHz) and future spectrum assignments (6 GHz); and
- Make assumptions as to how much of the 6 GHz band is likely to be allocated in the countries studied, based on existing announcements and communications about upcoming regulatory decisions.

With regard to the first issue, value estimates in this study were conducted according to two scenarios. We first analyzed a "baseline scenario" estimating the economic value of Wi-Fi up to its fifth technological generation (Wi-Fi 5), which relies on the 2.4 GHz and 5 GHz unlicensed spectrum bands. In the second scenario, we identified the acceleration of the economic effects with the allocation of the 6 GHz spectrum band and the release of Wi-Fi 6 equipment. The final results combine both scenarios to provide an estimate of total economic value.

Regarding the second issue (use of the 6 GHz band), assumptions needed to be made as to how much spectrum will be allocated for unlicensed use by country. This issue is important, since the amount of allocated spectrum has implications for Wi-Fi's economic value. If the full 6 GHz band were to be allocated for unlicensed use and added to the existing unlicensed bands in 2.4 GHz and 5 GHz, the combined spectrum would be able to support eight 160 MHz channels, or three 320 MHz channels.[25] Conversely, if only the bottom part of the band were allocated for unlicensed use, the 500 MHz model allows for only three 160 MHz channels.[26]

Because 6 GHz spectrum allocation decisions have not been completed in most cases, we made the following assumptions for our analysis:

United States (1200 MHz)

In October 2018, the United States Federal Communications Commission (FCC) presented a Notice of Proposed Rulemaking (NPRM) that recommended opening the 6 GHz band to unlicensed operations. In particular, the FCC sought comments on its

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[25] This would allow a router with tri-band configuration (2.4 GHz, 5 GHz, and 6 GHz), to deliver 1.2 Gbps on 2.4 GHz, 4.8 Gbps on one 5 GHz radio, 4.8 Gbps on the other 5 GHz radio, and 2.2 Gbps on the 6 GHz channel. In sum, once consumers have 6 GHz, there should be no difference between what they get from a computer plugged into a fiber port and a Wi-Fi 6E signal in their home.

[26] Under the 500 MHz allocation model, a reduced number of channels has an impact on speed because routers may be forced to use narrower channels, such as 80 MHz, 40 MHz, and even 20 MHz, with which the capability to allow broadband speed to grow unencumbered is limited.

proposal to open the band's full 1,200 MHz (5.925-7.125 GHz) to unlicensed devices, categorized in two classes:

- Standard power access points: In the 5.925-6.425 GHz and 6.525-6.875 GHz sub-bands, unlicensed access points would be permitted to transmit both indoors and outdoors under the control of an automated frequency coordination system at power levels that are currently permitted in the 5 GHz band.

- Low Power Indoor (LPI) devices (restricted to indoor) (LPI), operating approximately four times lower than standard Wi-Fi, and required to be non-weather proofed, plugged into the wall, and authorized to use only 1/4 of the power of standard-power Wi-Fi (i.e., 250 milliwatts conducted power), which excludes them from the need to be frequency coordinated. This is the closest designation to current Wi-Fi.

In April 2020, the FCC unanimously voted to allow the two classes of unlicensed devices to operate in the 6 GHz band. Low power indoor devices are permitted to operate throughout the 1,200 megahertz band. Standard power access points are allowed to operate in 850 megahertz in the sub bands described above. As a result, the capacity available for Wi-Fi quadrupled. The higher capacity available with 6 GHz suggests that the actual signal speed would be higher than the current speeds at 2.4 and 5 GHz. Speeds of 1 or 2 Gbps could be reached with a smartphone capable of Wi-Fi 6E when using the 160 MHz channel. Under this configuration, routers have access to seven new 160 MHz channels.

Concurrent with its decision to permit standard power and low power indoor devices, the FCC proposed a third category of 6 GHz Equipment – Very Low Power devices (VLP), authorized to power levels 160 times lower than standard-power Wi-Fi, and permitted for indoor or outdoor use in certain sub-bands, and not requiring frequency coordination because they would operate with 60 times less power than standard-power Wi-Fi. These VLP devices would be capable of operating using multiple extremely wide channels (160 MHz) with sub-millisecond latency performance. The category includes AR/VR headsets, Ultra High Definition Video Streaming, high-speed[27] tethering (watches, ear pods) or entertainment devices in the automobile. This proposal has not yet been voted on by the FCC.

The FCC decision has been challenged in the courts by some telecommunications operators and a diverse set of industry associations, but the courts have decided not to stand in the way of the decision.[28]

United Kingdom (500 MHz)

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[27] FCC ex parte notification from Apple Inc., Broadcom Inc., Facebook Inc., Google LLC, Hewlett Packard Enterprise, Intel Corp., Marvell Semiconductor Inc., Microsoft Corporation, Qualcomm Incorporated (July 2, 2019).

[28] Law 360 (2020). *DC Circuit won't block new FCC rules on 6 GHz for now* (October 1)

The United Kingdom telecommunications regulatory agency Office of Communications (Ofcom) reached a final decision allocating the lower 6 GHz band (5925-6425 MHz) for unlicensed use to support Wi-Fi connectivity indoors, as well as limited outdoor coverage and traffic hand-off.[29] The lower band is adjacent to the currently used 5 GHz band, has similar mid-range propagation characteristics, and offers, wide, non-overlapping channels.

Ofcom estimates that this band, in combination with currently used 2.4 GHz and 5 GHz frequencies, can handle between 200 and 400 client devices per access point with a maximum theoretical data rate of 6.6 Gbps. On 24 July 2020, Ofcom made the final decision to initially make 500 MHz available for unlicensed use low power indoor and very low power outdoor use.[30] The initial limited allocation to 500 MHz is to demonstrate how Wi-Fi can benefit from the lower part of the band, and then investigate the upper part.[31] In the words of Ofcom, "we will continue to review use of the upper 6 GHz band to determine what the optimal use may be".[32]

France, Germany, Spain, and Poland (500 MHz)

In response to a request from the European Commission to investigate spectrum between 5,925 to 6,425 MHz, the European Conference of Postal and Telecommunications Administrations (CEPT) has issued a technical report to the European Commission on the feasibility of Wi-Fi use in the 6 GHz band.[33] The purpose of the recommendation is to develop a harmonized approach for the 48 CEPT countries, which includes the 28 European Union countries, Switzerland, Turkey, and Russia, among others. In this case, routers will have access to three 160 Mbps channels. The underlying rationale for investigating only the 5,925 to 6,425 band (500 MHz) is that European countries have critical services in the upper part of the 6 GHz band (i.e. a large amount of point to point fixed services, earth to space communications, road intelligent traffic systems and communication-based train control, and some radio astronomy sites). It is expected that the release of 500 MHz to Wi-Fi will be enacted in the early part of 2021.[34]

Brazil (1200 MHz)

On 6 May 2020, ANATEL, the Brazilian telecommunications regulator approved the unlicensed use of spectrum in the 6 GHz band (5,925–7,125 MHz).[35] In reaching a decision to allocate the 6 GHz band for unlicensed use, ANATEL initially evaluated two options: (i) allocate the entire 6 GHz band (that is to say 1,200 MHz) for

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[29] Blackman, J. (2020). "UK to release 6 GHz and 100 GHz spectrum for Wi-Fi in smart homes, offices, factories". *Enterprise IoT insights* (January, 27).
[30] Ofcom (2020). *Statement: improving spectrum access for wi-fi – spectrum use in the 5 and 6 GHz bands* (July 24).
[31] Ebbecke, Ph. (2019). *Road to 6 GHz in Europe*. Presentation to WLPC Prague 2019
[32] Ofcom (2020). *Improving spectrum access for Wi-Fi*. London, p.21.
[33] Hetting, C. (2019). "Europe's process to release 6 GHz spectrum to Wi-Fi on track, expert says", *Wi-Fi Now* (June, 2).
[34] Hetting, C. (2020). "EU and CEPT countries 'highly likely' to release 6 GHz to Wi-Fi in early 2021, expert says". *Wi-Fi Now* (October 21).
[35] ANATEL (2020). Analise No 29/2020/CB. Processo no 53500.012176/2019-58.

unlicensed use, or (ii) allocate only 500 MHz. In December 2020, the regulator launched a public consultation focused only on the first option.[36]

Colombia and Mexico (1200 MHz)

The Colombian Ministry of ICT and *Agencia Nacional de Espectro* (ANE) have launched public consultations regarding the future allocation of the 6 GHz band.[37] In the case of Mexico, the Mexican *Instituto Federal de Telecomunicaciones* (IFT) started a similar process in November of 2020 for allocating 1100 MHz of the 6 GHz band.[38]

South Korea (1200 MHz)

In June 2020, the Ministry of Science and ICT (MSIT) issued a proposed "amendment of technical standards" for public consultation.[39] A decision had to take place later by the end of 2020 to release the entire 6 GHz band – meaning 5,925-7,125 MHz – for indoor operation, while outdoor use would follow in 2022.[40] On 15 October 2020 MSIT announced that it had approved the use of 1,200 MHz of spectrum in the 6GHz band—the 5,925MHz to 7,125MHz range—for unlicensed use. In the ministry's own testing, it demonstrated that 6GHz Wi-Fi could reach speeds of 2.1 Gbps, which is five times faster than currently available Wi-Fi speeds of around 400 to 600Mbps.[41] For South Korea, this will be the first Wi-Fi frequency upgrade in sixteen years.[42]

Australia, New Zealand, Singapore, Japan (1200 MHz)

The Australian regulatory agency, Australian Communications and Media Authority (ACMA), has recognized the economic and technological value of unlicensed spectrum and is monitoring developments in the 6 GHz band—particularly the matter of coexistence between Wi-Fi and similar uses of the band with other uses, such as satellite uplinks and fixed links.[43]

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[36] ANATEL (2020). *Anatel aprova consulta pública sobre Wi-Fi 6.* December 12, 2020). Retrieved in: https://www.gov.br/anatel/pt-br/assuntos/noticias/anatel-aprova-consulta-publica-sobre-wi-fi-6, and https://sistemas.anatel.gov.br/SACP/Contribuicoes/TextoConsulta.asp?CodProcesso=C2427&Tipo=1&Opcao=andamento.

[37] MINTIC (2020). *MINTIC y ANE consultan a los interesados sobre los posibles usos de la banda de 6 GHz.* Retrieved in: https://www.mintic.gov.co/portal/inicio/Sala-de-Prensa/Noticias/160952:MINTIC-y-ANE-consultan-a-los-interesados-sobre-los-posibles-usos-de-la-banda-de-6-GHz.

[38] Instituto federal de Telecomunicaciones (2020). *El IFT abre Consulta Pública sobre uso de la banda de 6 GHz en México (Comunicado 85/2020*) 06 de noviembre. Retrieved in: http://www.ift.org.mx/comunicacion-y-medios/comunicados-ift/es/el-ift-abre-consulta-publica-sobre-uso-de-la-banda-de-6-ghz-en-mexico-comunicado-852020-06-de

[39] Hetting, C. (2020). "South Korea could become Asia's first 6 GHz nation". *Wi-Fi News* (June, 27).

[40] Yonhap (2020). "Unlicensed frequency band to boost Wi-Fi speed, smart factory penetration: ministry," *The Korea Herald*, (June, 27).

[41] Cho Mu-Hyun (2020). "South Korea makes 6 GHz band available for Wi-Fi", *ZDNet* (October 16).

[42] Hetting, C. (2020). "South Korea could become Asia's first 6 GHz Wi-Fi nation". *Wi-Fi Now* (June, 27).

[43] ACMA (2019). *Five-year spectrum outlook 2019-23*, Canberra (September), p. 22

At the time of publishingpublishing this report, no decisions and/or specific plans to examine potential changes in allocation of the 6 GHz spectrum have been identified in Australia, New Zealand,[44] or Singapore. Japan is considering allocating 1200 MHz.[45]

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As the review of the regulatory context indicates, the use of unlicensed spectrum is in a state of transition around the world, with regulatory agencies recognizing that Wi-Fi is a critical component of a country's telecommunications infrastructure. As the analysis will show, the amount of spectrum allocated has an impact on Wi-Fi's economic value. Therefore, the assessment will be conducted according to two scenarios:

1. We first analyze a baseline scenario, estimating the economic value of Wi-Fi up to the fifth technological generation (Wi-Fi 5), which relies on the 2.4 GHz and 5 GHz unlicensed spectrum bands.

2. Then we identify the acceleration of the above-mentioned effects with the release of Wi-Fi 6 equipment and availability of the 6 GHz spectrum band allocation. Based on the review of the current state of regulatory decisions, we assumed 1200 megahertz allocation for the United States, South Korea, Japan, Singapore, Australia, New Zealand, Brazil, Colombia and Mexico, and 500 megahertz for the United Kingdom, France, Germany, Spain, and Poland.

Total economic value will result from adding the estimates of scenarios 1 and 2.

II.3. Methodologies for estimating the economic value of Wi-Fi

Measuring the economic value of Wi-Fi requires a formal approach that can integrate the various economic gains, whether consumer or producer benefits, as well as their net direct contributions to the GDP.[46] The methodology used in this study is structured around the benefits captured by each of the five economic agents reviewed above (individuals benefitting from free Wi-Fi service, residential Wi-Fi, enterprise Wi-Fi, Internet Service Providers, and Wi-Fi ecosystem companies). As outlined above, the economic value for each agent will be measured based on three

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[44] O'Neill, R. (2020). "New Zealand won't rush a spectrum upgrade for next generation Wi-Fi". *New Zealand Reseller News* (April 28).

[45] https://www.soumu.go.jp/main_content/000716599.pdf

[46] See the prior research in Thanki, R. (Sept. 8, 2009). *The economic value generated by current and future allocations of unlicensed spectrum*. Perspective Associates; Milgrom, P., Levin, J., & Eilat, A. (2011). *The case for unlicensed spectrum*. Stanford Institute for Economic Policy Research Discussion Paper No. 10-036; Cooper, M. (2011). *The consumer benefits of expanding shared use of unlicensed radio spectrum: Liberating Long-Term Spectrum Policy from Short-Term Thinking* . Washington D.C.: Consumer Federation of America, Katz, R. (2014a). *Assessment of the economic value of unlicensed spectrum in the United States.* New York: Telecom Advisory Services. Katz, R. (2014b). *Assessment of the future economic value of unlicensed spectrum in the United States.* New York: Telecom Advisory Services. Katz, R. (2018). *A 2017 assessment of the current and future economic value of unlicensed spectrum*. Washington, DC: Wi-Fi Forward. Katz, R. (2018). *The global economic value of Wi-Fi 2018-2023* . New York: Telecom Advisory Services.

potential economic dimensions: consumer surplus, producer surplus, and GDP growth. The contribution to GDP growth will also be used to estimate the impact on job creation. Table II-1 formalizes each source of value creation by economic agent.

Table II-1. Sources of economic value of Wi-Fi by economic agent

Agents	Sources	Type of Economic Value	Scenarios	
			Baseline	Wi-Fi 6 & 6 GHz
1. Free Wi-Fi	1.1. Savings generated by free Wi-Fi traffic offered in public sites	Consumer Surplus	X	X
	1.2. Deployment of free Wi-Fi in public sites	GDP contribution	X	X
	1.3. Benefit of faster free Wi-Fi under with Wi-Fi 6E devices	Consumer Surplus		X
2. Residential Wi-Fi	2.1. Internet access for home usage of devices that lack a wired port	Consumer Surplus	X	
	2.2. Avoidance of investment in in-house wiring	Consumer Surplus	X	
	2.3. Benefit to consumers from speed increases	Consumer Surplus	X	X
	2.4. Residential Wi-Fi devices and equipment deployed	Consumer Surplus	X	X
	2.5. Closing digital divide: use of Wi-Fi to increase coverage in rural and isolated areas	GDP contribution	X	X
3. Enterprise Wi-Fi	3.1. Business Internet traffic transmitted through Wi-Fi	Producer surplus	X	X
	3.2. Avoidance of enterprise inside wiring costs	Producer surplus	X	
	3.3. Return to speed: contribution to GDP derived from an increase in average mobile speed	GDP contribution	X	X
	3.4. Wide deployment of IoT	GDP contribution	X	X
	3.5. Deployment of AR/VR solutions	GDP contribution	X	X
4. ISPs	2.1 CAPEX and OPEX savings due to cellular off-loading	Producer surplus	X	X
	2.2. Revenues of service providers offering paid Wi-Fi access in public places	GDP contribution	X	X
	2.3. Aggregated revenues of WISPs	GDP contribution	X	X
5. Wi-Fi ecosystem	5.1. Locally manufactured residential Wi-Fi devices and equipment	Producer surplus	X	X
	5.2. Locally manufactured Wi-Fi enterprise equipment	Producer surplus	X	X
	5.3. Locally produced IoT products and services	Producer surplus	X	X
	5.4. Locally produced of AR/VR solutions	Producer surplus	X	X

Source: Telecom Advisory Services

The above table presents an overview of the different sources of Wi-Fi economic value channeled to each economic agent. The detailed methodologies are presented in "Theoretical Framework, Methodologies and Detailed Country Assessments for The Economic Value of Wi-Fi: A Global View (2021-2025)" starting on page 83.

III. ECONOMIC VALUE OF WI-FI IN THE UNITED STATES

The United States is the country with the widest Wi-Fi adoption and use in the world. In fact, Wi-Fi has become a pervasive feature in the U.S. telecommunications landscape. Cisco's Annual Internet Report Highlights Tool 2018-2023 estimates that there are currently 33,480,000 public Wi-Fi access points in the United States, [47] while according to Wiman (2020) there are 18,560,000 free Wi-Fi sites in the country.[48] In 2020, 85 percent of homes in the United States with broadband are equipped with a Wi-Fi router supporting access and interconnection of devices. [49]

Given the density of Wi-Fi access points, hotspots have become a very important connectivity feature. According to Opensignal[50], since the outbreak of COVID-19, wireless users in the United States have spent 59.9 percent of their communications time connected to Wi-Fi networks rather than relying on their cellular data connection. This has increased from 56.2 percent at the beginning of 2020.

The Wi-Fi standard has also created a world leading equipment manufacturing industry. Local manufacturing of Wi-Fi access points, external adapters, routers and controllers for consumers and enterprises is estimated to currently reach $7.4 billion. The importance of Wi-Fi technology in the digital ecosystem should have a significant contribution to its social and economic benefits. This chapter presents the summary of results of the economic assessment. The detailed calculations of each source of value are included in "Theoretical Framework, Methodologies and Detailed Country Assessments for The Economic Value of Wi-Fi: A Global View (2021-2025)" starting on page 83.

In our prior 2018 study, Wi-Fi's economic value for 2021 was estimated at $801.8 billion. In April 2020, the United States Federal Communications Commission (FCC) unanimously voted to allow two classes of unlicensed devices to operate in the 6 GHz band. Low power indoor devices were permitted to operate throughout the 1,200 MHz band, while standard power access points were allowed to operate in 850 MHz in the sub bands described above. As a result, the capacity available for Wi-Fi was quadrupled.

Before even considering the additional effect of Wi-Fi 6 and allocation of the 6 GHz spectrum band for unlicensed use, the baseline (2.4 and 5 GHz Wi-Fi) economic value of Wi-Fi in the United States in 2021 is estimated at $979 billion. The increase of $177.2 billion since the 2018 study is due to the increased importance of four sources of economic value:

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[47] Cisco includes within this category, free hotspots, homespots, and paid hotspots. The report provides a value for 2018 (22.3 million) and 2023 (61.3 million), which allows for interpolating a 2020 estimates.

[48] Retrieved in: https://www.wiman.me/united-states (November 17, 2020).

[49] Watkins, D. (2012). *Broadband and Wi-Fi Households Global Forecast 2012*. Strategy Analytics. Retrieved in: https://www.strategyanalytics.com/access-services/devices/connected-home/consumer-electronics/reports/report-detail/broadband-and-wi-fi-households-global-forecast-2012.

[50] Khatri, H. and Fenwick, S. (2020). "Analyzing mobile experience during the coronavirus pandemic: Time on Wi-Fi". *Opensignal* (March 30).

- The value of free Wi-Fi to address the needs of the population that cannot afford broadband service;[51]
- The increasing benefits of Wi-Fi technology broadband speed;
- A substantial boost to the deployment of IoT technology; and
- The growing adoption of AR/VR technology solutions.

The 2025 forecast of economic value will reach $1,392.7 billion—nearly $1.4 trillion—without considering the accelerating effect of Wi-Fi 6 and 6 GHz band allocation.

Adding to this baseline scenario, the allocation of the 6 GHz spectrum band for unlicensed use and the deployment of Wi-Fi 6 and Wi-Fi 6E devices will trigger an additional growth of economic value, reaching $187.4 billion in 2025. Considering that we forecast that by 2025 only 40 percent of Wi-Fi traffic will rely on 6 GHz channels, the accelerated effect derived from the new spectrum allocation and latest Wi-Fi technologies will continue to grow and still be far from reaching its maximum potential at this time. By combining the baseline and the Wi-Fi 6 and 6 GHz scenarios, the overall economic value of Wi-Fi for the United States will yield $1,580.1 billion—nearly $1.6 trillion—in 2025 (see Table III-1).

Table III-1. United States: Total economic value of Wi-Fi (in $Billions)

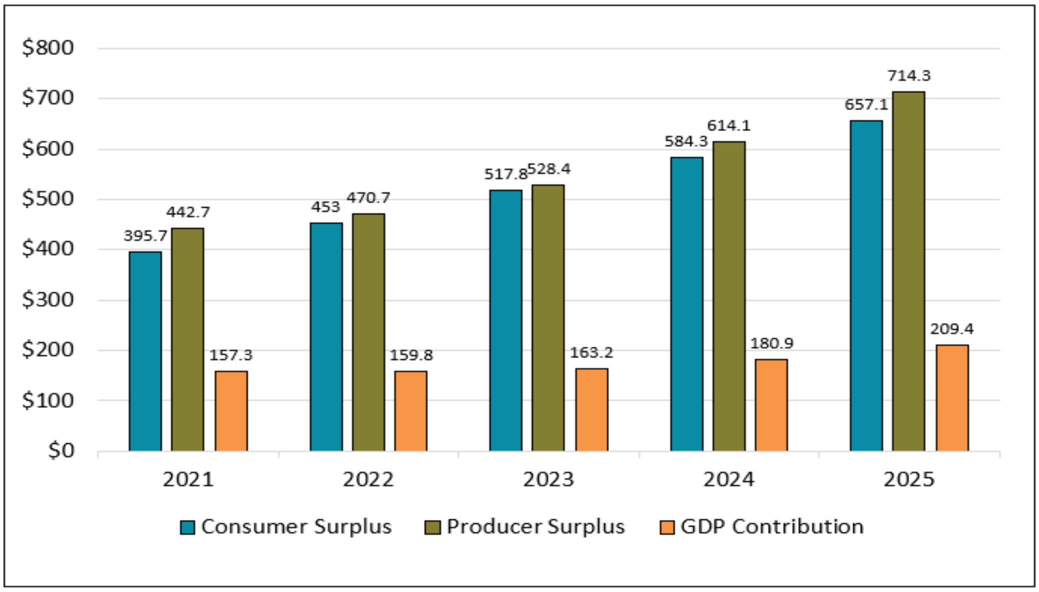
	2021	2022	2023	2024	2025
Baseline Scenario	$979.0	$1,026.0	$1,115.8	$1,243.8	$1,392.7
Wi-Fi 6 / 6 GHz Scenario	$16.0	$56.8	$93.1	$134.9	$187.4
Total	$995.0	$1,082.8	$1,208.9	$1,378.7	$1,580.1

Source: Telecom Advisory Services analysis

The primary source of economic value is producer surplus. This surplus is driven by the savings enjoyed by cellular operators who rely on Wi-Fi traffic rerouting, and the profit margins of an extremely vibrant ecosystem of Wi-Fi equipment manufacturers, software developers, and systems integrators. The contribution to producer surplus is closely followed by consumer surplus, as a result of the additional speed and capacity of Wi-Fi access points (see Graphic III-1).

[51] As a reference, a survey carried out by Connect Home stipulated that 10 percent of not connected households declare that they access Internet outside of home.

Graphic III-1. United States: Total economic value of Wi-Fi (by source) (in $Billions)



Note: Due to rounding, numbers presented in this graphic may not add up precisely to the totals above.
Source: Telecom Advisory Services LLC

The total economic value of Wi-Fi benefits five economic agents, of which residential Wi-Fi is the most important, followed by enterprises (see Table III-2).

Table III-2. United States: Total Economic Value of Wi-Fi (by agent) (in $Billions)

	2021	2022	2023	2024	2025
Free Wi-Fi	$25.7	$23.3	$19.7	$15.2	$13.8
Residential Wi-Fi	$407.4	$472.7	$544.9	$620.1	$705.6
Enterprise Wi-Fi	$337.3	$379.0	$422.6	$487.7	$565.2
Internet Service Providers	$71.8	$29.4	$12.7	$14.5	$16.9
Wi-Fi ecosystem	$152.8	$178.4	$209.0	$241.2	$278.6
Total	$995.0	$1,082.8	$1,208.9	$1,378.7	$1,580.1

Source: Telecom Advisory Services analysis

The economic value of consumer use of residential Wi-Fi is significant in terms of access and connectivity of home. The most important factor driving the value of Wi-Fi among enterprises is savings in wireless telecommunications, followed by the spillover of IoT applications, and enhanced speed of Wi-Fi access points. The boost in the development of manufacturers and service providers involved in the provision of Wi-Fi enabled solutions, such as AR/VR solutions, IoT networks, Wi-Fi access points, and household appliances, will result in producer surplus.[52]

Based on Wi-Fi's contribution to GDP, the technology will generate approximately 542,000 jobs in 2021, primarily in the communications sector (273,000), business services (134,000), and trade (58,000). By 2025, job creation estimates will reach 720,000.

[52] Detailed analysis is included in the "Theoretical Framework, Methodologies and Detailed Country Assessments for The Economic Value of Wi-Fi: A Global View (2021-2025)" section of this document.

IV. ECONOMIC VALUE OF WI-FI IN THE UNITED KINGDOM

As in the United States, Wi-Fi has also become a dominant component of the telecommunications infrastructure in the United Kingdom. According to the Cisco Annual Internet Report Highlights Tool 2018-2023, there were 200,000 paid Wi-Fi access points operating in the UK territory in 2018,[53] while Wiman reports 2,248,000 open Wi-Fi networks.[54] Eighty-nine percent of homes with Internet access in the United Kingdom are equipped with a Wi-Fi router.[55]

Given the Wi-Fi access point density, hotspots have become a very important connectivity feature. According to Opensignal[56], before the outbreak of COVID-19, UK wireless users were spending 65.1 percent of their connection time on Wi-Fi networks, rather than relying on their cellular data connection; that percentage increased to 68.9 percent by March 2020. The increasing importance of Wi-Fi in the British digital infrastructure should have a significant social and economic impact. This chapter presents a summary of the results of the economic assessment for the UK. The detailed calculations of each source of value are included in "Theoretical Framework, Methodologies and Detailed Country Assessments for The Economic Value of Wi-Fi: A Global View (2021-2025)" starting at page 83.

In the 2018 study of Wi-Fi's economic contribution[57], the value of Wi-Fi in the United Kingdom for 2021 was estimated at $64 billion. An updated baseline estimate for the same year according to the current study assumptions amounts to $96.9 billion. The increase of $32.9 billion is mainly due to the accelerated development of four sources of economic value:

- The increasing importance of free Wi-Fi;
- The contribution of Wi-Fi technology to improving broadband speed;
- A substantial boost to deployment of IoT technology; and
- The growing adoption of AR/VR technology use cases.

Wi-Fi 6 and the recent allocation of spectrum for unlicensed use will drive an additional increase in economic value. In July 2020, Ofcom, the British communications regulatory agency, decided to make 500 MHz of the 6 GHz band

[53] Cisco reports that In the United Kingdom, total public Wi-Fi hotspots (including homespots) will grow 2-fold from 2018 to 2023 from 16.5 million in 2018 to 26.1 million by 2023." https://www.cisco.com/c/dam/m/en_us/solutions/executive-perspectives/vni-forecast-highlights/total/pdf/United_Kingdom_Network_Performance.pdf
[54] Retrieved in: https://www.wiman.me/united-kingdom. (November 17, 2020).
[55] Value extrapolated from Watkins, D. (2012). *Broadband and Wi-Fi Households Global Forecast 2012*. Strategy Analytics. Retrieved in: https://www.strategyanalytics.com/access-services/devices/connected-home/consumer-electronics/reports/report-detail/broadband-and-wi-fi-households-global-forecast-2012.
[56] Khatri, H. and Fenwick, S. (2020). "Analyzing mobile experience during the coronavirus pandemic: Time on Wi-Fi". *Opensignal* (March 30).
[57] Katz, R. and Callorda, F. (2018). *The Economic value of Wi-Fi: A Global View (2018 and 2023)*. New York: Telecom Advisory Services. October.

available for unlicensed low power indoor use and very low power outdoor use.[58] The purpose of limiting the allocation to 500 MHz was to initially to show that Wi-Fi can benefit from the lower part of the band, and then investigate the convenience of allocating upper part of the spectrum.[59] In the words of Ofcom, "we will continue to review use of the upper 6 GHz band to determine what the optimal use may be".[60]

In addition to the value generated from the unlicensed use of the 2.4 GHz and 5 GHz bands (referred to as the baseline scenario above), the allocation of 500 MHz in the 6 GHz spectrum band for unlicensed use, and the deployment of Wi-Fi 6 and Wi-Fi 6E devices, will trigger an additional boost in economic value, reaching $10.7 billion in 2025. By combining the baseline and the Wi-Fi 6 and 6 GHz scenarios, the overall economic value of Wi-Fi for the United Kingdom will yield $108.5 billion in 2025 (see Table IV-1).

Table IV-1. United Kingdom: Total economic value of Wi-Fi (in $Billions)

	2021	2022	2023	2024	2025
Baseline Scenario	$96.9	$93.2	$87.6	$91.9	$97.8
Wi-Fi 6 / 6 GHz Scenario	$1.9	$3.9	$5.6	$8.0	$10.7
Total	$98.8	$97.1	$93.2	$99.9	$108.5

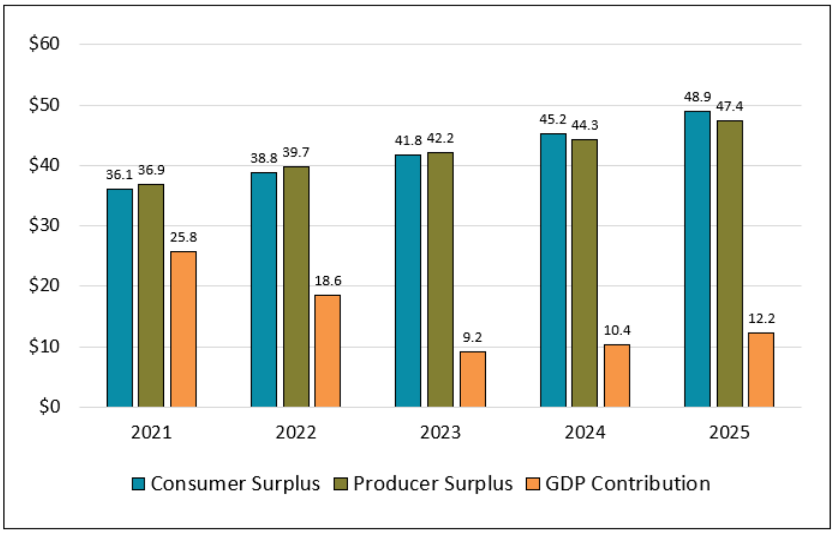
Source: Telecom Advisory Services analysis

Average projected speed fluctuations indicated in Cisco Annual Internet Report Highlights Tool 2018-2I023 account for the reduction in value in 2022 and 2023, but the overall effect results in a nearly $10B increase over five years. If Ofcom decides to allocate the upper part of the spectrum to unlicensed use, Wi-Fi economic value would increase significantly beyond the values presented in Table IV-1.

The primary source of economic value through 2023 is producer surplus, closely followed by consumer surplus, while the order is reversed in 2024 (see Graphic IV-1).

[58] Ofcom (2020). *Statement: improving spectrum access for wi-fi – spectrum use in the 5 and 6 GHz bands*.
[59] Ebbecke, Ph. (2019). *Road to 6 GHz in Europe*. Presentation to WLPC Prague 2019
[60] Ofcom (2020). *Improving spectrum access for Wi-Fi*. London, p.21.

Graphic IV-1. United Kingdom: Total economic value of Wi-Fi (by source) (in $Billions)



Note: Due to rounding, numbers presented in this graphic may not add up precisely to the totals presented above.
Source: Telecom Advisory Services LLC

This total value benefits five economic agents, of which residential Wi-Fi is the most important, followed by use by enterprises (see Table IV-2).

Table IV-2. United Kingdom: Total economic value of Wi-Fi (by agent) (in $Billions)

	2021	2022	2023	2024	2025
Free Wi-Fi	$1.1	$1.2	$1.2	$1.3	$1.4
Residential Wi-Fi	$35.4	$38.0	$41.1	$44.4	$48.1
Enterprise Wi-Fi	$41.2	$34.7	$26.5	$28.8	$31.7
Internet Service Providers	$9.9	$9.6	$8.0	$6.6	$5.5
Wi-Fi ecosystem	$11.2	$13.6	$16.4	$18.8	$21.8
Total	$98.8	$97.1	$93.2	$99.9	$108.5

Source: Telecom Advisory Services analysis

The economic value of consumer use of residential Wi-Fi is significant in terms of the cost savings gained by avoiding inside wiring and wireless device access at home. The most important factor driving the value of Wi-Fi among enterprises is savings in wireless telecommunications, followed by the enhanced speed of Wi-Fi access points, and the spillover of IoT applications[61]. According to the contribution to GDP, Wi-Fi will generate approximately 95,000 jobs in the UK in 2021, primarily in the communications sector (48,000), and business services (19,000). In 2025, the job creation effect will amount to 45,000.

[61] Detailed analysis is included in the "Theoretical Framework, Methodologies and Detailed Country Assessments for The Economic Value of Wi-Fi: A Global View (2021-2025)" section of this document.

V. ECONOMIC VALUE OF WI-FI IN FRANCE

Wi-Fi has also become a pervasive feature in the French telecommunications infrastructure. According to Wiman, there are currently 1,219,000 open public Wi-Fi access points in France.[62] Given the density of Wi-Fi access points, hotspots have become a very important connectivity feature. Furthermore, 87 percent of French homes with broadband are estimated to be equipped with a Wi-Fi access point.[63] The increasing importance of Wi-Fi technology in the country's digital infrastructure should have a significant social and economic impact. This chapter presents a summary of the results of the economic value assessment. The detailed calculations of each source of value are included in "Theoretical Framework, Methodologies and Detailed Country Assessments for The Economic Value of Wi-Fi: A Global View (2021-2025)" starting page 83.

In the 2018 study of Wi-Fi's economic contribution[64,], its value in France for 2021 was estimated at $55 billion. An updated projection for the same year, under the baseline scenario including the 2.4 and 5 GHz bands, estimates an economic value of Wi-Fi in France will be $61.2 billion. The increase of $6.2 billion is mainly due to the development of four sources of economic value:

- The increasing importance of free Wi-Fi;
- The increasing benefits of Wi-Fi technology broadband speed;
- A substantial boost to the deployment of IoT technology;
- The growing adoption of AR/VR technology.

The baseline forecast of economic value for 2025 is estimated to reach $95.0 billion.

These projections do not consider the acceleration effect resulting from the allocation of 500 MHz in the 6 GHz band. In response to a request from the European Commission to investigate spectrum between 5,925 to 6,425 MHz, the European Conference of Postal and Telecommunications Administrations (CEPT) has issued a technical report to the European Commission on the feasibility of using Wi-Fi in the 6 GHz band.[65] The recommendation for investigating only the 5,925 to 6,425 band (500 MHz) is due to the fact that European countries have critical services in the upper part of the 6 GHz band (i.e. large amount of point to point fixed services, earth to space communications, road intelligent traffic systems and communication-based train control, and some radio astronomy sites).

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[62] Of this installed base of Wi-Fi hotspots in France, 418,000 are deployed in Paris, 43,000 in Lyon, 29,000 in Nice, and 23,000 in Marseille (Retrieved in: https://www.wiman.me/france, November 17, 2020).

[63] Extrapolated value based on Watkins, D. (2012). *Broadband and Wi-Fi Households Global Forecast 2012*. Strategy Analytics. Retrieved in: https://www.strategyanalytics.com/access-services/devices/connected-home/consumer-electronics/reports/report-detail/broadband-and-wi-fi-households-global-forecast-2012.

[64] Katz, R. and Callorda, F. (2018). *The Economic value of Wi-Fi: A Global View (2018 and 2023)*. New York: Telecom Advisory Services. October.

[65] Hetting, C. (2019). "Europe's process to release 6 GHz spectrum to Wi-Fi on track, expert says", *Wi-Fi Now* (June, 2).

In addition to the value generated from the unlicensed use of the 2.4 GHz and 5 GHz bands (baseline scenario), by adding 500 MHz in the 6 GHz spectrum band for unlicensed use and the deployment of Wi-Fi 6 and Wi-Fi 6E devices will trigger an additional boost of $9.0 billion in economic value, reaching a total of $104.0 billion in 2025 (see Table V-1).

Table V-1. France: Total economic value of Wi-Fi (in $Billions)

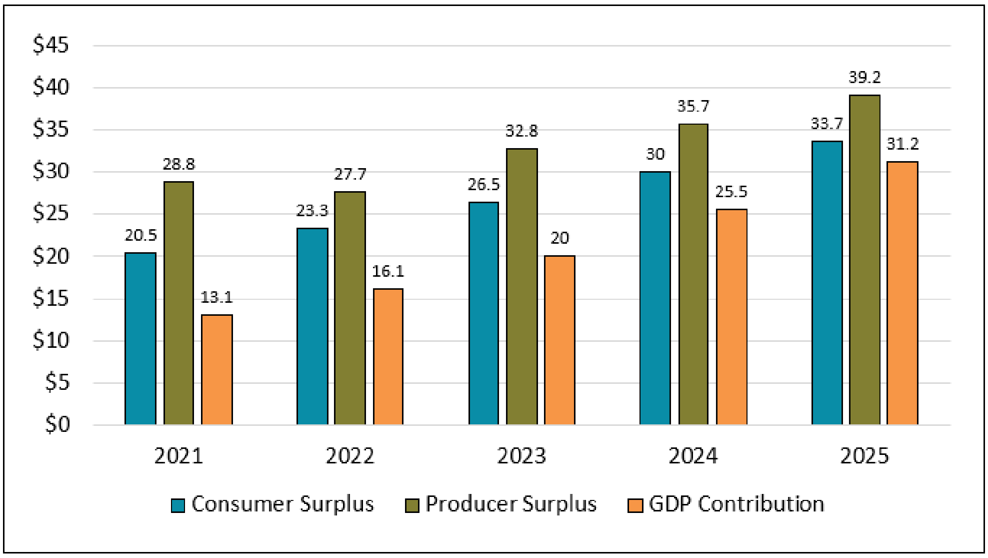
	2021	2022	2023	2024	2025
Baseline Scenario	$61.2	$63.4	$73.2	$83.0	$95.0
Wi-Fi 6 / 6 GHz Scenario	$1.3	$3.7	$6.2	$8.2	$9.0
Total	$62.5	$67.1	$79.4	$91.2	$104.0

Source: Telecom Advisory Services analysis

Considering that by 2025 only 40 percent of Wi-Fi traffic will rely on 6 GHz channels, the accelerated effect derived from the new spectrum allocation and latest Wi-Fi technologies will still be far from reaching its maximum potential at this time. Therefore, If the French telecommunications regulatory agencies decides to allocate the upper part of the spectrum to unlicensed use, Wi-Fi economic value would increase significantly beyond the values presented in Table V-1.

The initial primary source of economic value is producer surplus, followed by consumer surplus (see Graphic V-1).

Graphic V-1. France: Total Economic Value of Wi-Fi (by source) (in $Billions)



Note: Due to rounding, numbers presented in this graphic may not add up precisely to the totals presented above.
Source: Telecom Advisory Services LLC

This total value benefits five economic agents, of which residential Wi-Fi is the most important, followed by enterprises (see Table V-2).

Table V-2. France: Total economic value of Wi-Fi (by agent) (in $Billions)

	2021	2022	2023	2024	2025
Free Wi-Fi	$1.0	$0.9	$0.8	$0.6	$0.5
Residential Wi-Fi	$20.7	$23.3	$26.6	$30.0	$33.6
Enterprise Wi-Fi	$18.7	$22.2	$26.3	$32.2	$38.3
Internet Service Providers	$10.0	$7.4	$10.5	$11.7	$13.4
Wi-Fi ecosystem	$12.1	$13.3	$15.2	$16.7	$18.2
Total	$62.5	$67.1	$79.4	$91.2	$104.0

Source: Telecom Advisory Services analysis

The economic value of consumer use of residential Wi-Fi is significant in terms of the cost savings gained by avoiding inside wiring and wireless device access at home. The most important factor driving the value of Wi-Fi among enterprises is savings in wireless telecommunications, followed by the enhanced speed of Wi-Fi access points and the spillover of IoT applications.[66] According to the contribution to GDP, Wi-Fi will generate approximately 35,000 jobs in France in 2021, primarily in the communications sector (17,000), trade (32,000) and business services (9,000) and is expected to create 82,000 in 2025.

[66] Detailed analysis is included in the "Theoretical Framework, Methodologies and Detailed Country Assessments for The Economic Value of Wi-Fi: A Global View (2021-2025)" section of this document.

VI. ECONOMIC VALUE OF WI-FI IN GERMANY

Wi-Fi technology and networks have become a dominant component of the German telecommunications infrastructure. According to Wiman, there are 1,950,000 open Wi-Fi sites currently operating in the German territory.[67] Cisco Annual Internet Report Highlights Tool 2018-2023 estimates that there are 300,000 public commercial hot spots operating in the country. Eighty-five percent of homes with broadband have already installed a Wi-Fi access point; this number is expected to reach 100 percent by 2025.

Given the Wi-Fi access point density, the technology has become a very important connectivity infrastructure. According to Opensignal[68], before the outbreak of COVID-19 German wireless users spent 64.7 percent of their communications time connected to Wi-Fi networks rather than relying on their cellular data connection. In March 2020 that number reached 71.4 percent. This chapter presents a summary of the results of the economic assessment for Germany. The detailed calculations of each source of value are included in "Theoretical Framework, Methodologies and Detailed Country Assessments for The Economic Value of Wi-Fi: A Global View (2021-2025)" starting on page 83.

In the prior study of Wi-Fi's economic contribution[69], its value for 2021 in Germany was estimated at $115.3 billion. The update conducted in the current study estimates that the economic value for the same year in 2.4 and 5 GHz bands—the baseline scenario—will amount to $132.6 billion. The increase of $17.3 billion in the updated estimate is mostly due to four sources of economic value:

- The increasing benefits of Wi-Fi technology broadband speed;
- A substantial boost to deployment of IoT technology; and
- The growing adoption of AR/VR technology.

The baseline 2025 forecast will reach $158.0 billion.

This value will increase further due to the addition of 500 MHz in the 6 GHz band. As was the case for France, Germany is also expected to follow the recommendation of the European Conference of Postal and Telecommunications Administrations (CEPT) and allocate the 5,925 to 6,425 band (500 MHz) to Wi-Fi use. In addition to the baseline scenario, the allocation of the 6 GHz spectrum band for unlicensed use and the deployment of Wi-Fi 6 devices will trigger a growth of economic value, reaching $15.3 billion in 2025 (see Table VI-1).

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[67] Of this installed base of Wi-Fi hotspots in Germany, 95,000 are deployed in Berlin, 68,000 are deployed in Hamburg, and 116,000 in Munich (Retrieved in: https://www.wiman.me/germany, November 17, 2020)
[68] Khatri, H. and Fenwick, S. (2020). "Analyzing mobile experience during the coronavirus pandemic: Time on Wi-Fi". *Opensignal* (March 30).
[69] Katz, R. and Callorda, F. (2018). *The Economic value of Wi-Fi: A Global View (2018 and 2023)*. New York: Telecom Advisory Services. October.

Table VI-1. Germany: Total economic value of Wi-Fi (in $Billions)

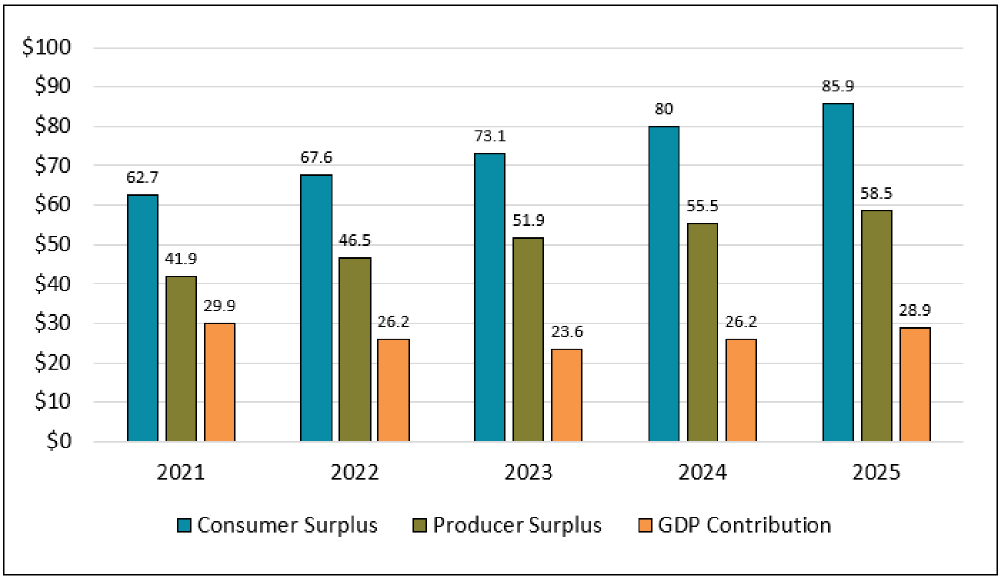
	2021	2022	2023	2024	2025
Baseline Scenario	$132.6	$135.4	$140.2	$149.9	$158.0
Wi-Fi 6 / 6 GHz Scenario	$1.9	$5.1	$8.4	$12.0	$15.3
Total	$134.5	$140.5	$148.6	$161.9	$173.3

Source: Telecom Advisory Services analysis

Considering that by 2025 only 40 percent of Wi-Fi traffic will be relying on 6 GHz channels, the accelerated effect derived from the new spectrum allocation and latest Wi-Fi technologies will still be far from reaching its maximum potential at this time. If the German telecommunications regulatory agencies decides to allocate the upper part of the spectrum to unlicensed use, Wi-Fi economic value would increase beyond the values presented in Table VI-1.

The initial primary source of economic value is producer surplus, followed by consumer surplus and GDP contribution (see Graphic V-1).

Graphic VI-1. Germany: Total economic value of Wi-Fi (by source) (in $Billions)



Note: Due to rounding, numbers presented in this graphic may not add up precisely to the totals presented above.
Source: Telecom Advisory Services LLC

This total value benefits five economic agents, of which residential Wi-Fi is the most important, followed by use by enterprises (see Table VI-2).

Table VI-2. Germany: Total economic value of Wi-Fi (by agent) (in $Billions)

	2021	2022	2023	2024	2025
Free Wi-Fi	$0.9	$0.8	$0.8	$0.9	$0.9
Residential Wi-Fi	$62.4	$67.5	$72.7	$79.9	$85.5
Enterprise Wi-Fi	$55.4	$52.7	$50.9	$54.2	$57.9
Internet Service Providers	$5.0	$7.5	$10.5	$11.9	$12.4
Wi-Fi ecosystem	$10.8	$12.0	$13.7	$15.0	$16.6
Total	$134.5	$140.5	$148.6	$161.9	$173.3

Source: Telecom Advisory Services analysis

The economic value of consumer use of residential Wi-Fi is significant in terms of the cost savings gained by avoiding inside wiring and allowing for wireless device access at home. The most important factor driving the value of Wi-Fi among enterprises is savings in wireless telecommunications, followed by the enhanced speed of Wi-Fi access points and the spillover of IoT applications.[70]

According to the contribution to GDP, Wi-Fi will generate approximately 92,000 jobs in Germany in 2021, primarily in the communications sector (50,000), and business services (20,000). Wi-Fi is expected to generate almost 90,000 jobs by 2025.

[70] Detailed analysis is included in the "Theoretical Framework, Methodologies and Detailed Country Assessments for The Economic Value of Wi-Fi: A Global View (2021-2025)" section of this document.

VII. ECONOMIC VALUE OF WI-FI IN SPAIN

As in other European nations, Wi-Fi has become a pervasive feature in the Spanish telecommunications landscape. The Cisco Annual Internet Report Highlights Tool 2018-2023 estimates that 200,000 public commercial hot spots are deployed in the country,[71] while Wiman estimates that there are currently 986,000 free Wi-Fi hotspots.[72] In addition, 87 percent of Spanish households with broadband are equipped with a Wi-Fi router.

Given the public and private Wi-Fi access point density, the technology has become a very important feature of broadband connectivity. According to Opensignal[73], before the outbreak of COVID-19, Spanish smartphone users spent 61.9 percent of their communications time connected to Wi-Fi networks rather than relying on their cellular data connection. Underlining the importance of Wi-Fi in the course of the pandemic, that number reached 73.1 percent in March 2020—one of the highest in Europe.

The extensive deployment and use of Wi-Fi in Spain should result in a significant social and economic contribution. This chapter presents a summary of the results of the economic assessment. The detailed calculations of each source of value are included in "Theoretical Framework, Methodologies and Detailed Country Assessments for The Economic Value of Wi-Fi: A Global View (2021-2025)" starting on page 83.

As in the case of other European countries, the technical recommendation of the European Conference of Postal and Telecommunications Administrations (CEPT) to the European Commission[74] would influence Spain's decision to allocate the spectrum band between 5,925 to 6,425 MHz for unlicensed use.[75] Before considering the additional effect of Wi-Fi 6 and allocating the 6 GHz spectrum band for unlicensed use, the total economic value of Wi-Fi in Spain in 2021 for only the 2.4 GHz and 5 GHz bands—the baseline scenario—will amount to $39.8 billion. The 2025 forecast of economic value for this baseline scenario is expected to reach $49.6 billion.

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[71] Cisco reports that in 2018 there were 2.9 million hotspots in Spain, of which 2.7. million were homespots. Retrieved in: https://www.cisco.com/c/en/us/solutions/executive-perspectives/annual-internet-report/air-highlights.html#

[72] Of this installed base of Wi-Fi hotspots in Spain 192,000 are deployed in Madrid, 201,000 in Barcelona, 41,000 in Valencia, and 29,000 in Seville (Retrieved in: https://www.wiman.me/spain , November 17, 2020).

[73] Khatri, H. and Fenwick, S. (2020). "Analyzing mobile experience during the coronavirus pandemic: Time on Wi-Fi". *Opensignal* (March 30).

[74] Hetting, C. (2019). "Europe's process to release 6 GHz spectrum to Wi-Fi on track, expert says", *Wi-Fi Now* (June, 2).

[75] The recommendation for investigating only the 5,925 to 6,425 band (500 MHz) is that European countries have critical services in the upper part of the 6 GHz band (i.e. large amount of point to point fixed services, earth to space communications, road intelligent traffic systems and communication-based train control, and some radio astronomy sites). In addition to the baseline scenario.

The allocation of 500 MHz in the 6 GHz spectrum band for unlicensed use and the deployment of Wi-Fi 6 and Wi-Fi 6E devices will trigger an additional growth of economic value, reaching $4.5 billion in 2025. By combining the baseline and the Wi-Fi 6 and 6 GHz scenarios, the overall economic value of Wi-Fi for Spain will yield $54.1 billion in 2025 (see Table VII-1).

Table VII-1. Spain: Total economic value of Wi-Fi (in $Billions)

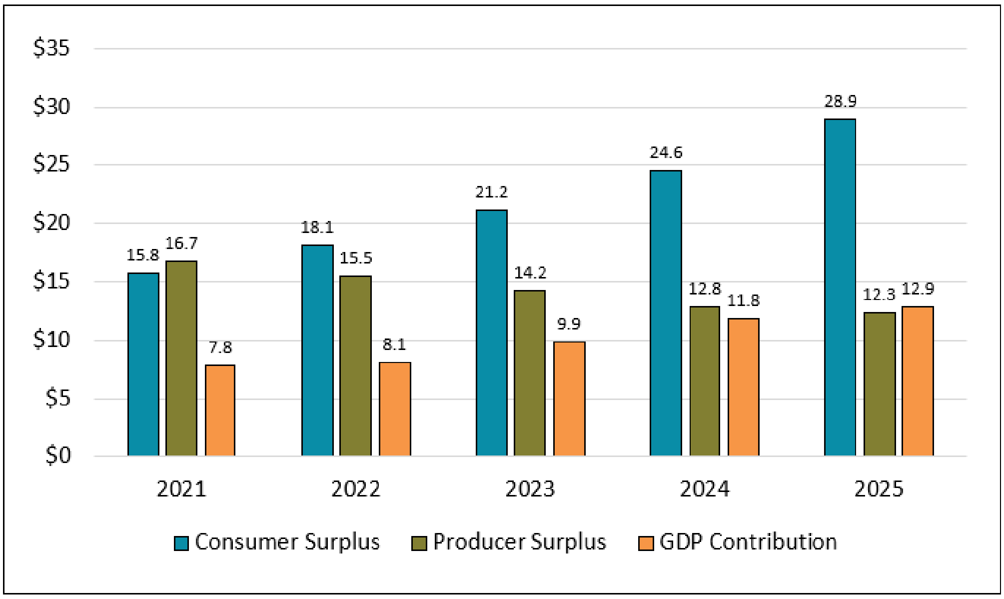
	2021	2022	2023	2024	2025
Baseline Scenario	$39.8	$39.6	$41.8	$44.7	$49.6
6 GHz Scenario	$0.6	$2.1	$3.5	$4.5	$4.5
Total	$40.4	$41.7	$45.3	$49.2	$54.1

Source: Telecom Advisory Services analysis

Considering that it is assumed that by 2025 only 40 percent of Wi-Fi traffic will be relying on the 6 GHz spectrum, the accelerated effect derived from the new spectrum allocation and latest Wi-Fi technologies will still be far from reaching its maximum potential at this time. If the Spanish telecommunications regulatory agencies decides to allocate the upper part of the spectrum to unlicensed use, Wi-Fi economic value would increase significantly beyond the values presented in Table VII-1.

The primary source of economic value is consumer surplus, while producer surplus stabilizes at approximately $13 billion and GDP contribution gradually increases over time reaching $12.9 billion by 2025 (see Graphic VII-1).

Graphic VII-1. Spain: Total economic value of Wi-Fi (by source) (in $Billions)



Note: Due to rounding, numbers presented in this graphic may not add up precisely to the totals presented above.
Source: Telecom Advisory Services LLC

This total value benefits five economic agents, of which residential Wi-Fi is the most important followed by use by enterprises (see Table VII-2).

Table VII-2. Spain: Total economic value of Wi-Fi (by agent) (in $Billions)

	2021	2022	2023	2024	2025
Free Wi-Fi	$0.3	$0.3	$0.3	$0.3	$0.3
Residential Wi-Fi	$15.8	$18.2	$21.2	$24.7	$28.7
Enterprise Wi-Fi	$15.3	$16.0	$18.2	$20.4	$21.9
Internet Service Providers	$7.1	$5.2	$3.4	$1.5	$0.5
Wi-Fi ecosystem	$1.9	$2.0	$2.2	$2.3	$2.7
Total	$40.4	$41.7	$45.3	$49.2	$54.1

Source: Telecom Advisory Services analysis

The economic value of free Wi-Fi service is generated through savings to consumers who access the Internet via free Wi-Fi sites, rather than incurring cellular costs, the use of Wi-Fi by households that cannot afford broadband service and the speed of Wi-Fi compared to the use of cellular service. Additionally, the economic value of consumer use of residential Wi-Fi is significant in terms of the cost savings gained by avoiding inside wiring and wireless device access at home. The most important factor driving the value of Wi-Fi among enterprises is savings in wireless telecommunications (enterprises use Wi-Fi for 57 percent of their total Internet traffic), followed by the enhanced speed of Wi-Fi access points and the spillover of IoT applications.[76]

According to the contribution to GDP, Wi-Fi will generate approximately 33,000 jobs in Spain in 2021, primarily in the communications sector (19,000), and business services (7,000). In addition, Wi-Fi will generate over 54,000 in 2025.

[76] Detailed analysis is included in the "Theoretical Framework, Methodologies and Detailed Country Assessments for The Economic Value of Wi-Fi: A Global View (2021-2025)" section of this document.

VIII. ECONOMIC VALUE OF WI-FI IN POLAND

Wi-Fi has become a critical component of Poland's telecommunications infrastructure. According to the Cisco Annual Internet Report Highlights Tool 2018-2023 for Europe, there were 3,100,000 public Wi-Fi access points operating in the Polish territory in 2018. In addition, 89 percent of the country's 12.7 million households with broadband rely on Wi-Fi routers to fulfill in-home device connectivity.

Given the Wi-Fi access point density in the country, hotspots have become a very important connectivity feature. This chapter presents a summary of the results of the economic assessment. The detailed calculations of each source of value are included in "Theoretical Framework, Methodologies and Detailed Country Assessments for The Economic Value of Wi-Fi: A Global View (2021-2025)" starting on page 83.

Before considering the additional effect of Wi-Fi 6 and allocating the 6 GHz spectrum band for unlicensed use as recommended by the European Conference of Postal and Telecommunications Administrations (CEPT)[77], the baseline economic value of Wi-Fi in Poland in 2021 will amount to $15.9 billion. The baseline 2025 forecast of economic value will remain stable at $15.9 billion.

However, the allocation of 500 MHz in the 6 GHz spectrum band for unlicensed use and the deployment of Wi-Fi 6 and Wi-Fi 6E devices will trigger an additional growth of economic value, reaching $5.7 billion in 2025. By combining the baseline and the Wi-Fi 6 and 6 GHz scenarios, the overall economic value of Wi-Fi for Poland is estimated at $16.1 billion, reaching $21.6 billion in 2025 (see Table VIII-1).

Table VIII-1. Poland: Total economic value of Wi-Fi (in $Billions)

	2021	2022	2023	2024	2025
Baseline Scenario	$15.9	$15.7	$16.0	$15.8	$15.9
Wi-Fi 6 / 6 GHz Scenario	$0.2	$1.6	$3.1	$4.6	$5.7
Total	$16.1	$17.3	$19.1	$20.4	$21.6

Source: Telecom Advisory Services analysis

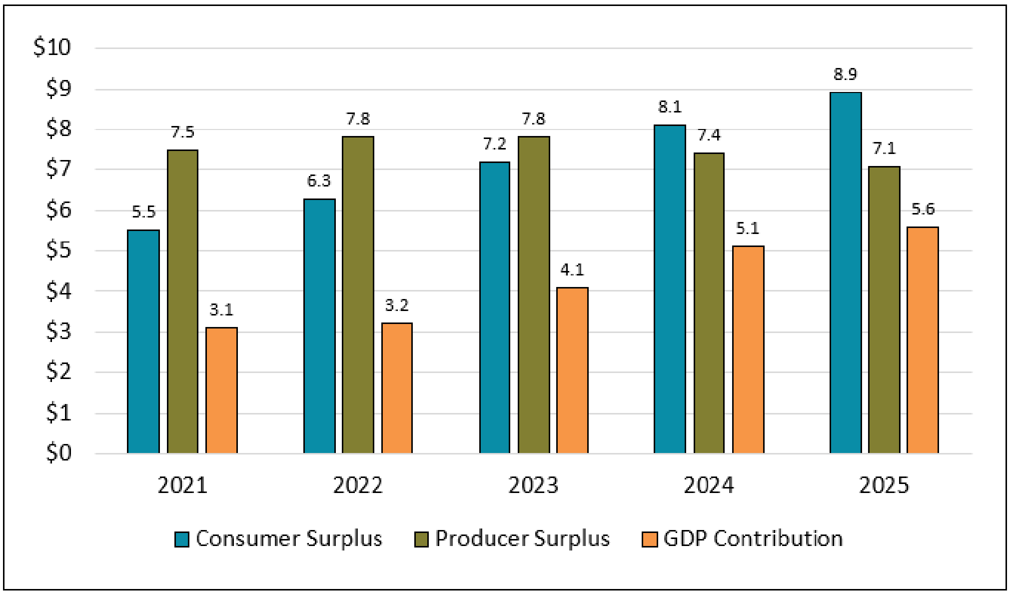
As indicated in Table VIII-1, the primary factor driving the increase in economic contribution is the introduction of Wi-Fi 6 combined with the allocation of 6 GHz spectrum. Assuming that by 2025 only 40 percent of Wi-Fi traffic will rely on 6 GHz spectrum, the accelerated effect derived from the new spectrum allocation and latest Wi-Fi technologies will still be far from reaching its maximum potential at this time. Therefore, if the Polish telecommunications regulatory agencies decides to

[77] In response to a request from the European Commission to investigate spectrum between 5,925 to 6,425 MHz, the CEPT (European Conference of Postal and Telecommunications Administrations) has issued a technical report to the European Commission on the feasibility of Wi-Fi in the 6 GHz band[77]. The report would apply to Poland's spectrum. The non-binding recommendation for investigating only the 5,925 to 6,425 band (500 MHz) is that European countries have critical services in the upper part of the 6 GHz band (i.e. large amount of point to point fixed services, earth to space communications, road intelligent traffic systems and communication-based train control, and some radio astronomy sites).

allocate the upper part of the spectrum to unlicensed use, Wi-Fi economic value would increase significantly beyond the values presented in Table VIII-1.

The primary source of economic value is producer surplus, although its share declines over time as consumer surplus and GDP become more important (see Graphic VIII-1).

Graphic VIII-1. Poland: Total economic value of Wi-Fi (by source) (in $Billions)



Note: Due to rounding, numbers presented in this graphic may not add up precisely to the totals presented above.
Source: Telecom Advisory Services LLC

Wi-Fi's total value benefits all five economic agents, of which residential Wi-Fi is the most important, followed by enterprises (see Table VIII-2).

Table VIII-2. Poland: Total economic value of Wi-Fi (by agent) (in $Billions)

	2021	2022	2023	2024	2025
Free Wi-Fi	$0.2	$0.2	$0.2	$0.2	$0.2
Residential Wi-Fi	$6.5	$7.1	$8.0	$8.7	$9.6
Enterprise Wi-Fi	$4.5	$4.9	$6.0	$7.3	$8.0
Internet Service Providers	$3.4	$3.2	$2.7	$1.5	$0.4
Wi-Fi ecosystem	$1.5	$1.9	$2.2	$2.7	$3.4
Total	$16.1	$17.3	$19.1	$20.4	$21.6

Source: Telecom Advisory Services analysis

The economic value of free Wi-Fi service is a combination of free Wi-Fi used by households that cannot afford broadband service, and speed of Wi-Fi compared to cellular service. The economic value of residential Wi-Fi is significant in terms of the cost savings gained by avoiding inside wiring and wireless device access at home. The most important factor driving the value of Wi-Fi among enterprises (which currently reaches 58.8 percent of total traffic) is savings in wireless telecommunications, followed by the enhanced speed of Wi-Fi access points and the spillover of IoT applications.[78]

According to the contribution to GDP, Wi-Fi will generate approximately 29,500 jobs in Poland in 2021, primarily in the communications sector (15,500), and business services (4,600). Additionally, Wi-Fi is expected to generate 53,000 jobs in 2025.

[78] Detailed analysis is included in the "Theoretical Framework, Methodologies and Detailed Country Assessments for The Economic Value of Wi-Fi: A Global View (2021-2025)" section of this document.

IX. ECONOMIC VALUE OF WI-FI IN THE EUROPEAN UNION

Having estimated Wi-Fi's economic value for four European Union (EU) countries (Germany, France, Spain, and Poland), we can generate a high-level estimation of the economic value for the other countries in the Union to provide a value for the twenty-seven nations.[79] To do so, we rely on the leading indicators methodology, selecting indicators existing for the four reviewed EU countries and the rest of the block, and relying on these indicators to interpolate the economic value of Wi-Fi for the rest of the EU. The two leading indicators selected are:

- Total GDP: the underlying assumption is that there is a direct link between the level of development of a given country and the economic value of Wi-Fi; and
- Human Development Index (constructed by the United Nations Development Program): this indicator introduces a variable that controls for a country's level of urbanization, literacy, and other social factors.

As the Table IX-1 indicates, the four countries under detailed study represent 55 percent of the EU's GDP.

Table IX-1. EU-27: Distribution of GDP (2019)

Groups	GDP ($Million)	Percent
Four countries studied (Germany, France, Spain, Poland)	$8,547,429	54.82%
Rest of European Union	$7,045,366	45.18%
Total EU-27	$15,592,795	100 %

Source: World Bank – World Development Indicators

Based on the initial assumption of a correlation between GDP and economic value, we then calculate a first estimate. We then discount these results by the level of development measured by the UN Human Development Index (HDI). The average EU HDI, normalized by population, is 0.895, while the average for the four countries under study is 0.905, and 0.884 for the remaining countries of the EU (see Table IX-2).

Table IX-2. Human Development Index (2018): Four Countries vs. Rest of EU-27

Groups	HDI
Four countries studied (Germany, France, Spain, Poland)	0.905
Rest of the European Union	0.884
Total EU-27	0.895

Sources: United Nations; Telecom Advisory Services analysis

These values are then used to discount the original GDP-based economic value estimates for the "rest of the European Union". The discount factor is calculated by dividing the "rest of European Union" HDI (0.884) by the four countries under study HDI (0.905). This allows a calculation for the economic value of Wi-Fi for the "rest

[79] The remaining European Union countries includes Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Portugal, Romania, Slovakia, Slovenia, Sweden.

of the European Union." Adding this to the four countries under study, we estimate the economic value for the whole of EU under the baseline scenario (see Table IX-3).

Table IX-3. European Union Wi-Fi Economic Value - Baseline scenario (in $Billions)

Countries	2021				2025			
	Consumer surplus	Producer surplus	GDP Contribution	Total	Consumer surplus	Producer surplus	GDP Contribution	Total
Four countries studied (Germany, France, Spain, Poland)	$104.2	$92.8	$52.4	$249.4	$148.4	$107.6	$62.5	$318.5
Rest of European Union estimation	$83.9	$74.7	$42.2	$200.8	$119.5	$86.7	$50.3	$256.5
Total EU-27	$188.1	$167.5	$94.6	$450.2	$267.9	$194.3	$112.8	$575.0

Source: Telecom Advisory Services

By considering specifically the economic value added by Wi-Fi 6 and the allocation of the 6 GHz band, we follow a similar approach to estimate the figures for the rest of European Union and the whole EU-27 (see Table IX-4).

Table IX-4. European Union Wi-Fi Economic Value Wi-Fi 6 and 6 GHz (in $Billions)

Countries	2021				2025			
	Consumer surplus	Producer surplus	GDP Contribution	Total	Consumer surplus	Producer surplus	GDP Contribution	Total
Four countries studied (Germany, France, Spain, Poland)	$0.4	$2.1	$1.5	$4.1	$8.6	$9.6	$16.2	$34.5
Rest of European Union estimation	$0.4	$1.7	$1.2	$3.3	$7.0	$7.7	$13.0	$27.7
Total EU-27	$0.8	$3.9	$2.8	$7.4	$15.6	$17.4	$29.2	$62.2

Source: Telecom Advisory Services

Finally, to calculate the total economic value of Wi-Fi (from current bands and 6 GHz allocation), we follow a similar approach (see Table IX-5).

Table IX-5. European Union Wi-Fi Economic Value – Total (in $Billions)

Countries	2021				2025			
	Consumer surplus	Producer surplus	GDP Contribution	Total	Consumer surplus	Producer surplus	GDP Contribution	Total
Four countries studied (Germany, France, Spain, Poland)	$104.6	$95.0	$53.9	$253.5	$157.0	$117.3	$78.7	$353.0
Rest of European Union estimation	$84.2	$76.5	$43.4	$204.1	$126.4	$94.4	$63.4	$284.2
Total EU-27	$188.8	$171.5	$97.3	$457.6	$283.4	$211.7	$142.1	$637.2

Source: Telecom Advisory Services

As indicated in Table IX-5, Wi-Fi economic value in the European Union amounts to $457.6 billion in 2021, reaching $637.2 in 2025. If the European telecommunications regulatory agencies decide to allocate the upper part of the spectrum to unlicensed use, Wi-Fi economic value would increase significantly beyond the values presented in Table IX-5.

The estimated contribution to GDP for the "rest of European Union" allows us to calculate Wi-Fi's impact on job creation. According to these estimates, the total annual employment generated for the rest of EU has been estimated in Table IX-6.

Table IX-6. Rest of European Union: Wi-Fi generated Annual Employment

Variable	2021			2025		
	Current bands	6 GHz	Total	Current bands	6 GHz	Total
Direct jobs	79,980	2,264	82,245	88,167	32,321	120,488
Indirect jobs	50,940	1,461	52,401	58,187	19,934	78,121
Induced jobs	17,843	505	18,348	19,243	8,045	27,287
Total	148,763	4,230	152,994	165,595	60,299	225,895

Source: Telecom Advisory Services analysis

Adding the four countries studied in detail and the "rest of European Union", Wi-Fi is estimated to contribute 343,000 jobs to the EU market in 2021; by 2025 Wi-Fi will generate 506,000 jobs for the whole economic area (see Table IX-7).

Table IX-7. EU-27: Wi-Fi generated Annual Employment

Variable	2021			2025		
	Four countries studied	Rest of EU	Total EU-27	Four countries studied	Rest of EU	Total EU-27
Direct jobs	102,150	82,245	184,395	149649	120,488	270,137
Indirect jobs	65,083	52,401	117,484	97,028	78,121	175,149
Induced jobs	22,789	18,348	41,137	33,891	27,287	61,178
Total	190,021	152,994	343,016	280,566	225,895	506,465

Source: Telecom Advisory Services analysis

X. ECONOMIC VALUE OF WI-FI IN JAPAN

Wi-Fi has become a significant component of Japan's telecommunications infrastructure. According to the Cisco Annual Internet Report Highlights Tool 2018-2023, there were 400,000 paid Wi-Fi access points operating in the Japanese territory in 2018,[80] while Wiman currently reports the activity of 1,230,000 free Wi-Fi sites in the country.[81] Additionally, 90 percent of Japanese households with broadband are equipped with a Wi-Fi access point.

Given the density of Wi-Fi access points, hotspots have become a very important connectivity feature. According to Opensignal[82], before the outbreak of COVID-19, Japanese smartphone users spent 62.1 percent of their communications time connected to Wi-Fi networks rather than relying on a cellular data connection. That percentage remained fairly stable through March 2020. The increasing importance of Wi-Fi in the digital infrastructure should result in a significant social and economic contribution. This chapter presents a summary of the economic assessment results. The detailed calculations of each source of value are included in "Theoretical Framework, Methodologies and Detailed Country Assessments for The Economic Value of Wi-Fi: A Global View (2021-2025)" starting on page 83.

In the 2018 study of the economic value of Wi-Fi[83], its economic value in Japan was estimated to reach $213.7 billion in 2021. An update of this study accounting for deployment changes indicates a 14.6 percent increase in value. Before considering the additional effect of the potential allocation of 1,200 MHz in the 6 GHz spectrum band for unlicensed use, the total economic value of Wi-Fi in Japan in 2021 will amount to $245.7 billion. The increase of $32.0 billion in the baseline scenario is due to the development of four new sources of economic value:

- The contribution of Wi-Fi technology to improving broadband speed;
- A substantial boost to deployment of IoT technology; and
- The growing adoption of AR/VR technology use cases.

Even before accounting for the accelerating effect of allocating the 6 GHz band, the 2025 economic value forecast will reach $296.2 billion, comprised of $143.6 billion in consumer surplus, $110.7 billion in producer surplus, and $41.9 billion in GDP contribution. In addition to the value generated from the unlicensed use of the 2.4 GHz and 5 GHz bands (referred to as the baseline scenario), the allocation of the 6 GHz spectrum band for unlicensed use and the deployment of Wi-Fi 6 and Wi-Fi 6E devices will trigger an additional boost in economic value, reaching $28.7 billion in

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[80] Cisco reports 12.4 million hotspots in 2018, of which 12.0 million are homespots. (Retrieved in: https://www.cisco.com/c/dam/m/en_us/solutions/executive-perspectives/vni-forecast-highlights/total/pdf/Japan_Network_Performance.pdf

[81] Of this installed base of Wi-Fi hotspots in Japan, 485,000 are deployed in Tokyo, 238,000 in Yokohama, and 132,000 in Osaka (Retrieved in: https://www.wiman.me/japan November 17 2020).

[82] Khatri, H. and Fenwick, S. (2020). "Analyzing mobile experience during the coronavirus pandemic: Time on Wi-Fi". *Opensignal* (March 30).

[83] Katz, R. and Callorda, F. (2018). *The Economic value of Wi-Fi: A Global View (2018 and 2023)*. New York: Telecom Advisory Services. October.

2025. By combining the baseline and the Wi-Fi 6 and 6 GHz scenarios, the overall economic value of Wi-Fi in Japan will reach $324.9 billion in 2025. Considering that only 40 percent of Wi-Fi traffic is anticipated to rely on the 6 GHz spectrum by 2025, the accelerating effect derived from the new spectrum allocation and latest Wi-Fi technologies will still be far from reaching its maximum potential at this time (see Table X-1).

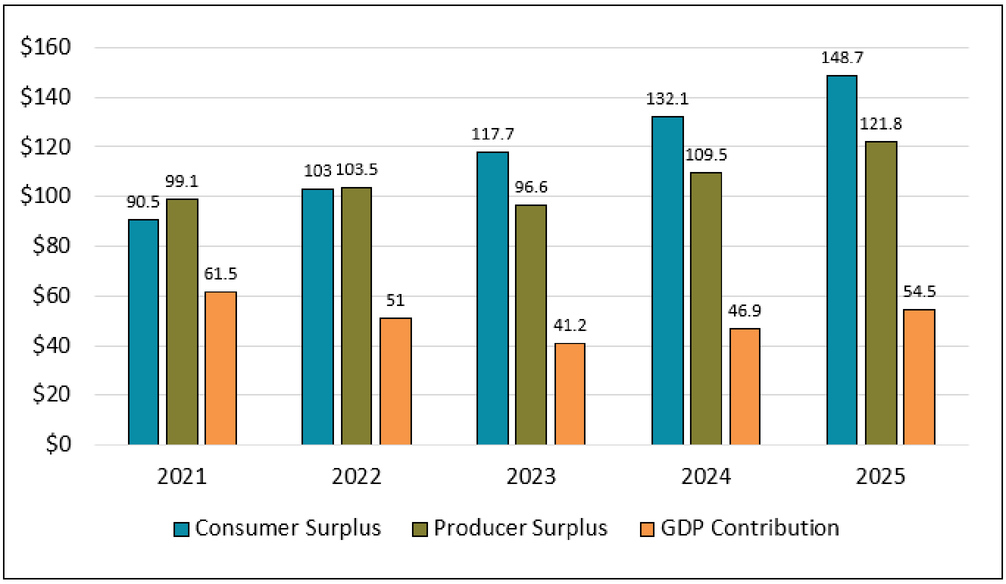
Table X-1. Japan: Total economic value of Wi-Fi (in $Billions)

	2021	2022	2023	2024	2025
Baseline Scenario	$245.7	$246.5	$240.5	$267.5	$296.2
Wi-Fi 6 / 6 GHz Scenario	$5.4	$10.9	$15.0	$21.0	$28.7
Total	$251.1	$257.4	$255.5	$288.5	$324.9

Source: Telecom Advisory Services analysis

After 2022, the primary source of economic value is consumer surplus, followed by producer surplus, and GDP (see Graphic X-1).

Graphic X-1. Japan: Total economic value of Wi-Fi (by source) (in $Billions)



Note: Due to rounding, numbers presented in this graphic may not add up precisely to the totals presented above.
Source: Telecom Advisory Services LLC

This total value benefits five economic agents, of which residential Wi-Fi is the most important, followed by enterprises (see Table X-2).

Table X-2. Japan: Total economic value of Wi-Fi (by agent) (in $Billions)

	2021	2022	2023	2024	2025
Free Wi-Fi	$1.1	$1.2	$1.2	$1.2	$1.2
Residential Wi-Fi	$89.6	$102.0	$116.7	$131.2	$147.7
Enterprise Wi-Fi	$99.2	$91.9	$85.8	$95.7	$108.2
Internet Service Providers	$37.8	$34.5	$18.1	$20.2	$19.4
Wi-Fi ecosystem	$23.4	$27.8	$33.7	$40.2	$48.4
Total	$251.1	$257.4	$255.5	$288.5	$324.9

Source: Telecom Advisory Services analysis

The economic value of residential Wi-Fi is significant in terms of the cost savings gained by avoiding inside wiring and wireless device access at home. The most important factor driving the value of Wi-Fi among enterprises is the spillover of IoT applications, savings in wireless telecommunications, which currently reaches 56 percent of total business traffic, followed by savings in inside wiring, and the enhanced speed of Wi-Fi access points.[84]

According to the contribution to GDP, Wi-Fi will generate approximately 285,000 jobs in Japan in 2021, primarily in the communications sector (192,000), business services (22,000) and manufacturing (15,000).

[84] Detailed analysis is included in the "Theoretical Framework, Methodologies and Detailed Country Assessments for The Economic Value of Wi-Fi: A Global View (2021-2025)" section of this document.

XI. ECONOMIC VALUE OF WI-FI IN SOUTH KOREA

As in all the cases of advanced economies, Wi-Fi has become a pervasive feature in South Korea's telecommunications landscape. According to the Cisco Annual Internet Report Highlights Tool 2018-2023, there were 400,000 paid Wi-Fi access points operating in the South Korean territory in 2018,[85] while Wiman estimates that there are currently 1,037,000 open hotspots in the country.[86] In addition, 90 percent of all South Korean homes with broadband are equipped with Wi-Fi access points.

Given the density of Wi-Fi access points, hotspots have become a very important connectivity feature. According to Opensignal[87], after the outbreak of COVID-19 South Korea wireless users spent 57.9 percent of their communications time connected to Wi-Fi networks, rather than relying on their cellular data connection. This value increased from 54.4 percent before the disruption of the pandemic.

The increasing importance of Wi-Fi technology in the digital ecosystem should have a significant social and economic contribution. This chapter presents a summary of the results of the economic assessment. The detailed calculations of each source of value are included in "Theoretical Framework, Methodologies and Detailed Country Assessments for The Economic Value of Wi-Fi: A Global View (2021-2025)" section starting on page 83.

In the 2018 Economic Value of Wi-Fi[88], the estimated economic value of Wi-Fi in South Korea was $103.52 billion for 2021. MSIT recently decided to approve the use of 1,200 MHz of spectrum in the 6GHz band, which will provide an additional boost to Wi-Fi's economic value.[89] Before considering the additional effect of Wi-Fi 6 and allocating the 6 GHz spectrum band for unlicensed use, the projected total economic value of Wi-Fi in South Korea for 2021 contracted to $87.2 billion. The decline in value between the 2018 study and the current update is mainly due to a faster-than-expected decline in local cellular prices. As a result, the economic benefits consumers experience when using Wi-Fi at home, as well as free Wi-Fi, have reduced considerably with respect to previous estimates. The decline in cellular prices has also reduced the producer surplus derived from business Internet traffic transmitted through Wi-Fi.

In the current update we have not assumed Wi-Fi triggered savings from off-loading cellular traffic, since by 2021 the country is expected to reach 97 percent of 5G coverage. Therefore, those savings will materialize before the time frame of the

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[85] Cisco reported that in 2018 there were 8.1 million hotspots in South Korea, of which homespots reached 7.7 million (Retrieved in: https://www.cisco.com/c/dam/m/en_us/solutions/executive-perspectives/vni-forecast-highlights/total/pdf/Korea_Network_Performance.pdf

[86] Of this installed base of Wi-Fi hotspots in South Korea, 603,000 are deployed in Seoul, 276,000 in Incheon, and 101,000 in Busan (Retrieved in: https://www.wiman.me/south-korea November 17, 2020).

[87] Khatri, H. and Fenwick, S. (2020). "Analyzing mobile experience during the coronavirus pandemic: Time on Wi-Fi". *Opensignal* (March 30).

[88] Katz, R. and Callorda, F. (2018). *The Economic value of Wi-Fi: A Global View (2018 and 2023)*. New York: Telecom Advisory Services. October.

[89] Cho Mu-Hyun (2020). "South Korea makes 6 GHz band available for Wi-Fi", *ZDNet* (October 16).

current study. Before accounting for Wi-Fi 6 and the accelerating effect resulting from the allocation of the entire 6 GHz band, the baseline forecast of economic value is expected to reach $126.1 billion in 2025.

That said, Wi-Fi will add value with the addition of the 6 GHz spectrum band for unlicensed use and the deployment of Wi-Fi 6 and Wi-Fi 6E devices. These will trigger an additional boost in economic value, reaching $13.4 billion in 2025. Considering that only 40 percent of Wi-Fi traffic is anticipated to rely on the 6 GHz channels by 2025, the accelerating effect derived from the new spectrum allocation and latest Wi-Fi technologies will still be far from reaching its maximum potential at this time. By combining the baseline and the Wi-Fi 6 and 6 GHz scenarios, the overall economic value of Wi-Fi for South Korea will yield $139.5 billion in 2025 (see Table XI-1).

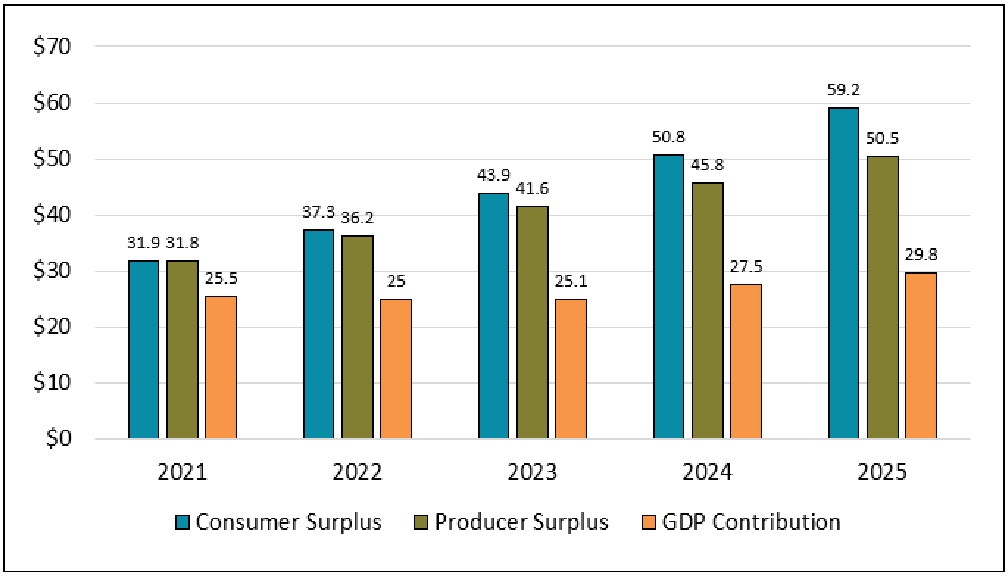
Table XI-1. South Korea: Total economic value of Wi-Fi (in $Billions)

	2021	2022	2023	2024	2025
Baseline Scenario	$87.2	$93.4	$102.6	$113.5	$126.1
Wi-Fi 6 / 6 GHz Scenario	$2.1	$5.1	$7.9	$10.6	$13.4
Total	$89.3	$98.5	$110.5	$124.1	$139.5

Source: Telecom Advisory Services analysis

As indicated in Table XI-1, the Wi-Fi 6 and 6 GHz spectrum allocation will compensate for the decline in value that has occurred in the use of the 2.4 GHz and 5 GHz bands. After 2022, the primary source of economic value will be consumer surplus, followed by producer surplus, and GDP contribution (see Graphic XI-1).

Graphic XI-1. South Korea: Total economic value of Wi-Fi (by Source) (in $Billions)



Note: Due to rounding, numbers presented in this graphic may not add up precisely to the totals presented above.
Source: Telecom Advisory Services LLC

This total value benefits five economic agents, of which residential Wi-Fi is the most important after 2024, followed by enterprises (see Table XI-2).

Table XI-2. South Korea: Total economic value of Wi-Fi (by Agent) (in $Billions)

	2021	2022	2023	2024	2025
Free Wi-Fi	$0.7	$0.7	$0.6	$0.6	$0.6
Residential Wi-Fi	$31.3	$36.8	$43.3	$50.3	$58.7
Enterprise Wi-Fi	$41.6	$43.0	$44.9	$49.3	$54.0
Internet Service Providers	$0.6	$0.6	$0.6	$0.6	$0.6
Wi-Fi ecosystem	$15.1	$17.4	$21.1	$23.3	$25.6
Total	$89.3	$98.5	$110.5	$124.1	$139.5

Source: Telecom Advisory Services analysis

The economic value of residential Wi-Fi is significant in terms of the cost savings gained by avoiding inside wiring and wireless device access at home. The most important factor driving the value of Wi-Fi among enterprises is the spillover of IoT applications, savings in wireless telecommunications (which currently reaches 52 percent of total business traffic), followed by savings in inside wiring, and the enhanced speed of Wi-Fi access points.[90]

According to the contribution to GDP, Wi-Fi will generate approximately 188,000 jobs in South Korea in 2021, primarily in the communications sector (112,000), trade (32,000) and business services (20,000). In 2025, Wi-Fi will contribute to the creation of 220,000 jobs.

[90] Detailed analysis is included in the "Theoretical Framework, Methodologies and Detailed Country Assessments for The Economic Value of Wi-Fi: A Global View (2021-2025)" section of this document.

XII. ECONOMIC VALUE OF WI-FI IN SINGAPORE

Wi-Fi has become a critical component of Singapore's telecommunications infrastructure. According to an interpolation from the Cisco Annual Internet Report Highlights Tool 2018-2023 for the rest of Asia-Pacific, there were 60,000 public Wi-Fi access points operating in the city-state in 2018. Given the density of Wi-Fi access points, hotspots have become a very important connectivity infrastructure. According to Opensignal[91], after the outbreak of COVID-19 Singapore wireless users spent 55.5 percent of their communications time connected to Wi-Fi networks rather than relying on their cellular data connection in the third week of March 2020. This percentage increased from 52.4 percent in January of the same year.

The increasing importance of Wi-Fi technology in the digital ecosystem should have a significant social and economic contribution. This chapter presents a summary of the results of the economic assessment. The detailed calculations of each source of value are included in "Theoretical Framework, Methodologies and Detailed Country Assessments for The Economic Value of Wi-Fi: A Global View (2021-2025)" starting on page 83.

Before considering the additional effect of Wi-Fi 6 and the potential allocation the 6 GHz spectrum band for unlicensed use, the baseline economic value of Wi-Fi in Singapore in 2021 will amount to $10.4 billion. Likewise, before accounting for the accelerating effect of Wi-Fi 6 and the allocation of the 6 GHz band, the 2025 forecast of economic value will remain stable at $10.4 billion, with a temporary decline in the intervening years.

In addition to the value generated from the baseline scenario (unlicensed use of the 2.4 GHz and 5 GHz bands), the allocation of the 6 GHz spectrum band for unlicensed use and the deployment of Wi-Fi 6 and Wi-Fi 6E devices will trigger a boost in the technology's economic value, reaching $2 billion in 2025. Considering that by 2025 only 40 percent of Wi-Fi traffic will rely on the 6 GHz channels, the accelerating effect of the new spectrum allocation and latest Wi-Fi devices will still be far from reaching its maximum potential at this time. By combining the baseline and the Wi-Fi 6 and 6 GHz scenarios, the overall economic value of Wi-Fi for Singapore will yield $12.4 billion in 2025 (see Table XII-1).

Table XII-1. Singapore: Total economic value of Wi-Fi (in $Billions)

	2021	2022	2023	2024	2025
Baseline Scenario	$10.4	$7.2	$8.3	$9.4	$10.4
Wi-Fi 6 / 6 GHz Scenario	$0.2	$0.5	$0.9	$1.4	$2.0
Total	$10.6	$7.7	$9.2	$10.8	$12.4

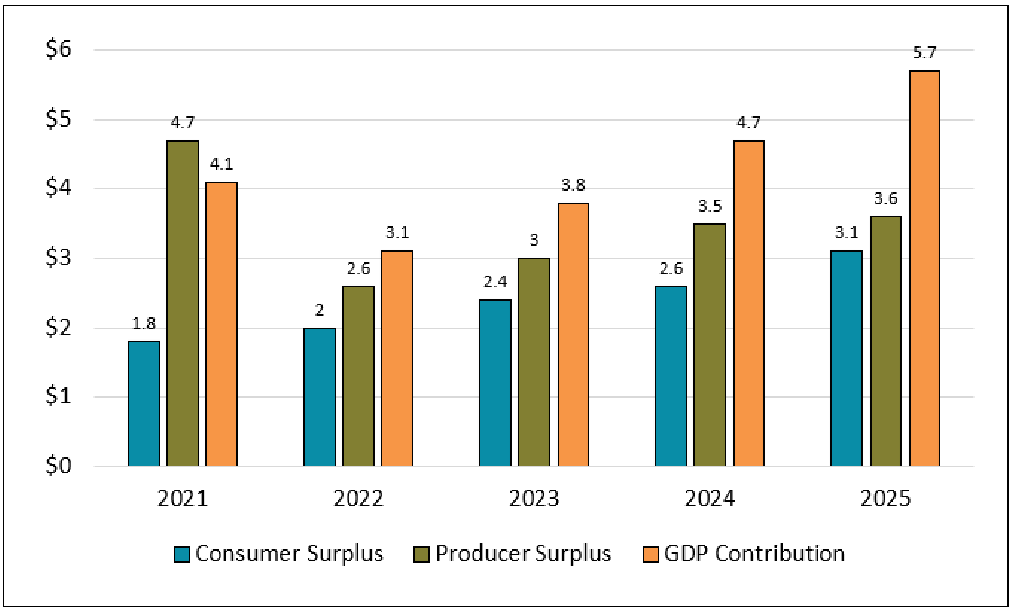
Source: Telecom Advisory Services analysis

While the total value fluctuates in the intervening years, the overall impact when considering the effect of the allocation of the 6 GHz spectrum is positive.

After 2022, the primary source of economic value is GDP, followed by producer surplus and GDP contribution (see Graphic XII-1).

[91] Khatri, H. and Fenwick, S. (2020). "Analyzing mobile experience during the coronavirus pandemic: Time on Wi-Fi". *Opensignal* (March 30).

Graphic XII-1. Singapore: Total economic value of Wi-Fi (by source) (in $Billions)



Note: Due to rounding, numbers presented in this graphic may not add up precisely to the totals presented above.
Source: Telecom Advisory Services LLC

This total value benefits five economic agents, of which enterprise Wi-Fi is the most important, followed by residential use (see Table XII-2).

Table XII-2. Singapore: Total economic value of Wi-Fi (by agent) (in $Billions)

	2021	2022	2023	2024	2025
Free Wi-Fi	$0.0	$0.0	$0.0	$0.0	$0.0
Residential Wi-Fi	$1.8	$2.1	$2.4	$2.7	$3.1
Enterprise Wi-Fi	$5.4	$4.4	$5.1	$6.1	$7.1
Internet Service Providers	$2.6	$0.2	$0.5	$0.5	$0.4
Wi-Fi ecosystem	$0.8	$1.0	$1.2	$1.5	$1.8
Total	$10.6	$7.7	$9.2	$10.8	$12.4

Source: Telecom Advisory Services analysis

The most important factor driving the value of Wi-Fi among enterprises is the spillover of IoT applications, savings in wireless telecommunications (which currently reaches 54.6 percent of total business traffic), followed by the enhanced speed of Wi-Fi access points and savings on inside wiring. . The economic value of IoT spillover in the enterprise Wi-Fi segment is a clear demonstration of the technology's contribution to one of Singapore's dominant sources of competitiveness: the logistics industry.[92]Due to its contribution to GDP, Wi-Fi will generate approximately 13,300 jobs in Singapore in 2021, primarily in the communications sector (9,400), and business services (1,300). In 2025, Wi-Fi technology will contribute to the creation of 18,000 jobs.

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[92] Detailed analysis is included in the "Theoretical Framework, Methodologies and Detailed Country Assessments for The Economic Value of Wi-Fi: A Global View (2021-2025)" section of this document.

XIII. ECONOMIC VALUE OF WI-FI IN AUSTRALIA

Wi-Fi technology has become a critical component in Australia's telecommunications infrastructure. According to the Cisco Annual Internet Report Highlights Tool 2018-2023, there were 100,000 public Wi-Fi access points operating in the Australian territory in 2018, while the Wiman site estimates that there are currently 673,000 free hotspots in the country.[93] Additionally, 90 percent of Australian households with broadband have installed a Wi-Fi access point.

Given the density of Wi-Fi access points, hotspots have become a very important connectivity feature. According to Opensignal[94], Australian wireless users currently spend 52.4 percent of their communications time connected to Wi-Fi networks rather than relying on their cellular data connection. This percentage has remained fairly stable during the outbreak of COVID-19.

The increasing importance of Wi-Fi technology in the digital ecosystem should have a significant social and economic contribution. This chapter presents a summary of the results of the economic assessment. The detailed calculations of each source of value are included in "Theoretical Framework, Methodologies and Detailed Country Assessments for The Economic Value of Wi-Fi: A Global View (2021-2025)" starting on page 83.

Before considering the additional effect of Wi-Fi 6 and the potential 6 GHz spectrum band for unlicensed use, the baseline economic value of Wi-Fi in Australia in 2021 will amount to $34.1 billion. Likewise, the 2025 baseline forecast of economic value will reach $36.3 billion.

In addition to the value generated from the unlicensed use of the 2.4 GHz and 5 GHz bands, the allocation of the 6 GHz spectrum band for Wi-Fi and the deployment of Wi-Fi 6 and Wi-Fi 6E devices will trigger a boost in economic value, reaching $5.4 billion in 2025. Considering that by 2025 only 40 percent of Wi-Fi traffic will rely on the 6 GHz channels, the accelerating effect of the new spectrum allocation and latest Wi-Fi technologies will still be far from reaching its maximum potential at this time. By combining the baseline and the Wi-Fi 6 and 6 GHz scenarios, the overall economic value of Wi-Fi for Australia will yield $41.7 billion in 2025 (see Table XIII-1).

Table XIII-1. Australia: Total economic value of Wi-Fi (in $Billions)

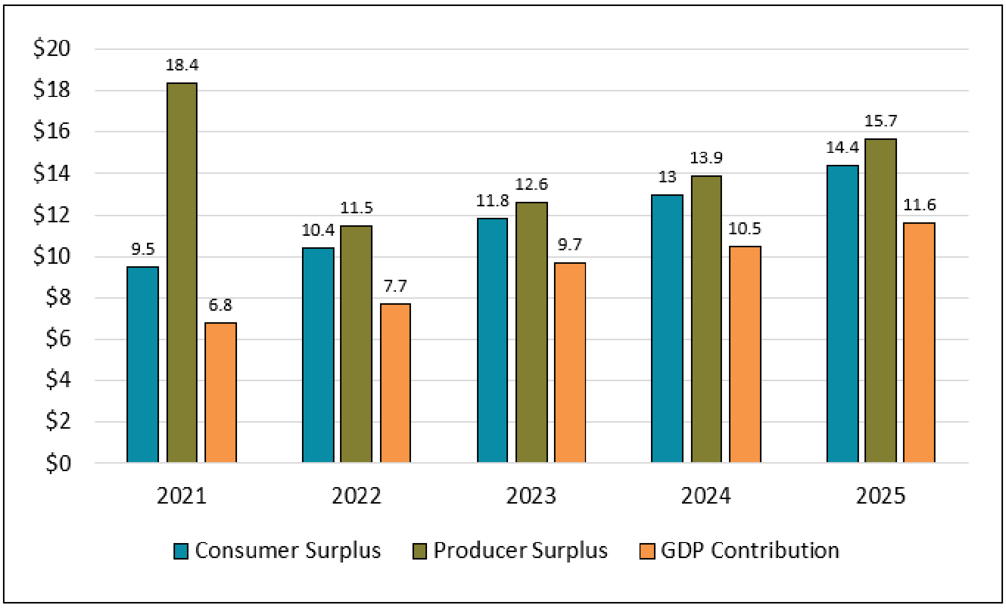
	2021	2022	2023	2024	2025
Baseline Scenario	$34.1	$28.0	$31.1	$33.3	$36.3
Wi-Fi 6 / 6 GHz Scenario	$0.6	$1.6	$2.9	$4.1	$5.4
Total	$34.7	$29.6	$34.0	$37.4	$41.7

Source: Telecom Advisory Services analysis

[93] Of this installed base of Wi-Fi hotspots in Australia, 36,000 are deployed in Sydney, 50,000 in Melbourne, 17,000 in Adelaide, and 15,000 in Perth (Retrieved in https://www.wiman.me/australia, November 17, 2020).
[94] Khatri, H. and Fenwick, S. (2020). "Analyzing mobile experience during the coronavirus pandemic: Time on Wi-Fi". *Opensignal* (March 30).

The primary source of economic value is producer surplus, although after 2022 the sources of surplus value creation are fairly balanced (see Graphic XIII-1).

Graphic XIII-1. Australia: Total economic value of Wi-Fi (by source) (in $Billions)



Note: Due to rounding, numbers presented in this graphic may not add up precisely to the totals presented above.
Source: Telecom Advisory Services LLC

This total value of Wi-Fi benefits five economic agents, of which consumer use of residential Wi-Fi is the most important, closely followed by enterprise use (see Table XIII-2).

Table XIII-2. Australia: Total Economic Value of Wi-Fi (by agent) (in $Billions)

	2021	2022	2023	2024	2025
Free Wi-Fi	$1.7	$1.9	$2.1	$2.3	$2.4
Residential Wi-Fi	$11.6	$12.6	$14.0	$15.1	$16.6
Enterprise Wi-Fi	$10.3	$11.3	$13.4	$14.4	$15.7
Internet Service Providers	$8.3	$0.4	$0.4	$0.4	$0.4
Wi-Fi ecosystem	$2.8	$3.4	$4.1	$5.2	$6.6
Total	$34.7	$29.6	$34.0	$37.4	$41.7

Source: Telecom Advisory Services analysis

The most important factor driving the value of Wi-Fi among consumer residential use is the cost savings gained by avoiding inside wiring and wireless device access at home. In the case of enterprise Wi-Fi, the highest source of value creation is the reduction of inside wiring costs: nearly half, or $5.5 billion, of the 10.3 billion value in 2021 is brought by reduction in wiring for networks. This is followed by spillover of IoT applications ($2.3 billion in 2021), and savings on wireless telecommunications ($1.9 billion). According to the contribution to GDP, Wi-Fi will generate approximately 22,000 jobs in Australia in 2021, primarily in the communications sector (8,000), and business services (6,600). In 2025, Wi-Fi will generate 37,800 jobs.

XIV. ECONOMIC VALUE OF WI-FI IN NEW ZEALAND

Wi-Fi has become a pervasive feature in New Zealand's telecommunications landscape. Wiman estimates that there are currently 153,000 open hotspots in the country.[95] In addition, 90 percent of households with broadband are estimated to be equipped with a Wi-Fi access point. The increasing importance of Wi-Fi technology in the digital ecosystem of New Zealand should result in a significant social and economic contribution. This chapter presents a summary of the results of the economic assessment. The detailed calculations of each source of value are included in "Theoretical Framework, Methodologies and Detailed Country Assessments for The Economic Value of Wi-Fi: A Global View (2021-2025)" starting on page 83.

Before considering the additional effect of Wi-Fi 6 and the potential allocation of the 6 GHz spectrum band for unlicensed use, the total economic value of Wi-Fi in New Zealand in 2021 will amount to $6.6 billion. Similarly, before accounting for Wi-Fi 6 and the 6 GHz band, the 2025 forecast of economic value will reach $8.8 billion.

Adding to the baseline value generated from the unlicensed use of the 2.4 GHz and 5 GHz bands, the allocation of the 6 GHz spectrum band for unlicensed use and the deployment of Wi-Fi 6 and Wi-Fi 6E devices will trigger an additional boost in economic value, reaching $1 billion in 2025. Considering that by 2025 only 40 percent of Wi-Fi traffic will rely on the 6 GHz channels, the accelerating effect of the new spectrum allocation and latest Wi-Fi technologies will still be far from reaching its maximum potential at this time. By combining the baseline and the Wi-Fi 6 and 6 GHz scenarios, the overall economic value of Wi-Fi for New Zealand will yield $9.8 billion in 2025 (see Table XIV-1).

Table XIV-1. New Zealand: Total economic value of Wi-Fi (in $Billions)

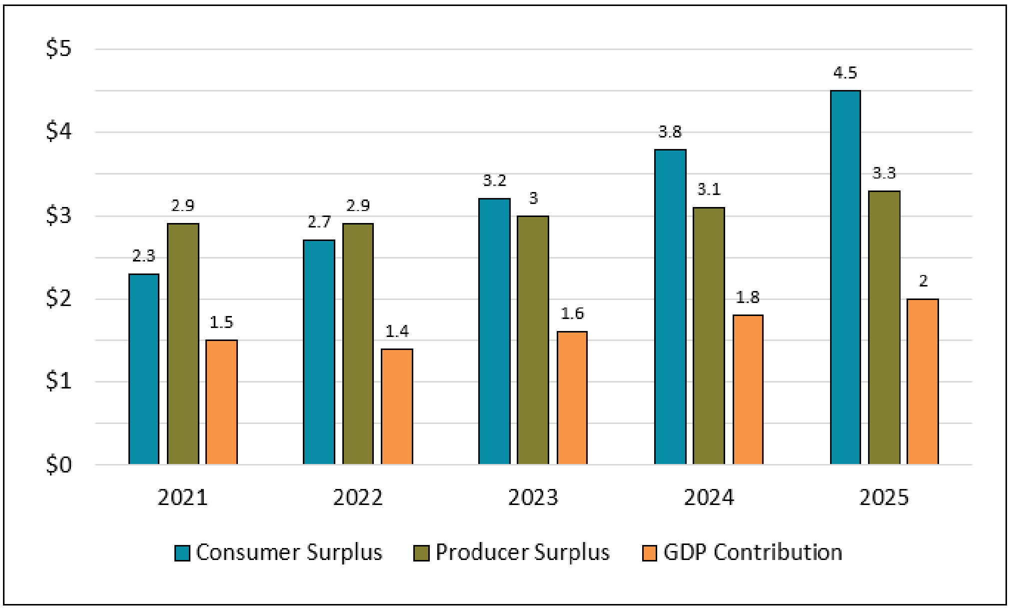
	2021	2022	2023	2024	2025
Baseline Scenario	$6.6	$6.7	$7.3	$8.0	$8.8
Wi-Fi 6 / 6 GHz Scenario	$0.1	$0.3	$0.5	$0.7	$1.0
Total	$6.7	$7.0	$7.8	$8.7	$9.8

Source: Telecom Advisory Services analysis

Beginning in 2023, the primary source of economic value is consumer surplus, followed by producer surplus and GDP contribution (see Graphic XIV-1).

[95] Of this installed base of Wi-Fi hotspots in New Zealand, 37,000 are deployed in Auckland, 22,000 in Wellington, and 26,000 in North Shore (Retrieved in: https://www.wiman.me/new-zealand, November 17, 2020).

Graphic XIV-1. New Zealand: Total economic value of Wi-Fi (by source) (in $Billions)



Note: Due to rounding, numbers presented in this graphic may not add up precisely to the totals presented above.
Source: Telecom Advisory Services LLC

This total value of Wi-Fi in New Zealand benefits five economic agents, of which consumer use of residential Wi-Fi is the most important, closely followed by enterprise use (see Table XIV-2).

Table XIV-2. New Zealand: Total economic value of Wi-Fi (by agent) (in $Billions)

	2021	2022	2023	2024	2025
Free Wi-Fi	$0.3	$0.3	$0.3	$0.3	$0.3
Residential Wi-Fi	$2.7	$3.2	$3.8	$4.4	$5.1
Enterprise Wi-Fi	$2.5	$2.4	$2.6	$2.9	$3.1
Internet Service Providers	$0.8	$0.6	$0.5	$0.3	$0.3
Wi-Fi ecosystem	$0.4	$0.5	$0.6	$0.8	$1.0
Total	$6.7	$7.0	$7.8	$8.7	$9.8

Source: Telecom Advisory Services analysis

The most important factor driving the value of Wi-Fi among consumer residential use is the cost savings gained by avoiding inside wiring and wireless device access at home. In the case of residential use, connectivity and access of wireless devices accounts. In the case of enterprises, the highest source of value creation is the savings on inside wiring costs followed by savings in telecommunications cost since 71 percent of telecommunications traffic is transported through Wi-Fi networks, and spillover of IoT applications.[96]

[96] Detailed analysis is included in the "Theoretical Framework, Methodologies and Detailed Country Assessments for The Economic Value of Wi-Fi: A Global View (2021-2025)" section of this document.

According to its contribution to GDP, Wi-Fi will generate approximately 3,500 jobs in New Zealand in 2021, primarily in the communications sector (1,300), and business services (1,000). In 2025, Wi-Fi will generate 4,700 jobs.

XV. ECONOMIC VALUE OF WI-FI IN BRAZIL

Wi-Fi has become a critical component of Brazil's telecommunications infrastructure. According to an interpolation of the Cisco Annual Internet Report Highlights Tool 2018-2023, there were approximately 8,800,000 public Wi-Fi access points operating in the country in 2020.[97] Public Wi-Fi sites represent a cost-advantaged approach for consumers with limited affordability to acquire broadband service.

Given the Wi-Fi access point density, hotspots have become a very important connectivity feature. According to Opensignal[98], after the outbreak of COVID-19, Brazilian wireless users spent 70.1 percent of their communications time connected to Wi-Fi networks rather than relying on their cellular data connection. This percent increased from 66.0 percent in January of 2020.

The growing importance of Wi-Fi technology in the digital ecosystem results in a significant social and economic impact. This chapter presents a summary of the results of the economic assessment. The detailed calculations of each source of value are included in "Theoretical Framework, Methodologies and Detailed Country Assessments for The Economic Value of Wi-Fi: A Global View (2021-2025)" starting on page 83.

The total economic value of Wi-Fi in Brazil in 2021 is estimated at $102.5 billion, before accounting for the accelerating effect resulting from Wi-Fi 6 and the allocation of 1,200 MHz in the 6 GHz band under consideration by the telecommunications regulatory agency. Under the current spectrum allocation (baseline scenario), the 2025 forecast of economic value will reach $109.6 billion.

In addition to the value generated from the baseline scenario involving unlicensed use of the 2.4 GHz and 5 GHz bands, the allocation of 1,200 MHz in the 6 GHz spectrum band for Wi-Fi use and the deployment of Wi-Fi 6 and Wi-Fi 6E devices will trigger an additional boost in economic value, reaching $14.7 billion in 2025. The constant increase in the value of Wi-Fi driven by 6 GHz cancels out the temporary decline in value between 2023 and 2025 that takes place in the baseline scenario. Considering that by 2025, only 37.5 percent of Wi-Fi traffic will rely on the 6 GHz channels, the accelerating effect derived from the new spectrum allocation and latest Wi-Fi technologies will still be far from reaching its maximum potential at this time.

By combining the baseline and the Wi-Fi 6 and 6 GHz scenarios, the overall economic value of Wi-Fi for Brazil will yield $124.3 billion in 2025 (see Table XV-1).

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[97] The Cisco Annual Internet Report Highlights Tool 2018-2023 states that "Brazil, total public Wi-Fi hotspots (including homespots) will grow 5-fold from 2018 to 2023 from 4.6 million in 2018 to 23.8 million by 2023." https://www.cisco.com/c/dam/m/en_us/solutions/executive-perspectives/vni-forecast-highlights/total/pdf/Brazil_Network_Performance.pdf

[98] Khatri, H. and Fenwick, S. (2020). "Analyzing mobile experience during the coronavirus pandemic: Time on Wi-Fi". *Opensignal* (March 30).

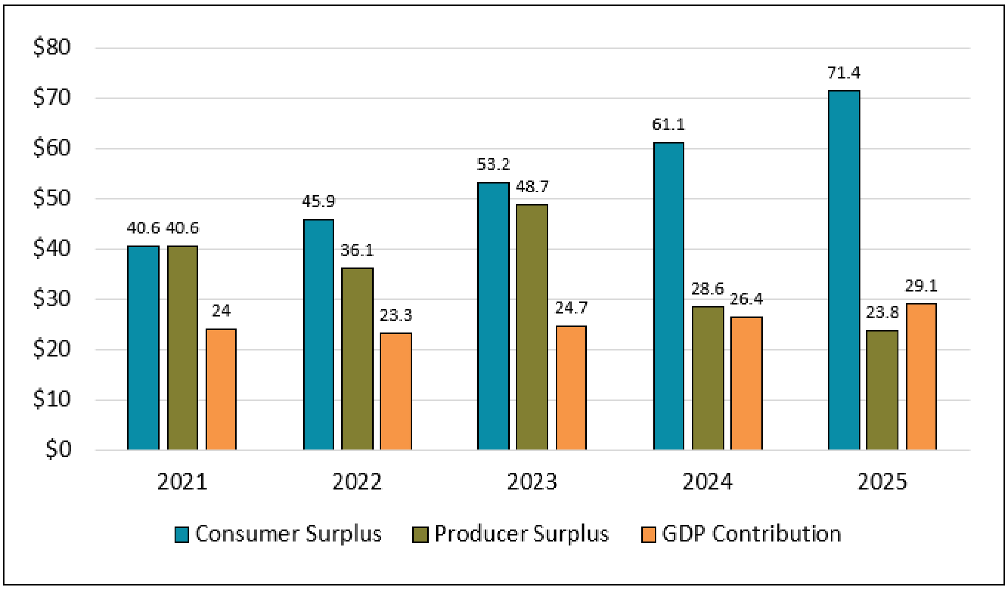
Table XV-1. Brazil: Total economic value of Wi-Fi (in $Billions)

	2021	2022	2023	2024	2025
Baseline Scenario	$102.5	$100.7	$117.8	$104.6	$109.6
Wi-Fi 6 / 6 GHz Scenario	$2.7	$4.6	$8.8	$11.5	$14.7
Total	$105.2	$105.3	$126.6	$116.1	$124.3

Source: Telecom Advisory Services analysis

After 2022, the primary source of economic value is consumer surplus, followed by producer surplus and GDP contribution (see Graphic XV-1).

Graphic XV-1. Brazil: Total economic value of Wi-Fi (by source) (in $Billions)



Note: Due to rounding, numbers presented in this graphic may not add up precisely to the totals presented above.
Source: Telecom Advisory Services LLC

This total value benefits five economic agents, of which residential Wi-Fi is the most important, closely followed by enterprise use (see Table XV-2).

Table XV-2. Brazil: Total economic value of Wi-Fi (by agent) (in $Billions)

	2021	2022	2023	2024	2025
Free Wi-Fi	$2.3	$2.4	$2.6	$2.9	$3.2
Residential Wi-Fi	$41.5	$46.9	$54.2	$62.4	$72.7
Enterprise Wi-Fi	$34.2	$33.2	$34.4	$35.7	$38.2
Internet Service Providers	$22.5	$17.4	$28.9	$7.7	$1.8
Wi-Fi ecosystem	$4.7	$5.4	$6.5	$7.4	$8.4
Total	$105.2	$105.3	$126.6	$116.1	$124.3

Source: Telecom Advisory Services analysis

The most important factor driving the value of Wi-Fi among consumer residential use is the cost savings gained by avoiding inside wiring and wireless device access at home. In the case of residential use, the economic value of connectivity and wireless devices access is. In the case of enterprises, the highest source of value creation is the return to speed in wireless telecommunications, followed by savings on inside wiring costs, and savings in telecommunications costs.[99]

According to the contribution to GDP, Wi-Fi will generate approximately 346,000 jobs in Brazil in 2021, primarily in the communications sector (223,000), and trade (1,000). By 2025, Wi-Fi will generate 421,000 jobs.

[99] Detailed analysis is included in the “Theoretical Framework, Methodologies and Detailed Country Assessments for The Economic Value of Wi-Fi: A Global View (2021-2025)” section of this document.

XVI. ECONOMIC VALUE OF WI-FI IN COLOMBIA

Wi-Fi has become a critical component of Colombia's telecommunications infrastructure. According to the Cisco Annual Internet Report Highlights Tool 2018-2023, there are approximately 520,000 public Wi-Fi access points operating in the country[100]. Wiman estimates that there are currently 412,000 free Wi-Fi sites across Colombia. As in the case of Brazil, public Wi-Fi sites represent a cost-advantaged approach for consumers that cannot afford to acquire access to broadband Internet service at home. Additionally, 85 percent of Colombian homes with broadband are equipped with a Wi-Fi router to support device connectivity.

Given the density of Wi-Fi access points, hotspots have become a very important connectivity feature. The increasing importance of Wi-Fi technology in the digital ecosystem results in a significant social and economic impact. This chapter presents a summary of the results of the economic assessment. The detailed calculations of each source of value are included in "Theoretical Framework, Methodologies and Detailed Country Assessments for The Economic Value of Wi-Fi: A Global View (2021-2025)" starting on page 83.

Before considering the additional effect of Wi-Fi 6 and allocating the 6 GHz spectrum band for unlicensed use, the baseline economic value of Wi-Fi in Colombia in 2021 will amount to $18.7 billion. The 2025 baseline forecast of economic value will reach $36.0 billion.

Adding to the baseline scenario, the potential allocation of the 6 GHz spectrum band for unlicensed use, and the deployment of Wi-Fi 6 and Wi-Fi 6E devices will trigger a growth in economic value, reaching $5.4 billion in 2025. Considering that we forecast that by 2025 only 40 percent of Wi-Fi traffic will be relying on 6 GHz channels, the accelerating effect derived from the new spectrum allocation and latest Wi-Fi technologies will still be far from reaching its maximum potential at this time.

By combining the baseline and the Wi-Fi 6 and 6 GHz scenarios, the overall economic value of Wi-Fi for Colombia will yield $41.4 billion in 2025 (see Table XVI-1).

Table XVI-1. Colombia: Total economic value of Wi-Fi (in $Billions)

	2021	2022	2023	2024	2025
Baseline Scenario	$18.7	$20.4	$22.6	$30.8	$36.0
Wi-Fi 6 / 6 GHz Scenario	$0.2	$1.0	$2.0	$3.4	$5.4
Total	$18.9	$21.4	$24.6	$34.2	$41.4

Source: Telecom Advisory Services analysis

The primary source of economic value is consumer surplus, followed by producer surplus after 2024 and GDP contribution (see Graphic XVI-1).

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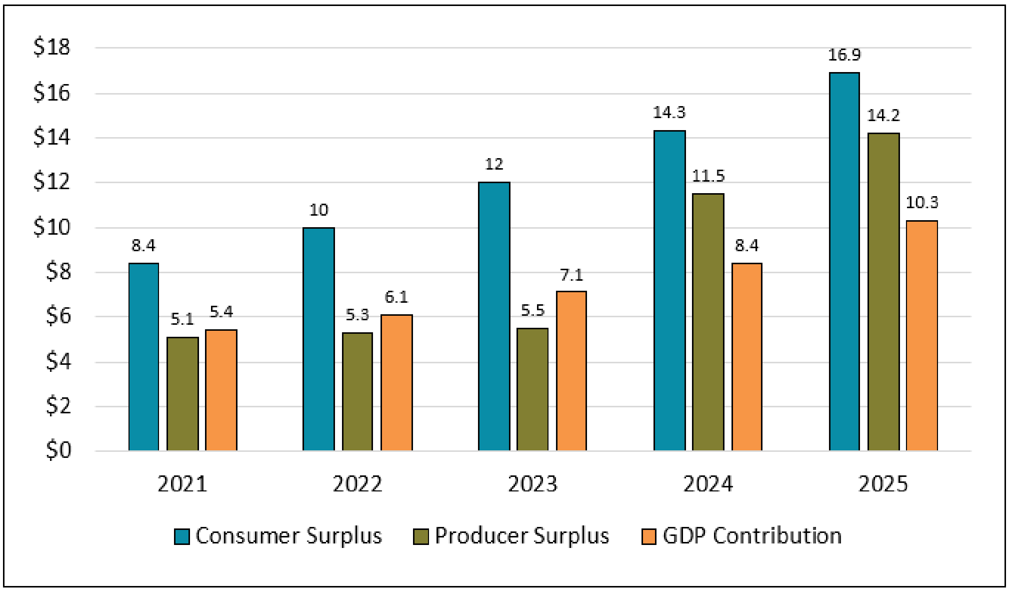
[100] Of this installed base, 218,000 are deployed in Bogota, 70,000 in Medellin and 34,000 in Cali (Retrieved in: https://www.wiman.me/colombia, November 17, 2020).

Graphic XVI-1. Colombia: Total economic value of Wi-Fi (by source) (in $Billions)



Note: Due to rounding, numbers presented in this graphic may not add up precisely to the totals presented above.
Source: Telecom Advisory Services LLC

This total value benefits five economic agents, of which residential Wi-Fi is the most important, closely followed by enterprise use (see Table XVI-2).

Table XVI-2. Colombia: Total Economic Value of Wi-Fi (by agent) (in $Billions)

	2021	2022	2023	2024	2025
Free Wi-Fi	$2.6	$2.9	$3.1	$3.4	$3.6
Residential Wi-Fi	$8.6	$10.3	$12.5	$14.9	$17.9
Enterprise Wi-Fi	$7.4	$7.8	$8.5	$9.6	$11.1
Internet Service Providers	$0.1	$0.2	$0.2	$5.9	$8.3
Wi-Fi ecosystem	$0.2	$0.2	$0.3	$0.4	$0.5
Total	$18.9	$21.4	$24.6	$34.2	$41.4

Source: Telecom Advisory Services analysis

The most important factor driving the value of Wi-Fi among consumer residential use is savings in wireless device access at home. In the case of enterprises, the highest source of value creation is savings on telecommunications costs, followed by the return to speed in wireless telecommunications.[101]

Based on the contribution to GDP, Wi-Fi will generate approximately 99,000 jobs in Colombia in 2021, primarily in the communications sector (47,000), and business services (15,000). In 2025, Wi-Fi will generate 187,000 jobs.

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[101] Detailed analysis is included in the "Theoretical Framework, Methodologies and Detailed Country Assessments for The Economic Value of Wi-Fi: A Global View (2021-2025)" section of this document.

XVII. ECONOMIC VALUE OF WI-FI IN MEXICO

Wi-Fi has become a critical component of Mexico's telecommunications infrastructure. According to the Cisco Annual Internet Report Highlights Tool 2018-2023, there are approximately 7,070,000 public Wi-Fi access points operating in the country. Wiman estimates that there are currently 1,787,000 free Wi-Fi sites in Mexico.[102] Additionally, 91 percent of Mexican homes with broadband are estimated to have installed a Wi-Fi router to support device access.

Given the density of Wi-Fi access points, hotspots have become a very important connectivity feature. According to Opensignal[103], Mexican wireless users currently spend 64.0 percent of their communications time connected to Wi-Fi networks rather than relying on their cellular data connection, having increased two percentage points since the start of the COVID-19 pandemic. The increasing importance of Wi-Fi technology in the digital ecosystem results in a significant social and economic impact. This chapter presents the summary of results of the economic assessment. The detailed calculations of each source of value are included in "Theoretical Framework, Methodologies and Detailed Country Assessments for The Economic Value of Wi-Fi: A Global View (2021-2025)" starting on page 83.

Before considering the additional effect of Wi-Fi 6 and the potential allocation of the 6 GHz spectrum band for unlicensed use, the baseline economic value of Wi-Fi in Mexico in 2021 will amount to $56.0 billion. The 2025 baseline forecast of economic value will reach $109.0 billion, without considering the accelerating effect from the allocation of Wi-Fi 6 and the 6 GHz band. The 2025 forecast of the baseline scenario will be composed of $67.9 billion in consumer surplus, $33.1 billion in producer surplus, and $8.0 billion in GDP contribution.

Adding to the baseline scenario, the allocation of the 6 GHz spectrum band for unlicensed use and the deployment of Wi-Fi 6 and Wi-Fi 6E devices will trigger a growth in economic value, reaching $8.5 billion in 2025. Considering that we forecast that only 40 percent of Wi-Fi traffic will be relying on 6 GHz channels by 2025, the accelerating effect derived from the new spectrum allocation and latest Wi-Fi technologies will still be far from reaching its maximum potential at this time.

By combining the baseline and the Wi-Fi 6 and 6 GHz scenarios, the overall economic value of Wi-Fi for Mexico will yield $117.5 billion in 2025 (see Table XVII-1).

Table XVII-1. Mexico: Total economic value of Wi-Fi (in $Billions)

	2021	2022	2023	2024	2025
Baseline Scenario	$56.0	$64.4	$76.4	$90.9	$109.0
Wi-Fi 6 / 6 GHz Scenario	$0.6	$2.2	$3.9	$6.3	$8.5
Total	$56.6	$66.6	$80.3	$97.2	$117.5

Source: Telecom Advisory Services analysis

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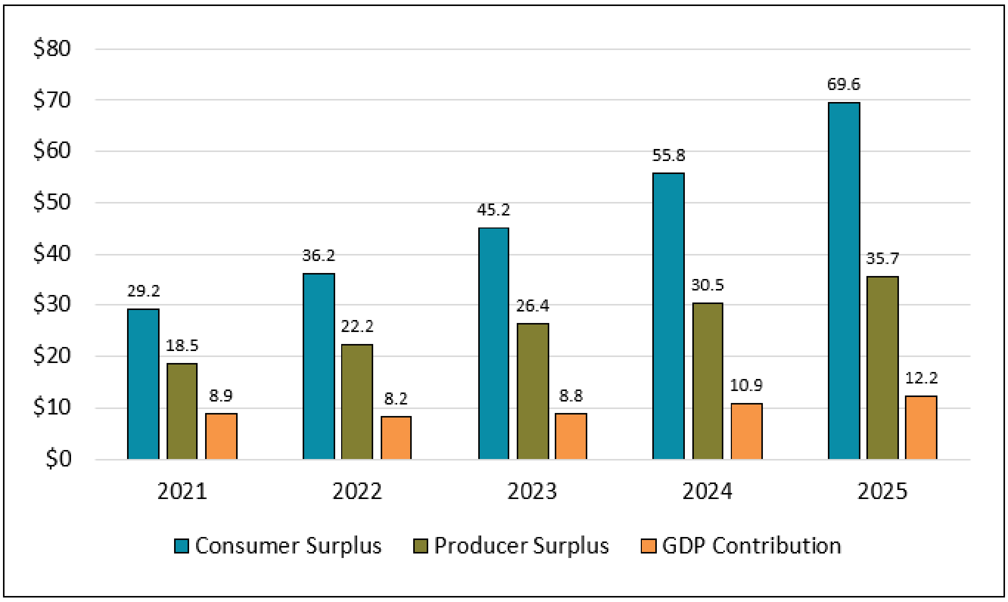
102 Of this installed base of Wi-Fi hotspots in Mexico, 926,000 are deployed in Mexico City, and 108,000 in Guadalajara (Retrieved in: https://www.wiman.me/mexico.)
103 Khatri, H. and Fenwick, S. (2020). "Analyzing mobile experience during the coronavirus pandemic: Time on Wi-Fi". *Opensignal* (March 30).

The primary source of economic value is consumer surplus, followed by producer surplus after 2024, and GDP contribution (see Graphic XVI-1).

Graphic XVII-1. Mexico: Total economic value of Wi-Fi (by source) (in $Billions)



Note: Due to rounding, numbers presented in this graphic may not add up precisely to the totals presented above.
Source: Telecom Advisory Services LLC

This total value benefits five economic agents, of which residential Wi-Fi is the most important, closely followed by enterprise use (see Table XVII-2).

Table XVII-2. Mexico: Total Economic Value of Wi-Fi (by agent) (in $Billions)

	2021	2022	2023	2024	2025
Free Wi-Fi	$6.4	$6.7	$7.0	$7.1	$7.1
Residential Wi-Fi	$28.9	$35.9	$44.7	$55.5	$69.2
Enterprise Wi-Fi	$16.4	$16.7	$18.3	$21.5	$24.1
Internet Service Providers	$1.3	$3.0	$5.2	$7.5	$10.9
Wi-Fi ecosystem	$3.6	$4.3	$5.1	$5.6	$6.2
Total	$56.6	$66.6	$80.3	$97.2	$117.5

Source: Telecom Advisory Services analysis

The most important factor driving the value of Wi-Fi among consumer residential use is savings in wireless device access at home. In the case of enterprises, the highest source of value creation is savings in telecommunications cost, followed by savings in inside wiring.[104]

[104] Detailed analysis is included in the "Theoretical Framework, Methodologies and Detailed Country Assessments for The Economic Value of Wi-Fi: A Global View (2021-2025)" section of this document.

Based on the contribution to GDP, Wi-Fi will generate approximately 129,000 jobs in Mexico in 2021, primarily in the communications sector (80,000), and business services (23,000). In 2025, Wi-Fi will generate 177,000 jobs.

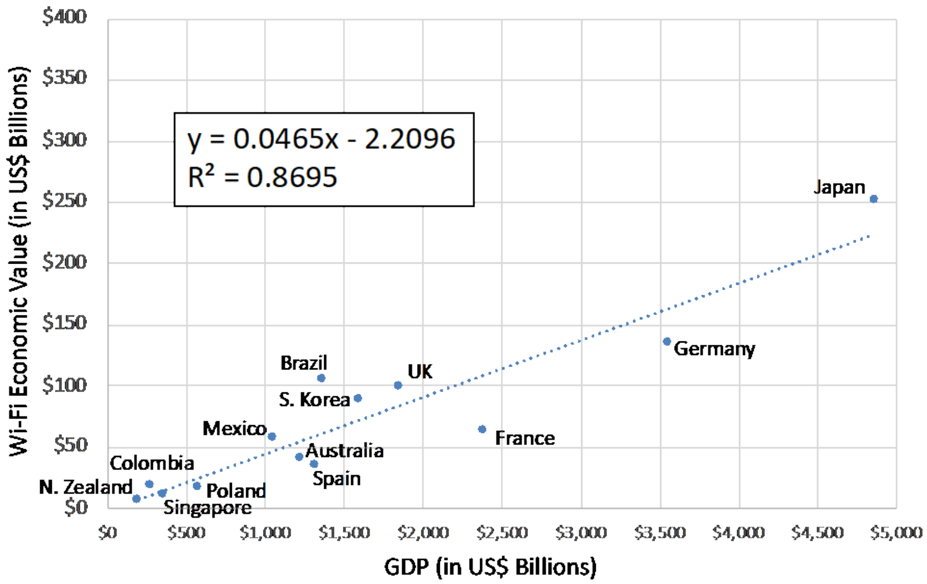
XVIII. GLOBAL ECONOMIC VALUE

Having quantified the economic value for the United States, United Kingdom, Germany, France, Spain, Poland, the rest of European Union, Japan, South Korea, Australia, New Zealand, Singapore, Brazil, Mexico, and Colombia, we can estimate the economic value for the remaining countries of the world. For this purpose, as in the case of the European Union, we use the leading indicators methodology. As explained before, this methodology consists of selecting indicators for two groups (the fourteen countries studied in detail, combined with the rest of the European Union, and the rest of world) and relying on them for the interpolation of values. The two indicators selected for this purpose are:

- Total GDP: the underlying assumption is that there is a direct link between the level of development of a given country and the economic value of Wi-Fi
- Human Development Index, constructed by the United Nations Development Program: this indicator introduces a variable that controls for a country's level of urbanization, literacy, and other social factors

As a starting point, we validated the starting assumption that a country's economy is directly correlated with the economic value of Wi-Fi (see graphic XVIII-1).

Graphic XVIII-1. GDP vs. Wi-Fi economic value



Note: United States observation excluded to depict the difference between countries.
Sources: IMF; Telecom Advisory Services analysis

This correlation supports the use of GDP as lead indicator. As the Table XVIII-1 indicates, the ten countries and the European Union studied in detail represent 59.2 percent of the world GDP.

Table XVIII-1. World distribution of GDP

Groups	GDP ($Billion)	Percent
10 countries and the European Union [105]	51,912	59.2%
Rest of the World	35,786	40.8%
Total	87,698	100.0%

Source: International Monetary Fund

With the initial assumption of a correlation between GDP and economic value, we then calculate a first estimate of Wi-Fi economic value. We then discount these results by the level of development measured by the UN Human Development Index (HDI). The average world HDI, normalized by population, is 0.731, while the average for the fifteen economies under study is 0.870, and 0.699 for the remaining countries of the world (see Table XVIII-2).

Table XVIII-2. Human Development Index: Ten countries plus the European Union vs. Rest of world

Groups	HDI
10 countries and the European Union	0.870
Rest of the World	0.699
Total	0.731

Source: United Nations

These values are then used to discount the original GDP-based economic value estimates for the "rest of the world". The discount factor is calculated by dividing the "rest of the world" HDI (0.699) by the fifteen countries under study HDI (0.870). This allows the Wi-Fi economic value for the "rest of the world" to be refined, adding it to the fifteen countries under study and estimating the economic value for the whole world for the baseline scenario (see Table XVIII-3).

Table XVIII-3. Global Wi-Fi economic value - Baseline scenario ($Billion)

Countries	2021				2025			
	Consumer surplus	Producer surplus	GDP Contribution	Total	Consumer surplus	Producer surplus	GDP Contribution	Total
Ten countries and the European Union	$831.9	$852.6	$403.0	$2,087.5	$1,319.6	$1,129.9	$348.5	$2,798.0
Rest of the World	$460.9	$472.4	$223.3	$1,156.6	$731.1	$626.0	$193.1	$1,550.2
Total	$1,292.8	$1,325.0	$626.3	$3,244.1	$2,050.7	$1,755.9	$541.6	$4,348.2

Source: Telecom Advisory Services analysis

As presented in Table XVIII-3, the global economic value of Wi-Fi under the baseline scenario in 2021 amounts to $3,244.1 billion, reaching $4,348.2 billion in 2025[106].

[105] The United States, the United Kingdom, the European Union, Japan, South Korea, Australia, New Zealand, Singapore, Brazil, Mexico, and Colombia.
[106] In 2023, the baseline scenario will reach $3,573.6 billion. For reference, the projection in the 2018 study was $3,472.44 (2.83 percent lower).

The extrapolation for the Wi-Fi 6 and 6 GHz scenario projects an additional economic value of $57.9 billion in 2021, reaching $527.5 billion in 2025 (see Table XVIII-4).

Table XVIII-4. Global Wi-Fi economic value – Wi-Fi 6 and 6 GHz ($Billion)

Countries	2021				2025			
	Consumer surplus	Producer surplus	GDP Contribution	Total	Consumer surplus	Producer surplus	GDP Contribution	Total
Ten countries and the European Union	$2.7	$19.4	$15.2	$37.3	$57.1	$112.1	$170.3	$339.5
Rest of the World	$1.5	$10.7	$8.4	$20.6	$31.6	$62.1	$94.3	$188.0
Total	$4.2	$30.1	$23.6	$57.9	$88.7	$174.2	$264.6	$527.5

Source: Telecom Advisory Services analysis

Table XVIII-5 presents the sum of both scenarios: $3,302.0 in 2021 and $4,875.8 in 2025.

Table XVIII-5. Global Wi-Fi economic value – Total ($Billion)

Countries	2021				2025			
	Consumer surplus	Producer surplus	GDP Contribution	Total	Consumer surplus	Producer surplus	GDP Contribution	Total
Ten countries and the European Union	$834.6	$872.0	$418.2	$2,124.8	$1,376.7	$1,242.0	$518.8	$3,137.5
Rest of the World	$462.4	$483.1	$231.7	$1,177.2	$762.8	$688.1	$287.4	$1,738.2
Total	$1,297.0	$1,355.1	$649.9	$3,302.0	$2,139.5	$1,930.1	$806.2	**$4,875.7**

Source: Telecom Advisory Services analysis

To sum up, the "rest of the world" estimation represents an amount of Wi-Fi economic value that is fairly close to half of the value for the fifteen economies under study.

The GDP contribution of the "rest of the world" estimation also enables the quantification of job creation from Wi-Fi. By conducting a similar methodology of GDP prorating, with a control for the Human Development Index, we developed an estimate of Wi-Fi GDP contribution. With these estimates, total annual employment generation for the rest of the world was estimated (see Table XVIII-6).

Table XVIII-6. Rest of World: Wi-Fi generated annual employment

	2021	2025
Direct jobs	651,325	806,685
Indirect jobs	354,910	454,234
Induced jobs	138,610	174,774
Total	1,144,846	1,435,693

Source: Telecom Advisory Services analysis

Total, global job contribution of Wi-Fi in 2021 amounts to 3.2 million jobs; by 2025 Wi-Fi it will reach 4.0 million jobs worldwide (see Table XVIII-7).

Table XVIII-7. Global: Wi-Fi generated annual employment

	2021			2025		
	Ten countries and EU-27	Rest of the World	Global	Ten countries and EU-27	Rest of the World	Global
Direct jobs	1,175,574	651,325	1,826,899	1,455,982	806,685	2,262,668
Indirect jobs	640,576	354,910	995,486	819,845	454,234	1,274,079
Induced jobs	250,176	138,610	388,786	315,448	174,774	490,222
Total	2,066,326	1,144,846	3,211,172	2,591,275	1,435,693	4,026,968

Source: Telecom Advisory Services analysis

It should be noted that, since the estimates for the rest of the world were based on a prorating methodology reflecting a large proportion of advanced country effects, the result might underestimate total employment effects in the developing world.

XIX. CONCLUSIONS

This study was predicated on the fact that Wi-Fi technology has taken a prominent position in the wireless ecosystem, with enormous importance in everyday life. As of today, most laptops, tablets, smartphones, security cameras, smart TVs, printers, scanners, home appliances, and even cars, increasingly utilize Wi-Fi. By the time the 2018 study was conducted, Wi-Fi was installed in 800 million households around the world, and wireless users in some of the largest countries spent more time connected to Wi-Fi than to cellular networks. Changes that took place since then have accelerated the adoption of the technology.

This study expanded the range of sources of value and analyzed the impact of Wi-Fi 6 for ten countries and the European Union, including three developing nations in Latin America. Additionally, the research identified key agents benefitting from Wi-Fi value, ranging from Wi-Fi usage in free sites, residences, and businesses, to savings enjoyed by cellular carriers through traffic offloading, profits due to Wi-Fi enabled equipment manufacturing, and benefits from faster network throughput.

The study concludes that the 2021 economic value of Wi-Fi for the ten countries and the European Union is $2,124.5 billion. The top three countries with the highest Wi-Fi economic value creation in 2021 are the United States ($995.0 billion), followed by Japan ($251.1 billion), and then Germany ($134.5 billion (see all countries considered in Table XIX).

Table XIX. Wi-Fi Economic Value (Baseline and 6 GHz Accelerator Scenarios)

	2021	2025
United States	$995.0	$1,580.1
United Kingdom	$98.8	$108.5
European Union	$457.6	$637.2
Australia	$34.7	$41.7
Japan	$251.1	$324.9
South Korea	$89.3	$139.5
New Zealand	$6.7	$9.8
Singapore	$10.6	$12.4
Brazil	$105.2	$124.3
Mexico	$56.6	$117.5
Colombia	$18.9	$41.4
Total World (*)	$3,302.0	$4,875.7

(*) Including "Rest of the World" nations not estimated above
Source: Telecom Advisory Services analysis

The most important sources of economic value are residential Wi-Fi ($1,341 billion) and enterprise Wi-Fi ($849 billion). The production side of the economy also benefits from Wi-Fi in terms of the profits received by equipment manufacturers (i.e. devices such as access points, controllers, routers, gateways, smart speakers, and home security systems), and the savings incurred by the cellular carriers that rely on the technology to offload traffic from their networks. Wi-Fi also generates economic value through social contributions: the technology represents a useful means of tackling the digital divide in rural and isolated geographies, while also providing an important platform for free Internet access.

Beyond estimates of the economic value in each nation, the study generated an extrapolation for the rest of the world that relied on two macro-indicators: GDP and the United Nations Human Development Index. When including the rest of the world, the global economic value associated to Wi-Fi in 2021 amounts to $3,302.0 billion, or nearly $3.3 trillion, and is expected to reach $4,875.7 billion, or $4.9 trillion by 2025.. This value could be considered conservative; if all countries allocate 1200 MHz of the 6 GHz band to Wi-Fi, this value level rises.

The study also provided an estimate of job creation by relying on Input / Output analysis. Job creation estimates include direct jobs (those jobs created by manufacturing Wi-Fi enabled equipment and Wi-Fi operating infrastructure), indirect jobs (those jobs created by suppliers to the Wi-Fi equipment manufacturing sector and operators), and induced jobs (those jobs created by spending of direct and indirect workers).

By conducting a similar methodology of GDP prorating, with a control for the Human Development Index, we developed an estimate of employment creation for the "rest of the world". According to this, global employment benefitting from Wi-Fi in 2021 amounts to 3.2 million jobs and is expected to reach 4.0 million jobs by 2025.

Based on this evidence, Wi-Fi technology should be recognized as one of the dominant economic engines of the digital economy. Governments around the world should develop the right incentives to stimulate the social and economic benefits of Wi-Fi. This includes assigning enough spectrum to avoid congestion, promoting the development of start-ups that rely on Wi-Fi to create new applications, and relying on the technology to address the digital divide barrier.

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Theoretical Framework, Methodologies and Detailed Country Assessments for

The Economic Value of Wi-Fi: a global view (2021-2025)

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Telecom Advisory Services LLC (URL: www.teleadvs.com) is an international consulting firm registered in the state of New York (United States), with physical presence in New York, Madrid, Bogotá and Buenos Aires. Founded in 2006, the firm specializes in the development of business strategies and public policies for digital and telecommunications companies, governments, and international organizations. Its clients include leading companies in the digital and telecommunications sectors, as well as international organizations such as the International Telecommunication Union, the World Bank, the Inter-American Development Bank, the World Economic Forum, the UN Economic Commission for Latin America and the Caribbean, CAF Development Bank for Latin America, the GSMA Association, the CTIA, the National Cable TV Association (U.S.), GigaEurope, Wi-Fi Alliance, and the FTTH Council (Europe), as well as the governments of Argentina, Brazil, Colombia, Ecuador, Costa Rica, Germany, Mexico, Peru, and Saudi Arabia.

This document is a companion piece to the "Economic Value of Wi-Fi: A Global View (2021 – 2025)". It lays out in detail the theoretical framework, methodology, and regions included to estimate global economic value of Wi-Fi.

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TABLE OF CONTENTS

A. THEORETICAL FRAMEWORK FOR ESTIMATING THE ECONOMIC VALUE OF WI-FI

Wi-Fi is what economists call a factor of production (or enabling resource) that yields economic value by complementing wireline and cellular technologies, enabling the development of alternative technologies that expand consumer choice, supporting the creation of innovative business models, and expanding access to communications services. This chapter defines the intrinsic value of Wi-Fi as a complementary technology that is part of the telecommunications ecosystem, enhancing the performance of networks and providing a platform for developing innovative applications. Next, we present the concept of economic value, calculated as gains to consumer and producer surplus, a contribution to GDP, and a creation of employment. Having formalized these sources of value, we then move to categorize the five economic agents that benefit from them:

- Individual consumers benefitting from accessing free Wi-Fi service;
- consumer residences;
- enterprises;
- Internet Service Providers; and
- manufacturers of communications equipment and consumer electronics.

A.1. The intrinsic value of Wi-Fi

Considered as a factor of production, a complementary technology is a resource that, due to its intrinsic strengths, compensates for the limitations of another one. In this regard, Wi-Fi can enhance the effectiveness of devices, such as smartphones, which use licensed spectrum. Wi-Fi access points can enhance the value of cellular networks by allowing wireless devices to switch to Wi-Fi hotspots, thereby reducing the cost of broadband access and increasing the access speed rate. Along these lines, consumers accessing the Internet within the reach of a Wi-Fi access point can reduce their costs of access by turning off their cellular service. They can also gain additional access speed because the transfer rate of Wi-Fi sites is generally faster than that offered by cellular technology, even 4G LTE at current loads.[107] Likewise, many wireless operators reduce their capital spending by complementing their cellular networks with carrier-grade Wi-Fi access points, which are considerably less expensive than cellular network equipment with similar capacity. In addition to reducing capital expenditures, wireless carriers can offer fast access service without a base station congestion challenge.

In addition to complementing cellular networks, Wi-Fi can provide the environment needed for operating technologies that can substitute for those operating under licensed uses, thereby providing consumers with a larger set of choices. By limiting

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[107] For example, in 2020 the average mobile connection speed in the United States is estimated at 25.51 Mbps while the average Wi-Fi speed from a mobile device is 69.6 Mbps (Source: data interpolated from Cisco Annual Internet Report Highlights Tool 2018-2023). Naturally, we can expect that speed gap to diminish with the progress of 5G deployments.

transmission power and relying on spectrum with low propagation, Wi-Fi avoids interference. This ensures the need for licensed spectrum property rights is not a barrier to innovation. In fact, some of the most important technological innovations in communications are intimately linked to Wi-Fi. Numerous products and services, such as the multi-AP/mesh networking systems and smart speakers, launched in the past ten years were developed leveraging Wi-Fi.

By providing consumers with service choices in addition to those offered through cellular services, Wi-Fi also supports the development of innovative business models. Firms developing new applications that rely on Wi-Fi do not need approval from cellular operators, do not incur time-to-market penalties, and do not face financial disincentives derived from costly revenue splits.

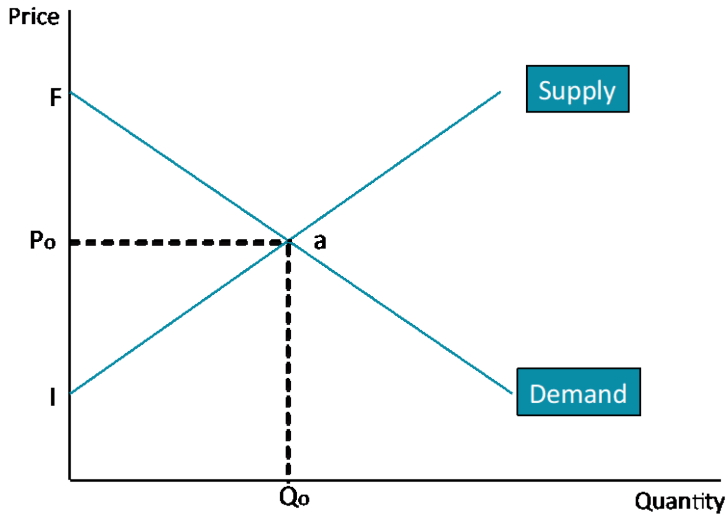
In addition to innovative applications, technologies that rely on Wi-Fi spectrum can help address the digital gap in broadband coverage. A large portion of the population that has not adopted the Internet around the world is located in rural and isolated areas. Many of them can gain access to broadband services provided by Wireless Internet Service Providers (WISPs), which typically operate through Wi-Fi. In addition, further developments in the areas of spectrum sensing, dynamic spectrum access, and geo-location techniques can improve the quality of Wi-Fi.

A.2. The derived value of Wi-Fi

Wi-Fi yields economic gains at several levels, both to consumers and producers, as well as a direct net contribution to output (GDP) and employment. Prior research agrees that, contrary to licensed bands where economic value could equate to whatever is paid at auction, the economic value of unlicensed spectrum, such as Wi-Fi, needs to be measured based on the concept of economic surplus.[108] The methodology implicit in relying on the economic surplus approach is captured in Figure A-1.

[108] Thanki, R. (2009). *The economic value generated by current and future allocations of unlicensed spectrum*. London: Perspective Associates; Thanki, R. (2012). *The Economic Significance of License-Exempt Spectrum to the Future of the Internet.* London; Perspective Associates; Milgrom, P., Levin, J., and Eilat, A. (2011). *The case for unlicensed spectrum*. Stanford Institute for Economic Policy Research Discussion Paper No. 10-036; Katz, R. ibid.

Figure A-1. Measurement of Economic Surplus



Source: Telecom Advisory Services

The concept of economic surplus is based on the difference between the value of units consumed and produced up to the equilibrium price and quantity, allowing for the estimation of consumer surplus (area of F, Po, a) and producer surplus (area of Po, I, a).[109] Consumer surplus measures the total amount consumers would be willing to pay to have the service, compared to what they actually pay, while producer surplus measures the analogous quantity for producers, which is essentially the economic profit they earn from providing the service. Thus, in Figure 1 the total surplus is contained in the area F, I, a.

Consistent with the concept presented above, the approach relied upon in this study to measuring economic value of Wi-Fi focuses first on the surplus generated after its adoption.[110] The underlying assumption is that Wi-Fi as a resource generates a shift both in the demand and supply curves resulting from changes in the production function of services, as well as the corresponding willingness-to-pay for its acquisition. On the supply side, the approach measures changes in the value of inputs in the production of wireless communications. The most obvious example is, as mentioned above, whether Wi-Fi represents a positive contribution to wireless carriers' capital expenditures (CAPEX) and operating expenses (OPEX) insofar as they can control their spending while meeting demand for increased wireless traffic. From an economic theory standpoint, the telecommunications industry can then increase its output, yielding a marginal benefit exceeding the marginal cost. This results in a shift in the supply curve by a modification in the production costs (see Figure A-2).

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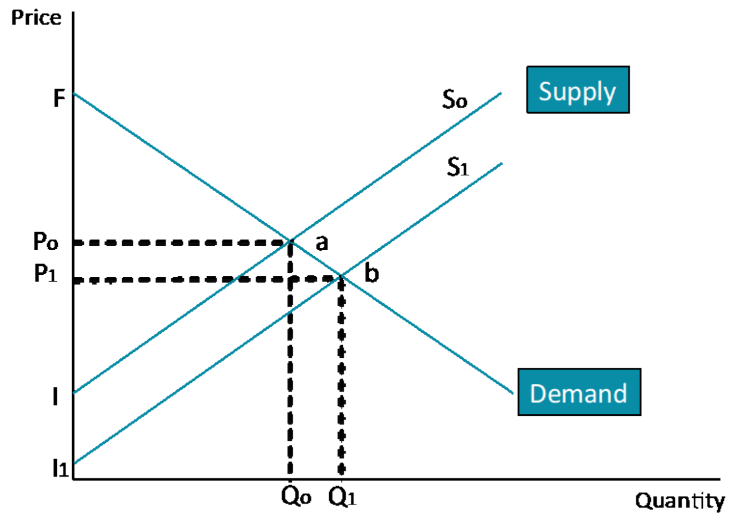
[109] Following Alston (1990), we acknowledge that this approach ignores effects of changes in other product and factor markets; for example, Wi-Fi also increases the economic value of technologies operating in licensed bands (Alston, J.M. and Wohlgenant, M.K. (1990). "Measuring Research Benefits Using Linear Elasticity Equilibrium Displacement Models". John D. Mullen and Julian M. Alston, *The Returns to Australian Wool Industry from Investment in R&D*, Sydney, Australia: New South Wales Department of Agriculture and Fisheries, Division of Rural and Resource Economics).

[110] See a similar approach used by Mensah and Wohlgenant (2010) to estimate the economic surplus of adoption of soybean technology (Mensah, E., and Wohlgenant, M. (2010). "A market impact analysis of Soybean Technology Adoption", *Research in Business and Economics Journal*).

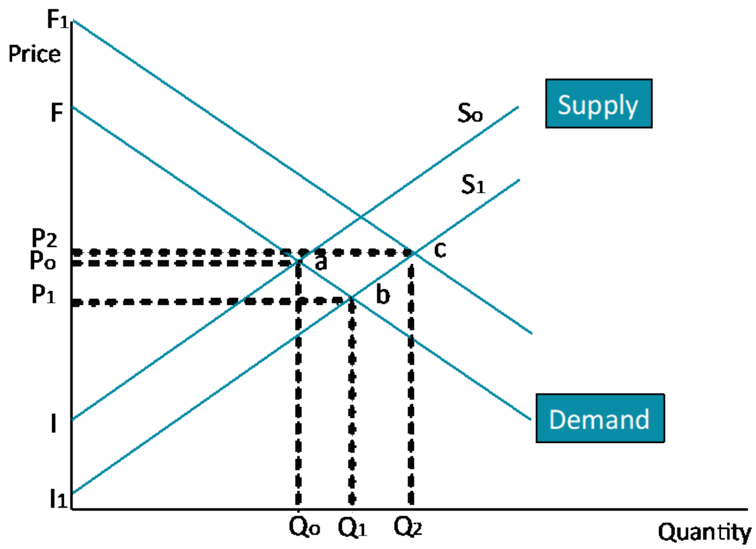
Figure A-2. Measurement of economic surplus resulting from a supply shift



Source: Telecom Advisory Services

The development and adoption of carrier-grade Wi-Fi technology causes a shift in the supply curve, yielding a new equilibrium price and quantity. Under this condition, consumer surplus is represented by the triangle F, b, P_1, and producer surplus by the area within P_1, b, I_1. Additionally, since the demand curve is derived from the utility function[111], higher benefit to the consumer derived from the reliance on Wi-Fi at a stable price will yield an increase in the willingness-to-pay, and consequently a shift in the demand curve (see Figure A-3).

Figure A-3. Measurement of Economic Surplus resulting from a supply and demand shift



Source: Telecom Advisory Services

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[111] A utility function measures the consumer preference for a service beyond the explicit monetary value paid for it.

Under these conditions, total economic value is now represented by the area I_1, c, F_1, in Figure A-3, representing both changes in consumer and producer surplus.

To quantify the incremental surplus derived from the adoption of Wi-Fi, we need to itemize all the effects linked to this standard. We complement the concept of economic surplus with an assessment of the direct contribution of the technologies and applications that rely on Wi-Fi, such as Wi-Fi service providers, to the nation's GDP. By including the GDP contribution measurement, we follow Greenstein et al. (2010) and prior literature measuring the economic gains of new goods.[112] We focus on consumer and producer surplus, but we also consider the new economic growth enabled by Wi-Fi. In measuring the direct contribution to GDP, we strictly consider the revenues added "above and beyond" what would have occurred had the Wi-Fi spectrum been licensed. After quantifying the contribution of Wi-Fi to GDP, the impact on job creation can also be ascertained not only on the telecommunications industry itself, but, more importantly, in terms of the spillovers through the rest of the economy.

[112] Greenstein, S. and McDevitt, R. (2009). *The broadband bonus: accounting for broadband Internet's impact on U.S. GDP.* National Bureau of Economic Research Working Paper 14758. Cambridge, MA.

B. METHODOLOGIES FOR ESTIMATING THE ECONOMIC VALUE OF WI-FI

Measuring Wi-Fi's economic value requires a formalized approach that can integrate the various economic gains, be it consumer or producer benefits, as well as their net direct contributions to the GDP[113]. The methodology used in this study is structured around the benefits captured by each of the five economic agents reviewed in Chapter A:

- Free Wi-Fi service;
- Residential Wi-Fi;
- Enterprise Wi-Fi;
- Internet Service Providers; and
- Wi-Fi ecosystem companies.

The economic value for each economic agent is measured based on three potential options: consumer surplus, producer surplus, and GDP growth. The contribution to GDP growth is also used to estimate the impact on job creation. Table B-1 presents the formalization of each value.

Table B-1. Sources of economic value of Wi-Fi by economic agent

Agents	Sources	Type of Economic Value	Scenarios	
			Baseline	Wi-Fi 6 & 6 GHz
1. Free Wi-Fi	1.4. Savings generated by free Wi-Fi traffic offered in public sites	Consumer Surplus	X	X
	1.5. Deployment of free Wi-Fi in public sites	GDP contribution	X	X
	1.6. Benefit of faster free Wi-Fi with Wi-Fi 6E devices	Consumer Surplus		X
2. Residential Wi-Fi	2.1. Home Internet access for devices that lack a wired port	Consumer Surplus	X	
	2.2. Avoidance of investment in in-house wiring	Consumer Surplus	X	
	2.3. Benefit to consumers from speed increases	Consumer Surplus	X	X
	2.4. Residential Wi-Fi devices and equipment deployed	Consumer Surplus	X	X
	2.6. Closing digital divide: use of Wi-Fi to increase coverage in rural and isolated areas	GDP contribution	X	X

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113 See the prior research in Thanki, R. (Sept. 8, 2009). *The economic value generated by current and future allocations of unlicensed spectrum*. Perspective Associates; Milgrom, P., Levin, J., & Eilat, A. (2011). *The case for unlicensed spectrum*. Stanford Institute for Economic Policy Research Discussion Paper No. 10-036; Cooper, M. (2011). *The consumer benefits of expanding shared use of unlicensed radio spectrum: Liberating Long-Term Spectrum Policy from Short-Term Thinking* . Washington D.C.: Consumer Federation of America, Katz, R. (2014a). *Assessment of the economic value of unlicensed spectrum in the United States.* New York: Telecom Advisory Services. Katz, R. (2014b). *Assessment of the future economic value of unlicensed spectrum in the United States.* New York: Telecom Advisory Services. Katz, R. (2018). *A 2017 assessment of the current and future economic value of unlicensed spectrum*. Washington, DC: Wi-Fi Forward. Katz, R. (2018). *The global economic value of Wi-Fi 2018-2023* . New York: Telecom Advisory Services.

Agents	Sources	Type of Economic Value	Scenarios	
			Baseline	Wi-Fi 6 & 6 GHz
3. Enterprise Wi-Fi	3.1. Business Internet traffic transmitted through Wi-Fi	Producer surplus	X	X
	3.2. Avoidance of enterprise inside wiring costs	Producer surplus	X	
	3.3. Return to speed: contribution to GDP derived from an increase in average mobile speed	GDP contribution	X	X
	3.4. Wide deployment of IoT	GDP contribution	X	X
	3.5. Deployment of AR/VR solutions	GDP contribution	X	X
4. ISPs	2.2 CAPEX and OPEX savings due to cellular off-loading	Producer surplus	X	X
	2.4. Revenues of service providers offering paid Wi-Fi access in public places	GDP contribution	X	X
	2.5. Aggregated revenues of WISPs	GDP contribution	X	X
5. Wi-Fi ecosystem	5.1. Locally manufactured residential Wi-Fi devices and equipment	Producer surplus	X	X
	5.2. Locally manufactured Wi-Fi enterprise equipment	Producer surplus	X	X
	5.3. Locally produced IoT products and services	Producer surplus	X	X
	5.4. Locally produced of AR/VR solutions	Producer surplus	X	X

Source: Telecom Advisory Services

Having presented the different sources of the economic value of Wi-Fi to be estimated for each economic agent, we detail the methodologies used to measure them.

B.2.1. Individuals benefitting from free Wi-Fi service

As indicated in Table III-1, the sources of economic value benefiting individuals relying on free Wi-Fi service comprise the following three economic effects, which contribute to consumer surplus:

- Public Wi-Fi traffic savings incurred by accessing free Wi-Fi at public sites;
- Bridging the digital divide: Reliance on Wi-Fi as a way to provide broadband to unserved populations; and
- Faster speeds: Benefit to consumers who enjoy higher speed with Wi-Fi 6E devices.

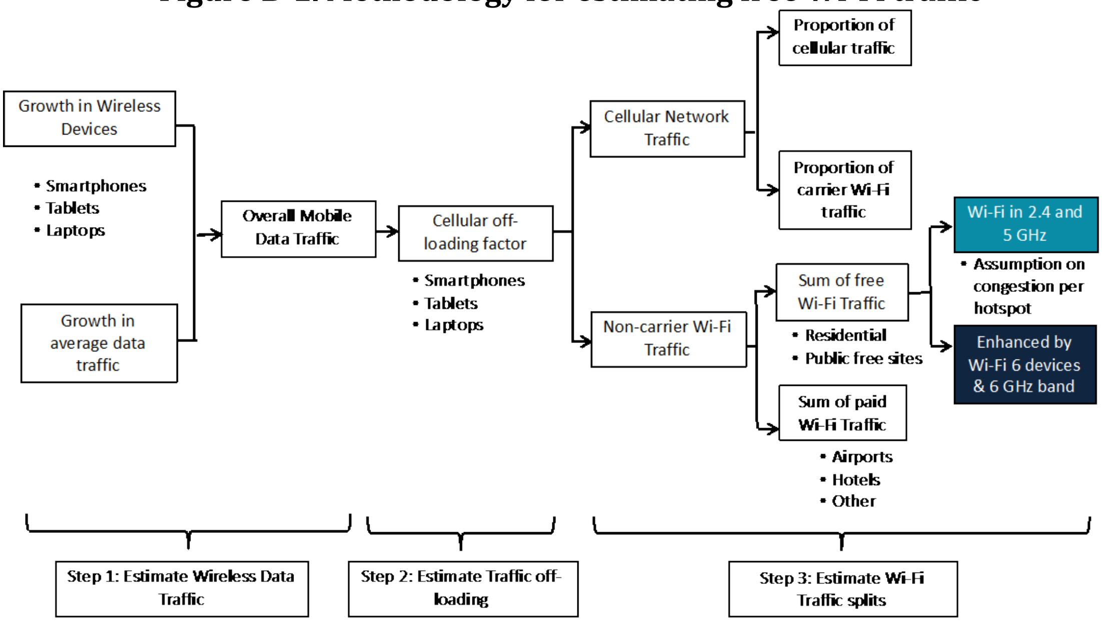
B.2.1.1. Savings incurred by accessing free Wi-Fi in public sites

A consumer that is already accessing the Internet through a wireless broadband plan has the opportunity to save money by switching to a free Wi-Fi access point. While this is less relevant for consumers who purchase unlimited plans, it is significant in the case of pre-paid and capped plans. The economic value should be calculated by multiplying the traffic generated at free sites by the difference between what the consumer would have to pay if he/she were to utilize a wireless broadband plan, and the cost of offering free Wi-Fi incurred by the free site operator.

Free Wi-Fi in the 2.4 GHz and 5 GHz bands

The estimation of the economic value of free Wi-Fi traffic first requires an estimate of the portion of mobile data traffic that is channeled through free Wi-Fi access points. We start by calculating current and future wireless data traffic. Estimates are estimated "bottom-up" from the installed base of devices and traffic by device. They are calibrated with existing measurements, such as Cisco's Annual Internet Report Highlights Tool 2018-2023. After quantifying wireless data traffic, we calculate the portion of traffic off-loaded to Wi-Fi access points. However, since off-loading patterns vary by device, off-loading traffic is calculated by type of terminal (Tablet, laptop, smartphone) and then aggregated. In addition, since the economic value differs by the type of Wi-Fi site (for example, revenues from a commercial site such as Boingo represent a direct contribution to GDP, which is addressed below, while the benefit of accessing the Internet via a free public site has to be measured in terms of consumer surplus), Wi-Fi traffic needs to be split between free and paid sites. Finally, we calculate the portion of free Wi-Fi traffic attributed to current spectrum bands to isolate its effect from the increased capacity derived from 6 GHz allocation. Figure B-1 presents a flowchart of this analysis.

Figure B-1. Methodology for estimating free Wi-Fi traffic

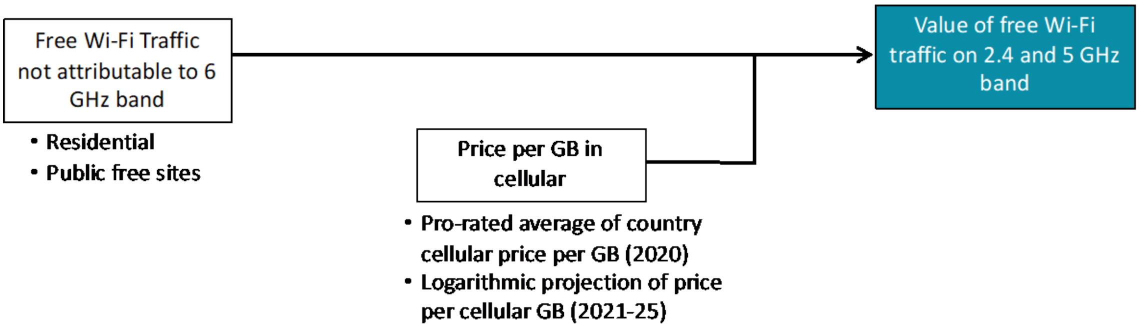


Source: Telecom Advisory Services

To isolate the traffic projection through current unlicensed spectrum bands, we assume that current traffic levels are already resulting in the congestion of most free Wi-Fi hotspots at the time of peak demand. The fact that we assume current hotspots are facing congestion does not necessarily mean a uniform congestion threshold considered for traffic per hotspot across all countries. Several factors can explain why traffic per hotspot may reach different levels across countries: different usage patterns and diverse urban/rural breakdown can have an impact on usage intensity across days and hours. However, as we assume some degree of congestion under current standards for every country, the estimate of traffic per hotspot from 2021 onwards can be expected to remain at 2020 levels, although overall free traffic will continue growing as new hotspots continue to be deployed.

Once the total free Wi-Fi traffic supported by hotspots operating in 2.4 GHz and 5 GHz bands is estimated, we calculate the consumer surplus by multiplying the total free traffic by the difference between what the consumer would have to pay if he/she were to utilize a wireless broadband plan and the cost of offering free Wi-Fi (incurred in this case by the public site operator). To do so, we need an estimate of the average price per GB of wireless data transmitted by wideband networks, which we calculate by prorating the market share of the most economic "dollar per GB" (generally the unlimited) plan of major wireless carriers of the country under analysis. Figure B-2 describes this approach.

Figure B-2. Methodology for estimating consumer surplus of free Wi-Fi traffic in 2.4 and 5 GHz bands



Source: Telecom Advisory Services

Free Wi-Fi in the 6 GHz band

Wi-Fi 6 is the latest among Wi-Fi standards. If supported by the allocation of the 6 GHz spectrum band,[114] it yields an important performance improvement in comparison with previous generations. For example, Wi-Fi 6E provides better efficiency due to its orthogonal frequency-division multiple access (OFDMA), allowing to simultaneously connect more client devices without affecting quality. When the entire 6 GHz band is opened up and added to the existing unlicensed bands in 2.4 GHz and 5 GHz, the combined spectrum will be able to support eight 160 MHz channels, or three 320 MHz channels. These channels will be a source of economic value, as their use will allow the support of a high number of devices on a single access point.[115]

In terms of free Wi-Fi service, the allocation of the 6 GHz band will remove the above-mentioned congestion, allowing the traffic per access point to continue to grow at the rate extrapolated from past experience. Once computed, the additional traffic "above and beyond" the forecast under the 2.4 GHz and 5 GHz spectrum bands, we follow a similar approach to calculate the consumer surplus, by multiplying it by the difference between what the consumer would have to pay if

[114] This is because the above-mentioned advances attributed to Wi-Fi 6 only apply when the devices connect using the 160 MHz channel. Although Wi-Fi 6 is available in the traditional 2.4 GHz and 5 GHz bands, that spectrum runs out of space fast if configured under the extra-wide 160MHz channels. Therefore, this shortage needs to be addressed by the allocation of 6 GHz frequency band for unlicensed use to enjoy the developments provided by the latest technological standard.
[115] Some Wi-Fi 6 solutions can handle up to 1,500 devices.

he/she were to utilize a wireless carrier, and the cost of gaining Internet access through free Wi-Fi.

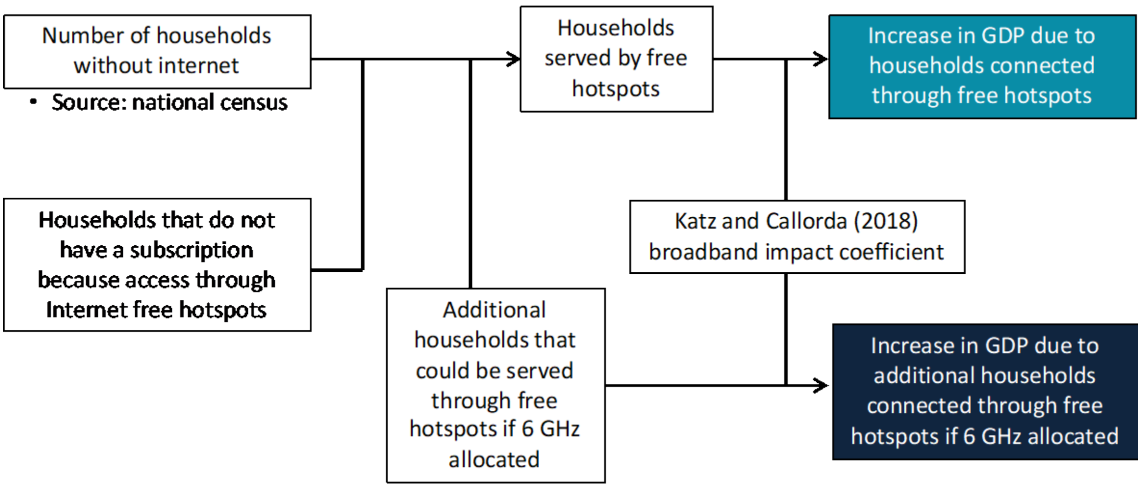
B.2.1.2. Free Wi-Fi provides broadband to the unserved population

In addition to the economic value generated by savings in wireless broadband, free Wi-Fi provides Internet access to the unserved population. Consumers that do not have broadband service because of an affordability barrier can rely on free Wi-Fi to gain Internet access.

Free Wi-Fi in the 2.4 GHz and 5 GHz bands

Through free Wi-Fi offered in public venues, more people can be connected, enhancing the economic contribution of broadband. More people connected implies that people can be more productive in their own activities and enjoy more leisure time. In this case, we assess the GDP contribution of free Wi-Fi by providing the economically disadvantaged population access to the Internet, as described in Figure B-3.

Figure B-3. Methodology for estimating the GDP contribution of increased broadband penetration due to free Wi-Fi



Source: Telecom Advisory Services

We start by calculating the unserved population and estimating which portion of those are already accessing to Internet through free hotspots. As an example, a survey carried out by Connect Home in the United States stipulates that 10% of unconnected households state that they access Internet outside of the home. We follow a conservative approach and assume that 5% of unconnected households rely on free hotspots for accessing the Internet. Once the additional broadband penetration due to free Wi-Fi hotspots is calculated, we apply the broadband impact coefficient from Katz and Callorda (2018b), that stipulates a 0.19% increase in GDP for every 1% increase in penetration[116].

Enhanced GDP contribution due to 6 GHz allocation

As stated above, the developments provided by Wi-Fi 6E equipment allows Wi-Fi to support a higher number of devices on a single access point. Thus, the improved throughput of free Wi-Fi hotspots utilizing the 6 GHz allocation will allow the possibility of serving additional unconnected households. We assume that a further 5% of unconnected consumers will be served through free hotspots in this situation and calculate the GDP contribution following the same criteria as described for the current spectrum bands[117].

B.2.1.3. Benefit to consumers enjoying higher speeds from free Wi-Fi if the 6 GHz band is allocated

When the 6 GHz band is added to the existing unlicensed bands, an additional effect will result from enabling users to access the Internet through faster than current levels of broadband speed. Wi-Fi 6 has a base speed of 1.2 Gbps per stream, therefore, a dual-stream connection has a ceiling speed of 2.4 Gbps, and a quad-stream connection can reach 4.8 Gbps.[118] Under these circumstances, free Wi-Fi customers are expected to benefit from faster services. Consumer surplus is defined as the value that consumers receive from purchasing a product for a price that is less than what they would be willing to pay. Early on, Rosston et al. (2010) noted that, in addition to the benefits consumers receive from broadband adoption (quick access to large amounts of information for learning and health services, access to the world's largest portal for social and entertainment services, and the potential for savings from online shopping), one must also consider consumer preferences and benefits received from the nature of the service, which include speed of access and reliability.

Most studies of consumer surplus derived from faster broadband speed are based on primary research, where users stipulate the amount they would be willing to pay for broadband service (Savage et al., 2004; Greenstein and McDewitt, 2011; Liu et al., 2017). Other studies of broadband speed consumer surplus focus on how consumers react to variations in price according to their data usage. For example, Nevo et al. (2016) studied hour-by-hour Internet usage for 55,000 U.S. subscribers facing different price schedules. They concluded that consumer surplus for speed is heterogeneous. Consumers will pay between $0 to $5 per month for a 1 Mbps increase in connection speed, with an average of $2.[119] In addition, they stipulated

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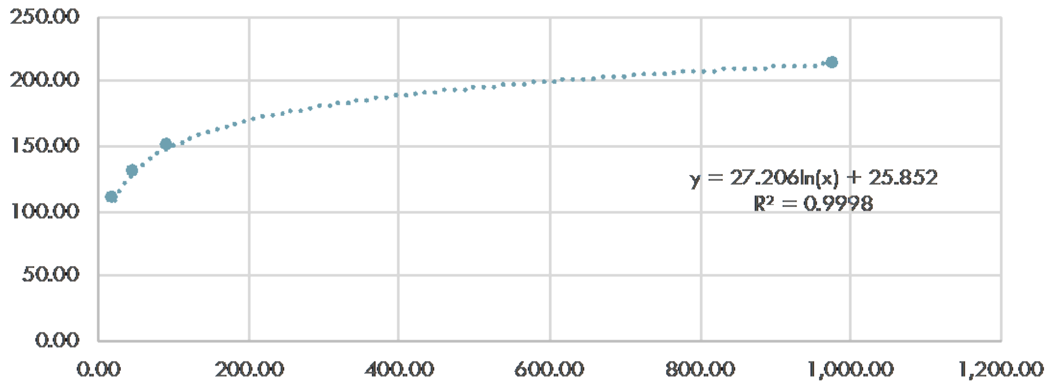
[116] Katz, R. and Callorda, F. (2018b). *The Economic Contribution of Broadband, Digitization, and ICT Regulation*. Geneva: International Telecommunications Union. Retrieved from: www.itu.int › D-PREF-EF.BDT_AM-2019-PDF-E.pdf

[117] It should be noted, however, that this benefit will flow to users operating Wi-Fi 6E devices.
[118] Ngo, D. (2020). "Wi-Fi 6 in Layman's Terms: Speed, Range, and More". *Dong Knows Tech* (April 29th). This performance assumes MCS coding scheme 11, OFDM, 2 streams, 1024 QAM (quadrature amplitude modulation), 160 MHz channels, and 0.8us guard interval (GI).
[119] Heterogeneity in willingness-to-pay for broadband was also highlighted by Rosston et al. (2010).

that with the availability of more content and applications, consumers will likely increase their usage, implying greater time savings and a greater willingness-to-pay for speed. At the time of the research, the increase in willingness-to-pay for high speeds dropped by approximately $0.11 per Mbps[120]. The authors found that the valuation of bandwidth is highly concave, with lesser added value beyond 100 Mbps (see Graphic B-1).

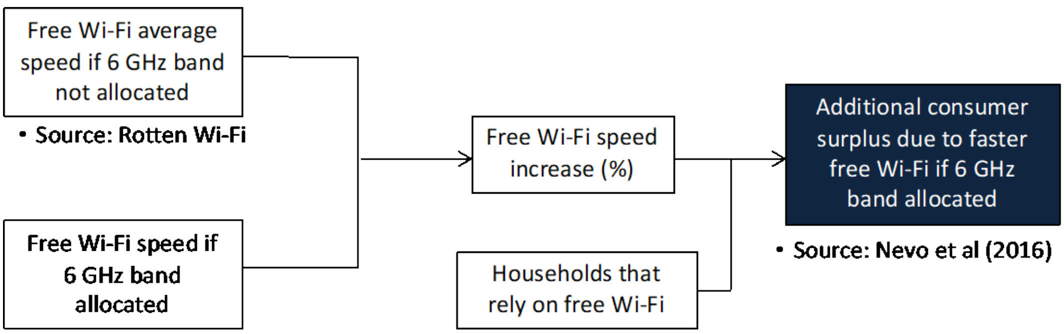
Graphic B-1. Log Curve of relationship between broadband speed and consumer surplus (based on Nevo et al., 2016)



Sources: Nevo et al. (2016); Telecom Advisory Services analysis

As reported in this study, U.S. households are willing to pay about $2.34 per Mbps ($14 total) monthly to increase bandwidth from 4 Mbps to 10 Mbps, $1.57 per Mbps ($24) to increase from 10 to 25 Mbps, and U.S. $0.02 per Mbps ($19) for an increase from 100 Mbps to 1000 Mbps. These figures will be adapted to each specific country, relying on the Purchasing Power Parity (PPP) differences with respect to the United States. Figure B-4 describes the process for estimating consumer surplus under these conditions.

Figure B-4. Methodology for estimating consumer surplus contribution of faster free Wi-Fi if 6 GHz allocated



Source: Telecom Advisory Services

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[120] This is confirmed by a more recent study. Liu et al. (2017) administered two national, discrete choice surveys of U.S. consumers to measure households' willingness-to-pay for changes in price, data caps, and speed.

First, we calculate the percentage of speed increase over current free Wi-Fi. For that purpose, we assume that under the 6 GHz allocation, speed from free hotspots will be similar to the Wi-Fi speeds from mobile devices reported by the Cisco Annual Internet Report Highlights Tool 2018-2023. In addition, we weight that increase by the quantity of households relying on free Wi-Fi, and the estimated percentage of traffic being carried through the 6 GHz channels, which we expect to gradually increase, reaching 40% in 2025. By applying to those figures the willingness-to-pay derived from Nevo et al. (2016), we calculate the resulting consumer surplus.

III.2.2. Residential Wi-Fi

As detailed in Table B-1, the economic value of residential Wi-Fi is driven by the following five sources:

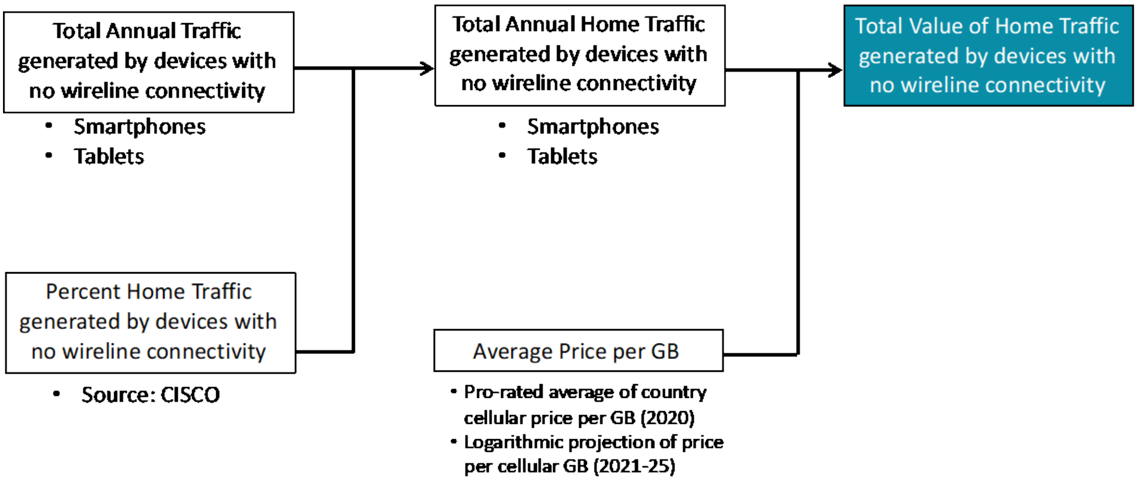
- Wi-Fi only devices (no Ethernet port): home traffic generated by devices that have no inside wiring and access the fixed network through Wi-Fi rather than relying on cellular networks;
- Home networking savings: avoidance of costs required to deploy inside Ethernet wiring to connect home devices and peripherals;
- Faster home Wi-Fi: benefit to consumers for faster broadband speed at home;
- Consumer Wi-Fi equipment: consumer surplus derived from the acquisition of Wi-Fi devices and equipment at prices below their willingness-to-pay; and
- Bridging the digital divide: GDP contribution from additional homes connected through WISPs in rural or isolated areas.

B.2.2.1. Internet access for home usage of Wi-Fi only devices

The underlying premise of this analysis is that, in the absence of Wi-Fi, users would have to depend on the cellular network to gain Internet access. For this reason, to estimate the economic value of Wi-Fi at home, we would first measure the traffic generated by these devices at home, and then multiply it by the consumer's willingness-to-pay.

To estimate this value, we selected a subset of available data on device traffic: smartphones and tablets. We add the total wireless traffic generated by devices with no wireline connectivity and multiply it by the percent that is generated at home. This estimate is used to calculate the consumer surplus in an approach similar to the one used for calculating the value of free Wi-Fi traffic (see Figure B-5).

Figure B-5. Methodology for estimating consumer surplus of residential Wi-Fi traffic



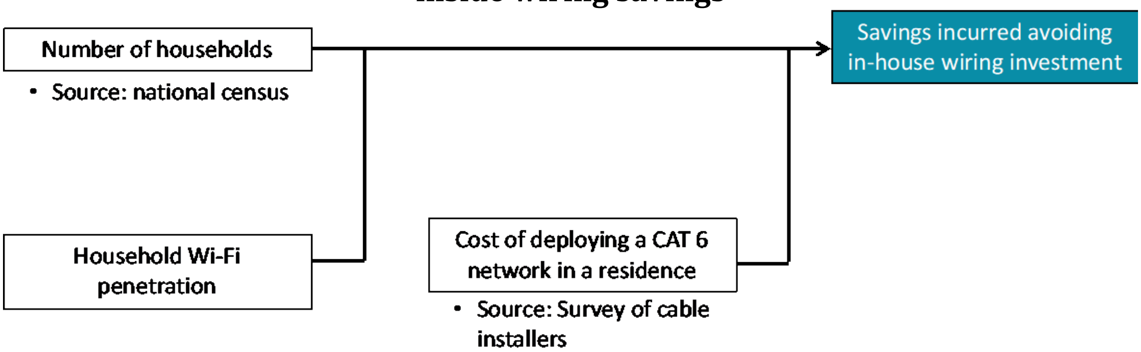
Source: Telecom Advisory Services

Note: future research can explore other home device traffic, such as that of smart TVs and laptops, once reliable sources are available. This study opted for a conservative approach to avoid over-estimation. It is likely that the values in home Internet access are even higher.[121]

B.2.2.2. Avoidance of inside wiring costs

Residential Wi-Fi access points allow consumers to avoid paying for wiring to connect all home devices (printers, laptops, storage units, etc.), which represents a saving to consumers. To calculate this consumer surplus, we estimate the number of households equipped with a Wi-Fi access point and multiply this value by the standard cost of deploying a CAT 6-based network with multiple connections (see Figure B-6).

Figure B-6. Methodology for estimating Consumer Surplus derived from inside wiring savings



Source: Telecom Advisory Services

[121] In particular, the development of Wi-Fi 6E will allow for more devices connected at home, although we prefer to be cautious and not quantify this additional economic effect.

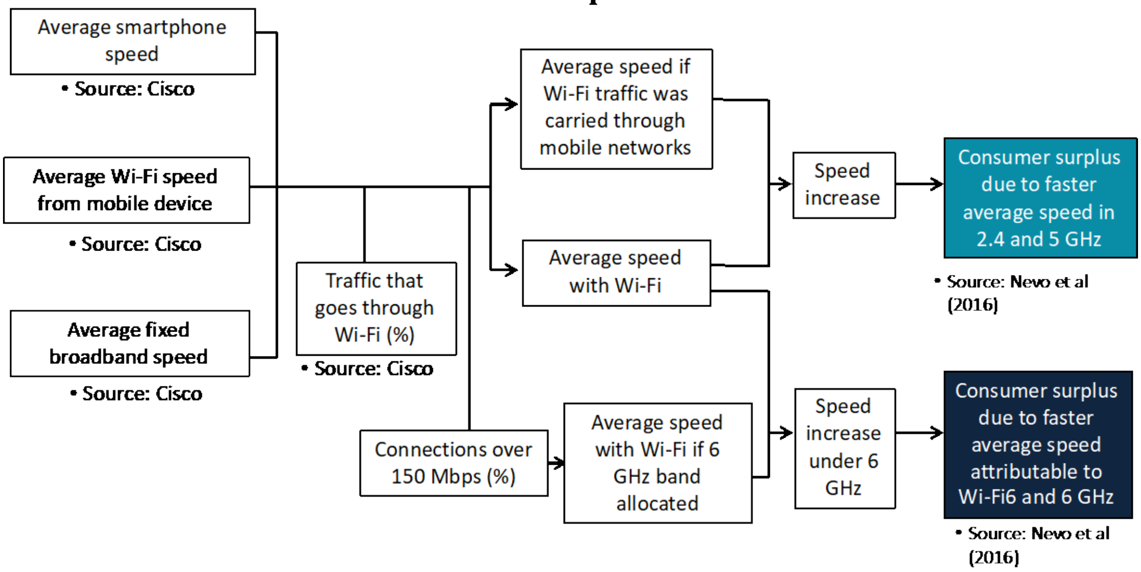
B.2.2.3. Benefit derived from a speed increase

The welfare of residential Wi-Fi customers is expected to benefit from faster broadband speeds than those provided by cellular networks.

Faster broadband speed in the 2.4 GHz and 5 GHz bands

Figure B-7 describes the methodology followed to calculate the consumer surplus generated from faster residential Wi-Fi speeds.

Figure B-7. Methodology for estimating consumer surplus derived from faster speed



Source: Telecom Advisory Services

First, we will calculate the average household speed if the Wi-Fi traffic were carried through cellular networks and compare it with the weighted average by using Wi-Fi.[122] Once the percentage of speed increase is computed, we follow the same procedure as described above, relying on Nevo et al (2016) estimates for the United States (adjusted to each country by PPP differential) to calculate the additional consumer surplus.

Additional benefit to consumers from speed increases due to 6 GHz spectrum allocation

The welfare of residential Wi-Fi customers is expected to benefit from the 6 GHz allocation and the consequent increase in access point performance, which will yield faster service. This will materialize in terms of an additional increase in speed.

When a consumer accesses the Internet, the access speed at the device level is a function of the performance of the fixed and/or wireless network and the router's

[122] In any case, it must be said that the progressive launch of 5G services will decrease the speed-advantage in favor of Wi-Fi. Hence, we will have to consider the progressive expansion of 5G in the cellular speed projections towards 2025.

throughput. The net result differs from the speed of the broadband connection. For example, if a user purchases a 20 Mbps fixed broadband line, it is highly unlikely that the Wi-Fi router will become a performance bottleneck. A dual band router can deliver peak speeds of 1.2 Gbps on 2.4 GHz radio, 4.8 Gbps on one 5 GHz radio, and 4.8 Gbps on the other 5 GHz radio. Based on the current 2.4 GHz and 5 GHz allocation, dual router performance is estimated to be 266.50 Mbps (which results from assuming an even split of traffic between the 2.4 GHz band (at 173 Mbps) and the 5 GHz band (at 360 Mbps)). This does not mean, however, that each user is receiving the total speed. Under this circumstance, if the user acquires a 150 Mbps fixed broadband line, the router operating on the 2.4 GHz and 5 GHz bands becomes a choke point, and the speed experienced by the consumer will not be equivalent to that delivered by the fixed network.

Through the use of multiple bands and spatial streams, Wi-Fi 6 routers have total throughput capabilities well in excess of the speeds they can enable for individual devices. For example, a Wi-Fi 6E device can, in theory, handle total throughput of 4.8 Gbps.[123] In this context, relying on the 6 GHz band allows users who acquire broadband lines in excess of 150 Mbps to get the full benefit of enhanced speed. The speed increase over the previous Wi-Fi baseline scenario, where routers only rely on the 2.4 GHz and 5 GHz bands, will be calculated in terms of additional consumer surplus.

B.2.2.4. Residential Wi-Fi devices and equipment

Consumers receive an economic surplus from acquiring Wi-Fi devices at a lower price than their willingness-to-pay for them. Value is calculated based on devices that can be acquired either under the baseline scenario of 2.4 GHz and 5 GHz bands, or the 6 GHz band.

Residential Wi-Fi devices and equipment in the 2.4 GHz and 5 GHz bands

Products in this ecosystem include a full range of consumer electronics (see Table B-2):

Table B-2. Wi-Fi enabled residential equipment

Market segment	Equipment
Consumer	• Wireless speakers • Home security systems • Home networking devices • Tablets • Access points • External adapters • Routers • Gateways

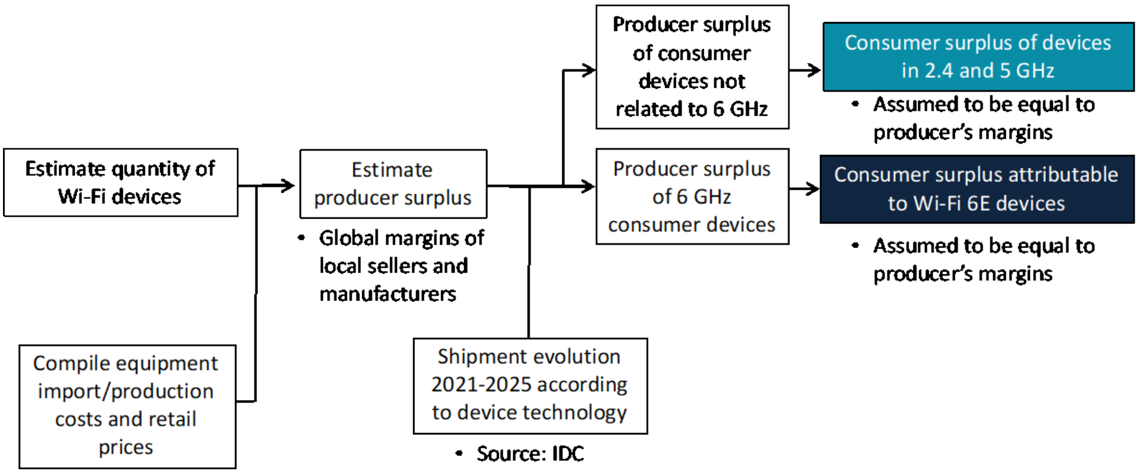
Source: Telecom Advisory Services

The absence of data on the willingness-to-pay for each piece of equipment makes it very difficult to reliably estimate consumer surplus. To overcome that limitation, a

[123] Estimate provided by Broadcom. This refers to the throughput received by each user device (PC, tablet, etc.) within the user premise.

possible approximation is to assume that consumer surplus would equal the producer surplus (see Milgrom et al., 2011). Therefore, we calculate the producer's margin based on the total sales of Wi-Fi enabled residential equipment in a given country, and attribute that value to the consumer surplus.

Figure B-8. Methodology for estimating consumer surplus derived from residential Wi-Fi devices



Source: Telecom Advisory Services

We also calculate the consumer surplus derived from the adoption of tablets (a product that is enabled mostly by Wi-Fi access), by considering the difference between the users' willingness-to-pay and the current market prices. In this case, sales by country and data on the willingness-to-pay is available from research in the United States.

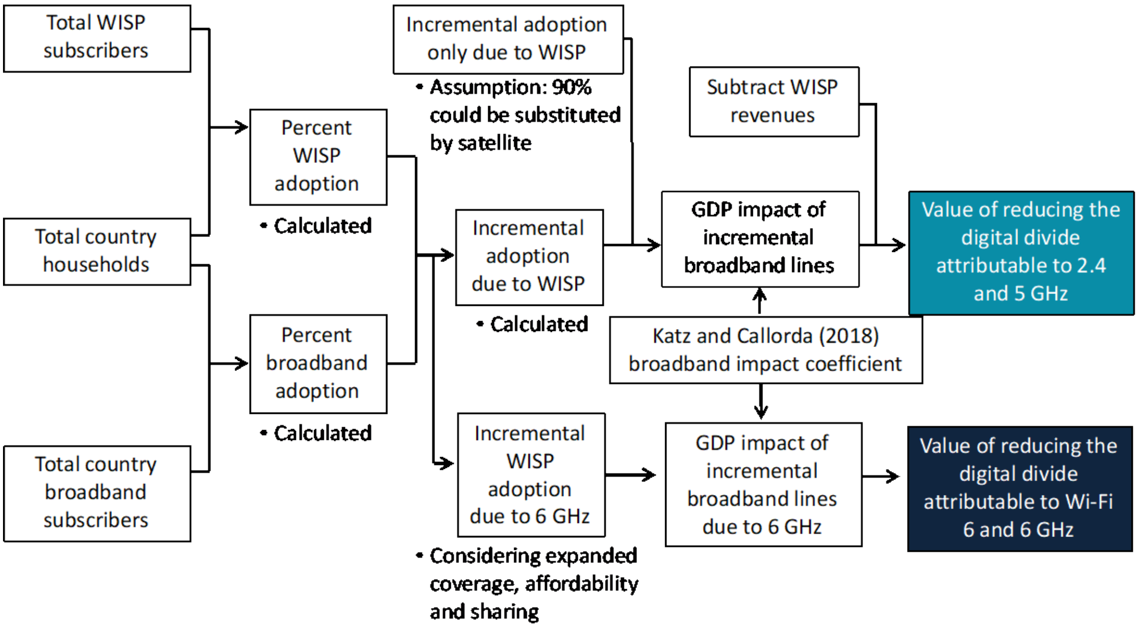
Residential Wi-Fi 6 devices and equipment

As we have seen before, the acquisition of Wi-Fi residential devices yields consumer surplus as long as the price paid is below the amount consumers are willing to pay for them. In this section, we follow the same approach as in the baseline scenario but consider only Wi-Fi 6 devices and equipment. For that purpose, we will follow the forecasts provided by IDC regarding the evolution of shipments for consumer 802.11ax devices for the 6 GHz band.

B.2.2.5. Bridging the digital divide: use of Wi-Fi to increase coverage in rural and isolated areas

Wi-Fi is an appropriate technology to offer Internet access in rural and isolated areas. Given that Wireless Internet service Providers (WISPs) tend to be prevalent in rural areas, to calculate the value of Wi-Fi in reducing the digital divide, we must subtract the impact of Wi-Fi 6 on WISP revenues to avoid double counting. The analysis then proceeds to subtract WISP broadband lines from the incremental growth in rural areas that results from extending broadband service via Wi-Fi. Once this is done, we calculate the impact on GDP by relying on the coefficient estimated by Katz and Callorda (2018b; 2019) through regression models that link the increase in broadband lines to economic growth. The contribution to GDP materializes through multiple effects: creation of new businesses, increasing productivity of existing enterprises (in particular, agriculture), and growth of average income per household (see Figure B-9).

Figure B-9. Methodology for estimating GDP Contribution derived from bridging the digital divide



Source: Telecom Advisory Services

Economic impact of enhanced coverage and affordability due to 6 GHz

As stated above, the WISP industry is a critical contributor to tackling the digital divide. In that respect, WISPs tend to have a primary focus on the vulnerable population and part of their deployment is in rural areas. In that sense, it is critical to understand how these players could benefit from the allocation of 6 GHz.[124]

The allocation of the 6 GHz band to unlicensed use would allow WISPs to potentially increase their subscriber base within their same coverage footprint. Since WISPs rely on the 2.4 and 5 GHz bands for unlicensed Wi-Fi use, these bands support between 50 and 100 client devices per access point at a theoretical maximum aggregate data rate of 6.9 Gbps. The allocation of the 6 GHz band would allow WISPs to sign up new devices and increase download speed, which would trigger several simultaneous positive effects. As an example, the temporary assignment of spectrum by the FCC to deal with the COVID-19 pandemic allowed WISPs in the United States to immediately increase their subscriber base between 20% and 30%. We will follow a cautious approach and consider that the expanded coverage will yield

[124] As background, the WISP association in the United States were a key stakeholder supporting the FCC decision to allocate the 6 GHz spectrum (see WISPA, 2020: *Letter to the FCC Commissioners*, March 5).

gradual increases in WISP subscribers, from 2% in 2022 to 5% in 2025 over the figures projected without assuming the additional spectrum allocation.

Recognizing the economies of scale in telecommunications services, an increase of the user base would allow service providers to lower their operating costs. Under a conservative scenario, prices will remain stable within the context of increasing GDP per capita. In consequence, affordability would increase for those potential subscribers that indicate that they do not purchase broadband service because of its cost. With an increase in affordability, the penetration of broadband will further grow. An additional effect on broadband adoption relates to an increase in the household sharing ratio as result of increased access point performance. This is a particularity especially common in developing countries. The increase in affordability, combined with an improved capability to share lines, will result in the growth of broadband connections and hence, a contribution to GDP.

B.2.3. Enterprise Wi-Fi

The economic value of enterprise Wi-Fi is generated from five sources:

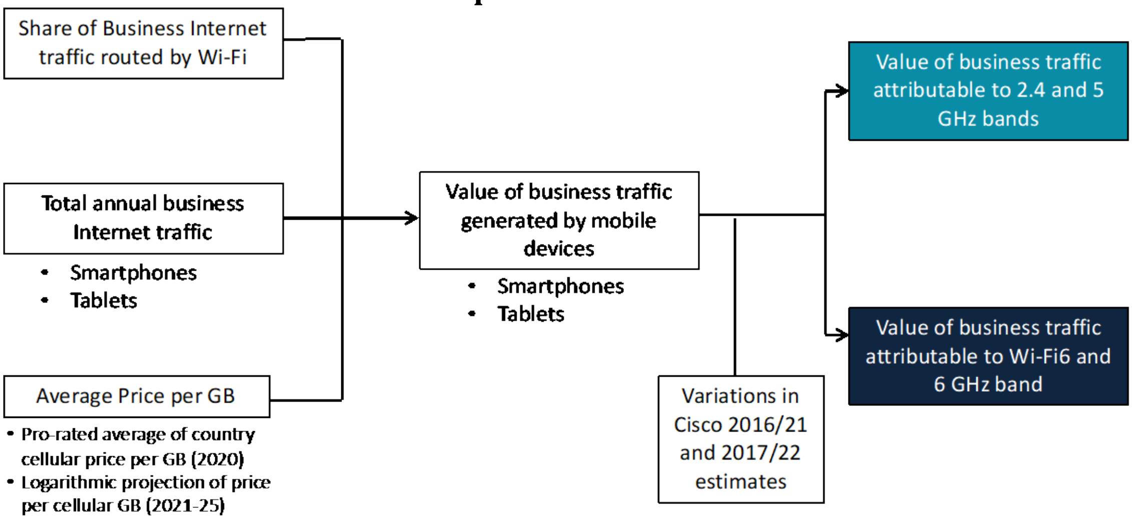
- Business Wi-Fi use: mobile business traffic routed through Wi-Fi access points rather than cellular networks;
- Networking savings: avoidance of capital investment to deploy Ethernet wiring inside enterprise buildings and campuses to connect devices and peripherals;
- Increased speed: enhanced productivity due to faster connectivity via Wi-Fi;
- IoT: economic spillovers generated through the deployment of IoT; and
- AR/VR: economic spillovers generated by the diffusion of AR/VR solutions in the production sector of the economy.

B.2.3.1. Business Internet traffic transmitted through Wi-Fi

Wi-Fi enterprise savings results from wireless traffic that is routed through Wi-Fi access points. The cost of Wi-Fi traffic is calculated by multiplying it by the average price per gigabyte of wireless data transmitted by wideband networks, which we calculate by averaging the most economic dollar per GB plan of major wireless carriers[125] in each country (see Figure B-10).[126]

[125] We acknowledge that enterprises are likely to negotiate wireless rates lower than those offered in the consumer market; however, data in this area is not available.
[126] This economic value is computed as producer surplus, although a different interpretation could justify its consideration as consumer surplus, if assuming that the enterprises are effectively consumers of Internet services in this context.

Figure B-10. Methodology for estimating economic surplus of Enterprise Wi-Fi traffic



Source: Telecom Advisory Services

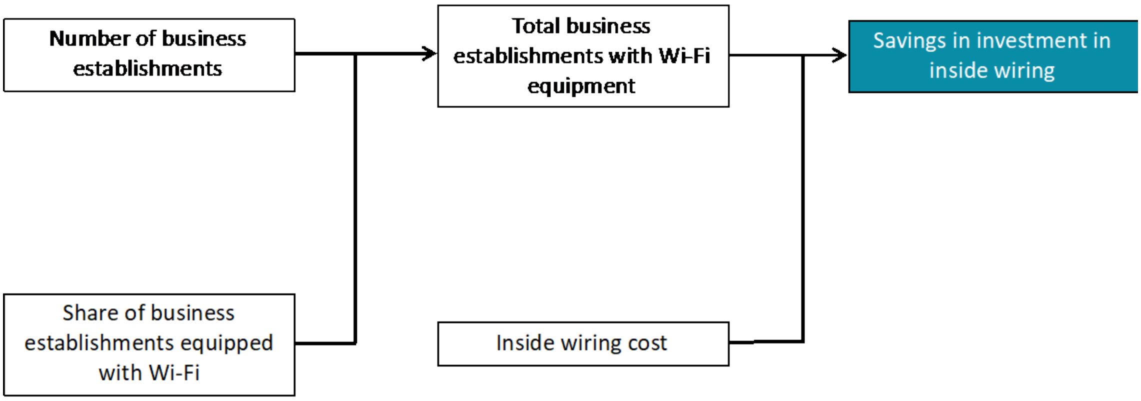
Business traffic if 6 GHz allocated

The increase in unlicensed channel capacity enables more extensive delivery of ubiquitous, high throughput wireless connectivity across multiple access points in business facilities, such as industrial plants, enterprise campuses, and the like. This will allow firms to leverage Wi-Fi infrastructure and generate further savings in the use of wideband wireless communications. As reported above, Wi-Fi 6E will be able to handle up to 1,500 devices, which makes them ideal for enterprise applications. This will help increase the producer surplus of enterprises. To estimate the specific effect attributed to 6 GHz, we begin by analyzing the variations in Cisco's Annual Internet Report Highlights Tool 2018-2023 enterprise Internet traffic forecasts for 2016-21 and 2017/22. We assume that part of the growth in forecasted traffic between both projections was driven by "natural" growth (that is to say, the extrapolation of historical growth), and another portion was triggered by Wi-Fi traffic stimulated by the 6 GHz spectrum allocation.

B.2.3.2. Savings in enterprise building inside wiring

Similar to residential Wi-Fi savings due to capital investment avoidance in inside wiring, we assume the total number of business establishments that are equipped with Wi-Fi access points and multiply this value by a standard cost of deploying a CAT 6-based network (although in this case, the cost is obviously higher than for a residence) (see Figure B-11).

Figure B-11. Methodology for estimating economic surplus derived from inside wiring savings



Source: Telecom Advisory Services

B.2.3.3. Return to speed: contribution to GDP derived from an increase in average mobile speed

The off-loading of cellular traffic to Wi-Fi generates a "return to speed" economic value.[127] As such, the speed of access could be significantly higher via a Wi-Fi access point than on cellular networks, although 5G developments are expected to decrease that speed differential. Literature on econometric research has attempted to measure the impact on GDP of higher broadband speed (see for instance Rohman and Bohlin 2012; Bohlin et al., 2013; Kongaut and Bohlin 2014). More recently, Katz and Callorda (2019) analyzed the impact of fixed broadband speed in GDP for a sample of 159 countries during the period 2008-2019, providing further evidence of the positive economic effect of broadband quality (Table B-3).

Table B-3. Impact of downloading speed of fixed broadband on GDP

Impact on GDP	Speed < 10 Mbps	Speed 10 Mbps - 40 Mbps	Speed > 40 Mbps
Ln Download speed$_{t-4}$	-0.00206 (0.00136)	0.00264 (0.00138) ***	0.00730 (0.00211) ***
Ln Employment t$_{t}$	0.00664 (0.00189) ***	0.00525 (0.00168) ***	0.00458 (0.00165) ***
Ln Investment t$_{t-4}$	0.01459 (0.00216) ***	-0.00616 (0.00382)	-0.00085 (0.00481)
Countries included	116	105	49
Observations	2.113	1.792	575
R-Squared	0.9516	0.9262	0.9438

*Note: all estimates include country and quarterly fixed-effects, and controls for GDP growth in the previous period and for broadband penetration. Robust standard errors in brackets. *p<10%, **p<5%, ***p<1%*

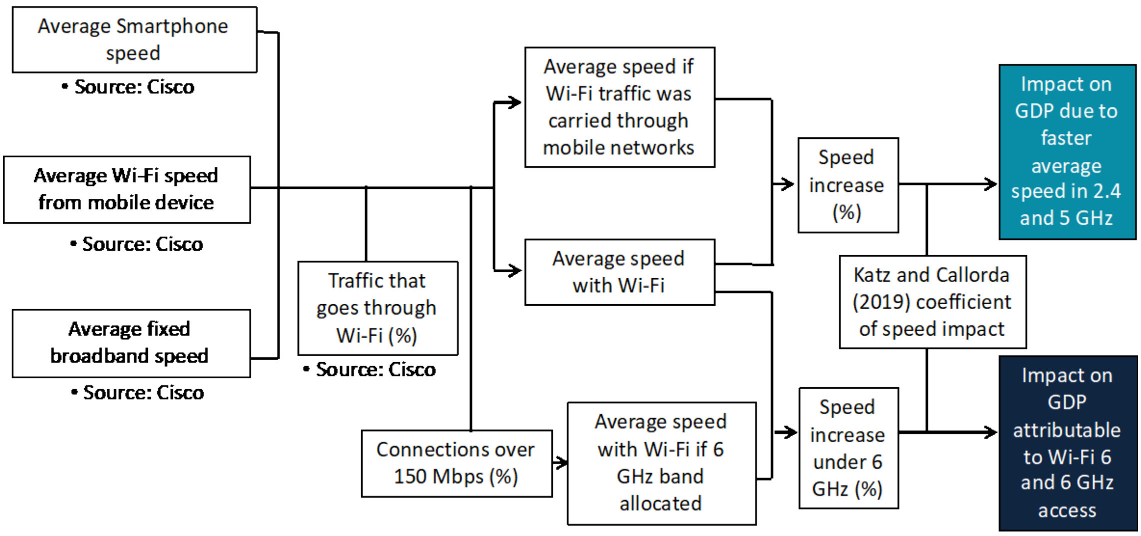
Source: Katz and Callorda (2020)

[127] This effect was allocated as part of the economic value related to enterprises as the productivity gains derived from more speed are expected to be especially prominent in the productive sector. However, gains are expected for each economic agent. For instance, individuals enjoying faster speeds will be quicker in performing their online tasks, hence having more spare time for leisure.

The results in Table B-3 suggest that the coefficient that measures the impact of speed on GDP increases with the speed: from non-significant for lower than 10 Mbps speeds to 0.73025 if speeds are doubled for countries above 40 Mbps speed.

To estimate the "return to speed" in enterprise traffic, we first calculate the average speed if the business Wi-Fi traffic were carried through cellular networks and compare it with the average when using Wi-Fi. After finding out the percentage of speed increase by relying on Wi-Fi, we apply the coefficient of GDP impact from Katz and Callorda (2019) to assess the economic contribution (see Figure B-12).

Figure B-12. Methodology for estimating enterprise Wi-Fi return to speed



Source: Telecom Advisory Services

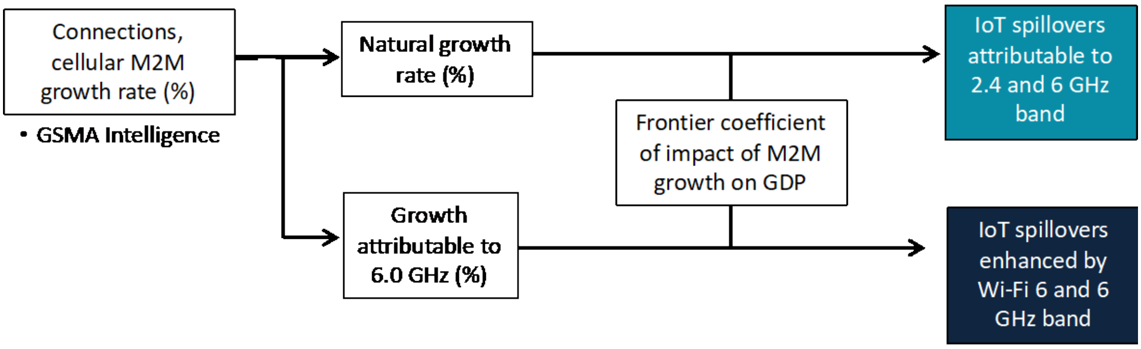
Effects of a return to accelerate speed accelerated due to 6 GHz

The economic value of allocating the 6 GHz band to unlicensed use reduces router congestion, increases Wi-Fi throughput, and has a net effect of accelerating broadband speed. This result does not affect all fixed broadband connections, although its impact among high speed broadband users has a net effect on increasing average broadband speed. As previously described for the case individuals, under current spectrum allocations, the router becomes a choke point in the network for 150 Mbps fixed broadband lines, and the speed experienced will not be equivalent to that delivered by the fixed network. Wi-Fi 6E contributes to overcome this setback, yielding faster speeds, which, in turn, drive a contribution to GDP. Therefore, we calculate the average speed if 6 GHz were allocated, and after assessing the increase with respect to Wi-Fi under the current spectrum bands, we measure the impact of that increased speed on GDP by using Katz and Callorda (2019) coefficient as presented above.

B.2.3.4. IoT deployment

The economic value linked to a wider deployment of IoT in enterprises includes the spillovers that this technology generates on the economy, which is focused on those sectors that are IoT intensive (i.e. logistics, healthcare, natural resources). As research has shown, the use cases associated with IoT (such as predictive maintenance, asset tracking, smart grid demand management, traffic coordination, and the like) have an impact on GDP growth. The evolution of cellular Machine to Machine (M2M) connections will be used jointly with the coefficient of M2M impact on GDP (from Frontier Economics) in order to assess the indirect impact of IoT on GDP (Figure B-13).

Figure B-13. Methodology for estimating IoT spillovers



Source: Telecom Advisory Services

Accelerated effect of IoT due to 6 GHz

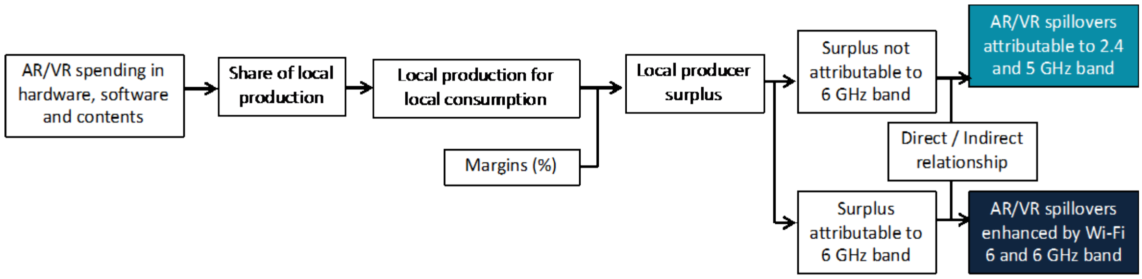
Spectrum availability is one of the barriers to IoT development. While IoT roll-out has already been proceeding for a few years in several countries, large scale deployment has suffered from the risk of congestion. The assignment of the 6 GHz band will result in a broader scale IoT deployment, as it will mitigate congestion. We will compute the economic value added by allocating the 6 GHz band related to the wider deployment of IoT, considering the spillover of IoT on the economy, which is focused on those sectors that are IoT intensive. In order to split the economic contribution linked to 6 GHz from that of the current bands, we will assume that part of the growth in M2M is driven by "natural" growth, and another portion will be triggered by 6 GHz.

B.2.3.5. AR/VR solutions deployment

Virtual Reality (VR) is already being used within a wide array of areas, ranging from the gaming industry and entertainment, to training and simulation, in particular in the medical field. Other areas of application include education and culture, sports, live broadcasting, real estate, advertising, architecture, and the arts. Augmented Reality (AR) has an almost limitless range of use in a wide variety of areas, be it commerce, technical applications, work processes or education. As previously mentioned, AR and VR serve both consumers and professional users that can be private and public.

The adoption of AR/VR among enterprises will in turn have a spillover effect on productivity, thereby contributing to the growth of GDP. The spillover effects range from improved training to the acceleration of product design and delivery. For example, automotive companies are already incorporating virtual reality in their product development processes to reduce the time incurred between initial design and physical modelling. AR glasses also help warehouse workers provide parts information for engineers and technicians in the field. Finally, AR/VR solutions can be used to sell and showcase products in retailing. Figure B-14 describes the methodology used for estimating the AR/VR spillovers.

Figure B-14. Methodology for estimating AR/VR spillovers



Source: Telecom Advisory Services

The direct/indirect relationship ratio was extracted from PwC (2019).

Wider deployment of AR/VR solutions (accelerated effect due to 6 GHz)

As stated for the baseline scenario, the adoption of AR/VR among enterprises produces spillovers effects on productivity, thereby contributing to the growth of GDP. Higher throughput enabled by the allocation of the 6 GHz band is expected to spur the adoption and use of AR/VR among enterprises, hence increasing the associated spillover effects. By relying on a ratio built from 5 GHz and 6 GHz AR/VR related products (from ABI research data[128]), we were able to split the economic contribution from both scenarios.

B.2.4. Internet Service Providers

As detailed in Table B-1, economic gains of ISPs comprise the following effects:

- Expenditure savings: the total cost of ownership—cumulative CAPEX and OPEX—required of cellular operators to accommodate future capacity requirements with Wi-Fi;
- Paid, public Wi-Fi: revenues from Wi-Fi carriers offering paid services in public spaces; and
- Revenues from WISPs.

B.2.4.1. Expenditure savings: total cost of ownership (cumulative CAPEX and OPEX) to accommodate future capacity with Wi-Fi

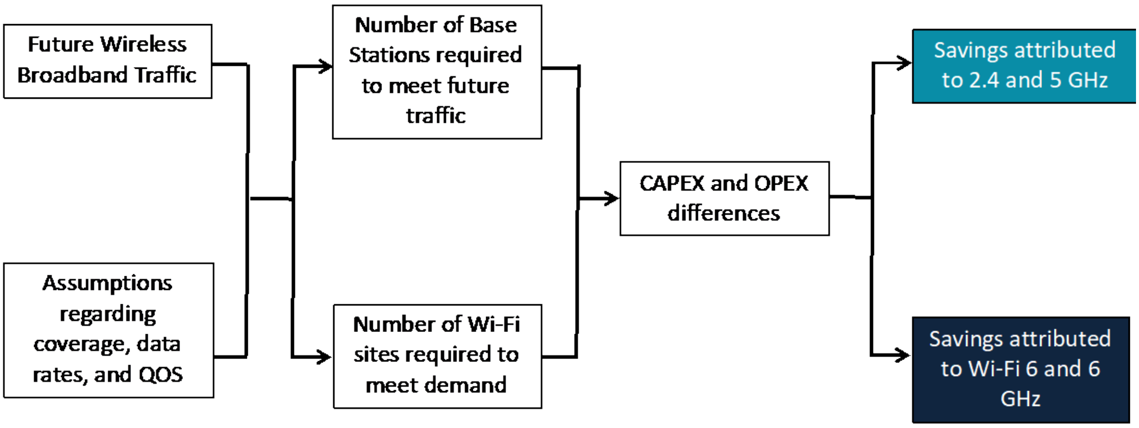
Wi-Fi yields a benefit to the producers of wireless communications. Carrier-class Wi-Fi allows the operator to leverage wideband access (for mobility) and Wi-Fi

[128] See ABI Research, *Augmented and Mixed Reality Market Data: devices, use cases, verticals and value chain*. MD-ARMR-103, QTR 4 2019, and ABI Research, *Virtual Reality Market Data: devices, verticals, and value chain*. MD-VR-108, QTR 1 2020.

offloading (for network capacity).[129] By building hybrid networks, carriers preserve spectrum and reduce the capital expenditures required to deploy additional base stations.[130] In addition, some service providers also claim they monetize their Wi-Fi offerings by directly charging customers. Carriers also benefit from service differentiation and an improvement in the customer experience.

The estimate of producer surplus is predicated on the assumption that in the absence of Wi-Fi, service providers would have to deploy cellular base stations to accommodate the growth in traffic. For example, a cellular pico-cell (needed to offer access via conventional cellular service) in the United States costs between $7,500 and $15,000,[131] while a carrier-grade Wi-Fi access point requires an investment of $2,500.[132] Thus, the calculation of producer surplus is based on the portion of capital investments (and potential incremental network operations and maintenance operating expenses) that service providers can avoid when they shift allocations from cellular network to carrier-grade Wi-Fi. Thus, the analysis is then based on the following methodology (see Figure B-15).

Figure B-15. Methodology for estimating producer surplus derived from cellular re-routing through Wi-Fi



Source: Telecom Advisory Services

Enhanced capability for cellular off-loading if 6 GHz is allocated

As mentioned before, another source of economic value is based on the complementarity between Wi-Fi and cellular networks, which allows cellular service providers to decrease the capital and operating expenses required to accommodate exploding data traffic. This feature remains for Wi-Fi 6E and 5G. To begin with, access devices like smartphones and sensors will tend to be equipped with both generations for users and service providers to optimize infrastructure use. This will be critical not only for traffic handling in densely packed

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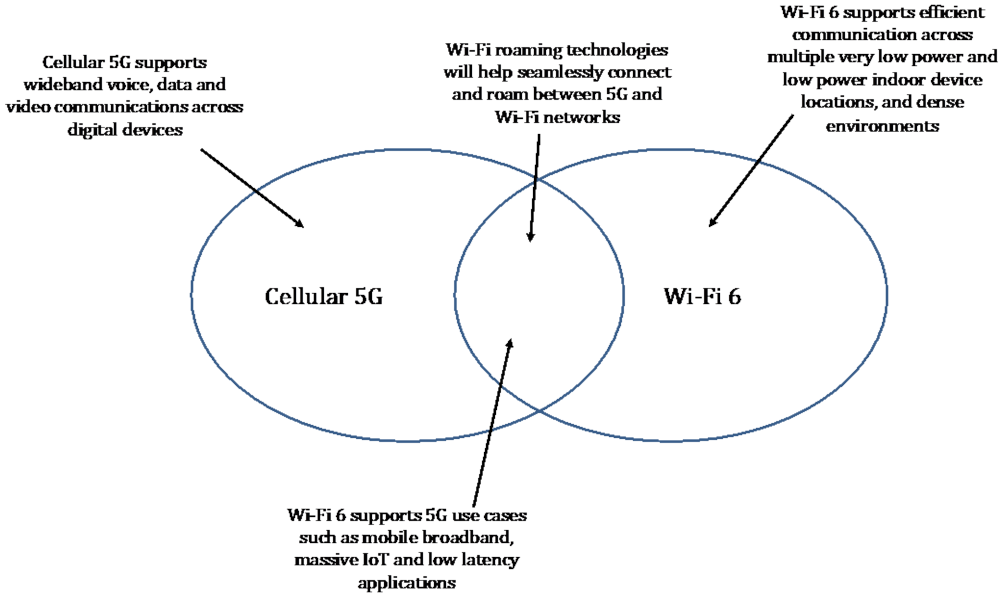
[129] Carriers can also off-load traffic by deploying femtocells, which provide higher capacity. However, since these operate in licensed spectrum bands, they are not part of this analysis.
[130] Hybrid network architectures allow wireless operators to shift traffic away from the cellular network, where the capacity constraints are most acute, to cheaper shorter-range small cells network, connected over a variety of backhaul connections.
[131] "When Femtocells become Picocells", the 3G4G Blog and Ubiquisys.
[132] Cisco Airnet 1552H Wireless Access Point.

environments, such as apartment complexes and hospitals, but also to support surveillance cameras, point of sale terminals, environmental sensors, and other IoT devices. Complementarity will also manifest itself at homes and enterprises, although this benefit has already been accounted for in the sections above (see Figure B-16).

Figure B-16. Complementary nature of Wi-Fi 6 and 5G



Sources: Suarez (2020); Telecom Advisory Services analysis

Consequently, the economic value of spectrum allocation in 6 GHz not only manifests itself in the ability of cellular carriers to reduce capital in 5G deployment by off-loading traffic, but, most importantly, to indirectly account for Wi-Fi use in calculating their investment.

B.2.4.2. Wi-Fi carrier revenues

In addition to the value generated by the other effects, Wi-Fi off-loading can create new business opportunities for service providers offering wireless broadband services in public places (airports, hotels) for a fee. In the last three years, operators in this space have deployed next-generation hotspot technologies to replicate the ease of access and security provided by cellular networks. At the same time, to facilitate interoperability, they are signing roaming agreements. From a business model standpoint, innovation has allowed this sector to expand beyond the original pay-as-you-go access offering. In particular, it is worth mentioning retailer "push" marketing and promotions, neutral host provision to multiple cellular carriers, and bandwidth exchange for Wi-Fi capacity[133] (Maravedis-Rethink, 2013).

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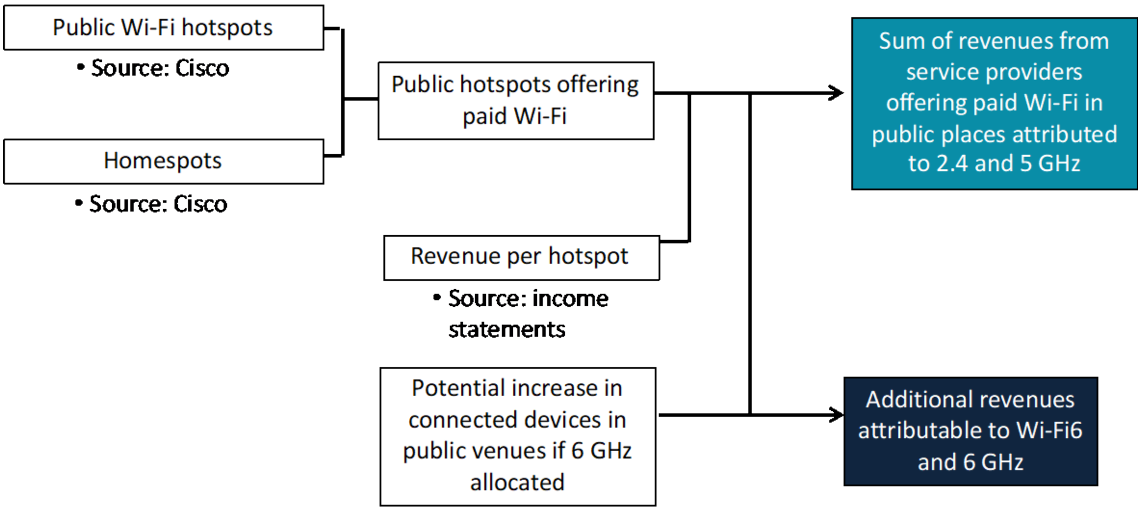
[133] BandwidthX offers an open market exchange of capacity between public Wi-Fi operators and any partners in need of Wi-Fi capacity. The solution allows carriers to bid for and purchase Wi-Fi capacity dynamically from available WISPs, with pricing based on a range of network selection policies, including place, time of day, etc.

Figure B-17. Methodology for estimating the economic value generated by paid public Wi-Fi services



Source: Telecom Advisory Services

The methodology described in Figure B-17 starts by estimating the number of paid access points, subtracting the home spots from overall public hotspots reported by Cisco. Revenue per hotspots is estimated from the financial statements of the biggest enterprises offering these services. Once the number of public hotspots is estimated, this can be multiplied by the revenue expected for each one, allowing a straightforward assessment of the overall revenue figures.

Increased revenues of Wi-Fi carriers in public places due to 6 GHz

When the 6 GHz band is opened and added to the existing unlicensed bands in 2.4 GHz and 5 GHz, a higher number of devices will be supported by each access points. Therefore, Wi-Fi carriers offering paid services in public places will be able to widen their user base and increase revenues. By assuming a conservative growth of 40% in their user base, weighted by the expected gradual increase in traffic over the 6 GHz channels, we can calculate the additional revenues attributed to 6 GHz.

B.2.4.3. Wireless ISP revenue

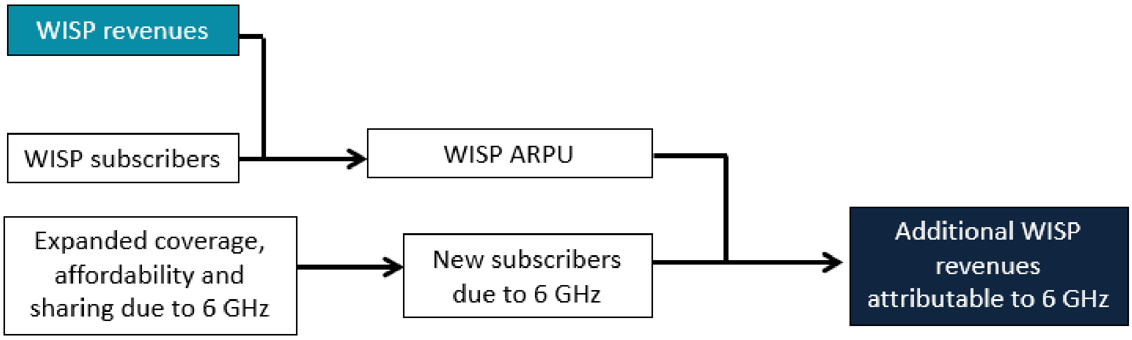
Revenues from WISPs would not exist if Wi-Fi technology was not available. By considering the estimated ARPU figures from WISP providers and their user base, it is straightforward to estimate overall revenues for these players.

Increased revenues of WISPs due to 6 GHz[134]

[134] Another potential gain for WISPs from opening the 6 GHz band is derived from increased capacity in backhaul, that is, in the network linking the consumer connection point (edge network) and the core network (Internet connection point). This higher throughput can be leveraged to bring down CAPEX requirements, hence, the producer surplus is increased. However, due to lack of reliable data, this specific effect was not assessed.

As described before in section 2.5, the allocation of the 6 GHz band is expected to increase the number of WISP subscribers due to expanded coverage, better affordability, and potential sharing. Considering the WISP average revenue per user (ARPU) and the estimated incremental subscriptions, it is straightforward to assess the additional revenue figures after the 6 GHz band is opened. Figure B-18 describes this procedure.

Figure B-18. Methodology for estimating the economic value generated by WISPs as a result of Wi-Fi 6 and 6 GHz



Source: Telecom Advisory Services

B.2.5. Wi-Fi ecosystem

Wi-Fi technology generates value for IT companies from the following sources:

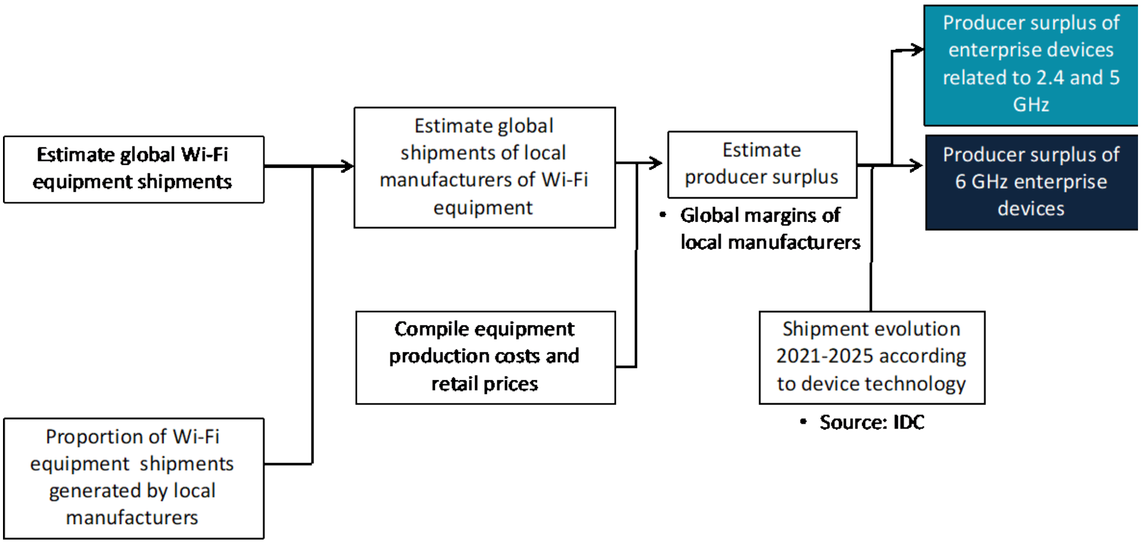
- Producer surplus derived from locally manufactured Wi-Fi devices and equipment for residential and enterprise use; and
- Margins from firms belonging to the ecosystem of IoT and AR/VR.

B.2.5.1. Locally manufactured residential Wi-Fi devices and equipment

The difference between market prices and locally manufactured costs of Wi-Fi enabled residential products represents the manufacturer's margin and, consequently, producer surplus. Such products include those previously reported in Table B-2.

Once the list of equipment is defined, we start by compiling statistics on worldwide shipments (even if a piece of locally produced equipment is shipped beyond the borders of the local market, that yields economic value to the country of origin). With these statistics, we calculate average retail value and gross margins. The margin represents producer surplus. An alternative approach could have been to consider the weight of the production of devices in the GDP, rather than the production surplus. However, a deep analysis suggested that a large share of the costs of these enterprises are attributed to equipment imports, which means that part of the economic value is originated abroad if we followed this approach. Therefore, we understand that it is more appropriate to measure this economic contribution as producer surplus.

Figure B-19. Methodology for estimating economic value derived from locally manufactured Wi-Fi devices



Source: Telecom Advisory Services

Locally manufactured Wi-Fi 6 devices and equipment for residential use

As we have seen before, we will follow the forecasts provided by IDC regarding the evolution of consumer devices shipments until 2025 in order to extrapolate the evolution of those Wi-Fi 6 devices and equipment, and therefore, the producer surplus generated as a result.

B.2.5.2. Locally manufactured enterprise Wi-Fi devices and equipment

The procedure to estimate the producer surplus attributed to enterprise devices and equipment is like that for residential products, although focusing exclusively on access points and controllers for enterprises. To isolate the economic contribution of Wi-Fi 6 devices and equipment, we will follow the forecasts provided by IDC regarding the evolution of shipments for industrial purposes of 802.11ax devices for the 6 GHz band.

B.2.5.3. Firms belonging to the IoT ecosystem

The economic value linked to a wider deployment of IoT includes the development of firms within the IoT ecosystem, which generate a producer surplus (i.e. margin) through selling their output. It is important to distinguish the different components of the ecosystem, which includes hardware, software, and services. As it is clear, this distinction is grounded in traditional IT components, although their combination within the IoT value proposition represents a different format. The ecosystem contributing to delivery of the IoT economic value comprises multiple types of companies (see Table B-4).

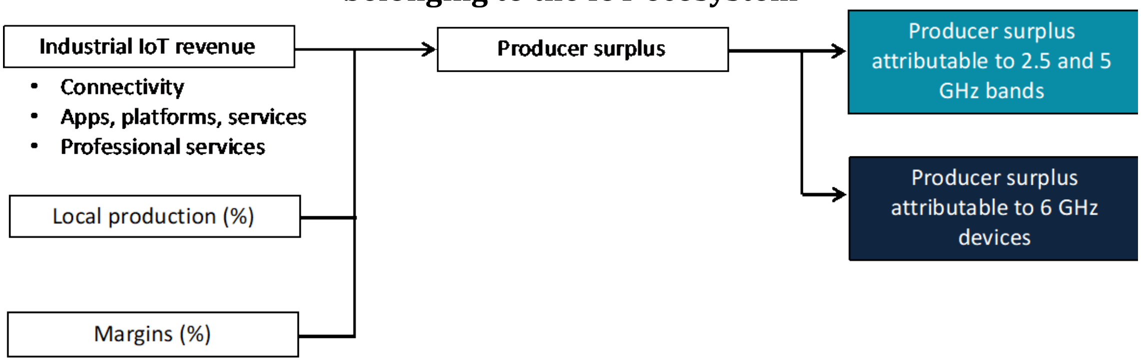
Table B-4. IoT Ecosystem

Categories	Components	Type of firms
Hardware	Sensors/chips	Manufacturers of sensors and compute components
	Miniature devices	Specialized providers of small-scale sensors
	Connectivity	Manufacturers of network equipment
Software	Apps	Connectivity software
	Cloud service providers	Software provided by public cloud providers
	Platform providers	New operating systems
	Carriers	Telecom players providing cloud-based solutions
Services	Systems integration	Integration of devices and components within a single platform
	Analytics	Providers of data warehousing and analytic tools
	IT services	Platform providers
	Security	Developers of security protocols and technologies

Source: Telecom Advisory Services

The methodology for estimating economic value derived from firms belonging to the IoT ecosystem is described in Figure B-20.

Figure B-20. Methodology for estimating economic value derived from firms belonging to the IoT ecosystem



Source: Telecom Advisory Services

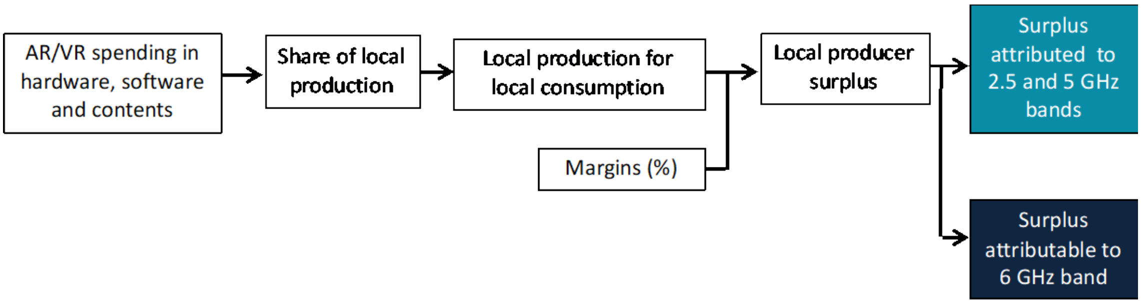
Wider deployment of Internet of Things under 6 GHz

The assignment of the 6 GHz band will result in a broader scale IoT deployment. Thus, we will compute the economic value added by allocating the 6 GHz band related to the wider deployment of IoT specifically related to the development of firms within the IoT ecosystem, which generate a producer surplus (i.e. margin) by selling.

B.2.5.4. Firms belonging to the AR/VR ecosystem

As stated above, the AR/VR solutions market is developing at a fast pace driven by a broad range of applications. The development and diffusion of AR/VR applications in the production side of the economy is being driven by an ecosystem comprised of firms ranging from software development to hardware production and applications development. The margins of firms involved in this endeavor represent producer surplus (Figure B-21).

Figure B-21. Methodology for estimating economic value derived from firms belonging to the AR/VR ecosystem



Source: Telecom Advisory Services

Wider deployment of AR/VR solutions if 6 GHz allocated

The introduction of Wi-Fi 6E is expected to accelerate the development and diffusion of AR/VR applications. As one of the economic effects of AR/VR is related to the production of firms belonging to its ecosystem (software, hardware, applications development), the margins of those firms represent producer surplus. In this section we will calculate the margins specifically attributed to developments linked to Wi-Fi 6E.

B.2.6. Wi-Fi contribution to employment

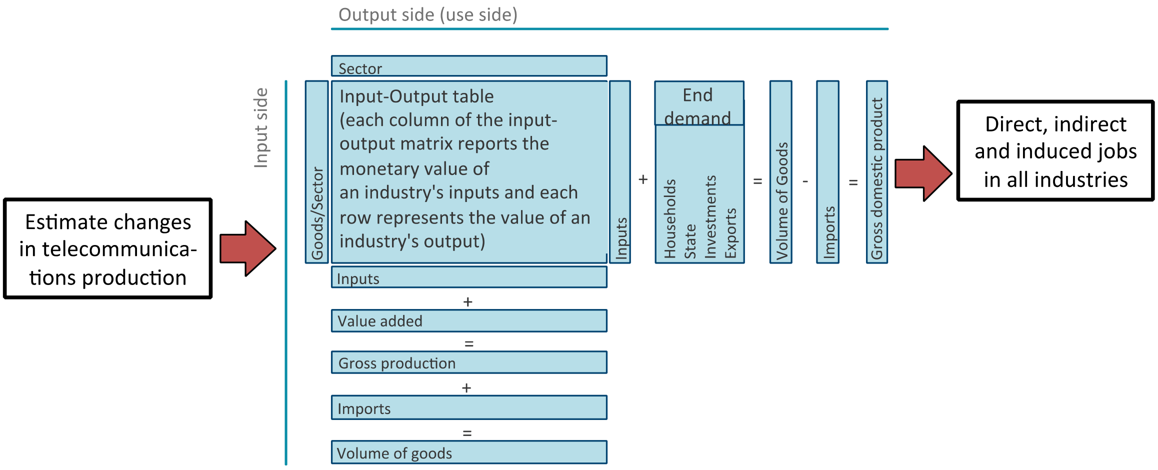
This economic technique, which measures the interdependence of an economy's various productive sectors, has been applied to estimate what the impact on all sectors of employment might be as a result of changes in output of the telecommunications sector. According to this approach, telecommunications output related to Wi-Fi is defined as a factor of production of other goods and services, creating spillover economic effects, with significant job creation effects.

- Employment effects are calculated based on input/output table (I/O table) for each country's economy. I/O tables depict the interdependencies between economic sectors and are used to estimate the impact of positive or negative economic shocks through an economy.

- I/O tables assume that some inputs are used by sectors that produce output (intermediate output), which in turn is sold to another sector for consumption (final output); total output adds intermediate and final outputs. By using labor productivities, one can calculate job creation from output.

The structure of an I/O table comprises horizontal rows describing how an industry's total output is divided among various production processes and final consumption, and each column denotes the combination of productive resources used within one industry (see Figure B-22).

Figure B-22. Example of an Input / Output Table



Source: Katz (2012)

Each country has a specific table to reflect the particularities of its economy.

In order to calculate employment impact, the multiplier cumulative impact on GDP resulting from the effects analyzed above would become an input that would generate employment effects through different sectors of the economy of the country under study. Employment effects can be disaggregated among direct, indirect, and induced.

C. COMPARISON OF CURRENT STUDY WITH PRIOR STUDY RESULTS

C.1. The 2018 study assessing the global value of Wi-Fi

In 2018, we published a study assessing the worldwide economic value of Wi-Fi[135]. The study's purpose was to measure Wi-Fi's economic surplus to consumers and producers, as well as Wi-Fi's direct net contribution to output (Gross Domestic Product, or GDP) and employment between 2018 and 2023. The analysis focused on the United States, United Kingdom, France, Germany, Japan, and South Korea and used the detailed country estimates to extrapolate the results to the whole world. We concluded at the time that global economic value of Wi-Fi in 2018 was $1.96 trillion, and that by 2023, global value of Wi-Fi should increase to $3.47 trillion[136] (see Table C-1).

Table C-1. Wi-Fi Global Economic Value (2018 Study) (in $billion)

	2018	2023
United States	$499.1	$1,002.4
United Kingdom	$54.5	$71.2
France	$44.2	$63.9
Germany	$94.0	$132.0
Japan	$171.5	$247.5
South Korea	$67.6	$137.6
Six countries total	$930.9	$1,654.6
Rest of World	$1,033.7	$1,827.1
Total	$1,964.6	$3,472.7

Source: Katz, R. and Callorda, F. (2018a). *The Economic value of Wi-Fi: A Global View (2018 and 2023)*. New York: Telecom Advisory Services.

The study also estimated that, as a derived contribution to economic value, Wi-Fi generated 616,000 jobs in 2018 and was expected to create 934,000 jobs in 2023.

Significant changes have taken place since 2018 in the Wi-Fi ecosystem, warranting a new study. Starting in 2019, Wi-Fi equipment manufacturers launched Wi-Fi 6, a sixth generation of consumer and enterprise Wi-Fi devices offering higher performance, lower latency, and faster data rates. Concurrently with the launch of Wi-Fi 6 and in anticipation of the WRC-23 conference of the International Telecommunication Union, regulators in many countries have recognized the importance of unlicensed spectrum in driving the performance of Wi-Fi. Triggered by the allocation of new Wi-Fi spectrum and the release of Wi-Fi 6 and Wi-Fi 6E devices capable of operating in the 6 GHz band, new sources of Wi-Fi economic value have become prominent since our 2018 study. For example, the creation of a Very Low Power device category will enable the deployment of a new generation of Augmented Reality/Virtual solutions and unlock wide deployment of IoT devices. In sum, the combination of enhanced devices, additional unlicensed spectrum, and new

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[135] Katz, R. and Callorda, F. (2018a). *The Economic value of Wi-Fi: A Global View (2018 and 2023)*. New York: Telecom Advisory Services. October.
[136] All values in this report are in U.S. dollars.

sources of value has yielded an increase in Wi-Fi economic contribution when compared to the 2018-23 study estimate.

In parallel with the changes in the Wi-Fi technology and the regulatory context, a major disruption has taken place in the world economy. COVID-19 has resulted in a downward adjustment in the economic forecast. While before the pandemic the world economy was projected to grow at 2.90% in 2020, the International Monetary Fund now projects a contraction of 6.10%. This revised perspective has had an impact of the base upon which Wi-Fi's economic value is projected.

In order to trace the new projections vis-à-vis the 2018-2023 study, we estimate Wi-Fi economic value for two scenarios: (i) a baseline case that addresses only Wi-Fi's value dependent on the 2.4 GHz and 5 GHz original unlicensed bands, and (ii) an acceleration scenario of value creation considering the 6 GHz spectrum band allocation and the release of Wi-Fi 6 equipment. Both scenarios reflect the changes in the economic context.

C.2. Increase in the value of Wi-Fi in the original unlicensed bands

The changes in the Wi-Fi ecosystem, while occurring concurrently with the economic contraction, have yielded an increase in Wi-Fi value. As indicated in Table C-1, the updated Wi-Fi value for the six countries analyzed in the 2018 study is estimated at $1,602.6 billion in 2021 and projected to reach $2,165.8 billion in 2025.

Table C-1. Wi-Fi Economic Value: 2018 Study versus Current Study (in $Billions)

		2021	2022	2023	2024	2025
United States	2018-2023 Study	$801.8	$894.8	$1,002.4		
	Current study (baseline scenario)	$979.0	$1,026.0	$1,115.8	$1,243.8	$1,392.7
United Kingdom	2018-2023 Study	$64.0	$67.5	$71.2		
	Current study (baseline scenario)	$96.9	$93.2	$87.6	$91.9	$97.8
France	2018-2023 Study	$55.2	$59.4	$63.9		
	Current study (baseline scenario)	$61.2	$63.4	$73.2	$83.0	$95.0
Germany	2018-2023 Study	$115.3	$123.6	$132.0		
	Current study (baseline scenario)	$132.6	$135.4	$140.2	$149.9	$158.0
Japan	2018-2023 Study	$213.7	$230.0	$247.5		
	Current study (baseline scenario)	$245.7	$246.5	$240.5	$267.5	$296.2
South Korea	2018-2023 Study	$103.5	$119.3	$137.6		
	Current study (baseline scenario)	$87.2	$93.4	$102.6	$113.5	$126.1
Six countries	2018-2023 Study	$1,353.5	$1,494.6	$1,654.6		
	Current study (baseline scenario)	$1,602.6	$1,657.9	$1,759.9	$1,949.6	$2,165.8

Note: It should be noted that the decline economic value in 2023 in Japan is due to a decreasing growth rate of M2M and IoT installed base.
Source: Katz, R. and Callorda, F. (2018a). The Economic value of Wi-Fi: A Global View (2018 and 2023). New York: Telecom Advisory Services; Telecom Advisory Services analysis

While our original estimate for the baseline scenario (that is, without considering Wi-Fi 6 and the 6 GHz allocation) for the six countries in 2023 amounted to $1,654.6, the consideration of new sources of value in the updated study has resulted in an increase to $1,759.9 for the same year (an increase of 6.36%). The increase between the two forecasts is primarily due to the following factors:

- In most countries Wi-Fi traffic has grown at a faster rate than originally envisioned (the only exception being Japan);
- Wi-Fi speed from mobile devices has increased faster than originally forecasted, yielding a larger economic impact;
- New sources of economic value have become more relevant in this study and must be addressed:
    - Contribution of free Wi-Fi to provide Internet to unconnected households (a critical contribution to address the digital divide under the ongoing pandemic);
    - Consumer surplus (social benefit) derived from the increase of Wi-Fi speed as an enabler of new applications; and
    - Accelerated deployment of Internet of Things and Augmented Reality/Virtual Reality solutions with their corresponding economic spillovers.

To reiterate, despite the economic contraction caused by COVID-19, the economic value of Wi-Fi in the six countries originally studied has continued to grow over time despite momentary declines. That said, the economic value of Wi-Fi will undergo an additional boost, driven by the launch of Wi-Fi 6 and the corresponding allocation of 6 GHz spectrum to Wi-Fi.

C.3. Increase in Wi-Fi value yielded by Wi-Fi 6 and the allocation of the 6 GHz band

The sum of the value in the traditional Wi-Fi spectrum bands coupled with the additional boost driven by Wi-Fi 6, Wi-Fi 6E, and the 6 GHz band will yield an increase in economic value for the six countries originally studied, amounting to $1,631.2 billion in 2021 and reaching $2,430.4 billion in 2025 for the six countries analyzed in the 2018 study (see Table C-2).

Table C-2. Six countries in 2018 study: Wi-Fi Economic Value (in $Billions)

		2021	2022	2023	2024	2025
United States	2018-2023 Study	$801.8	$894.8	$1,002.4		
	Current study (baseline scenario)	$979.0	$1,026.0	$1,115.8	$1,243.8	$1,392.7
	Current study (Wi-Fi 6 and 6 GHz)	$16.0	$56.8	$93.1	$134.9	$187.4
	Current Study (total)	$995.0	$1,082.8	$1,208.9	$1,378.7	$1,580.1
United Kingdom	2018-2023 Study	$64.0	$67.5	$71.2		
	Current study (baseline scenario)	$96.9	$93.2	$87.6	$91.9	$97.8
	Current study (Wi-Fi 6 and 6 GHz)	$1.9	$3.9	$5.6	$8.0	$10.7
	Current Study (total)	$98.8	$97.1	$93.2	$99.9	$108.5
France	2018-2023 Study	$55.2	$59.4	$63.9		
	Current study (baseline scenario)	$61.2	$63.4	$73.2	$83.0	$95.0
	Current study (Wi-Fi 6 and 6 GHz)	$1.3	$3.7	$6.2	$8.2	$9.0
	Current Study (total)	$62.5	$67.1	$79.4	$91.2	$104.0
Germany	2018-2023 Study	$115.3	$123.6	$132.0		
	Current study (baseline scenario)	$132.6	$135.4	$140.2	$149.9	$158.0
	Current study (Wi-Fi 6 and 6 GHz)	$1.9	$5.1	$8.4	$12.0	$15.3
	Current Study (total)	$134.5	$140.5	$148.6	$161.9	$173.3
Japan	2018-2023 Study	$213.7	$230.0	$247.5		
	Current study (baseline scenario)	$245.7	$246.5	$240.5	$267.5	$296.2
	Current study (Wi-Fi 6 and 6 GHz)	$5.4	$10.9	$15.0	$21.0	$28.7
	Current Study (total)	$251.1	$257.4	$255.5	$288.5	$324.9

		2021	2022	2023	2024	2025
South Korea	2018-2023 Study	$103.5	$119.3	$137.6		
	Current study (baseline scenario)	$87.2	$93.4	$102.6	$113.5	$126.1
	Current study (Wi-Fi 6 and 6 GHz)	$2.1	$5.1	$7.9	$10.6	$13.4
	Current Study (total)	$89.3	$98.5	$110.5	$124.1	$139.5
Six countries total	2018-2023 Study	$1,353.5	$1,494.6	$1,654.6		
	Current study (baseline scenario)	$1,602.6	$1,657.9	$1,759.9	$1,949.6	$2,165.8
	Current study (Wi-Fi 6 and 6 GHz)	$28.6	$85.5	$136.2	$194.7	$264.6
	Current Study (total)	$1,631.2	$1,743.4	$1,896.1	$2,144.3	$2,430.4

Source: Katz, R. and Callorda, F. (2018a). The Economic value of Wi-Fi: A Global View (2018 and 2023). New York: Telecom Advisory Services; Telecom Advisory Services analysis

When compared to the 2018 study estimate for 2023, the economic value of Wi-Fi for the six countries originally studied has increased by 15.6%. The value derived from Wi-Fi 6, and the devices operating in the 6 GHz band represent the primary driving force behind the future growth of Wi-Fi's economic value. Given the compound annual growth rates of the baseline scenario (5.02%) versus the 6 GHz outlook (61.53%), it is fair to conclude that the latter represents the primary source of economic growth going forward.

The importance of Wi-Fi 6 devices and the allocation of the 6 GHz spectrum increases the economic value of Wi-Fi as a result of the following factors, among others:

- Wi-Fi 6 represents an important performance improvement in comparison to prior generations, supporting a higher number of devices on a single public access point, allowing WISPs to increase the number of subscribers within their same coverage footprint;
- Through the use of multiple bands and spatial streams, Wi-Fi 6 routers have total throughput capabilities well in excess of the speeds they can enable for individual devices, eliminating congestion and, consequently driving additional consumer benefit;
- Enterprises benefit from additional Wi-Fi speed and the enablement of newly developed use cases built around advanced technologies such as AR/VR; and
- Wi-Fi 6 will result in a broader scale of IoT deployment, without the risk of congestion.

C.4. Economic value of Wi-Fi in new countries included in this study

The combination of all the changes that have taken place since the publication of our 2018 study have prompted us to develop an updated version of Wi-Fi's global economic value. In addition, since Wi-Fi has become a more prevalent communications technology around the world, it has required us to enhance our original assessment by adding countries to the detailed analysis, namely Poland, Spain, Australia, New Zealand, Singapore, Brazil, Mexico, and Colombia. The combined value of Wi-Fi derived from the baseline scenario and the availability of Wi-Fi 6 and the 6 GHz band for these nations in 2021 amounts to $289.1 billion, reaching $422.8 billion in 2025 (see Table C-3).

Table C-3. New countries under study: Wi-Fi Economic Value (in $Billions)

		2021	2022	2023	2024	2025
Spain	Current study (baseline scenario)	$39.8	$39.6	$41.8	$44.7	$49.6
	Current study (Wi-Fi 6 and 6 GHz)	$0.6	$2.1	$3.5	$4.5	$4.5
	(Current Study (total)	$40.4	$41.7	$45.3	$49.2	$54.1
Poland	Current study (baseline scenario)	$15.9	$15.7	$16.0	$15.8	$15.9
	Current study (Wi-Fi 6 and 6 GHz)	$0.2	$1.6	$3.1	$4.6	$5.7
	(Current Study (total)	$16.1	$17.3	$19.1	$20.4	$21.6
Australia	Current study (baseline scenario)	$34.1	$28.0	$31.1	$33.3	$36.3
	Current study (Wi-Fi 6 and 6 GHz)	$0.6	$1.6	$2.9	$4.1	$5.4
	(Current Study (total)	$34.7	$29.6	$34.0	$37.4	$41.7
New Zealand	Current study (baseline scenario)	$6.6	$6.7	$7.3	$8.0	$8.8
	Current study (Wi-Fi 6 and 6 GHz)	$0.1	$0.3	$0.5	$0.7	$1.0
	(Current Study (total)	$6.7	$7.0	$7.8	$8.7	$9.8
Singapore	Current study (baseline scenario)	$10.4	$7.2	$8.3	$9.4	$10.4
	Current study (Wi-Fi 6 and 6 GHz)	$0.2	$0.5	$0.9	$1.4	$2.0
	(Current Study (total)	$10.6	$7.7	$9.2	$10.8	$12.4
Brazil	Current study (baseline scenario)	$102.5	$100.7	$117.8	$104.6	$109.6
	Current study (Wi-Fi 6 and 6 GHz)	$2.7	$4.6	$8.8	$11.5	$14.7
	(Current Study (total)	$105.2	$105.3	$126.6	$116.1	$124.3
Mexico	Current study (baseline scenario)	$56.0	$64.4	$76.4	$90.9	$109.0
	Current study (Wi-Fi 6 and 6 GHz)	$0.6	$2.2	$3.9	$6.3	$8.5
	(Current Study (total)	$56.6	$66.6	$80.3	$97.2	$117.5
Colombia	Current study (baseline scenario)	$18.7	$20.4	$22.6	$30.8	$36.0
	Current study (Wi-Fi 6 and 6 GHz)	$0.2	$1.0	$2.0	$3.4	$5.4
	(Current Study (total)	$18.9	$21.4	$24.6	$34.2	$41.4
Total new countries	Current study (baseline scenario)	$284.0	$282.7	$321.3	$337.5	$375.6
	Current study (Wi-Fi 6 and 6 GHz)	$5.2	$13.9	$25.6	$36.5	$47.2
	(Current Study (total)	$289.2	$296.6	$346.9	$374.0	$422.8

Source: Telecom Advisory Services analysis

C.5. An updated view of Wi-Fi economic value

The economic value calculated in detail for fourteen countries was used to estimate through a leading indicators methodology the total value for the European Union and the world. In summary, Wi-Fi global economic value according to the current study in 2021 is $3,302 billion and is expected to reach $4,875.7 billion by 2025. For comparative purposes, the estimation for the global economy calculated for 2023 in the 2018 study was $3,472.4 billion. The updated view accounting for new sources of value and the effect of Wi-Fi 6 and the allocation of the 6 GHz band is 11 percent higher (see Table C-4).

Table C-4. Wi-Fi Economic Value (in $Billions)

	2021	2022	2023	2024	2025
United States	$995.0	$1,082.8	$1,208.9	$1,378.7	$1,580.1
United Kingdom	$98.8	$97.1	$93.2	$99.9	$108.5
France	$62.5	$67.1	$79.4	$91.2	$104.0
Germany	$134.5	$140.5	$148.6	$161.9	$173.3
Spain	$40.4	$41.7	$45.3	$49.2	$54.1
Poland	$16.1	$17.3	$19.1	$20.4	$21.6
Rest of European Union	$204.1	$214.7	$235.4	$259.8	$284.2
Australia	$34.7	$29.6	$34.0	$37.4	$41.7
Japan	$251.1	$257.4	$255.5	$288.5	$324.9
South Korea	$89.3	$98.5	$110.5	$124.1	$139.5
New Zealand	$6.7	$7.0	$7.8	$8.7	$9.8
Singapore	$10.6	$7.7	$9.2	$10.8	$12.4
Brazil	$105.2	$105.3	$126.6	$116.1	$124.3
Mexico	$56.6	$66.6	$80.3	$97.2	$117.5
Colombia	$18.9	$21.4	$24.6	$34.2	$41.4
Rest of World	$1,177.5	$1,249.4	$1,373.1	$1,539.3	$1,738.4
Total World	$3,302.0	$3,504.1	$3,851.5	$4,317.4	$4,875.7

Source: Telecom Advisory Services analysis

In addition to the economic surplus benefitting consumers and enterprises, Wi-Fi represents a net contribution to the GDP of all nations driven by productivity spillovers (for example in IoT and VR/AR) and revenues of providers of Wi-Fi services, such as WISPs and operators of Wi-Fi services (see Table C-5).

Table C-5. Total world: Wi-Fi enabled GDP contribution (2021-2025)

Year	GDP contribution enabled by Wi-Fi ($Million)		
	Attributed to 2.4 and 5 GHz bands	Attributed to Wi-Fi 6 / 6 GHz	Total
2021	$626,276	$23,682	$649,958
2022	$537,097	$86,230	$623,327
2023	$480,263	$138,820	$619,083
2024	$504,384	$198,118	$702,503
2025	$541,625	$264,639	$806,264

Source: Telecom Advisory Services analysis

According to the contribution to GDP, Wi-Fi will generate approximately 3,200,000 jobs in 2021 and is expected to generate over 4,000,000 in 2025 (see Table C-6).

Table C-6. Wi-Fi Economic Value: Employment impact

	2021	2022	2023	2024	2025
United States	541,626	549,985	561,743	622,480	720,804
United Kingdom	95,268	68,757	33,756	38,291	44,906
Germany	92,969	81,425	73,468	81,312	89,934
France	34,646	42,936	52,907	67,478	82,493
Spain	32,900	33,916	41,579	49,630	54,409
Poland	29,506	30,627	39,326	49,149	53,730
Rest of European Union	152,994	152,095	166,890	199,328	225,896
Japan	285,168	236,621	191,136	217,453	252,935
South Korea	188,008	184,224	185,008	202,543	219,754
Australia	22,303	25,139	31,623	34,236	37,813
New Zealand	3,516	3,299	3,724	4,229	4,699
Singapore	13,263	9,772	11,971	14,821	18,026
Brazil	346,567	336,976	357,711	382,112	421,576
Mexico	128,953	119,272	128,654	158,021	176,979
Colombia	98,639	110,351	128,353	152,437	187,321
Rest of World	1,144,846	1,100,006	1,112,447	1,259,642	1,435,693
Total	3,211,172	3,085,400	3,120,296	3,533,162	4,026,968

Source: Telecom Advisory Services analysis

In conclusion, this updated study indicates that Wi-Fi represents one of the most important contributors to economic value in the telecommunications ecosystem. Governments around the world should develop the right incentives to stimulate the social and economic benefits of Wi-Fi. This includes assigning enough spectrum to avoid congestion, promoting the development of start-ups that rely on Wi-Fi to create new applications, and relying on the technology to address the digital divide barrier.

D. ECONOMIC VALUE OF WI-FI IN THE UNITED STATES

The United States is the country with the widest adoption and use of Wi-Fi in the world. In fact, Wi-Fi has become a pervasive feature in the U.S. telecommunications landscape. The Cisco Annual Internet Report Highlights Tool 2018-2023 estimates that there are currently 33,480,000 public Wi-Fi access points. According to Wiman (2020), there are 18,560,000 free Wi-Fi sites in the country (of which 2,779,000 are in the New York metropolitan area, 490,000 in Los Angeles, 339,000 in Chicago, and 216,000 in Houston). In addition, 85 percent of U.S. broadband homes in 2020 are equipped with a Wi-Fi router supporting access and interconnection of devices. Given the Wi-Fi access point density, hotspots have become a very important connectivity feature. According to Opensignal[137], after the outbreak of COVID-19 U.S. wireless users spend 59.9% of their communications time connected to Wi-Fi networks rather than relying on their cellular data connection. Furthermore, the Wi-Fi standard has created an industry around equipment manufacturing that is a world leader. The important weight of Wi-Fi technology on the digital ecosystem should have a significant contribution on its social and economic benefits. This section presents the results and calculations of the economic assessment.

D1. Total economic value of Wi-Fi in the United States (2021-2025)

Before considering the additional effect of allocating the 6 GHz spectrum band for unlicensed use, the total economic value of Wi-Fi in the United States in 2021 will amount to $979.2 billion. In our prior study, Wi-Fi's economic value for 2021 was estimated at $801.8 billion. The increase of $177.4 billion is due to the development of four new sources of economic value:

- The increasing importance of free Wi-Fi as a platform to address the needs of the population that cannot afford to acquire broadband service;
- The increasing benefits of Wi-Fi technology broadband speed;
- A substantial boost to deployment of IoT technology;
- The growing adoption of AR/VR technology.

The total economic value in 2021 is comprised of $394.15 billion in consumer surplus, $433.82 billion in producer surplus, and $151.29 billion in contribution to GDP. The 2025 forecast of economic value will reach $1,393 billion without considering the acceleration effect from Wi-Fi 6 and the allocation of the 6 GHz band. The 2025 forecast of the baseline scenario will be composed of $630.15 billion in consumer surplus, $652.80 billion in producer surplus, and $109.90 billion in GDP contribution (see Table D-1).

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[137] Khatri, H. and Fenwick, S. (2020). "Analyzing mobile experience during the coronavirus pandemic: Time on Wi-Fi". *Opensignal* (March 30).

Table D-1. United States: Economic value of Wi-Fi (Baseline Scenario)

Agent	Source	Economic Value ($Billions)					
		2021	2022	2023	2024	2025	Category
1. Free Wi-Fi	1.1. Savings generated by free Wi-Fi traffic offered in public sites	$8.3	$8.3	$8.1	$7.7	$7.1	Consumer Surplus
	1.2. Deployment of free Wi-Fi in public sites	$17.4	$13.5	$9.6	$5.7	$4.7	GDP contribution
2. Residential Wi-Fi	2.1. Internet access for home usage of devices that lack a wired port	$281.3	$327.8	$380.0	$439.5	$507.7	Consumer Surplus
	2.2. Avoidance of investment in in-house wiring	$67.5	$73.6	$80.3	$83.1	$84.3	Consumer Surplus
	2.3. Benefit to consumers from speed increases	$6.6	$6.4	$5.3	$3.3	$0.7	Consumer Surplus
	2.4. Residential Wi-Fi devices and equipment deployed	$30.3	$30.9	$31.7	$31.2	$30.2	Consumer Surplus
	2.5. Bridging digital divide: use of Wi-Fi to increase coverage in rural and isolated areas	$20.7	$23.1	$27.8	$28.8	$32.0	GDP contribution
3. Enterprise Wi-Fi	3.1. Business Internet traffic transmitted through Wi-Fi	$206.6	$243.7	$287.5	$339.2	$400.1	Producer surplus
	3.2. Avoidance of enterprise inside wiring costs	$17.9	$18.1	$18.2	$18.4	$18.5	Producer surplus
	3.3. Return to speed: contribution to GDP derived from an increase in average mobile speed	$29.0	$26.2	$19.6	$11.6	$2.5	GDP contribution
	3.4. Wide deployment of IoT	$73.5	$56.3	$46.7	$47.4	$48.5	GDP contribution
	3.5. Deployment of AR/VR solutions	$4.2	$5.1	$5.6	$7.2	$9.0	GDP contribution
4. ISPs	4.1. CAPEX and OPEX savings due to cellular off-loading	$62.6	$18.4	$0	$0	$0	Producer surplus
	4.2. Revenues of service providers offering paid Wi-Fi access in public places	$1.2	$1.2	$1.2	$1.0	$0.8	GDP contribution
	4.3. Aggregated revenues of WISPs	$5.2	$6.9	$8.3	$10.2	$12.4	GDP contribution
5. Wi-Fi ecosystem	5.1. Locally manufactured residential Wi-Fi devices and equipment	$33.9	$34.4	$34.9	$34.3	$33.2	Producer surplus
	5.2. Locally manufactured Wi-Fi enterprise equipment	$4.5	$4.6	$4.7	$4.6	$4.1	Producer surplus
	5.3. Locally produced IoT products and services	$106.0	$124.8	$145.4	$167.0	$192.1	Producer surplus
	5.4. Locally produced of AR/VR solutions	$2.2	$2.7	$3.0	$3.8	$4.8	Producer surplus
Total		$979.0	$1,026.0	$1,115.8	$1,243.8	$1,392.7	

Source: Telecom Advisory Services analysis

In addition to the baseline scenario, the allocation of the 6 GHz spectrum band for unlicensed use and the deployment of Wi-Fi 6 and Wi-Fi 6E devices will trigger a growth of economic value, reaching $187.4 billion in 2025 (see Table D-2).

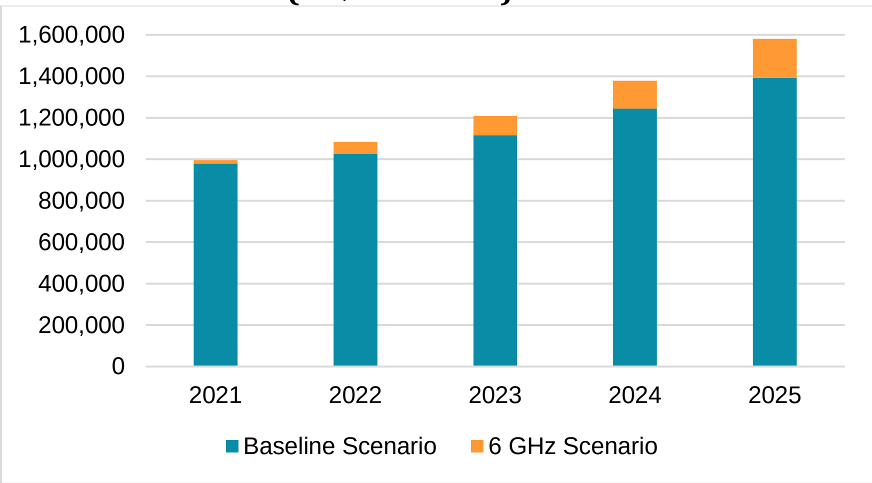
Table D-2. United States: Economic Value of Wi-Fi (only attributed to 6 GHz)

Agent	Source	Economic Value ($Billions)					
		2021	2022	2023	2024	2025	Category
1. Free Wi-Fi	1.1. Savings generated by free Wi-Fi traffic offered in public sites	$0	$0.1	$0.2	$0.4	$0.7	Consumer Surplus
	1.2. Deployment of free Wi-Fi in public sites	$0	$1.3	$1.7	$1.3	$1.2	GDP contribution
	1.3. Benefit of faster free Wi-Fi with Wi-Fi 6E devices	$0	$0.1	$0.1	$0.1	$0.1	Consumer Surplus
2. Residential Wi-Fi	2.3. Benefit to consumers from speed increases	$0	$2.5	$5.9	$9.7	$13.7	Consumer Surplus
	2.4. Residential Wi-Fi devices and equipment deployed	$1.1	$2.7	$5.8	$8.8	$12.0	Consumer Surplus
	2.5. Bridging digital divide: use of Wi-Fi to increase coverage in rural and isolated areas	$0	$5.7	$10.2	$15.7	$25.1	GDP contribution
3. Enterprise Wi-Fi	3.1. Business Internet traffic transmitted through Wi-Fi	$0	$9.5	$10.9	$12.6	$14.6	Producer surplus
	3.3. Return to speed: contribution to GDP derived from an increase in average mobile speed	$0	$9.6	$22.0	$37.3	$55.6	GDP contribution
	3.4. Wide deployment of Internet of Things	$3.6	$7.3	$7.4	$7.6	$7.7	GDP contribution
	3.5. Deployment of AR/VR solutions	$2.5	$3.4	$4.7	$6.4	$8.8	GDP contribution
4. ISPs	4.1 CAPEX and OPEX savings due to cellular off-loading	$2.7	$2.7	$2.7	$2.7	$2.7	Producer surplus
	4.2. Revenues of service providers offering paid Wi-Fi access in public places	$0	$0	$0.1	$0.1	$0.1	GDP contribution
	4.3. Aggregated revenues of WISPs	$0	$0.2	$0.3	$0.5	$0.9	GDP contribution
5. Wi-Fi ecosystem	5.1. Locally manufactured residential Wi-Fi devices and equipment	$1.0	$2.5	$5.5	$8.4	$11.4	Producer surplus
	5.2. Locally manufactured Wi-Fi enterprise equipment	$0.4	$1.0	$2.0	$3.3	$4.8	Producer surplus
	5.3. Locally produced IoT products and services	$3.4	$6.5	$11.1	$16.4	$23.3	Producer surplus
	5.4. Locally produced of AR/VR solutions	$1.3	$1.8	$2.5	$3.4	$4.7	Producer surplus
Total		$16.0	$56.8	$93.1	$134.9	$187.4	

Source: Telecom Advisory Services analysis

Considering that we forecast that by 2025 only 40% of Wi-Fi traffic will rely on 6 GHz channels, the accelerated effect derived from the new spectrum allocation and latest Wi-Fi technologies will still be far from reaching its maximum potential at this time. However, a visual depiction of the trend provides a perspective of the growing importance of Wi-Fi 6 in the overall economic value (see Graphic D-1)

Graphic D-1. United States: economic value of Wi-Fi (2021-2025) (in $Thousand)



Source: Telecom Advisory Services analysis

By combining the baseline and the Wi-Fi 6 and 6 GHz scenarios, the overall economic value of Wi-Fi for the United States will yield $1,580 billion in 2025 (see Table D-3).

Table D-3. United States: Total Economic Value of Wi-Fi (including Wi-Fi 6 and 6 GHz)

Agent	Source	Economic Value ($Billion)					
		2021	2022	2023	2024	2025	Category
1. Free Wi-Fi	1.1. Savings to consumers of free Wi-Fi traffic offered in public sites	$8.3	$8.4	$8.3	$8.1	$7.8	Consumer Surplus
	1.2. Deployment of free Wi-Fi in public sites	$17.4	$14.8	$11.3	$7.0	$5.9	GDP contribution
	1.3. Benefit of faster free Wi-Fi with Wi-Fi 6E devices	$0.0	$0.1	$0.1	$0.1	$0.1	Consumer Surplus
2. Residential Wi-Fi	2.1. Internet access for home usage of devices that lack a wired port	$281.2	$327.8	$380.0	$439.5	$507.7	Consumer Surplus
	2.2. Avoidance of investment in in-house wiring	$67.7	$73.8	$80.3	$83.1	$84.5	Consumer Surplus
	2.3. Benefit to consumers from speed increases	$6.6	$8.9	$11.2	$13.0	$14.4	Consumer Surplus
	2.4. Residential Wi-Fi devices and equipment deployed	$31.4	$33.6	$37.5	$40.0	$42.1	Consumer Surplus
	2.5. Bridging digital divide: use of Wi-Fi to increase coverage in rural and isolated areas	$20.7	$28.8	$35.9	$44.5	$57.1	GDP contribution
3. Enterprise Wi-Fi	3.1. Business Internet traffic transmitted through Wi-Fi	$206.6	$253.2	$298.4	$351.8	$414.7	Producer surplus
	3.2. Avoidance of enterprise inside wiring costs	$17.9	$18.1	$18.2	$18.4	$18.5	Producer surplus
	3.3. Return to speed: contribution to GDP derived from an increase in average mobile speed	$29.0	$35.6	$41.6	$48.9	$58.0	GDP contribution
	3.4. Wide deployment of IoT	$77.1	$63.6	$54.1	$55.0	$56.2	GDP contribution
	3.5. Deployment of AR/VR solutions	$6.7	$8.5	$10.3	$13.6	$17.8	GDP contribution

Agent	Source	Economic Value ($Billion)					
		2021	2022	2023	2024	2025	Category
4. ISPs	4.1 CAPEX and OPEX savings due to cellular off-loading	$65.3	$21.1	$2.7	$2.7	$2.7	Producer surplus
	4.2. Revenues of service providers offering paid Wi-Fi access in public places	$1.2	$1.2	$1.3	$1.1	$0.9	GDP contribution
	4.3. Aggregated revenues of WISPs	$5.2	$7.0	$8.7	$10.7	$13.3	GDP contribution
5.Wi-Fi ecosystem	5.1. Locally manufactured residential Wi-Fi devices and equipment	$34.9	$36.9	$40.4	$42.7	$44.6	Producer surplus
	5.2. Locally manufactured Wi-Fi enterprise equipment	$4.9	$5.6	$6.7	$7.9	$8.9	Producer surplus
	5.3. Locally produced IoT products and services	$109.4	$131.3	$156.4	$183.4	$215.4	Producer surplus
	5.4. Locally produced of AR/VR solutions	$3.5	$4.5	$5.5	$7.2	$9.5	Producer surplus
Total		$995.0	$1,082.8	$1,208.9	$1,378.7	$1,580.1	

Source: Telecom Advisory Services analysis

The following sections will present in detail the calculation of each source of value, disaggregating the economic contribution under current the spectrum ecosystem and the enhanced effect due to Wi-Fi 6 availability and the 6 GHz band.

D.2. Value from free Wi-Fi service

The economic value of free Wi-Fi service originates from three contribution sources:

- Savings to consumers by accessing the Internet in free Wi-Fi sites rather than incurring cellular costs
- The use of Wi-Fi to expand broadband coverage to the unserved population
- The return to speed of Wi-Fi compared to the use of cellular service

D.2.1. Savings incurred by accessing free Wi-Fi in public sites

In the United States, free Wi-Fi offered in retail shops, libraries, schools, coffee shops, city halls, and corporate guest accounts allows consumers to save money that would otherwise be spent purchasing cellular service. In addition, free hotspots provide access to the Internet for consumers that cannot afford to purchase broadband service. This last effect has been particularly important in the ongoing coronavirus pandemic, allowing households to access the Internet for telecommuting and continuing education.

As noted earlier, the economic value of free Wi-Fi is measured in terms of consumer surplus, by estimating the benefit that flows to consumers as a result of the savings in wireless broadband service acquisition. We start by quantifying the mobile Internet traffic. While total Internet traffic in the United States is growing at 24.66%, mobile Internet traffic has been growing at 36.56% per annum, indicating a growing share of wireless. Table D-4 presents historical data.

Table D-4. United States: Internet Traffic (2018-2020)
(exabytes[138] per month)

Variable	2018	2019	2020	CAGR
Total Internet	36.36	45.33	56.50	24.66%
Wireless Internet	1.64	2.24	3.06	36.56%

Sources: Cisco; Telecom Advisory Services analysis

The increased adoption of wireless data-enabled devices (smartphones, tablets, PCs) combined with an increase in usage has driven overall traffic growth. The installed base of smartphones in the U.S. reached 307 million in 2020, while the installed base for laptops reached 194 million. On the other hand, the number of tablets has remained relatively stable at 126 million (2018-20 CAGR: 0.16%) due to smartphone substitution (see Table D-5).

Table D-5. United States: Device Installed Base and Penetration (2018-2020)

Device	Metrics	2018	2019	2020	CAGR
Smartphones	Units (in Millions)	283	295	307	4.16%
	Penetration (%)	86.58%	89.66%	92.88%	3.57%
Tablets	Units (in Millions)	126	126	126	0.16%
	Penetration (%)	38.40%	38.24%	38.09%	-0.40%
Laptops	Units (in Millions)	182	190	194	3.03%
	Penetration (%)	55.71%	57.63%	58.48%	2.46%
Devices per user		1.81	1.86	1.89	

Sources: Cisco; GSMA Intelligence; Telecom Advisory Services analysis

The installed base of smartphones has shifted to 4G network standards that provide faster speed of access and, consequently, stimulate more intense data usage. Looking forward, progressive 5G deployments will substantially increase mobile speeds. By 2025, it is projected that the average mobile connection speed will triple from the current 31.07 Mbps. Data also shows that as connected devices increasingly penetrate the subscriber base, the number of "devices per user" has increased commensurately: from 1.81 in 2018 to 1.89 in 2020.

Adding to the proliferation of devices, traffic per device has grown 18.41% per annum, driven by increased applications and content availability (see Table D-6).

Table D-6. United States: Average Traffic Per Device (gigabytes per month)

Device	2018	2019	2020	CAGR
Smartphones	16.00	20.31	25.79	26.97%
Tablets	20.06	25.15	31.53	25.37%
Laptops	53.30	60.20	67.98	12.93%

Sources: Cisco Annual Internet Report Highlights Tool 2018-2023; Telecom Advisory Services analysis

With the installed base and average data usage per device, total mobile Internet traffic in the United States can be calculated for the next five years. We estimate a total traffic of 14.52 Exabytes per month in 2025. Projections regarding traffic growth from other sources vary, although they all agree directionally (see Table D-7).

[138] 1 Exabyte equals 1,073,741,824 gigabytes.

Table D-7. United States: Internet Traffic (2020-2025) (Exabytes per month)

Variable	2020	2021	2022	2023	2024	2025
Total Internet	56.50	66.67	87.81	109.46	136.46	170.11
Mobile Internet	3.06	4.17	5.70	7.78	10.63	14.52

Sources: Cisco; Telecom Advisory Services analysis

This growth has and will continue to put pressure on the public networks of all service providers to accommodate the traffic without incurring congestion, while also generating acceptable levels of revenue. We now estimate the portion of traffic that is off-loaded to Wi-Fi.

Based on the premise that cellular off-loading varies by device, and assuming that off-loading will increase over time with the deployment of more Wi-Fi sites, we calculate the portion of overall mobile traffic by device transmitted through Wi-Fi (see Table D-8).

Table D-8. United States: Wireless Device Off-Loading Factors (2018-2020)

Device	2018	2019	2020
Smartphones[139]	48%	48%	48%
Tablets	40%	42%	44%
Laptops	40%	42%	44%

Sources: Cisco; Opensignal; Telecom Advisory Services analysis

By applying these off-loading factors to the total data traffic generated by each type of device, we project that total Wi-Fi traffic in the United States is currently 9.76 Exabytes per month in 2020, reflecting a 27.25% annual growth rate (see Table D-9).

Table D-9. United States: Total Wi-Fi Traffic Per Device (2018-2020) (In Exabytes per month)

Device	2018	2019	2020	CAGR
Smartphones	2.02	2.67	3.53	32.25%
Tablets	0.74	0.98	1.32	33.86%
Laptops	3.28	4.05	4.92	22.50%
Total	6.03	7.70	9.76	27.25%

Sources: Cisco; Telecom Advisory Services analysis

The estimation of consumer surplus proceeds, then, by multiplying the total Wi-Fi traffic from Table D-9 by 4.32%, representing the "true free traffic"[140] transmitted by public sites (Table D-10).

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[139] In 2020, the smartphone offloading factor grew to an average of 60%, which would imply an increase in economic value. This increase is primarily due to COVID-19, so assuming that it represents a temporary value, we prefer to continue estimating 48% for conservative purposes.
[140] Source: Mobidia

Table D-10. United States: Total Free Wi-Fi Traffic (2018-2020)

Variable	2018	2019	2020
Total Wi-Fi traffic (Exabytes per month)	6.03	7.70	9.76
Total free traffic (Exabytes per month)	0.26	0.33	0.42
Total free traffic (Exabytes per year)	3.13	4.00	5.06
Total free traffic (Million GB per year)	3,357.08	4,290.99	5,436.02

Sources: Cisco; Mobidia; Telecom Advisory Services analysis

Finally, in order to isolate the effect from the increased capacity derived from the 6 GHz allocation, we calculate the portion of free Wi-Fi traffic attributed to current spectrum bands. For this, we relied on the assumption than current traffic levels are already producing congestion in most free Wi-Fi hotspots at times of peak demand. Thus, we assume that traffic per hotspot beyond 2021 will remain at the average 2020 levels (292.84 GB per year), although overall free traffic will continue growing as new hotspots will continue to be deployed.

Table D-11. United States: Total free Wi-Fi Traffic projection (2021-2025)

Variable	2021	2022	2023	2024	2025
Free Wi-Fi traffic (Million GB Per year) - considering current trends	6,751.37	9,018.04	11,462.64	14,562.37	18,502.89
Free Wi-Fi hotspots (Million)	22.75	27.87	34.15	41.85	51.28
Traffic per hotspot - considering current trends	296.81	323.55	335.63	347.98	360.83
Traffic per hotspot - capped due to congestion	292.84	292.84	292.84	292.84	292.84
Total traffic (not attributed to 6 GHz) (Million GB)	6,660.95	8,161.91	10,001.08	12,254.68	15,016.10

Sources: Cisco; Wiman; Telecom Advisory Services analysis

We calculate consumer surplus by multiplying the total free traffic (not attributed to 6 GHz) by the difference between what the consumer would have to pay if she/he were to rely on a wireless carrier and the cost of offering free Wi-Fi (incurred by the retailer or public site). To do so, we needed an estimate of the average price per GB of wireless data transmitted by wideband networks, which we calculated by averaging the most economic "dollar per GB" plan of four major U.S. wireless carriers (see Table D-12).

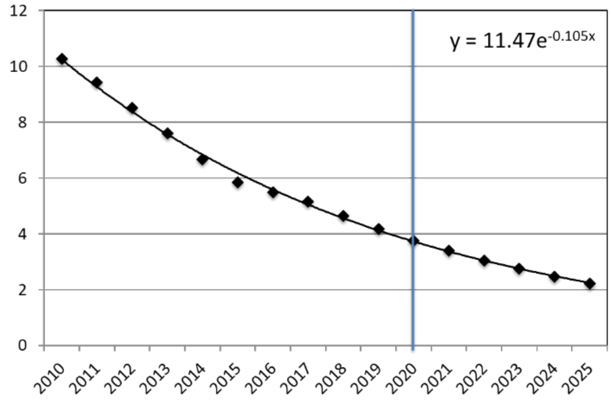
Table D-12. United States: Average Price Per Gigabyte (2020)

Carrier	Plan	Price per GB ($)
AT&T	Mobile Share Plus 9 GB: $60/9 gigabytes cap	$6.66
Verizon	Connected Home: $150/40 gigabytes cap	$3.75
Sprint	50 GB Mobile Hotspot: $50/50 gigabytes cap	$1.00
T-Mobile	Magenta Plus: $85/20 gigabytes cap (for 4G LTE Hot spot data)	$4.25

Sources: Operator websites; Telecom Advisory Services analysis

Historical data allowed for a projection of future prices per gigabyte (see Graphic C-2).

Graphic D-2. United States: Estimate of future average price per gigabyte (2010-2025)



Source: Telecom Advisory Services analysis

Based on these prices, we expect the average price per GB will reach an estimated $2.23 in 2025. As to the cost of offering the Wi-Fi service, this would include an additional router and bandwidth for the provider of free service. We assume those costs to be prorated at $2.50 per gigabyte in 2020, which was what some Wi-Fi services in public sites charge per 2-hour service (assuming this to be costs passed through to the customer)[141]. By relying on the total free Wi-Fi traffic not attributed to 6 GHz allocation shown in Table D-10 and the average price per cellular gigabyte minus the cost of provisioning Wi-Fi service, we calculated the consumer surplus of free Wi-Fi traffic (see Table D-13).

Table D-13. United States: consumer surplus of free Wi-Fi traffic (2021-2025)

Variable	2021	2022	2023	2024	2025
Total Free Traffic (not attributed to 6 GHz) (Million GB)	6,660.95	8,161.91	10,001.08	12,254.68	15,016.10
Price per cellular gigabyte ($)	$3.39	$3.05	$2.75	$2.47	$2.23
Cost per Wi-Fi provisioning ($)	$2.14	$2.04	$1.94	$1.84	$1.75
Consumer surplus per gigabyte ($)	$1.25	$1.01	$0.81	$0.63	$0.47
Total Consumer surplus ($Million)	$8,328.60	$8263.32	$8,082.61	$7,722.81	$7,129.19

Sources: Websites of cellular operators; Telecom Advisory Services analysis

As indicated in Table D-13, consumer surplus of free Wi-Fi traffic in 2021 would reach an estimated $8.329 billion, decreasing to $7.129 billion in 2025 due to congestion created if we do not consider the 6 GHz spectrum band. These estimates are consistent with the results reported in our previous study for the United States, although we are now explicitly considering the congestion effect derived from current standards and spectrum allocations.

Incremental free Wi-Fi traffic due to 6 GHz allocation

The allocation of the 6 GHz spectrum band and the technological advances provided by the Wi-Fi 6 standard will remove the above-mentioned bottlenecks causing congestion. As a result, the traffic per hotspot will be able to continue growing at its

[141] This is assumed to decline to $1.75 per gigabyte by 2025.

natural rate as determined by the extrapolation of past recent trends. That being said, we must take into account that not all Wi-Fi traffic will benefit immediately from opening the 6 GHz band, as most current devices are not prepared to support the new standards. Thus, we expect the traffic through the 6 GHz channel to gradually increase until reaching 40% of total free traffic by 2025[142].

Once computed the additional traffic "above and beyond" the future previsions under current spectrum bands, we will follow a similar approach to calculate the consumer surplus, by multiplying it by the difference between what the consumer would have to pay if he were to utilize a wireless carrier and the cost of offering free Wi-Fi (Table D-14). As a result, we project an additional consumer surplus of $662 million from free Wi-Fi traffic attributed to 6 GHz.

Table D-14. United States: Additional consumer surplus of Free Wi-Fi Traffic generated due to 6 GHz (2021-2025)

Variable	2021	2022	2023	2024	2025
Demand not satisfied due to congestion in the 2.4 and 5 GHz bands (Million GB)	90.41	856.13	1,461.56	2,307.69	3,486.79
Traffic through the 6 GHz channel (%)	0%	10%	20%	30%	40%
Total traffic (attributed to 6 GHz) (Million GB)	0.00	85.61	292.31	692.31	1,394.72
Consumer surplus (attributed to 6 GHz) ($Million)	$0.00	$86.68	$236.24	$436.29	$662.17

Source: Telecom Advisory Services analysis

The additional surplus generated by the allocation of the 6 GHz spectrum band will mitigate the decreasing trend of consumer surplus derived from free Wi-Fi (because of declining prices and congestion).

D.2.2. Free Wi-Fi to provide broadband to the unserved population

As explained in section B, deployment of free Wi-Fi provides Internet access to the unserved population. Consumers that do not have broadband at home because they lack the economic means to acquire services can rely on free Wi-Fi to gain Internet access. As a result, more people can be connected, which in turn enhances the economic contribution of broadband.

The calculation of this economic impact starts by calculating which portion of U.S. households that lack broadband service are already accessing the Internet through free hotspots. As a reference, a 2016 survey carried out by Connect Home stipulated that 10% of not connected households declare that they access the Internet outside of home. However, accessing the Internet outside the home may not necessarily mean that they access through a free Wi-Fi hotspot (they may connect at a friend's house, or at their workplace). Therefore, we follow a conservative approach and

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[142] In a previous study assessing the economic effect of the 5.9 GHz and 6 GHz bands in the United States (Katz, 2020), we assumed that traffic through 6 GHz will start by reaching a 20% in 2023 before gradually increasing to 50% in 2025. However, following the decision taken by the FCC regarding the 6 GHz spectrum band, we advanced that previsions by assuming that a 10% of the traffic will already be carried through 6 GHz by 2022.

assume that only 5% of unconnected households rely on free hotspots for accessing the Internet. After calculating the increase in broadband penetration due to households relying on free Wi-Fi, we rely on the broadband impact coefficient from Katz and Callorda (2018b), that estimates for the American region a 0.19% increase in GDP for every 1% increase in penetration. As a result, the GDP contribution of this particular effect is expected to amount to $17 billion in 2021, declining to $4.7 billion in 2025. This reduction is explained by the positive development that the digital divide is expected to diminish in the future, and hence, fewer homes will have to rely on free Wi-Fi hotspots.

Table D-15. United States: GDP contribution due to households relying on free Wi-Fi (2021-2025)

Variable	2021	2022	2023	2024	2025
Households without Internet	11,537,058	9,123,104	6,597,341	3,955,685	3,282,706
Households that don't buy because access the Internet via free hotspots (%)	5%	5%	5%	5%	5%
Households served by free Wi-Fi hot spots	576,853	456,155	329,867	197,784	164,135
Increase in national broadband penetration	0.51%	0.39%	0.27%	0.16%	0.13%
Impact of fixed broadband adoption in GDP	18.8%	18.8%	18.8%	18.8%	18.8%
Increase in the GDP due to the new broadband adoption (% GDP)	0.10%	0.07%	0.05%	0.03%	0.02%
GDP ($Billion)	$18,339.88	$18,625.80	$18,920.09	$19,226.59	$19,661.37
Total impact in GDP ($Million)	$17,430.92	$13,546.04	$9,628.82	$5,677.16	$4,738.14

Sources: U.S. Census; IMF; Telecom Advisory Services analysis

Enhanced GDP contribution due to 6 GHz allocation

As stated above, Wi-Fi 6 technology supports a high number of devices on a single access point. Accordingly, the improved throughput of free Wi-Fi hotspots under the 6 GHz allocation will allow for the possibility of serving additional unconnected households.

The potential universe of additional households that could be served under this effect is enormous: 80% of unconnected households in the U.S. declare that costs are their main barrier to connectivity[143] and thus, may potentially be served by free hotspots as long as they are in proximity to the access point. However, evidence suggests that not many people rely exclusively on free Wi-Fi as their main source of Internet access, so we will follow again a conservative approach and assume that a further 5% of unconnected households will be served through free hotspots under the allocation of the 6 GHz band. We have also considered that the expansion of traffic through the new band will take place gradually, reaching 40% in 2025. All in all, we estimate that additional 41,424 households will be served in 2025 due to free hotspots operating under 6 GHz spectrum, yielding an additional GDP contribution of approximately $1,196 million (Table D-16).

[143] Source: ConnectHome

Table D-16. United States: GDP contribution due to households relying on Free Wi-Fi due to Wi-Fi 6 and 6 GHz (2021-2025)

Variable	2021	2022	2023	2024	2025
Households without Internet (not served by free Wi-Fi and not new adopters of WISP)	10,960,205	8,444,136	5,861,240	3,114,792	2,071,186
Potential households that could be served through free Wi-Fi hotspots under increased capacity (% of those not connected)	5%	5%	5%	5%	5%
Traffic through the 6 GHz Channel (%)	0%	10%	20%	30%	40%
Additional households served by free Wi-Fi hot spots with 6 GHz	0	42,221	58,612	46,722	41,424
Increase in national broadband penetration	0	0.04%	0.05%	0.04%	0.03%
Increase in the GDP due to the new broadband adoption (% GDP)	0	0.01%	0.01%	0.01%	0.01%
Total impact in GDP ($Million)	$0	$1,253.79	$1,710.89	$1,341.10	$1,195.79

Sources: U.S. Census; IMF; Telecom Advisory Services analysis

D.2.3. Benefit to consumers enjoying higher speed from free Wi-Fi if 6 GHz band is allocated

When the 6 GHz band is adopted by free Wi-Fi access points, it will deliver service at faster broadband speeds. Current speeds from free hotspots are quite modest. Extrapolating the data provided by Rotten Wi-Fi, we estimate that public Wi-Fi hotspots currently average 10.79 Mbps of download speed. Thus, the expanded capabilities due to the allocation of 6 GHz spectrum band will enhance free Wi-Fi speed, and as a result, will increase consumer surplus. We assume that under the 6 GHz allocation, speed from free hotspots will be similar to the Wi-Fi speeds from mobile devices reported by Cisco. After calculating the average speed by considering the expected share of traffic through 6 GHz, we follow Nevo et al. (2016) and calculate the additional consumer surplus per household relying on free Wi-Fi. We expect the consumer surplus resulting from faster speed in free Wi-Fi sites to reach $108.33 million in 2025 (Table D-17).

Table D-17. United States: consumer surplus for enjoying higher speed from free Wi-Fi if 6 GHz band allocated (2021-2025)

Variable	2021	2022	2023	2024	2025
Free Wi-Fi mean speed with no 6 GHz (Mbps)	11.62	12.52	13.49	13.49	13.49
Wi-Fi Speeds from Mobile Device (Mbps)	81.07	94.44	110.00	128.13	149.25
Traffic through the 6 GHz Channel (%)	0%	10%	20%	30%	40%
Free Wi-Fi mean speed with 6 GHz (Mbps)	11.62	20.71	32.80	47.88	67.79
Demand for average download speed	92.58	94.62	96.65	96.65	96.65
New Demand for average download speed	92.58	108.31	120.81	131.11	140.57
Additional Monthly Consumer surplus	$0.00	$13.69	$24.16	$34.46	$43.92
Additional Yearly Consumer Surplus	$0.00	$164.30	$289.92	$413.49	$527.01
Households that rely on Free Wi-Fi	576,853	498,376	388,479	244,506	205,559
Consumer surplus ($Million)	$0.00	$81.88	$112.63	$101.10	$108.33

Sources: Rotten Wi-Fi; Nevo et al. (2016); Telecom Advisory Services analysis

D.3. Residential Wi-Fi

D.3.1. Home Internet access for devices that lack an Ethernet port

The underlying premise of this analysis is that in the absence of Wi-Fi, users of devices lacking an Ethernet port would have to depend on the cellular network to gain Internet access. For this reason, estimating value would first measure the traffic generated by these devices at home, and then multiply it by the average price charged by cellular carriers.

To estimate the traffic of smartphones and tablets, we relied on 2018 Cisco estimates for the period 2016-21 and extrapolated those growth rates to 2025. It must be said, however, that in 2019 Cisco adjusted its predictions upwards. However, we preferred to rely on the original figures to avoid incurring in the risk of overestimation. Thus, it may be possible that our predictions reported here are slightly downward biased. Based on our traffic model, the total traffic generated by these types of devices in 2021 in the United States will amount to 192,401 million gigabytes. According to Cisco IBSG (2012), 43.12% of use time of devices that lack an Ethernet port occurs at home.[144] Therefore, the portion of traffic generated at home will reach 82,959 million gigabytes in 2021 (see Table D-18).

Table D-18. United States: Total Mobile Internet Traffic (2021-2025) (million gigabytes)

Variable	2021	2022	2023	2024	2025
Total Annual traffic - Smartphones	139,355.39	182,418.07	237,017.67	306,890.30	396,651.11
Total Annual traffic - Tablets	53,045.73	66,609.74	83,642.12	105,029.74	131,886.27
Share of traffic at Home	43.12%	43.12%	43.12%	43.12%	43.12%
Total Traffic at Home - Smartphones	60,086.90	78,654.56	102,196.67	132,324.18	171,027.01
Total Traffic at Home - Tablets	22,872.12	28,720.62	36,064.59	45,286.46	56,866.38
Total Traffic at Home	82,959.02	107,375.18	138,261.27	177,610.63	227,893.39
Average Price per GB ($)	$3.39	$3.05	$2.75	$2.47	$2.23
Price per home traffic ($Million)	$281,261.09	$327,754.74	$379,965.98	$439,452.78	$507,661.32

Sources: Cisco; GSMA Intelligence; Websites of cellular operators; Telecom Advisory Services analysis

If this traffic had to be transported by cellular networks, at the average price per GB estimated in the model of Graphic IV-2, it would result in costs of $281.26 billion in 2021, reaching $507.66 billion in 2025. These projections are consistent with the results provided in our previous study for the United States (Katz and Callorda, 2018a).

D.3.2. Avoidance of inside wiring investment

Residential Wi-Fi allows consumers to avoid paying for wiring to connect all home devices (printers, laptops, storage units, etc.). The average cost of deploying inside

[144] While this study is not up to date, our reliance for the analysis indicates a conservative assumption.

wiring in an average U.S. residence reaches approximately $660 per household[145]. Considering that 90% of U.S. connected households will have Wi-Fi in 2021[146], the avoidance costs of inside wiring for 102.6 million households yields a total savings of $67.5 billion. By 2025, all connected households are expected to have adopted Wi-Fi, so the savings would have reached $84.5 billion (Table D-19).

Table D-19. United States: Consumer surplus from avoidance of investment in in-house wiring (2021-2025)

Variable	2021	2022	2023	2024	2025
Total Wiring Cost (*)	$660	$660	$660	$660	$660
Households with Internet	114,085,336	117,897,240	121,836,510	125,907,403	127,725,524
Households with Wi-Fi (%)	90%	95%	100%	100%	100%
Households with Internet and Wi-Fi	102,318,905	111,580,000	121,651,018	125,907,403	127,725,524
Consumer Surplus (Inside Wiring Costs) ($Million)	$67,528.48	$73,642.59	$80,289.67	$83,098.89	$84,296.85

(*) Wiring costs assumed to be stable in the future based on findings between the 2018 and 2020.
Sources: U.S. Census; Watkins (2012); Telecom Advisory Services analysis

D.3.3. Benefits derived from speed increase

As described before, consumer surplus increases if users enjoy faster Internet speeds. Thus, residential Wi-Fi customers are expected to benefit from faster services than those provided by cellular networks. After weighting the corresponding broadband speeds with the percentage of traffic carried through Wi-Fi at home, we calculated the average speed advantage of using Wi-Fi in comparison to cellular networks. By applying the parameters determined in Nevo et al. (2016), the expected consumer surplus will yield $6,569.6 million in 2021, although it will be reduced to only $710 million in 2025. This is explained due to gradual 5G deployments that will reduce the speed advantage that Wi-Fi enjoys over cellular networks.

Table D-20. United States: Consumer surplus from faster speed in households (2021-2025)

Variable	2021	2022	2023	2024	2025
Average Speed in households if Wi-Fi traffic were carried through mobile networks (Mbps)	75.29	89.68	109.93	135.86	169.34
Average Speed in household with Wi-Fi (Mbps)	91.60	106.95	125.50	147.11	172.24
Demand for average download speed	143.42	148.18	153.72	159.48	165.47
New Demand for average download speed	148.75	152.97	157.32	161.64	165.93
Additional Monthly Consumer surplus	$5.33	$4.79	$3.60	$2.16	$0.46

[145] National average for wiring a 2-room residence with CAT 6.
[146] Extrapolation based on data from Watkins (2012).

Variable	2021	2022	2023	2024	2025
Additional Yearly Consumer Surplus	$64.02	$57.50	$43.23	$25.95	$5.55
Households with Internet and Wi-Fi	102,618,905	111,882,715	121,651,018	125,907,403	128,025,524
Impact ($Million)	$6,569.60	$6,433.45	$5,259.56	$3,267.83	$710.15

Sources: Cisco; Nevo et al. (2016); Telecom Advisory Services analysis

Additional benefit to consumers from speed increase due to 6 GHz

Residential Wi-Fi customers are expected to benefit further from the 6 GHz allocation due to faster Internet service under Wi-Fi 6E. As previously described in Chapter III, only households acquiring a 150 Mbps (or faster) fixed broadband line will be affected due to current router bottlenecks, and hence, the speed experienced will not be equivalent to that delivered by the fixed network. After calculating the difference in average speed attributed to 6 GHz, the additional consumer surplus will yield $13.7 billion in 2025.

Table D-21. United States: Consumer surplus from faster speed in households if 6 GHz allocated (2021-2025)

Variable	2021	2022	2023	2024	2025
Households that have connections over 150 Mbps (%)	43.69%	50.01%	57.24%	65.52%	75.00%
Percentage of household traffic that goes through Wi-Fi	45.95%	51.34%	53.86%	56.37%	58.84%
Traffic through the 6 GHz Channel (%)	0.00%	10.00%	20.00%	30.00%	40.00%
Share of traffic affected due to 6 GHz (%)	0.00%	2.57%	6.17%	11.08%	17.65%
Average speed with no 6 GHz (Mbps)	91.60	106.95	125.50	147.11	172.24
Average speed with 6 GHz (Mbps)	91.60	114.47	145.51	186.20	238.92
Demand for average download speed	148.75	152.97	157.32	161.64	165.93
New Demand for average download speed	148.75	154.82	161.34	168.05	174.84
Additional Yearly Consumer Surplus	$0.00	$22.20	$48.30	$76.95	$106.83
Households with Wi-Fi	102,618,905	111,882,715	121,651,018	125,907,403	128,025,524
Impact ($Million)	$0	$2,483	$5,875	$9,688	$13,677

Sources: FCC; Cisco; Nevo et al. (2016); Telecom Advisory Services analysis

D.3.4. Residential Wi-Fi devices and equipment

Consumers receive an economic surplus from acquiring Wi-Fi devices at a lower price than their willingness-to-pay for them. The absence of willingness-to-pay data for each piece of equipment makes it very difficult to reliably estimate consumer surplus. To overcome that limitation, a possible approximation is to assume that consumer surplus would equal the producer surplus (see Milgrom et al., 2011). Therefore, we calculate the producer's margin, and attribute that value to the consumer surplus. In addition, we also calculate the consumer surplus derived from the adoption of tablets (a product that is enabled mostly by Wi-Fi access), by considering the difference between the users' willingness-to-pay and the current market prices.

As detailed before in section B, we identified seven consumer products which are intrinsically linked to Wi-Fi: smart home devices and systems such as Wi-Fi speakers and home security systems, home networking systems, external adapters[147], routers, and gateways.

Since our focus is estimating economic surplus in the United States, the estimation of economic value begins by compiling revenues of U.S. manufacturers for each product[148]. After computing the global sales of U.S. manufacturers, we applied the prorated margin estimated by CSI markets (39.44%) which yields an estimated producer surplus for these particular products of $27.6 billion in 2021, which we assume to be of the same magnitude as consumer surplus.

By adding the estimated surplus related to tablets (by considering their price and the consumer's estimated willingness-to-pay), consumer surplus for Wi-Fi residential devices is expected to yield $29.2 billion in 2021. This figure is slightly below the estimations reported in our previous study for the U.S., since margins have been reduced, and hence, producer surplus. This methodology was used to calculate the consumer surplus up to 2023. However, the gradual adoption of Wi-Fi 6 devices will reduce the sales and economic value from the devices from the previous generations. By considering the global evolution of non 6 GHz consumer devices shipments is likely to decrease over time, we extrapolated the consumer surplus from these type of devices for those years (Table D-22).

Table D-22. United States: Economic Value of Wi-Fi enabled consumer products (2021-2025)

Variable	2021	2022	2023	2024	2025
Consumer surplus (ex. Tablets) ($Million)	$29,189.52	$30,067.20	$31,039.46	$30,654.34	$29,703.43
Tablet consumer surplus ($Million)	$1,069.43	$829.86	$648.32	$540.91	$449.84
Total consumer surplus ($Million)	$30,258.95	$30,897.06	$31,687.78	$31,195.25	$30,153.27

Sources: Consumer Technology Association; ABI Research; CS Markets; IDC; Telecom Advisory Services analysis

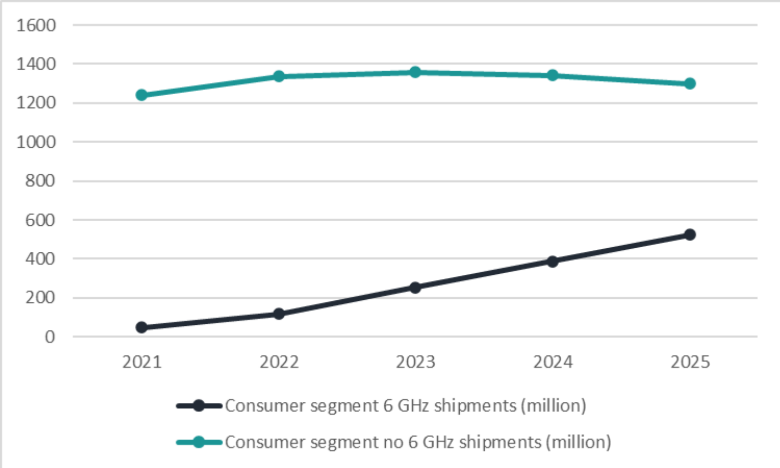
Consumer surplus derived from Wi-Fi enabled residential equipment for 6 GHz

[147] Wireless client device. It can be PCI adapter, which A PCI wireless adapter card is a device that is connected to a desktop computer's PCI bus to provide wireless capability to the desktop, a PC card, or a USB adapter.

[148] Lack of data of U.S. manufacturers worldwide revenues for wireless speakers, home security systems, and home networking devices obliged us to rely on the U.S. market size for these three products. We believe the U.S. manufacturers control most of this market, so the only portion missing in this estimate would be overseas revenues of U.S. manufacturers.

As commented before, devices for 6 GHz are expected to gradually replace those of former generations. According to IDC, global shipments of consumer devices linked to 6 GHz (802.11ax standard) will represent 40% of the shipments from previous generations (Graphic D-3).

Graphic D-3. Evolution of global shipments of consumer devices by technological standard



Source: IDC

As a result, if the shipments ratio reaches 40% in 2025, we can expect that, at least, the consumer surplus derived from 6 GHz devices will represent an amount of 40% of that of former technology residential devices. This global threshold may actually be modest for the United States, given that this country is expected to be among the leaders in the diffusion of the last technology. As Table D-23 indicates, our conservative estimates for consumer surplus attributed to 6 GHz residential devices amount to $12 billion in 2025.

Table D-23. United States: Economic Value of Wi-Fi enabled consumer products for 6 GHz (2021-2025)

Variable	2021	2022	2023	2024	2025
Consumer surplus (ex. Tablets) ($Million)	$29,189.52	$30,067.20	$31,039.46	$30,654.34	$29,703.43
Consumer 6 GHz / no 6 GHz device ratio	4%	9%	19%	29%	40%
Consumer surplus 6 GHz devices ($Million)	$1,098.96	$2,656.01	$5,768.82	$8,845.77	$11,969.31

Sources: IDC; Telecom Advisory Services analysis

D.3.5. Bridging the digital divide: use of Wi-Fi to increase coverage in rural and isolated areas

Wi-Fi is an appropriate technology to offer Internet access in rural and isolated areas. The calculation of the Wi-Fi contribution to the reduction of the digital divide must subtract the direct impact of WISPs (Section C.4.3.) to avoid double counting. On the other hand, we assume that 90% of WISP potential connections may be theoretically served by other technologies (i.e. satellite) covering the same isolated footprint. Thus, we can conservatively expect 10% of broadband subscriptions in remote locations exclusively attributed to WISPs. Once this is done, we calculate the impact on GDP by relying on the coefficient estimated by Katz and Callorda (2018b) through regression models that links increase in broadband penetration to economic growth. The contribution to GDP materializes through multiple effects: creation of new businesses, increasing productivity of existing enterprises, and growth of average income per household. We expect a GDP contribution of $20.7 billion in 2021, increasing to $32 billion in 2025 (see Table D-24).

Table D-24. United States: Estimation of GDP Contribution derived from reducing the digital divide (2021-2025)

Variable	2021	2022	2023	2024	2025
WISP subscribers	8,100,000	9,290,451	10,653,931	12,212,571	13,881,250
Additional broadband penetration due to WISP	6.17%	6.80%	7.49%	8.24%	9.00%
Impact of fixed broadband adoption in GDP	18.80%	18.80%	18.80%	18.80%	18.80%
GDP ($Billion)	$18,339.88	$18,625.80	$18,920.09	$19,226.59	$19,661.37
WISP TOTAL impact ($Million)	$212,596	$237,914	$266,255	$297,968	$332,735
WISP Revenues ($Million)	$5,200.00	$6,854.41	$8,333.86	$10,156.47	$12,377.70
Share that exist because WISP	10%	10%	10%	10%	10%
WISP spillovers on GDP ($Million)	$20,739.58	$23,106.00	$25,792.13	$28,781.20	$32,035.77

Sources: WISPA; IMF; Telecom Advisory Services analysis

Economic impact of enhanced coverage and affordability due to 6 GHz

The allocation of the 6 GHz band to unlicensed use would allow WISPs to potentially increase their subscriber base within their same coverage footprint. Therefore, a first effect derived from the allocation of the new spectrum band is related to additional households served due to additional coverage. As an example, the temporary assignment of spectrum by the FCC to deal with the COVID-19 pandemic allowed WISPs in the United States to immediately increase between 20% and 30% of their subscriber base. In any case, we will follow a cautious approach and consider that the expanded coverage will yield a gradual increase on WISP subscribers, from 2% in 2022 to 5% in 2025 over the figures projected without assuming the additional spectrum allocation. In addition, an increase of the user base would allow service providers to lower their operating costs. Thus, by assuming stability in prices, affordability would increase as GDP per capita grows as economic growth resumes. All in all, we can expect an overall increase in WISP connections of over 1 million in 2025, contributing to an increase of 0.8% in national broadband penetration. Considering the impact coefficient of broadband on the economy, which will yield $25.1 billion of GDP contribution.

Table D-25. United States: GDP Contribution derived from reducing the digital divide due to 6 GHz (2021-2025)

Variable	2021	2022	2023	2024	2025
New subscribers due to expanded coverage (%)	0%	2%	3%	4%	5%
New subscribers due to expanded coverage	0	185,809	319,618	488,503	694,062
New WISP adoption after price decrease (% households)	7.45%	7.61%	8.63%	9.80%	11.24%
Traffic through the 6 GHz Channel (%)	0%	10%	20%	30%	40%
Increase in WISP connections due to lower prices (households that buy the service)	0	37,004	86,616	154,606	353,322
Overall increase in WISP connections due to 6 GHz	0	222,813	406,234	643,109	1,047,384
Increase in national broadband penetration	0.00%	0.18%	0.32%	0.50%	0.80%
Impact of fixed broadband adoption in GDP	18.80%	18.80%	18.80%	18.80%	18.80%
Increase in the GDP due to the new broadband adoption (% GDP)	0.00%	0.03%	0.05%	0.08%	0.13%
Total impact in GDP ($Million)	$0.00	$5,706	$10,152	$15,691	$25,106

Sources: IMF; Telecom Advisory Services analysis

D.4. Enterprise Wi-Fi

Beyond the impact on consumers, Wi-Fi also contributes significant economic value in the United States enterprise segment. This section provides estimates in five areas:

- Support of business Internet traffic;
- Avoidance of campus and enterprise facilities inside wiring;
- Contribution to GDP resulting from Wi-Fi speed faster than cellular connections;
- Deployment of IoT solutions; and
- Implementation of business focused AR/VR use cases.

D.4.1. Business Internet traffic transmitted through Wi-Fi

Wi-Fi enterprise savings results from wireless traffic that is routed through Wi-Fi access points. Considering Cisco 2016-21 projections, we estimate that total business Internet traffic will reach 141.7 billion GB in 2021, of which 60.9 billion GB would have been transported through Wi-Fi access points. Considering the average price per GB transported by cellular carriers (from Table C-12), savings from Wi-Fi will reach $206.6 billion, an addition to the producer surplus[149]. By 2025, this benefit will reach $400.1 billion (see Table D-26).

[149] We acknowledge that enterprises are likely to negotiate wireless rates lower than those offered in the consumer market; however, data in this area is not available.

Table D-26. United States: Savings in business wireless traffic (2021-2025)

Variable	2021	2022	2023	2024	2025
Share of Business Internet Traffic by Wi Fi	43.00%	44.81%	46.69%	48.65%	50.70%
Total Business Internet Traffic (Million GB)	141,733.92	178,212.73	224,080.29	281,753.02	354,269.30
Total GB Wi-Fi enterprise traffic	60,945.59	79,852.27	104,624.23	137,081.01	179,606.60
Average Price per GB	$3.39	$3.05	$2.75	$2.47	$2.23
Savings ($Million)	$206,627.57	$243,743.12	$287,525.56	$339,172.43	$400,096.39

Sources: Cisco; Websites of cellular operators; Telecom Advisory Services analysis

Enhanced business Internet traffic transmitted through Wi-Fi due to 6 GHz

The deployment of the latest enterprise applications will generate an exponential growth in data traffic that will be handled by devices operating in unlicensed spectrum, through the combination of the existing bands and the 6 GHz band. In 2019, an updated Cisco traffic forecast based on the explosion of IoT and AR/VR applications, among other factors, increased total business Internet traffic previsions from the previous 2016-21 estimates from 2018. We assume that part of the growth was driven by "natural" growth (that is to say, the extrapolation of historical growth rate by averaging the growth rate between 2018 and 2019 and between 2017 and 2018), and another portion was triggered by Wi-Fi traffic stimulated by changes in 6 GHz. The sum of the difference due to broader Wi-Fi traffic between will reach $14.59 billion in 2025 (see Table D-27).

Table D-27. United States: Savings in business wireless traffic due to 6 GHz (2021-2025)

Variable	2021	2022	2023	2024	2025
Total value of business Wi-Fi traffic 2016-21 ($Million)	$206,627.57	$243,743.12	$287,525.56	$339,172.43	$400,096.39
Total value of business Wi-Fi traffic 2017/22 ($Million)	$282,510.03	$331,474.97	$388,926.56	$456,335.72	$535,428.31
Difference between the 2 estimations ($Million)	$75,882.46	$87,731.85	$101,401.00	$117,163.29	$135,331.92
Difference because natural growth ($Million)	$71,089.41	$78,274.23	$90,469.83	$104,532.92	$120,742.94
Difference due to 6 GHz ($Million)	$0	$9,457.62	$10,931.18	$12,630.37	$14,588.98

Sources: Cisco; Telecom Advisory Services analysis

D.4.2. Avoidance in enterprise building inside wiring

Similar to residential Wi-Fi savings due to capital investment avoidance in inside wiring, we assume that the total number of business establishments are equipped with Wi-Fi access points and multiply this value by a standard cost of deploying a CAT 6 network (although in this case, the cost is $2,200 per building) (see Table D-28).

Table D-28. United States: Savings in business wiring CAPEX (2021-2025)

Variable	2021	2022	2023	2024	2025
Total Wiring Cost (*)	$2,200	$2,200	$2,200	$2,200	$2,200
Number of Establishments	8,138,800	8,209,855	8,281,531	8,353,833	8,426,766
Establishments with Wi-Fi (%)	100%	100%	100%	100%	100%
Establishments with Wi-Fi	8,138,800	8,209,855	8,281,531	8,353,833	8,426,766
Inside wiring savings ($Million)	$17,905.36	$18,061.68	$18,219.37	$18,378.43	$18,538.89

(*) Wring costs assumed to be stable in the future based on findings between the 2018 and 2020.
Sources: U.S. Census; Telecom Advisory Services analysis

D.4.3. Return to speed: contribution to GDP derived from an increase in average mobile speed

Since Wi-Fi accessibility allows, in general, faster access to the Internet than cellular networks do, higher speeds have a positive contribution on the economy in terms of increased overall efficiency and innovation. This contribution is measured in terms of economic growth. As described in section B.2.3 for the case of consumer surplus, we start with the quantification of the average broadband speed if cellular networks transported all Wi-Fi traffic, and compare it with the presence of Wi-Fi technology (see Table D-29).

Table D-29. United States: Estimation of speed differential for total traffic (2021-2025)

Variable	2021	2022	2023	2024	2025
Average Download Speed if Wi-Fi traffic were carried through mobile networks (Mbps)	75.29	89.68	109.93	135.86	169.34
Average Speed with Wi-Fi (Mbps)	91.60	106.95	125.50	147.11	172.24
Speed increase (%)	21.66%	19.26%	14.16%	8.27%	1.71%
Impact of speed in GDP	0.73%	0.73%	0.73%	0.73%	0.73%
Increase in GDP	0.16%	0.14%	0.10%	0.06%	0.01%
GDP ($Billion)	$18,339.88	$18,625.80	$18,920.09	$19,226.59	$19,661.37
GDP increase ($Million)	$29,004.27	$26,186.67	$19,557.27	$11,613.56	$2,459.47

Sources: Cisco; IMF; Telecom Advisory Services analysis

Having calculated the speed increase percentage, we then apply this percentage to the coefficient derived from the model developed by Katz and Callorda (2019) to gauge the potential impact on GDP from Wi-Fi enhanced speed. Table D-29 indicates that the economic value of Wi-Fi in terms of increasing the speed of transporting wireless will account to $29 billion in 2021, before being reduced to $2.5 billion in 2025, due to expectations that, while Wi-Fi 6 will continue to be faster than 5G service, Wi-Fi's speed advantage over cellular will diminish.

Return to Speed additional effect due to 6 GHz

As previously described, only those broadband connections above 150 Mbps will be affected due to current router bottlenecks, and hence, the speed experienced will not be equivalent to that delivered by the fixed network. Thus, the allocation of the 6 GHz band will remove those barriers, increasing broadband speed. After calculating the difference in average speed attributed to 6 GHz, the additional GDP contribution will yield $55.6 billion in 2025 (Table D-30).

Table D-30. United States: Estimation of speed differential due to 6 GHz (2021-2025)

Variable	2021	2022	2023	2024	2025
Mean speed with no 6 GHz (Mbps)	91.60	106.95	125.50	147.11	172.24
Mean speed with 6 GHz (Mbps)	91.60	114.47	145.51	186.20	238.92
Speed increase due to 6Ghz (%)	0%	7%	16%	27%	39%
Impact speed on GDP	0.73%	0.73%	0.73%	0.73%	0.73%
Increase in GDP (%)	0.00%	0.05%	0.12%	0.19%	0.28%
GDP increase ($Million)	$0	$9,565	$22,021	$37,304	$55,562

Sources: Cisco; IMF; Telecom Advisory Services analysis

D.4.4. IoT Deployment

IoT adoption has a contribution to GDP growth through the multiplicity of use cases that improve efficiency in processes such as preventive maintenance, production monitoring and the like. To estimate this, we rely on a coefficient of GDP impact calculated through an aggregate simple production function which estimates that a 10% rise in M2M connections results in annual increases in GDP of between 0.3% and 0.9%[150]. Following a conservative approach, we relied on the lower-bound of that interval and assumed a 0.3% GDP increase after a 10% raise in M2M.

Starting with a 2021 installed base of 158,177,000 M2M devices, we estimate the growth between 2020 and 2021 that can be exclusively attributed to the allocation of additional spectrum to indoor Wi-Fi devices (1.31%). Thus, by subtracting the growth in M2M attributed to 6 GHz, it is estimated that the IoT impact for 2021 according to the natural growth would reach $73.5 billion (see Table D-31). For the following years, we relied on GSMA Intelligence forecasts for M2M connections, and assuming for 2024 and 2025 a similar growth rate as in 2023.

Table D-31. United States: GDP Contribution of IoT Deployment (2021-2025)

Variable	2021	2022	2023	2024	2025
Connections, Cellular M2M	158,177,000	176,183,777	192,981,251	211,380,207	231,533,331
Growth Rate (%)	14.67%	11.38%	9.53%	9.53%	9.53%
Natural Growth Rate (%)	13.36%	10.07%	8.22%	8.22%	8.22%
Impact of 1% M2M Growth on GDP	3%	3%	3%	3%	3%
Impact on GDP (%)	0.40%	0.30%	0.25%	0.25%	0.25%
GDP ($Billion)	$18,339.88	$18,625.80	$18,920.09	$19,226.59	$19,661.37
Impact ($Million)	$73,505.08	$56,283.51	$46,672.84	$47,428.94	$48,501.46

Sources: GSMA Intelligence; Frontier Economics; IMF; Telecom Advisory Services analysis

Accelerated effect of IoT due to 6 GHz

As described above, 1.31% of the M2M growth can be attributed to 6 GHz developments. According to the data in Table D-32, cumulative impact of enhanced IoT deployment driven by 6 GHz spectrum proposals will reach $7.7 billion by 2025.

[150] See Frontier Economics (2018)

This amount is slightly below our initial previsions in Katz (2020) due to the GDP adjustments because of the current economic crisis.

Table D-32. United States: GDP Contribution of IoT Deployment Boost caused by 6 GHz (2021-2025)

Variable	2021	2022	2023	2024	2025
Growth due to 6 GHz (%)	1.31%	1.31%	1.31%	1.31%	1.31%
Level of development of new bands (%)	50%	100%	100%	100%	100%
Impact on GDP (%)	0.02%	0.04%	0.04%	0.04%	0.04%
Impact ($Million)	$3,607.26	$7,327.00	$7,442.76	$7,563.34	$7,734.37

Sources: GSMA Intelligence; Frontier Economics; IMF; Telecom Advisory Services analysis

D.4.5. Deployment of AR/VR solutions

The adoption of AR/VR among U.S. business will in turn have a spillover effect on productivity, thereby contributing to the growth of GDP. Estimating spillover effects of AR/VR is a not a trivial exercise considering the embryonic adoption of some of these use cases. Since the objective is to estimate the spillover effect of AR/VR sales by U.S. firms in the domestic market, we will take as points of departure the estimate by PwC of the total GDP contribution of AR/VR for 2021 and 2022, and the sales of AR/VR components as estimated by ABI Research[151]. The extrapolation of these two parameters allow estimating the indirect (spillover) contribution of AR/VR to the U.S. economy for the period under analysis.

Starting values are reduced by the proportion that can be attributed to the impact of the 6 GHz spectrum bands. To do so, we took as a reference a ratio of AR/VR product developments according to each technology (built from data of ABI Research). Once the amount to be attributed in both GDP contribution and direct sales is estimated, the annual indirect to direct multiplier can be calculated. The lowest multiplier value is applied to sales of AR/VR in the U.S. market to calculate the total spillovers (see Table D-33). Total spillover value of AR/VR in the United States in 2021 will account for $4.2 billion and is expected to increase by 2025 to $8.98 billion.

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[151] See ABI Research, *Augmented and Mixed Reality Market Data: devices, use cases, verticals and value chain*. MD-ARMR-103, QTR 4 2019, and ABI Research, *Virtual Reality Market Data: devices, verticals, and value chain*. MD-VR-108, QTR 1 2020.

Table D-33. United States: GDP contribution resulting from AR/VR spillovers (2021-2025)

Variable	2021	2022	2023	2024	2025
AR/VR total contribution to GDP ($Billion)	$48.90	$68.20	$91.10	$122.60	$171.80
Share attributed to Wi-Fi (excluding 6 GHz)	42.02%	38.80%	32.18%	30.88%	29.32%
Portion of GDP contribution attributed to Wi-Fi (excluding 6 GHz) ($Billion)	$20.55	$26.46	$29.31	$37.86	$50.38
Direct impact (sales) attributed to Wi-Fi (excluding 6 GHz) ($Billion)	$4.20	$5.13	$5.63	$7.15	$8.98
Indirect impact ($Billion)	$16.34	$21.33	$23.68	$30.71	$41.39
Indirect/Direct multiplier	1.00	1.00	1.00	1.00	1.00
Indirect impact ($Million)	$4,202.70	$5,134.41	$5,633.00	$7,152.35	$8,985.17

Sources: ABI; PwC, IDC; Telecom Advisory Services analysis

Wider deployment of AR/VR solutions (accelerated effect due to 6 GHz)

Higher throughput enabled by Wi-Fi 6 and the allocation of the 6 GHz band is expected to spur the adoption and use of AR/VR among enterprises, hence increasing the associated spillover effects. By relying on the ratio built from 5 GHz and 6 GHz AR/VR related products, we were able to isolate the specific economic contribution of the new spectrum allocation. Following a similar procedure as that described above, spillovers from AR/VR in the United States attributed to 6 GHz in 2021 will account for $2.5 billion and are expected to increase by 2025 to $8.8 billion (Table D-34).

Table D-34. United States: GDP contribution resulting from AR/VR spillovers due to 6 GHz (2021-2025)

Variable	2021	2022	2023	2024	2025
AR/VR total contribution to GDP ($Billion)	$48.90	$68.20	$91.10	$122.60	$171.80
Share attributed to 6 GHz (%)	25%	26%	27%	28%	29%
Portion of GDP contribution attributed to 6 GHz ($Billion)	$12.02	$17.45	$24.27	$34.00	$49.60
Direct impact (sales) attributed to 6 GHz ($Billion)	$2.46	$3.39	$4.66	$6.42	$8.85
Indirect impact ($Billion)	$9.56	$14.06	$19.60	$27.58	$40.76
Indirect/Direct multiplier	1.00	1.00	1.00	1.00	1.00
Indirect impact ($Million)	$2,458.22	$3,385.84	$4,663.49	$6,423.28	$8,847.12

Sources: ABI; PwC, IDC; Telecom Advisory Services analysis

D.5. Internet Service Providers

In addition to the economic value generated by the sources analyzed above, Wi-Fi will also contribute to either producer surplus or GDP of Internet Service Providers. This section will assess the economic value in three sources:

- Producer surplus of cellular operators resulting from CAPEX savings incurred in network deployment
- Revenues of Wi-Fi carriers offering service in public spaces

- Revenues of Wireless ISPs (this effect differs from the GDP impact of WISPs as a result of their deployment in rural and isolated areas analyzed in section D.3.5.)

D.5.1. Cellular network savings by off-loading traffic to Wi-Fi

The value of cellular off-loading relates to the total cost of ownership required to accommodate future capacity requirements using Wi-Fi to complement cellular networks. It is obvious that a cellular-only network could not economically handle all future traffic predicted. While the economic advantage of Wi-Fi off-loading varies substantially by topography and size of the urban environment, carrier-grade Wi-Fi sites are considerably less expensive than cellular network equipment with similar capacity. For example, a cellular pico-cell (needed to offer access via conventional cellular service) costs between $7,500 and $15,000[152], while a carrier-grade Wi-Fi access point requires an investment of $2,500[153]. In addition, other capital and operating expense items show a clear advantage to Wi-Fi vis-à-vis an LTE macro cell (see Table D-35).

Table D-35. Comparative Carrier Grade Wi-Fi and LTE Macro Cell CAPEX and OPEX

Variable	Wi-Fi Site	LTE Macro Cell
New Site acquisition	$600	$150,000
Collocation	-	$50,000
Backhaul	$300	$5,000
Monthly site rental	$20	$1,000
Site maintenance/month	$10	$200

Source: LCC Wireless (2012)

As it can be seen, Wi-Fi has significant economic advantages at the unit level. However, we must add a caveat here. Site density requirements for Wi-Fi are much higher than for cellular. For example, in a dense urban environment with high traffic, for each cellular site, 23 Wi-Fi hotspots are required. The difference means that, from a total cost of ownership (CAPEX and OPEX) standpoint, the driver that erodes some of the Wi-Fi economic advantage is OPEX, especially Wi-Fi site rental and backhaul costs. Along these lines, for the carrier-class Wi-Fi off-loading to materialize, site deployment needs to be managed on a case-by-case basis, by surgically placing sites primarily in high traffic areas.

In this context, a simulation was run to determine the economic advantage of relying on carrier-grade Wi-Fi sites to complement the deployment of LTE in the United States. According to Thanki (2012), achieving full LTE coverage in the United States relying on 2100 MHz to accommodate incremental wireless data traffic would require approximately 34,000 new base stations[154], representing a total capital investment of $8.5 billion. On two simulation cases of off-loading in New York and

[152] "When Femtocells become Picocells", the 3G4G Blog and Ubiquisys.
[153] Cisco Aironet 1552H Wireless Access Point.
[154] This model was adapted by the author from Ofcom, the UK regulator, to assess the effect of differing traffic levels on cell site numbers in urban areas in its consultation "Application of spectrum liberalization and trading to the mobile sector" (Ofcom, 2009).

San Diego, LCC Wireless assumed a CAPEX benefit of Wi-Fi off-loading ranging between 22.3% and 44.7%. When averaging these two estimates, the CAPEX reduction would amount to $2.76 billion. Even under the OPEX considerations mentioned above, the total cost of ownership remains lower under the Wi-Fi off-loading scenario (see Table D-36).

Table D-36. United States: Total Cost of Ownership of LTE only versus LTE+ Wi-Fi Off-Load

Variable	LTE Only	LTE + Wi-Fi Off-Loading	Delta %/$
Total CAPEX	$8.5 billion	$5.7 billion	32.9 %/$2.8 billion
Total OPEX (*)	$48.7 billion	$40.8 billion	16.2 %/ $7.9 billion

(*) OPEX to CAPEX ratios assumed from LCC San Diego case

Sources: LCC Wireless (2012); Thanki (2012); Telecom Advisory Services analysis

In sum, the savings of deploying carrier-grade Wi-Fi complementing the rollout of 5G to accommodate future traffic growth would amount to 32.9% of CAPEX, while the OPEX savings are $2.82 for each dollar saved in CAPEX. In this context, Wi-Fi becomes a key enabler of 5G services. The upcoming flexible, radio-neutral 5G environment will be intrinsically supported by the next wave of 802.11 Wi-Fi standards (802.11n/ac, 802.11ax, WiGig), and short-range wireless technologies operating in unlicensed bands.

Moving on to estimating the value in the period 2021-2025, 5G deployment will increase the value of cellular re-routing. The estimation of CAPEX savings starts by considering the GSMA Intelligence aggregate investment estimates of mobile deployments, which account to $222.12 billion for the United States between 2019 and 2025. It is assumed that all the CAPEX invested during the period would be dedicated to 5G deployment. Considering the total CAPEX required to deploy 5G in the United States, and the incremental 5G coverage between 2021 and 2025 we are able to interpolate the 5G CAPEX for each year of the period considered. Assuming that this amount already reflects the savings incurred by relying on Wi-Fi sites, this would result in a total producer surplus (adding CAPEX and OPEX savings) of $62.6 billion in 2021, and $18.4 billion in 2022, when the value of Wi-Fi will shift to the 6 GHz band (see Table D-37).

Table D-37. United States: Savings due to Wi-Fi traffic off-loading (2021-25)

Variable	2021	2022	2023	2024	2025
5G coverage	79%	83%	83%	83%	83%
CAPEX without saving	$49,782.3	$14,646.6	$0.0	$0.0	$0.0
CAPEX reduction due to Wi-Fi off-loading	$16,378.4	$4,818.7	$0.0	$0.0	$0.0
OPEX reduction due to Wi-Fi off-loading	$46,187.0	$13,588.8	$0.0	$0.0	$0.0
Total Cost of Ownership ($Million)	$62,565	$18,408	$0.0	$0.0	$0.0

Sources: GSMA; Telecom Advisory Services analysis

Enhanced capability for cellular off-loading if 6 GHz allocated

The complementarity between Wi-Fi and cellular networks for Wi-Fi 6E and 5G, adds further potential gains derived from the savings in capital and operating expenses required to accommodate exploding data traffic. The key objective is to estimate the savings in capital investment as a result of an increase in traffic offloading with Wi-Fi benefits from the additional spectrum allocated, particularly, due to the ability to leverage 160 MHz within single contiguous channels.

To calculate the economic value of Wi-Fi in this context, we rely on the only known cost estimation of 5G to date: the one developed by Oughton and Frias (2016) for Ofcom in the United Kingdom. The authors' baseline case estimates a CAPEX of £42 billion, of which urban coverage investment amounts only to £700 million, while suburban deployment demands £5.6 billion, and rural coverage £35.6 billion. We have used Oughton and Frias (2016) cost decomposition by zone of the UK and applied it to United States, relying on a cost per population (POP) metric (see Table D-38).

Table D-38. Producer surplus of 5G in the United Kingdom vs. United States

Geography	United Kingdom			United States	
	Population Breakdown (%)	5G CAPEX (£ Billion)	5G CAPEX (%)	Population Breakdown (%)	5G CAPEX ($Billion)
Urban (cities>1 Million)	29%	£0.7	1.66%	27%	$3.14
Suburban	54%	£5.6	13.33%	53%	$26.58
Rural	17%	£35.6	84.76%	19%	$192.40
Total	100%	£41.9	100%	100%	$222.12

Sources: Oughton and Frias (2016); Trading Economics; World Bank; U.S. Census Bureau; Trulia; Telecom Advisory Services analysis

By relying again on the geographic disaggregation of Oughton and Frias, we estimate that CAPEX to be split as follows: $3.14 billion in urban areas, $26.58 billion in suburban settings, and $192.40 billion in rural geographies. We conservatively assume that Wi-Fi will not be critical in sustaining investment in urban areas, but that it will play a significant role beyond those geographies. Based on the cost advantage of carrier grade Wi-Fi, we assume that it will become effective for a portion of the suburban (approximately 15%) and rural network (approximately 5%) deployment. Therefore, using the GSMA CAPEX estimations, the implementation of Wi-Fi hotspots leveraging the 6 GHz, will yield CAPEX savings of $13.60 billion, that is, $2.72 billion a year until 2025.

D.5.2 Wi-Fi carrier revenue

The value of Wi-Fi carriers includes the sum of revenues through paid public Wi-Fi access. In order to estimate those aggregated revenues, we start by calculating the number of commercial Wi-Fi hotspots in the United States. According to Cisco, in 2021 there will be 41.03 million public Wi-Fi hotspots in the U.S., although that figure includes home spots (such as the guest account service provided by cable operators). By subtracting the home spots from the public Wi-Fi estimates of Cisco, we calculated a total of 1.95 million paid Wi-Fi hotspots for 2021, which will gradually decrease, reaching 1.29 million in 2025. On the other hand, based on revenue figures from Boingo financial statements and the number of hotspots deployed by this company in the U.S., we were able to estimate an average revenue figure per hotspot. By extrapolating that amount to the overall number of paid Wi-Fi hotspots in the country, we estimate total revenues generated by this sector in the United States: $1.2 billion in 2021, gradually decreasing to reach $800 million in 2025 (Table D-39).

Table D-39. United States: Revenues of Wi-Fi carriers (2021-2025)

Variable	2021	2022	2023	2024	2025
Public Wi-Fi hotspots (Million)	41.03	50.27	61.60	75.48	92.49
Home spots (Million)	39.08	48.30	59.70	73.79	91.20
Commercial Wi-Fi hotspots (Million)	1.95	1.97	1.90	1.69	1.29
Revenue per hotspot ($)	$618.76	$618.76	$618.76	$618.76	$618.76
Revenue ($Million)	$1,203.74	$1,218.33	$1,175.64	$1,048.48	$800.16

Sources: Cisco, Boingo, Telecom Advisory Services

Increased revenues of Wi-Fi carriers in public places due to 6 GHz

The allocation of the 6 GHz spectrum band offers an opportunity for commercial Wi-Fi carriers to enhance their business. As Wi-Fi 6E developments will allow up to 1,500 connected devices per access point, Wi-Fi carriers will have the possibility of adding more clients without quality limitations due to congestion. By considering a conservative potential increase of 40% in the number of connected devices in public venues and weighting that figure by the gradual expansion of the latest technology, we expect commercial Wi-Fi carriers to increase their user base by 16% in 2025. If the revenue per hotspot increases in the same amount, that will yield an increase in overall revenues for the sector of an additional $128 million by 2025 (Table D-40).

Table D-40. United States: Revenues of Wi-Fi carriers due to 6 GHz (2021-2025)

Variable	2021	2022	2023	2024	2025
Potential increase in connected devices in public venues	40%	40%	40%	40%	40%
Traffic through the 6 GHz Channel (%)	0%	10%	20%	30%	40%
Increase in connected devices due to 6 GHz	0%	4%	8%	12%	16%
Revenue per hotspot if 6 GHz allocated ($)	$618.76	$643.51	$668.26	$693.01	$717.76
Revenue if 6 GHz allocated ($Million)	$0.00	$48.73	$94.05	$125.82	$128.03

Sources: Boingo; Telecom Advisory Services analysis

In sum, while revenues according to the baseline scenario decline as a result of legacy access points consolidation, the allocation of the 6 GHz spectrum allows commercial Wi-Fi providers to counter the declining revenue trend.

D.5.3 Wireless ISPs revenues

WISPs, such as MIDCO and King Street Wireless rely primarily on unlicensed spectrum to offer broadband accessibility in rural areas of the United States. While some WISPs utilize licensed spectrum (Clear and Digital Bridge), the majority relies on UNII and ISM bands or lightly licensed spectrum in the 3.65 GHz band: 26 MHz of unlicensed spectrum just above 900 MHz, 50 MHz in 2.4 GHz and 100 MHz in 5.8 GHz (Larsen, 2011). While WISPs initially utilized the 802.11b platform, they have mostly migrated to 802.11n, which allows them to deliver 10 Mbps service or higher to 200 customers from a single four sector base station (Larsen, 2011). The 2021

GDP contribution related to the WISP industry was calculated as a function of the number of subscribers (8,100,000, as projected by the WISPA, 2017) and the ARPU ($641.98 per year), yielding a total of $5.2 billion (Table D-41).

Table D-41. United States: WISP revenues (2021-2025)

Variable	2021	2022	2023	2024	2025
Subscribers (Million)	8.10	9.29	10.65	12.21	13.88
WISP annual ARPU ($)	$641.98	$737.79	$782.23	$831.64	$891.68
Revenues ($Million)	$5,200.00	$6,854.41	$8,333.86	$10,156.47	$12,377.70

Sources: WISPA, Telecom Advisory Services analysis

Increased revenues of WISPs due to 6 GHz

As described in section III.2.5, the allocation of 6 GHz spectrum band will potentially increase the WISP user base in 1.05 million subscribers by 2025, due to expanded coverage and better affordability. Thus, by assuming the same ARPU values as described above, the new subscriptions will account for an additional $933.94 million in revenues in 2025 (Table D-42).

Table D-42. United States: WISP revenues due to 6 GHz (2021-2025)

Variable	2021	2022	2023	2024	2025
WISP annual ARPU ($)	$641.98	$737.79	$782.23	$831.64	$891.68
New subscribers if 6 GHz allocated (Million)	0.00	0.22	0.41	0.64	1.05
New revenue ($Million)	$0.00	$164.39	$317.77	$534.84	$933.94

Sources: WISPA; Telecom Advisory Services analysis

D.6. Wi-Fi ecosystem

The economic value generated by Wi-Fi within Wi-Fi ecosystem companies is calculated based on the following three sources:

- The producer surplus (i.e. margins) of residential Wi-Fi devices and equipment manufactured in the United States;
- The producer surplus of local firms providing products and services in the IoT ecosystem (hardware, software and systems integration) in the United States; and
- The producer surplus of local firms providing products and services in the AR/VR ecosystem (hardware, software and content) in the United States.

D.6.1 Locally manufactured residential Wi-Fi devices and equipment

In section D.3.4 we calculated the producer surplus attributed to residential Wi-Fi devices and equipment, relying on Milgrom et al. (2011) assumption that consumer surplus could be approximated by that of the producers. By adding to that value the producer surplus estimated for the case of tablets, we estimate a total economic value of $33.95 billion in 2021, which we expect to slightly decrease to $33.15 billion in 2025 due to the replacement of current devices by those from Wi-Fi 6 (Table D-43).

Table D-43. United States: producer surplus from locally manufactured residential Wi-Fi devices and equipment (2021-2025)

Variable	2021	2022	2023	2024	2025
Producer surplus ($Million)	$27,594.09	$28,511.82	$29,492.13	$29,126.20	$28,222.70
Tablet producer surplus ($Million)	$6,351.54	$5,839.47	$5,448.09	$5,181.76	$4,928.44
Total producer surplus ($Million)	$33,945.63	$34,351.28	$34,940.22	$34,307.96	$33,151.14

Sources: Consumer Technology Association; ABI Research; CS Markets; Telecom Advisory Services analysis

Locally manufactured Wi-Fi 6 devices and equipment for residential use

As mentioned above, devices for 6 GHz are expected to gradually replace those of prior generations. According to IDC, global shipments of consumer devices linked to 6 GHz (802.11ax) will represent 40% of the shipments of those from previous generations in 2025. Therefore, we expect the producer surplus attributed to 6 GHz devices to yield $11.37 billion by 2025.

Table D-44. United States: Producer Surplus from locally manufactured residential Wi-Fi 6 devices and equipment (2021-2025)

Variable	2021	2022	2023	2024	2025
Consumer 6 GHz / no 6 GHz	3.76%	8.83%	18.59%	28.86%	40.30%
Producer surplus 6 GHz devices ($Million)	$1,038.89	$2,518.61	$5,481.24	$8,404.80	$11,372.63

Sources: IDC; Telecom Advisory Services analysis

D.6.2 Locally manufactured enterprise Wi-Fi devices and equipment

U.S. manufacturers control the largest share of the enterprise access points and controller's world market. For example, in 2020 Cisco controlled 45.7% of the enterprise wireless local area network market share worldwide[155]. Of the revenues of U.S. manufacturers, the prorated margin estimated by CSI markets is 39.44%, which yields a producer surplus for U.S. manufacturers of these particular products of $2.25 billion. Following again Milgrom et al. (2011) in their assumption that consumer value for enterprises[156] is of the same magnitude as producer value, total economic value in 2021 will amount to $4,504 million (see Table D-45). That figure is expected to decrease by 2025 due to the replacement of current devices by those specific for 6 GHz.

[155] Source: IDC (2020). *Worldwide Enterprise WLAN Market Declines Moderately in the Second Quarter of 2020, according to IDC* (September 2). Retrieved in: https://www.idc.com/getdoc.jsp?containerId=prUS46826820
[156] The enterprise surplus is considered here as a producer surplus for companies that benefit from Wi-Fi technology.

Table D-45. United States: Economic Value of Wi-Fi enabled enterprise equipment (2021-2025)

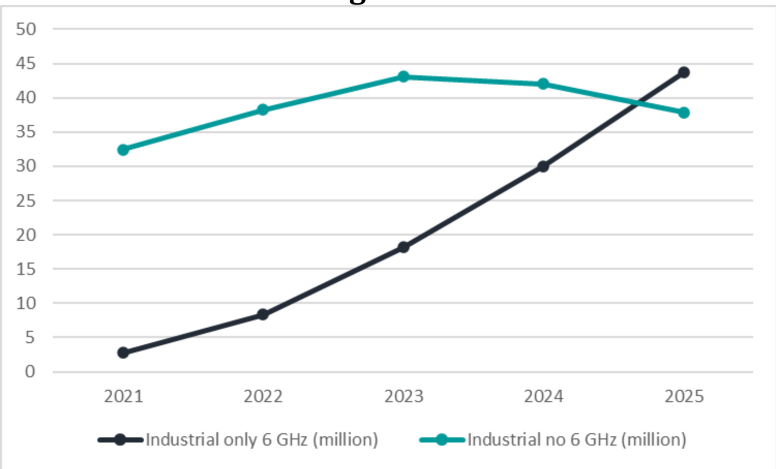
Variable	2021	2022	2023	2024	2025
Total producer surplus ($Million)	$4,504.78	$4,568.59	$4,693.86	$4,578.76	$4,128.02

Sources: ABI Research; CS Markets; Telecom Advisory Services analysis

Locally manufactured Wi-Fi 6 devices and equipment for enterprises

As commented before, devices for 6 GHz are expected to gradually replace those of former generations. According to IDC, global shipments of enterprise devices linked to 6 GHz (802.11ax) will overtake those from the previous generations by 2025 (Graphic D-4).

Graphic D-4. Global: Evolution of shipments of enterprise devices by technological standard



Source: IDC

In total, global shipments for industrial devices for 6 GHz will account for 115% of those attributed to previous generations in 2025. Thus, by applying the corresponding ratios, we expect the producer surplus linked to enterprise 6 GHz devices to yield $4.76 billion by 2025.

Table D-46. United States: Economic Value of Wi-Fi 6 enabled enterprise equipment (2021-2025)

Variable	2021	2022	2023	2024	2025
Shipments of industrial 6 GHz devices (Million)	2.74	8.36	18.16	30.06	43.71
Shipments of industrial no 6 GHz devices (Million)	32.47	38.22	43.08	42.02	37.89
Ratio 6 GHz / no 6 GHz	8.45%	21.87%	42.15%	71.53%	115.38%
Producer surplus 6 GHz devices ($Million)	$380.50	$999.27	$1,978.59	$3,275.03	$4,763.03

Sources: IDC; Telecom Advisory Services analysis

C.6.3. Firms belonging to the IoT ecosystem

According to estimates from Statista for North America, we expect total industrial IoT revenue in the United States to reach $164 billion in 2021 (interpolation made by considering the share of U.S. M2M devices in North America). That figure includes revenues attributed to IoT connectivity, apps, platforms, and related professional services. By weighting those amounts by the share of local production (49.8% for hardware, 90% for software and services) and the assumed margins (39.44% and 77.46%, respectively), we can estimate the overall producer surplus. However, we should extract the share attributed to 6 GHz developments from that economic value. To do so, we estimated a natural growth rate, by subtracting the corresponding share attributed to 6 GHz according to the growth rates indicated in Table D-46. Thus, we estimate a producer surplus not attributed to 6 GHz of $106 million in 2021, expected to reach $192 million in 2025 (Table D-47).

Table D-47. United States: IoT ecosystem direct contribution (2021-2025)

Variable	2021	2022	2023	2024	2025
IoT connectivity revenue ($Billion)	$10.30	$11.74	$13.64	$14.11	$15.05
Apps, platforms, and services IoT revenue ($Billion)	$111.93	$133.89	$158.00	$182.47	$209.73
Professional services IoT ($Billion)	$42.15	$51.21	$62.54	$76.66	$94.99
Total Industrial IoT revenue in ($Billion)	$164.38	$196.83	$234.17	$273.23	$319.76
Local production (%) - Hardware	49.80%	49.80%	49.80%	49.80%	49.80%
Local production (%) - Software & Services	90.00%	90.00%	90.00%	90.00%	90.00%
Margins (%) - Hardware	39.44%	39.44%	39.44%	39.44%	39.44%
Margins (%) - Software & Services	77.46%	77.46%	77.46%	77.46%	77.46%
Margins - IoT connectivity revenue ($Billion)	$2.02	$2.31	$2.68	$2.77	$2.96
Margins - Apps, platforms, and services IoT revenue ($Billion)	$78.03	$93.34	$110.15	$127.21	$146.21
Margins - Professional services IoT ($Billion)	$29.38	$35.70	$43.60	$53.44	$66.22
Producer surplus ($Million)	$109,434.91	$131,340.43	$156,423.76	$183,415.64	$215,383.19
Growth rate (%)	21.67%	20.02%	19.10%	17.26%	17.43%
Growth rate not attributed to 6 GHz (%)	19.73%	17.71%	16.47%	14.88%	15.03%
Producer surplus not attributed to 6 GHz ($Million)	$106,025.76	$124,804.28	$145,361.19	$166,994.39	$192,096.86

Sources: Statista, CSI, Telecom Advisory Services analysis

Wider deployment of Internet of Things under 6 GHz

Following the previous analysis, we were able to estimate which portion of IoT producer surplus growth can be attributed to 6 GHz. As Table D-48 indicates, we expect the additional IoT surplus generated by 6 GHz to account for $23.3 billion in 2025.

Table D-48. United States: IoT direct contribution attributed to 6 GHz (2021-2025)

Variable	2021	2022	2023	2024	2025
Producer surplus ($Million)	$109,434.91	$131,340.43	$156,423.76	$183,415.64	$215,383.19
Growth rate attributed to 6 GHz (%)	1.94%	2.31%	2.63%	2.37%	2.40%
Additional surplus due to 6 GHz ($Million)	$3,409.15	$6,536.15	$11,062.56	$16,421.25	$23,286.32

Sources: Statista, CSI, Telecom Advisory Services analysis

D.6.4. Firms belonging to the AR/VR ecosystem

Following a similar procedure as with the case of IoT, we can estimate the direct contribution of this ecosystem to the U.S. economy. Starting with the local spending in AR/VR by category (hardware, software, and contents), and weighting those figures by the respective shares of local production and margins, we were able to estimate the total producer surplus. By relying on a ratio built from 5 GHz and 6 GHz AR/VR related products, we were able to subtract the specific contribution attributed to 6 GHz from the surplus corresponding to current bands. Then, we expect by 2021 a direct contribution from the AR/VR ecosystem of $2.2 billion, which will increase until reaching $4.8 billion by 2025 (Table D-49).

Table D-49. United States: AR/VR ecosystem direct contribution (2021-2025)

Variable	2021	2022	2023	2024	2025
Spending in AR/VR - Hardware ($Billion)	$3.28	$4.33	$5.73	$7.59	$10.04
Spending in AR/VR - Software ($Billion)	$2.26	$2.99	$3.96	$5.23	$6.93
Spending in AR/VR - Content ($Billion)	$4.47	$5.91	$7.82	$10.34	$13.68
Share of local production – Hardware (%)	49.80%	49.80%	49.80%	49.80%	49.80%
Share of local production – Software (%)	90.00%	90.00%	90.00%	90.00%	90.00%
Share of local production – Content (%)	90.00%	90.00%	90.00%	90.00%	90.00%
Local production for local consumption - Hardware ($Billion)	$1.63	$2.16	$2.86	$3.78	$5.00
Local production for local consumption - Software ($Billion)	$2.03	$2.69	$3.56	$4.71	$6.23
Local production for local consumption - Content ($Billion)	$4.02	$5.32	$7.03	$9.31	$12.31
Local Producer Surplus - Hardware ($Billion)	$0.64	$0.85	$1.13	$1.49	$1.97
Local Producer Surplus - Software ($Billion)	$1.58	$2.09	$2.76	$3.65	$4.83
Local Producer Surplus - Content ($Billion)	$3.11	$4.12	$5.45	$7.21	$9.54
Total Producer Surplus	$5.33	$7.05	$9.33	$12.35	$16.34
Share attributed to Wi-Fi (not including 6 GHz)	42.02%	38.80%	32.18%	30.88%	29.32%
Producer Surplus attributed to Wi-Fi (not including 6 GHz) ($Million)	$2,240.59	$2,737.32	$3,003.13	$3,813.14	$4,790.28

Sources: ABI; PwC, IDC; Telecom Advisory Services analysis

Wider deployment of AR/VR solutions if 6 GHz allocated

By relying on a ratio built from 5 GHz and 6 GHz AR/VR related products, we were able to isolate the specific economic contribution of the new spectrum allocation.

Following a similar procedure as that described above, the direct contribution from the AR/VR ecosystem in the United States attributed to 6 GHz in 2025 will yield $4.7 billion.

Table D-50. United States: AR/VR direct contribution attributed to 6 GHz (2021-2025)

Variable	2021	2022	2023	2024	2025
Spending in AR/VR ($Billion)	$10.00	$13.23	$17.51	$23.16	$30.64
Share attributed to 6 GHz	24.58%	25.59%	26.64%	27.73%	28.87%
Spending in AR/VR attributed to 6 GHz ($Billion)	$2.46	$3.39	$4.66	$6.42	$8.85
Local production for local consumption 6 GHz ($Billion)	$1.89	$2.60	$3.58	$4.94	$6.80
Local Producer Surplus ($Million)	$1,310.56	$1,805.10	$2,486.26	$3,424.45	$4,716.68

Sources: ABI; PwC, IDC; Telecom Advisory Services analysis

D.7. Wi-Fi contribution to employment

The estimation of employment generated is calculated by relying on the total GDP contribution resulting from the effects analyzed above and using that as an input in the communications sector of an input-output matrix of the U.S. economy. Table C-51 presents the GDP contribution enabled by Wi-Fi projected for the period 2021-2025.

Table D-51. United States: Wi-Fi enabled GDP contribution (2021-2025)

Year	GDP contribution enabled by Wi-Fi ($Million)		
	Attributed to current bands	Attributed to 6 GHz	Total
2021	$151,286	$6,065	$157,352
2022	$132,329	$27,451	$159,780
2023	$116,794	$46,402	$163,196
2024	$111,858	$68,983	$180,841
2025	$109,898	$99,508	$209,406

Sources: Telecom Advisory Services analysis

These inputs generate the following annual employment effects based on the input/output matrix for the U.S. economy (Table D-52).

Table D-52. United States: Wi-Fi generated Annual Employment

Variable	2021			2025		
	Current bands	6 GHz	Total	Current bands	6 GHz	Total
Direct jobs	262,564	10,526	273,092	190,733	172,701	363,434
Indirect jobs	196,729	7,887	204,617	142,909	129,398	272,307
Induced jobs	61,454	2,464	63,918	44,642	40,421	85,063
Total	520,747	20,877	541,627	378,284	342,520	720,804

Sources: GTAP; Telecom Advisory Services analysis

According to the contribution to GDP, Wi-Fi will generate approximately 542,000 jobs in 2021 and is expected to generate over 720,000 in 2025. These estimates are larger than those reported in our previous 2018 study (Katz and Callorda, 2018a), given that for this research we have identified several new sources of economic value generated by Wi-Fi. Job estimates include direct jobs (those jobs created by the specific Wi-Fi contribution), indirect jobs (those jobs created by suppliers to the Wi-Fi sector) and induced jobs (those jobs created by spending of direct and indirect workers). The sector breakdown of 2021 employment (including the additional jobs created by 6 GHz) is as follows (Table D-53).

Table D-53. United States: Sector Breakdown of Wi-Fi generated annual employment (2021)

Sector	Direct	Indirect	Induced	Total
Agriculture	0	0	784	784
Extractive industries	0	0	605	605
Manufacturing	0	19,988	744	20,732
Construction	0	4,477	0	4,477
Trade	0	23,543	34,598	58,141
Transportation	0	12,003	0	12,003
Communications	273,092	0	0	273,092
Financial Services	0	10,643	0	10,643
Business services	0	133,963	0	133,963
Other services	0	0	27,187	27,187
Total	273,092	204,617	63,918	541,627

Sources: GTAP; Telecom Advisory Services analysis

E. ECONOMIC VALUE OF WI-FI IN THE UNITED KINGDOM

Wi-Fi has become a pervasive feature in the United Kingdom telecommunications landscape. According to the Cisco Annual Internet Report Highlights Tool 2018-2023, there were 200,000 paid Wi-Fi access points operating in the UK territory in 2018, while Wiman reports 2,223,000 open Wi-Fi networks (of which 1,517,000 are located in London, 69,000 in Birmingham, and 46,000 in Glasgow). Eighty-nine percent of Internet homes in the United Kingdom are equipped with a Wi-Fi router. Given the Wi-Fi access point density, hotspots have become a very important connectivity feature. According to Opensignal[157], after the outbreak of COVID-19 UK wireless users spend 68.9% of their communications time connected to Wi-Fi networks rather than relying on their cellular data connection.

The increasing importance of Wi-Fi technology in the digital infrastructure ecosystem should have a significant contribution on its social and economic contribution. This section presents the results and calculations of the economic assessment.

E.1. Total economic value of Wi-Fi in the United Kingdom (2021-2025)

In the prior study of Wi-Fi's economic contribution[158], its value for 2021 was estimated at $64 billion. Before considering the additional effect of allocating the 6 GHz spectrum band for unlicensed use, the total economic value of Wi-Fi in the United Kingdom in 2021 will amount to $96.9 billion. The increase of $32.9 billion is mainly due to the development of four new sources of economic value:

- The increasing importance of free Wi-Fi;
- The contribution of Wi-Fi technology to improving broadband speed;
- A substantial boost to deployment of IoT technology; and
- The growing adoption of AR/VR technology use cases.

The total economic value in 2021 of $96.9 billion is broken down by $35.9 billion in consumer surplus, $36.0 billion in producer surplus, and $25.0 billion in a net contribution to GDP. Even before accounting for the acceleration effect resulting from the allocation of 500 MHz in the 6 GHz band, the 2025 forecast of economic value will reach $97.8 billion, composed of $46.5 billion in consumer surplus, $42.6 billion in producer surplus, and $8.7 billion in GDP contribution (see Table E-1).

[157] Khatri, H. and Fenwick, S. (2020). "Analyzing mobile experience during the coronavirus pandemic: Time on Wi-Fi". *Opensignal* (March 30).
[158] Katz, R. and Callorda, F. (2018). *The Economic value of Wi-Fi: A Global View (2018 and 2023)*. New York: Telecom Advisory Services. October.

Table E-1. United Kingdom: Economic value of Wi-Fi (Baseline Scenario)

Agent	Source	Economic Value ($Million)					
		2021	2022	2023	2024	2025	Category
1. Free Wi-Fi	1.1. Savings generated by free Wi-Fi traffic offered in public sites	$759	$763	$724	$707	$689	Consumer Surplus
	1.2. Deployment of free Wi-Fi in public sites	$342	$347	$353	$358	$364	GDP contribution
2. Residential Wi-Fi	2.1. Internet access for home usage of devices that lack a wired port	$7,715	$9,150	$10,864	$12,922	$15,407	Consumer Surplus
	2.2. Avoidance of investment in in-house wiring	$23,481	$24,206	$24,942	$25,649	$26,377	Consumer Surplus
	2.3. Benefit to consumers from speed increases	$27	$14	$7	$4	$2	Consumer Surplus
	2.4. Residential Wi-Fi devices and equipment deployed	$3,994	$4,087	$4,199	$4,135	$3,997	Consumer Surplus
	2.5. Bridging digital divide: use of Wi-Fi to increase coverage in rural and isolated areas	$27	$26	$25	$25	$24	GDP contribution
3. Enterprise Wi-Fi	3.1. Business Internet traffic transmitted through Wi-Fi	$6,070	$6,562	$7,093	$7,668	$8,289	Producer surplus
	3.2. Avoidance of enterprise inside wiring costs	$9,859	$10,323	$10,808	$11,317	$11,850	Producer surplus
	3.3. Return to speed: contribution to GDP derived from an increase in average mobile speed	$172	$87	$44	$22	$11	GDP contribution
	3.4. Wide deployment of IoT	$23,652	$14,932	$5,491	$5,575	$5,661	GDP contribution
	3.5. Deployment of AR/VR solutions	$550	$897	$1,137	$1,536	$2,380	GDP contribution
4. ISPs	4.1. CAPEX and OPEX savings due to cellular off-loading	$9,226	$8,558	$7,300	$5,878	$4,819	Producer surplus
	4.2. Revenues of service providers offering paid Wi-Fi access in public places	$184	$535	$196	$202	$208	GDP contribution
	4.3. Aggregated revenues of WISPs	$53	$60	$62	$64	$68	GDP contribution
5. Wi-Fi ecosystem	5.1. Locally manufactured residential Wi-Fi devices and equipment	$4,684	$5,038	$5,417	$5,350	$5,184	Producer surplus
	5.2. Locally manufactured Wi-Fi enterprise equipment	$0	$0	$0	$0	$0	Producer surplus
	5.3. Locally produced IoT products and services	$5,876	$7,130	$8,359	$9,657	$11,186	Producer surplus
	5.4. Locally produced of AR/VR solutions	$262	$443	$576	$787	$1,250	Producer surplus
Total		$96,933	$93,158	$87,597	$91,856	$97,766	

Source: Telecom Advisory Services analysis

It should be noted that the reason for the decline in annual economic value in the intervening years between 2021 and 2025 is due to the fact that, as reported by the Cisco Annual Internet Report Highlights Tool 2018-2023, Wi-Fi average speed between 2022 and 2024 is lower than that of mobile networks. For example, the average smartphone connection speed in 2022 is 67.23 Mbps, while the average Wi-Fi speed is 58.52 Mbps.

In addition to the value generated from the unlicensed use of the 2.4 GHz and 5 GHz bands (referred to as the baseline scenario), the allocation of 500 MHz in the 6 GHz spectrum band for unlicensed use[159] and the deployment of Wi-Fi 6 and Wi-Fi 6E devices will trigger an additional boost in economic value, reaching $10.7 billion in 2025 (see Table E-2).

Table E-2. United Kingdom: Economic value of Wi-Fi (only attributed to Wi-Fi 6 and 6 GHz)

Agent	Source	Economic Value ($Millions)					
		2021	2022	2023	2024	2025	Category
1. Free Wi-Fi	1.1. Savings generated by free Wi-Fi traffic offered in public sites	$0	$9	$35	$77	$141	Consumer Surplus
	1.2. Deployment of free Wi-Fi in public sites	$0	$33	$67	$102	$138	GDP contribution
	1.3. Benefit of faster free Wi-Fi with Wi-Fi 6E devices	$0	$8	$17	$27	$38	Consumer Surplus
2. Residential Wi-Fi	2.3. Benefit to consumers from speed increases	$0	$150	$326	$523	$656	Consumer Surplus
	2.4. Residential Wi-Fi devices and equipment deployed	$145	$351	$763	$1,170	$1,583	Consumer Surplus
	2.5. Bridging digital divide: use of Wi-Fi to increase coverage in rural and isolated areas	$0	$5	$8	$12	$14	GDP contribution
3. Enterprise Wi-Fi	3.1. Business Internet traffic transmitted through Wi-Fi	$0	$169	$198	$230	$236	Producer surplus
	3.3. Return to speed: contribution to GDP derived from an increase in average mobile speed	$0	$337	$751	$1,235	$1,578	GDP contribution
	3.4. Wide deployment of Internet of Things	$580	$972	$438	$445	$451	GDP contribution
	3.5. Deployment of AR/VR solutions	$267	$386	$561	$778	$1,241	GDP contribution
4. ISPs	4.1 CAPEX and OPEX savings due to cellular off-loading	$395	$395	$395	$395	$395	Producer surplus
	4.2. Revenues of service providers offering paid Wi-Fi access in public places	$0	$21	$16	$24	$33	GDP contribution
	4.3. Aggregated revenues of WISPs	$0	$1	$2	$2	$3	GDP contribution
5. Wi-Fi ecosystem	5.1. Locally manufactured residential Wi-Fi devices and equipment	$176	$445	$1,007	$1,544	$2,089	Producer surplus
	5.2. Locally manufactured Wi-Fi enterprise equipment	$0	$0	$0	$0	$0	Producer surplus

[159] On July 24, 2020 Ofcom made the final decision to make 500 MHz available for unlicensed use low power indoor and very low power outdoor use. The purpose in limiting the allocation to 500 MHz is to initially show Wi-Fi can benefit from the lower part of the band and then investigate the upper part. In the words of Ofcom, "we will continue to review use of the upper 6 GHz band to determine what the optimal use may be".

Agent	Source	Economic Value ($Millions)					
		2021	2022	2023	2024	2025	Category
	5.3. Locally produced IoT products and services	$221	$438	$722	$1,059	$1,497	Producer surplus
	5.4. Locally produced of AR/VR solutions	$127	$190	$284	$399	$652	Producer surplus
Total		$1,911	$3,910	$5,590	$8,022	$10,745	

Source: Telecom Advisory Services analysis

As indicated in Table E-2, the constant increase in Wi-Fi value driven by the 6 GHz is important in terms of cancelling the temporary decline between 2022 and 2024 in the baseline case. Furthermore, considering that by 2025 only 40% of Wi-Fi traffic will rely on the 6 GHz channels, the accelerated effect derived from the new spectrum allocation and latest Wi-Fi technologies will still be far from reaching its maximum potential at this time. If Ofcom decides to allocate the upper part of the spectrum to unlicensed use, Wi-Fi economic value would increase significantly beyond the values presented in Table E-2.

By combining the baseline and the Wi-Fi 6 and 6 GHz scenarios, the overall economic value of Wi-Fi for the United Kingdom will yield $108.5 billion in 2025 (see Table E-3).

Table E-3. United Kingdom: Total economic value of Wi-Fi (including Wi-Fi 6 and 6 GHz)

Agent	Source	Economic Value ($Million)					
		2021	2022	2023	2024	2025	Category
1. Free Wi-Fi	1.1. Savings to consumers of free Wi-Fi traffic offered in public sites	$759	$772	$759	$784	$830	Consumer Surplus
	1.2. Deployment of free Wi-Fi in public sites	$342	$380	$420	$460	$502	GDP contribution
	1.3. Benefit of faster free Wi-Fi with Wi-Fi 6E devices	$0	$8	$17	$27	$38	Consumer Surplus
2. Residential Wi-Fi	2.1. Internet access for home usage of devices that lack a wired port	$7,715	$9,150	$10,864	$12,922	$15,407	Consumer Surplus
	2.2. Avoidance of investment in in-house wiring	$23,481	$24,206	$24,942	$25,649	$26,377	Consumer Surplus
	2.3. Benefit to consumers from speed increases	$27	$163	$333	$527	$658	Consumer Surplus
	2.4. Residential Wi-Fi devices and equipment deployed	$4,139	$4,439	$4,962	$5,305	$5,580	Consumer Surplus
	2.5. Bridging digital divide: use of Wi-Fi to increase coverage in rural and isolated areas	$27	$31	$34	$37	$39	GDP contribution
3. Enterprise Wi-Fi	3.1. Business Internet traffic transmitted through Wi-Fi	$6,070	$6,731	$7,291	$7,898	$8,525	Producer surplus
	3.2. Avoidance of enterprise inside wiring costs	$9,859	$10,323	$10,808	$11,317	$11,850	Producer surplus
	3.3. Return to speed: contribution to GDP derived from an	$172	$424	$795	$1,256	$1,589	GDP contribution

Agent	Source	Economic Value ($Million)					
		2021	2022	2023	2024	2025	Category
	increase in average mobile speed						
	3.4. Wide deployment of IoT	$24,233	$15,904	$5,929	$6,020	$6,112	GDP contribution
	3.5. Deployment of AR/VR solutions	$817	$1,283	$1,698	$2,314	$3,620	GDP contribution
4. ISPs	4.1 CAPEX and OPEX savings due to cellular off-loading	$9,621	$8,953	$7,695	$6,273	$5,214	Producer surplus
	4.2. Revenues of service providers offering paid Wi-Fi access in public places	$184	$556	$212	$227	$242	GDP contribution
	4.3. Aggregated revenues of WISPs	$53	$61	$64	$67	$71	GDP contribution
5. Wi-Fi ecosystem	5.1. Locally manufactured residential Wi-Fi devices and equipment	$4,860	$5,483	$6,424	$6,894	$7,273	Producer surplus
	5.2. Locally manufactured Wi-Fi enterprise equipment	$0	$0	$0	$0	$0	Producer surplus
	5.3. Locally produced IoT products and services	$6,097	$7,569	$9,081	$10,715	$12,682	Producer surplus
	5.4. Locally produced of AR/VR solutions	$389	$633	$860	$1,186	$1,902	Producer surplus
	Total	$98,845	$97,069	$93,188	$99,878	$108,511	

Source: Telecom Advisory Services analysis

As indicated in Tables E-1 through E-3, if the 6 GHz spectrum had not been allocated by Ofcom, Wi-Fi economic value would have remained stable. The following sections will present in detail the calculation of each source of value, disaggregating the economic contribution between the current spectrum allocation and the enhanced effect due to Wi-Fi 6 availability and the 6 GHz band.

E.2. Value from free Wi-Fi service

The economic value of free Wi-Fi service originates from three contribution sources:

- Savings to consumers by accessing the Internet in free Wi-Fi sites rather than incurring cellular costs
- The use of Wi-Fi to expand broadband coverage to the unserved population
- The return to speed of Wi-Fi compared to the use of cellular service

E.2.1. Savings incurred by accessing free Wi-Fi in public sites

The economic value of free Wi-Fi is measured in terms of consumer surplus, calculated by estimating the benefit that flows to consumers as a result of savings incurred by not relying on cellular service. We begin by forecasting the traffic generated at free Wi-Fi access points. In order to isolate the effect from the increased capacity derived from the 6 GHz allocation, we calculate the portion of free Wi-Fi traffic attributed to current spectrum bands. For this, we relied on the assumption (verified in field studies) that current traffic levels are already producing congestion in most free Wi-Fi hotspots at times of peak demand. Thus, we assume that traffic per hotspot beyond 2021 will remain at 2020 levels (567.94 GB per year), although overall free traffic will continue growing as new hotspots will continue to be deployed (see Table E-4).

Table E-4. United Kingdom: Total free Wi-Fi traffic projection (2021-2025)

Variable	2021	2022	2023	2024	2025
Free Wi-Fi traffic (Million GB Per year) - considering current trends	1452.82	1711.33	2036.37	2449.19	2978.96
Free Wi-Fi hotspots (Million)	2.40	2.71	2.89	3.17	3.47
Traffic per hotspot - considering current trends	604.39	631.33	705.18	773.81	858.71
Traffic per hotspot - capped due to congestion	567.94	567.94	567.94	567.94	567.94
Total traffic (not attributed to 6 GHz) (Million GB)	1,365.19	1,539.51	1,640.04	1,797.57	1,970.24

Sources: Cisco; Wiman; Telecom Advisory Services analysis

We calculate consumer surplus by multiplying the total free traffic (not attributed to 6 GHz) by the difference between what the consumer would have to pay if she/he were to rely on a wireless carrier and the cost of offering free Wi-Fi (incurred by the retailer or public site). To do so, we needed an estimate of the average price per GB of wireless data transmitted by wideband networks, which we calculated by averaging the most economic "dollar per GB" plan of four major wireless carriers in the United Kingdom[160] (see Table E-5).

Table E-5. United Kingdom: Average price per gigabyte (2020)

Carrier	Plan	Price per GB ($)
EE (BT)	4G SIM Plan - 200	$0.275
Vodafone	30-pound bundle	$2.064
O2 (Telefonica)	18 Months Sim 150	$0.211
3 (CK Hutchison)	Advanced Plan	$0.826

Note: The average price per GB is converted to U.S. dollars in order to calculate total economic value.
Sources: Operator websites; Telecom Advisory Services analysis

Historical data allowed for a projection of future prices per gigabyte. Based on these prices, we expect the average price per GB will reach an estimated $0.43 in 2025 from $0.65 in 2021. By relying on the total free Wi-Fi traffic not attributed to 6 GHz allocation shown in Table D-4 and the average price per cellular gigabyte minus the cost of provisioning Wi-Fi service, we calculated the consumer surplus of free Wi-Fi traffic (see Table E-6).

Table E-6. United Kingdom: Consumer surplus of free Wi-Fi Traffic (2021-2025)

Variable	2021	2022	2023	2024	2025
Total Free Traffic (not attributed to 6 GHz) (Million GB)	1365.19	1539.51	1640.04	1797.57	1970.24
Price per cellular gigabyte ($)	$0.65	$0.59	$0.53	$0.48	$0.43
Cost per Wi-Fi provisioning ($)	$0.10	$0.09	$0.09	$0.08	$0.08
Consumer surplus per gigabyte ($)	$0.56	$0.50	$0.44	$0.39	$0.35
Total Consumer surplus ($Million)	$758.94	$762.99	$724.16	$706.70	$689.15

Sources: Cisco; Websites of cellular operators; Telecom Advisory Services analysis

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[160] The average is calculated by prorating every price per GB by the carrier's market share.

As indicated in Table E-6, consumer surplus of free Wi-Fi traffic in 2021 would reach an estimated $759 million, decreasing to $689 million in 2025 due to lower prices and to congestion created if the 6 GHz spectrum had not been allocated.

Enhanced free Wi-Fi traffic due to 6 GHz allocation

The allocation of the 6 GHz spectrum band coupled with the technological advances provided by the Wi-Fi 6 standard will remove the above-mentioned bottlenecks causing congestion. As a result, the traffic per hotspot will be able to continue growing at its natural rate as determined by the extrapolation of past recent trends. That being said, we must take into account that not all Wi-Fi traffic will benefit immediately from opening the 6 GHz band, as most current devices are not prepared to support the new standards. Thus, as in the case of the United States, we expect the traffic through the 6 GHz channel to gradually increase until reaching a 40% of total free traffic by 2025.

Once computed the additional traffic "above and beyond" the future previsions under current spectrum bands, we will follow a similar approach to calculate the consumer surplus, by multiplying it by the difference between what the consumer would have to pay if he were to utilize a wireless carrier and the cost of offering free Wi-Fi (Table E-7). As a result, we project an additional consumer surplus of $141 million from free Wi-Fi traffic attributed to 6 GHz.

Table E-7. United Kingdom: Additional consumer surplus of free Wi-Fi traffic generated due to 6 GHz (2021-2025)

Variable	2021	2022	2023	2024	2025
Demand not satisfied due to congestion (Million GB)	87.63	171.83	396.33	651.62	1008.72
Traffic through the 6 GHz Channel (%)	0%	10%	20%	30%	40%
Total traffic (attributed to 6 GHz) (Million GB)	0.00	17.18	79.27	195.48	403.49
Consumer Surplus (attributed to 6 GHz) ($Million)	$0.00	$8.52	$35.00	$76.85	$141.13

Source: Telecom Advisory Services analysis

The additional surplus generated by the allocation of the 6 GHz spectrum band will mitigate the decreasing trend of consumer surplus derived from free Wi-Fi under the current spectrum allocation.

E.2.2. Free Wi-Fi to provide broadband to the unserved population

As explained in Chapter II, free Wi-Fi in public sites can provide Internet access to the unserved population. Consumers that do not have broadband at home because they lack the economic means to acquire services can rely on free Wi-Fi to gain Internet access. The net result is that more people can be connected, which in turn enhances the economic contribution of broadband.

The estimation of this particular economic impact starts by calculating which portion of households that lack broadband service are already accessing Internet through free hotspots. We follow a conservative approach and assume that only 5% of unconnected households rely on free hotspots for accessing Internet. After calculating the increase in broadband penetration due to households relying on free

Wi-Fi, we rely on the broadband impact coefficient calculated by Katz and Callorda (2018b) in their econometric models developed for Europe. As a result, the GDP contribution of this particular effect is expected to amount to $342 million in 2021, reaching $364 million in 2025 (see Table E-8).

Table E-8. United Kingdom: GDP contribution due to households relying on free Wi-Fi (2021-2025)

Variable	2021	2022	2023	2024	2025
Households without Internet	1,981,778	1,999,050	2,016,473	2,034,047	2,051,775
Households that don't buy because access Internet free hotspots (%)	5%	5%	5%	5%	5%
Households served by Free Wi-Fi hot spots	99,089	99,953	100,824	101,702	102,589
Increase in national broadband penetration	0.4%	0.4%	0.4%	0.4%	0.4%
Impact of fixed broadband adoption in GDP	4.63%	4.63%	4.63%	4.63%	4.63%
Increase in the GDP due to the new broadband adoption (% GDP)	0.02%	0.02%	0.02%	0.02%	0.02%
GDP ($Billion)	$1965.05	$1994.57	$2025.15	$2056.13	$2087.59
Total impact in GDP ($Million)	$342.26	$347.40	$352.72	$358.12	$363.60

Sources: UK Census; IMF; Telecom Advisory Services analysis

Enhanced GDP contribution due to 6 GHz allocation

As stated above, Wi-Fi 6 technology operating in the 6 GHz band supports a higher number of devices per access point than Wi-Fi sites relying on the 2.4 GHz and 5 GHz bands. Accordingly, the improved throughput of free Wi-Fi hotspots under the 6 GHz allocation will allow the possibility of serving additional unconnected households. The potential universe of additional users that could be served under this effect is significant, as most unconnected households usually identify that costs are their main barrier for accessing connectivity and thus, may potentially be served by free hotspots as long as they are in proximity to the access point. However, evidence suggests that not many people with an affordability barrier rely exclusively on free Wi-Fi as their main source of Internet access[161], so we will follow again a conservative approach and assume that a further 5% of unconnected households will be served through free hotspots under the allocation of the 6 GHz band. On the other hand, we have also considered that the expansion of traffic through the new band will take place gradually, reaching 40% in 2025. All in all, we estimate that additional 38,853 households in the United Kingdom will be served by free hotspots operating under 6 GHz spectrum in 2025, yielding an additional GDP contribution of approximately $138 million (Table E-9).

[161] They tend to use also broadband service provided at work or at an educational institution.

Table E-9. United Kingdom: GDP contribution due to households relying on free Wi-Fi due to 6 GHz (2021-2025)

Variable	2021	2022	2023	2024	2025
Households without Internet (not served by free Wi-Fi and not new adopters of WISP)	1,882,689	1,896,704	1,911,813	1,927,072	1,942,645
Potential households that could be served through free Wi-Fi hotspots under increased capacity (% of those not connected)	5%	5%	5%	5%	5%
Traffic through the 6 GHz Channel (%)	0%	10%	20%	30%	40%
Additional households served by Free Wi-Fi hot spots with 6 GHz	0	9,484	19,118	28,906	38,853
Increase in national broadband penetration	0	0.036%	0.07%	0.11%	0.14%
Increase in the GDP due to the new broadband adoption (% GDP)	0.000%	0.002%	0.003%	0.005%	0.007%
Total impact in GDP ($Million)	$0.00	$32.96	$66.88	$101.79	$137.70

Sources: UK Census; IMF; Telecom Advisory Services analysis

E.2.3. Benefit to consumers for enjoying higher speed from free Wi-Fi if 6 GHz band is allocated

When the 6 GHz band is adopted by free Wi-Fi access points it will deliver service at faster broadband speeds. Current speeds from free hotspots are quite modest[162]. Thus, the expanded capabilities due to the allocation of 6 GHz spectrum band will enhance free Wi-Fi speed, and as a result, will increase consumer surplus. We assume that under the 6 GHz allocation, speed from free hotspots will be similar to the Wi-Fi speeds from mobile devices reported by Cisco. After calculating the average speed by considering the expected share of traffic through 6 GHz, we follow Nevo et al. (2016) and calculate the additional consumer surplus per household relying on free Wi-Fi. We expect the consumer surplus resulting from faster speed in free Wi-Fi sites to reach $38 million in 2025 (Table E-10).

Table E-10. United Kingdom: Consumer surplus for enjoying higher speed from free Wi-Fi if 6 GHz band allocated (2021-2025)

Variable	2021	2022	2023	2024	2025
Free Wi-Fi mean speed with no 6 GHz (Mbps)	13.74	14.19	14.66	15.14	15.63
Wi-Fi Speeds from Mobile Device (Mbps)	50.36	58.52	68.00	79.02	91.81
Traffic through the 6 GHz Channel (%)	0.00%	10.00%	20.00%	30.00%	40.00%
Free Wi-Fi mean speed with 6 GHz (Mbps)	13.745	18.627	25.327	34.302	46.107
Demand for average download speed	80.61	79.50	78.41	77.32	76.24
New Demand for average download speed	80.61	85.50	90.20	94.56	98.53
Additional Monthly Consumer surplus	$0.00	$6.00	$11.79	$17.24	$22.29
Additional Yearly Consumer Surplus	$0.00	$71.96	$141.53	$206.93	$267.44
Households that rely on Free Wi-Fi	99,089	109,436	119,942	130,608	141,442
Consumer surplus ($Million)	$0	$8	$17	$27	$38

Sources: Rotten Wi-Fi; Nevo et al. (2016); Telecom Advisory Services analysis

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[162] By extrapolating data from the site Rotten Wi-Fi, download speed at free sites in the United Kingdom es projected to reach 13.3 Mbps in 2020.

E.3. Residential Wi-Fi

E.3.1. Home Internet access for devices that lack an Ethernet port

The underlying premise of this analysis is that in the absence of Wi-Fi, users of devices lacking an Ethernet port would have to depend on the cellular network to gain Internet access. For this reason, estimating value would first measure the traffic generated by these devices at home and then multiply it by the average price charged by cellular carriers.

To estimate the traffic of smartphones and tablets, we relied on 2018 Cisco estimates for the period 2016-21 and extrapolated those growth rates to 2025. It must be said, however, that in 2019 Cisco adjusted its predictions upwards. However, we preferred to rely on the original estimates to avoid incurring in the risk of overestimation. Thus, it may be possible that our previsions reported here are slightly downward biased. In addition, we have to consider that according to Cisco IBSG (2012), 43.12% of use time of devices that lack an Ethernet port occurs at home. Therefore, the portion of said traffic generated at home in the United Kingdom will reach 11,791 million gigabytes in 2021 (see Table E-11).

Table E-11. United Kingdom: Total mobile Internet traffic (2021-2025) (Million gigabytes)

Variable	2021	2022	2023	2024	2025
Total Annual traffic - Smartphones	13,201.6	18,286.4	25,268.0	34,876.1	48,148.9
Total Annual traffic - Tablets	14,144.9	17,735.8	22,238.3	27,883.8	34,962.6
Share of traffic at Home	43.12%	43.12%	43.12%	43.12%	43.12%
Total Traffic at Home - Smartphones	5,692.2	7,884.7	10,895.0	15,037.8	20,760.7
Total Traffic at Home - Tablets	6,098.9	7,647.3	9,588.6	12,022.9	15,075.1
Total Traffic at Home	11,791.1	15,531.9	20,483.6	27,060.7	35,835,8
Average Price per GB ($)	$0.65	$0.59	$0.53	$0.48	$0.43
Price per home traffic ($Million)	$7,715.34	$9,150.02	$10,864.32	$12,922.11	$15,406.73

Sources: Cisco; GSMA; Telecom Advisory Services analysis

If this traffic had to be transported by cellular networks, at the average price per GB estimated above (Table E-6), it would result in costs of $7.7 billion in 2021 reaching $15.4 billion in 2025.

E.3.2. Avoidance of inside wiring investment

Residential Wi-Fi allows consumers to avoid paying for wiring to connect all home devices (printers, laptops, storage units, etc.). Considering that 91% of connected households will have Wi-Fi in 2021[163], and the wiring cost estimated for households[164], the avoidance costs of inside wiring over 23.9 million households

[163] Extrapolation based on data from Watkins (2012).
[164] The national average for wiring a 2-bedroom residence in the United Kingdom with CAT 6 and dual sockets per room amounts to $980.

yields a total of $23.4 billion. By 2025, almost all connected households are expected to have adopted Wi-Fi. Therefore, the savings from inside wiring avoidance would have reached $26.4 billion (Table E-12).

Table E-12. United Kingdom: Consumer surplus from avoidance of investment in in-house wiring (2021-2025)

Variable	2021	2022	2023	2024	2025
Total Wiring Cost	$980	$980	$980	$980	$980
Households with Internet	26,329,335	26,558,808	26,790,281	27,023,771	27,259,297
Households with Wi-Fi (%)	91%	93%	95%	97%	99%
Households with Internet and Wi-Fi	23,959,695	24,699,691	25,450,767	26,172,638	26,914,983
Inside Wiring Costs ($Million)	$23,481	$24,206	$24,942	$25,649	$26,377

Sources: UK Census; Watkins (2012); Telecom Advisory Services analysis

E.3.3. Benefits derived from speed increase

As described before, consumer surplus increases if users enjoy faster Internet speeds through Wi-Fi than from cellular networks. However, as estimated by the Cisco Annual Internet Report Highlights Tool 2018-2023, smartphone speeds in the United Kingdom are expected to reach that of Wi-Fi in 2021. Thus, only a small share of UK households will benefit of faster speeds from Wi-Fi: the share of the population possessing older mobile devices that access the Internet at slower speeds. By weighting the percentage of affected users by the benefits of relying in Wi-Fi rather than from cellular speeds and applying the willingness-to-pay parameters defined in Nevo et al. (2016), the expected consumer surplus will yield $27 million in 2021, being reduced to $2 million in 2025 as the non-smartphone mobile connections will become negligible.

Table E-13. United Kingdom: Consumer surplus from faster speed in households (2021-2025)

Variable	2021	2022	2023	2024	2025
Demand for average download speed	108.84	110.25	111.54	112.72	113.79
New Demand for average download speed	112.77	113.85	114.82	115.69	116.46
Additional Monthly Consumer surplus	$3.92	$3.60	$3.28	$2.97	$2.67
Additional Yearly Consumer Surplus	$47.09	$43.17	$39.36	$35.66	$32.06
Affected Households	568,119	319,092	178,674	99,689	55,525
Impact ($Million)	$27	$14	$7	$4	$2

Sources: Cisco; Nevo et al. (2016); Telecom Advisory Services analysis

The reduction in the consumer surplus derived from faster speeds in the 2.4 and 5 GHz bands is compensated by the value derived from the 6 GHz band, which is expected to grow even further beyond 2025.

Additional benefit to consumers from speed increase due to 6 GHz

The well-being of residential Wi-Fi customers is expected to receive further benefit from the 6 GHz allocation due to faster Internet service under Wi-Fi 6E. As previously described in section B, only households acquiring a 150 Mbps (or faster) fixed broadband line will receive the benefit since they are undergoing current router bottlenecks. To assess the percentage of households with connections above 150 Mbps, we interpolated from OECD estimates for the United Kingdom by speed tiers. After calculating the difference in average speed attributed to 6 GHz, the additional consumer surplus will yield $656 million in 2025 (see Table E-14).

Table E-14. United Kingdom: Consumer surplus from faster speed in households if 6 GHz allocated (2021-2025)

Variable	2021	2022	2023	2024	2025
Households that have connections over 150 Mbps (%)	7.48%	8.56%	9.80%	11.22%	12.84%
Percentage of household traffic that goes through Wi-Fi	53.95%	54.69%	55.42%	56.16%	56.89%
Traffic through the 6 GHz Channel (%)	0.00%	10.00%	20.00%	30.00%	40.00%
Share of traffic affected due to 6 GHz (%)	0.00%	0.47%	1.09%	1.89%	2.92%
Average speed with no 6 GHz (Mbps)	57.12	67.32	79.32	93.44	110.05
Average speed with 6 GHz (Mbps)	57.12	68.88	83.35	101.13	121.45
Demand for average download speed	112.77	113.85	114.82	115.69	116.46
New Demand for average download speed	112.77	114.36	115.89	117.36	118.49
Additional Yearly Consumer Surplus	$0.00	$6.06	$12.82	$20.00	$24.37
Households with Wi-Fi	23,959,695	24,699,691	25,450,767	26,172,638	26,914,983
Impact ($Million)	$0	$150	$326	$523	$656

Sources: OECD; Cisco; UK Census; Nevo et al. (2016); Telecom Advisory Services analysis

E.3.4. Residential Wi-Fi devices and equipment

The consumer surplus derived from the adoption of residential Wi-Fi devices and equipment focuses on seven consumers products which are intrinsically linked to Wi-Fi: smart home devices and systems such as Wi-Fi speakers and home security systems, home networking systems, Wi-Fi tablets, access points, external adapters, routers, and gateways. Two different approaches are used in these cases: one assuming that consumer surplus is roughly equal to producer surplus in six of the seven products (excluding tablets), and an assessment of tablets' willingness-to-pay.

The estimation of economic value in the first approach begins by compiling local sales in the six product categories in the United Kingdom[165]. After computing the sales in the United Kingdom, we applied the prorated margin estimated by CSI markets (39.44%) which yields an estimated producer surplus for these particular products of $3.9 billion in 2021. As mentioned above, it is assumed that the consumer surplus is of the same magnitude. This methodology was also used to calculate the consumer surplus up to 2023. However, the gradual adoption of Wi-Fi 6 devices is forecast to reduce the sales and economic value from the devices relying on the 2.4 GHz and 5 GHz spectrum bands. Non 6 GHz consumer devices shipments are expected by IDC to decrease by 1.2% in 2024 and 3.1% in 2025. Based on this

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[165] Calculated by prorating data for the United States based on GDP.

estimate, we extrapolated the consumer surplus from non 6 GHz reliant residential Wi-Fi devices and equipment between 2021 and 2025.

In addition, we calculated the consumer surplus attributable to tablets bought by local consumers. Starting with CTA/Statista worldwide tablet revenue estimates, we interpolated the revenue figures for the United Kingdom (prorating the worldwide value by the country's share of global GDP), and extrapolated the evolution of local revenue until 2025 considering Cisco estimates of tablet evolution for the period. We reviewed the data on tablet prices for the market leader (taking as a reference the Apple iPad 10.2 Inch 128 GB, as Apple has 62.2% of the British market share in tablets[166]) and for the rest of the market (taking as a reference a Samsung Wi-Fi tablet 128GB), and assumed consumer willingness-to-pay levels in a similar percentage above prices as in the United States average. On the basis of that information, we were able to estimate a consumer surplus attributed to tablets of $133 million in 2021, expected to reach $69 million in 2025.

In sum, overall consumer surplus for Wi-Fi enabled residential products is expected to amount to $4.0 billion in 2021 and remain stable until 2025 (Table E-15).

Table E-15. United Kingdom: Economic value of Wi-Fi enabled consumer products (2021-2025)

Variable	2021	2022	2023	2024	2025
Consumer surplus (exc. Tablets) ($Million)	$3,861	$3,997	$4,105	$4,055	$3,929
Tablet consumer surplus ($Million)	$133	$111	$94	$80	$69
Total consumer surplus ($Million)	$3,994	$4,087	$4,199	$4,135	$3,997

Sources: Consumer Technology Association; ABI Research; CS Markets; IDC; Telecom Advisory Services analysis

Consumer surplus derived from Wi-Fi enabled residential equipment for 6 GHz

As discussed above, sales of residential Wi-Fi devices and equipment operating in the 6 GHz band are expected to gradually replace those of former generations. According to IDC, global shipments of consumer devices operating in 6 GHz (802.11ax standard) will represent 40% of sales from prior generations. As a result, if the shipments ratio reaches 40% in 2025, we can expect that, at least, the consumer surplus derived from 6 GHz devices will represent 40% of that of former technology residential devices. As a result, our estimates for consumer surplus attributed to 6 GHz residential devices amount to $1.6 billion in 2025 (see Table E-16).

Table E-16. United Kingdom: Economic value of Wi-Fi enabled consumer products for 6 GHz (2021-2025)

Variable	2021	2022	2023	2024	2025
Consumer surplus (ex. Tablets) ($Million)	$3,994	$4,087	$4,199	$4,135	$3,997
Consumer 6 GHz / no 6 GHz device ratio	3.76%	8.83%	18.59%	28.86%	40.30%
Consumer surplus 6 GHz devices ($Million)	$145	$351	$763	$1,170	$1,583

Sources: IDC; Telecom Advisory Services analysis

[166] Source: Gs StatCounter

E.3.5. Bridging the digital divide: use of Wi-Fi to increase coverage in rural and isolated areas

Wi-Fi is an appropriate technology to offer Internet access in rural and isolated areas. The incremental number of lines supported by WISPs represents an increase in penetration, which in turn contributes to the UK GDP.

According to the UK association WISPA, there are approximately 120 WISPs operating in the country, with a coverage of 2.15 million premises and around 100,000 connections[167]. In order to estimate Wi-Fi's contribution, we assume that 90% of WISP potential connections may be theoretically served by other technologies (i.e. satellite) covering the same isolated footprint. Thus, we can conservatively expect 10% of broadband subscriptions in remote locations exclusively attributed to WISPs. With this value, we calculate the impact on GDP by relying on the coefficient estimated by Katz and Callorda (2018b) through regression models that links increase in broadband penetration to economic growth. The contribution to GDP materializes through multiple effects: creation of new businesses, increasing productivity of existing enterprises, and growth of average income per household. However, the calculation of Wi-Fi contribution to GDP must subtract the direct impact of WISPs sales (estimated in Section E.5.3.) to avoid double counting. As a result, by reducing the digital divide and increasing broadband penetration, we estimate a GDP contribution of $27 million in 2021, which will decrease until reaching $24 million in 2025 (see Table E-17).

Table E-17. United Kingdom: Estimation of GDP contribution derived from reducing the digital divide (2021-2025)

Variable	2021	2022	2023	2024	2025
WISP subscribers	100,000	100,000	100,000	100,000	100,000
Additional broadband penetration due to WISP	0.35%	0.34%	0.34%	0.33%	0.32%
Impact of fixed broadband adoption in GDP	4.63%	4.63%	4.63%	4.63%	4.63%
GDP ($Billion)	$1,965	$1,995	$2,025	$2,056	$2,088
WISP TOTAL impact ($Billion)	$0.320	$0.318	$0.316	$0.314	$0.312
WISP Revenues ($Billion)	$0.05	$0.06	$0.06	$0.06	$0.07
Share that exist because WISP	10.00%	10.00%	10.00%	10.00%	10.00%
WISP spillovers on GDP ($Million)	$26.70	$25.82	$25.39	$24.94	$24.42

Note: Given the lack of data on future subscriber evolution, it was conservatively assumed a constant value.
Sources: UKWISPA; IMF; Telecom Advisory Services analysis

Economic impact of enhanced coverage and affordability due to 6 GHz

The allocation of the 6 GHz band to unlicensed use would allow WISPs to potentially increase their subscriber base within their same coverage footprint. Therefore, a first effect derived from the allocation of the new spectrum band is related to additional households served due to additional coverage. We will follow a cautious approach and consider that the expanded coverage will yield a gradual increase on

[167] Data retrieved from WISPA site. It should be noted that this estimate is not consistent with that reported by Ofcom (subscriptions by "other" technology) of 30,000 fixed wireless subscriptions.

WISP subscribers, from 2% in 2022 to 5% in 2025 over the figures projected above. In addition, an increase of the user base would allow service providers to lower their operating costs. Thus, by assuming stability in prices, affordability would increase as GDP per capita grows as economic growth resumes. All in all, we can expect an overall increase in almost 6,500 WISP connections in 2025, contributing to an increase 0.02% in national broadband penetration. Considering the impact coefficient of broadband on the economy that will yield $14.3 million in GDP contribution.

Table E-18. United Kingdom: GDP contribution derived from reducing the digital divide due to 6 GHz (2021-2025)

Variable	2021	2022	2023	2024	2025
New subscribers due to expanded coverage (%)	0%	2%	3%	4%	5%
New subscribers due to expanded coverage	0	2,000	3,000	4,000	5,000
New WISP adoption after price decrease (% households)	0.43%	0.36%	0.36%	0.36%	0.35%
Traffic through the 6 GHz Channel (%)	0.00%	10.00%	20.00%	30.00%	40.00%
Increase in WISP connections due to lower prices (households that buy the service)	0	393	836	1,273	1,542
Overall increase in WISP connections due to 6 GHz	0	2,393	3,836	5,273	6,542
Increase in national broadband penetration	0.00%	0.01%	0.01%	0.02%	0.02%
Impact of fixed broadband adoption in GDP	4.63%	4.63%	4.63%	4.63%	4.63%
Increase in the GDP due to the new broadband adoption (% GDP)	0.000%	0.000%	0.001%	0.001%	0.001%
Total impact in GDP ($Million)	$0.000	$5.329	$8.484	$11.582	$14.273

Sources: UKWISPA; IMF; Telecom Advisory Services analysis

E.4. Enterprise Wi-Fi

Beyond the impact on consumers, Wi-Fi also contributes significant economic value in the British enterprise segment. This section provides estimates in five areas:

- Support of business Internet traffic;
- Avoidance of campus and enterprise facilities inside wiring;
- Contribution to GDP resulting from Wi-Fi speed faster than cellular connections;
- Deployment of IoT solutions; and
- Implementation of business focused AR/VR use cases.

E.4.1. Business Internet traffic transmitted through Wi-Fi

Wi-Fi enterprise savings results from wireless traffic that is routed through Wi-Fi access points. Based on Cisco 2016-21 projections for the United Kingdom, we estimate that total business Internet traffic will reach 19.3 billion GB in 2021, of which 9.3 billion GB would have been transported through Wi-Fi access points. Considering the average price per GB transported by cellular (from Table E-5), savings from Wi-Fi will reach $6.1 billion, an addition to the producer surplus[168]. By 2025, this benefit will reach $8.3 billion (see Table E-19).

Table E-19. United Kingdom: Savings in business wireless traffic (2021-2025)

Variable	2021	2022	2023	2024	2025
Share of Business Internet Traffic by Wi Fi	48.00%	47.80%	47.61%	47.41%	47.21%
Total Business Internet Traffic (Million GB)	19,327.4	23,301.7	28,093.2	33,870.1	40,834.9
Total Wi-Fi enterprise traffic (million GB)	9,277.1	11,138.8	13,373.9	16,057.8	19,280.1
Average Price per GB	$0.65	$0.59	$0.53	$0.48	$0.43
Economic Impact ($Million)	$6,070.31	$6,561.96	$7,093.44	$7,667.95	$8,289.01

Sources: Cisco; Telecom Advisory Services analysis

Enhanced business Internet traffic transmitted through Wi-Fi due to 6 GHz

The deployment of the latest enterprise applications will generate an exponential growth in data traffic that will be handled by devices operating in unlicensed spectrum, through the combination of the existing bands and the 6 GHz band. In 2019, an updated Cisco traffic forecast based on the explosion of IoT and AR/VR applications, among other factors, increased total business Internet traffic projections from the prior 2016-21 estimates from 2018. As in the case of the United States, we assume that part of the growth was driven by "natural" growth, while the remainder was triggered by Wi-Fi traffic stimulated by shifting traffic to the 6 GHz band. The sum of the difference due to broader Wi-Fi traffic will reach $236 million in 2025 (see Table E-20).

Table E-20. United Kingdom: Savings in business wireless traffic due to 6 GHz (2021-2025) ($Million)

Variable	2021	2022	2023	2024	2025
Total value of business Wi-Fi traffic 2016/21	$6,070.31	$6,561.96	$7,093.44	$7,667.95	$8,289.01
Total value of business Wi-Fi traffic 2017/22	$7,403.93	$8,129.56	$8,926.31	$9,801.14	$10,761.72
Difference between the 2 estimations	$1,333.62	$1,567.60	$1,832.87	$2,133.19	$2,472.71
Difference because natural growth	$1,249.38	$1,398.61	$1,635.28	$1,903.23	$2,206.15
Difference due to 6 GHz	$0.00	$168.99	$197.59	$229.96	$236.27

Sources: Cisco; Telecom Advisory Services analysis

E.4.2. Avoidance in enterprise building inside wiring

Similar to residential Wi-Fi savings due to capital investment avoidance in inside wiring, we assume that the total number of business establishments are equipped with Wi-Fi access points and multiply this value by a standard cost of deploying a

[168] We acknowledge that enterprises are likely to negotiate wireless rates lower than those offered in the consumer market; however, data in this area is not available.

CAT 6 network (although in this case, the cost is $3,072 per building) (see Table E-21).

Table E-21. United Kingdom: Savings in business wiring CAPEX (2021-2025)

Variable	2021	2022	2023	2024	2025
Total Wiring Cost	$3,072	$3,072	$3,072	$3,072	$3,072
Number of Establishments	3,209,191	3,360,212	3,518,340	3,683,908	3,857,269
Establishments with Wi-Fi (%)	100%	100%	100%	100%	100%
Establishments with Wi-Fi	3,209,191	3,360,212	3,518,340	3,683,908	3,857,269
Inside Wiring Costs ($Million)	$9,859	$10,323	$10,808	$11,317	$11,850

Note: A comparison between the 2018 and the current study indicated a relatively constant wiring cost; therefore, it was assumed this value to remain constant in the future.
Sources: UK Census; Telecom Advisory Services analysis

E.4.3. Return to speed: contribution to GDP derived from an increase in average mobile speed

As described before, United Kingdom smartphone average speeds are expected to reach that of Wi-Fi from mobile devices in 2021. Thus, only a small share of UK subscribers will benefit of faster speeds from Wi-Fi: only those possessing older mobile devices. By weighting the percentage of impacted connections by the benefits of relying in Wi-Fi rather than in mobile speeds, and applying the coefficient linking the impact of speed in GDP, the expected contribution will yield $172 million in 2021, declining to $11 million in 2025 (see Table E-22).

Table E-22. United Kingdom: Estimation of speed differential for total traffic (2021-2025)

Variable	2021	2022	2023	2024	2025
Speed increase for affected premises (%)	1.197%	0.598%	0.297%	0.146%	0.071%
Impact of speed in GDP	0.73%	0.73%	0.73%	0.73%	0.73%
Increase in GDP	0.01%	0.00%	0.00%	0.00%	0.00%
GDP ($Billion)	$1,965.05	$1,994.57	$2,025.15	$2,056.13	$2,087.59
GDP increase ($Million)	$172	$87	$44	$22	$11

Sources: Cisco; IMF; Telecom Advisory Services analysis

Additional return to speed effect due to 6 GHz

As previously described, only those broadband connections above 150 Mbps will be affected due to current router bottlenecks, and hence, the speed experienced will not be equivalent to that delivered by the fixed network. Thus, the allocation of spectrum in the 6 GHz band will remove those barriers, increasing broadband speed. After calculating the difference in average speed attributed to 6 GHz, the additional GDP contribution will yield $1.6 billion in 2025 (Table E-23).

Table E-23. United Kingdom: Estimation of speed differential due to 6 GHz (2021-2025)

Variable	2021	2022	2023	2024	2025
Mean speed with no 6 GHz (Mbps)	57.12	67.32	79.32	93.44	110.05
Mean speed with 6 GHz (Mbps)	57.12	68.88	83.35	101.13	121.45
Speed increase due to 6Ghz (%)	0%	2%	5%	8%	10%
Impact speed on GDP	0.73%	0.73%	0.73%	0.73%	0.73%
Increase in GDP (%)	0.00%	0.02%	0.04%	0.06%	0.08%
GDP increase ($Million)	$0	$337	$751	$1,235	$1,578

Sources: Cisco; IMF; Telecom Advisory Services analysis

E.4.4. IoT Deployment

IoT adoption has a contribution to GDP growth through the multiplicity of use cases that improve efficiency in processes such as preventive maintenance, production monitoring and the like. To estimate this, we rely on a coefficient of GDP impact calculated through an aggregate simple production function which estimates that a 10% rise in M2M connections results in annual increases in GDP of between 0.3% and 0.9%[169]. Given the strength of the industrial and technological sector in the United Kingdom, we assume a 0.9% GDP increase after a 10% increase in the M2M installed base.

Starting with a 2021 installed base of 20.3 million M2M devices in the United Kingdom, we estimate the growth between 2020 and 2021 that can be exclusively attributed to the allocation of additional spectrum to indoor Wi-Fi devices. By subtracting the growth in M2M attributed to 6 GHz, the IoT impact for 2021 according to the natural growth is forecast to reach $23.7 billion (see Table E-24).

Table E-24. United Kingdom: GDP contribution of IoT deployment boost (2021-2025)

Variable	2021	2022	2023	2024	2025
Connections, Cellular M2M	20,366,223	22,280,838	23,059,179	23,864,710	24,698,381
Growth Rate (%)	14.69%	9.40%	3.49%	3.49%	3.49%
Natural Growth Rate (%)	13.37%	8.32%	3.01%	3.01%	3.01%
Impact of 1% M2M Growth on GDP	9.00%	9.00%	9.00%	9.00%	9.00%
Impact on GDP (%)	1.20%	0.75%	0.27%	0.27%	0.27%
GDP ($Billion)	$1,965	$1,995	$2,025	$2,056	$2,088
Impact ($Million)	$23,652.23	$14,931.90	$5,491.35	$5,575.37	$5,660.67

Sources: GSMA Intelligence; Frontier Economics; IMF; Telecom Advisory Services analysis

It should be noted that the GDP impact of IoT declines due to a decreasing growth rate of M2M installed base. The same effect will be apparent in the case of traffic shifting to the 6 GHz band.

[169] See Frontier Economics (2018).

Accelerated effect of IoT due to 6 GHz

As described above, a share of the M2M growth can be attributed to IoT traffic shifting to the 6 GHz spectrum. According to the data in Table E-25, cumulative impact of enhanced IoT deployment driven by 6 GHz spectrum proposals will reach$451 million by 2025.

Table E-25. United Kingdom: GDP contribution of IoT deployment boost caused by 6 GHz (2021-2025)

Variable	2021	2022	2023	2024	2025
Growth due to 6 GHz (%)	1.31%	1.08%	0.48%	0.48%	0.48%
Level of development of new bands (%)	50%	100%	100%	100%	100%
Impact on GDP (%)	0.03%	0.05%	0.02%	0.02%	0.02%
Impact ($Million)	$580.37	$971.92	$437.84	$444.54	$451.34

Sources: GSMA Intelligence; Frontier Economics; IMF; Telecom Advisory Services analysis

E.4.5. Deployment of AR/VR solutions

The adoption of AR/VR among UK business will have a spillover effect on productivity, thereby contributing to the growth of GDP. Estimating spillover effects of AR/VR is not a trivial exercise considering the embryonic adoption of some of the use cases based on this technology. Since the objective is to estimate the spillover effect of AR/VR sales in the domestic UK market, we consider the estimate by PwC of the total GDP contribution of AR/VR for 2021 and 2022[170], and the sales of AR/VR components as estimated by ABI Research[171]. The extrapolation of these two parameters allow estimating the indirect (spillover) contribution of AR/VR to the United Kingdom economy for the period under analysis.

Starting values are reduced by the proportion that can be attributed to other technologies rather than Wi-Fi. After computing the resulting value, we subtracted the impact of the 6 GHz spectrum bands. To do so, we took as a reference a ratio of AR/VR product developments for each technology (built with data from ABI Research). Once the amounts to be attributed to GDP contribution and direct sales were estimated, the annual indirect to direct multiplier can be calculated. The lowest multiplier value is applied to sales of AR/VR in the UK market to calculate the total spillovers (see Table E-26). Accordingly, total spillover value of AR/VR in the United Kingdom in 2021 will account for $550 million and is expected to increase by 2025 to $2.4 billion.

[170] See PWC (2019). *Seeing is believing how virtual reality and augmented reality are transforming business and the economy.*
[171] See ABI Research, *Augmented and Mixed Reality Market Data: devices, use cases, verticals and value chain*. MD-ARMR-103, QTR 4 2019, and ABI Research, *Virtual Reality Market Data: devices, verticals, and value chain*. MD-VR-108, QTR 1 2020.

Table E-26. United Kingdom: GDP contribution resulting from AR/VR spillovers (2021-2025)

Variable	2021	2022	2023	2024	2025
AR/VR total contribution to GDP ($Billion)	$6.30	$8.80	$11.80	$15.90	$22.30
Share attributed to Wi-Fi (excluding 6 GHz)	42.02%	38.80%	32.18%	30.88%	29.32%
Portion of GDP contribution attributed to Wi-Fi (excluding 6 GHz) ($Billion)	$2.65	$3.41	$3.80	$4.91	$6.54
Direct impact (sales) attributed to Wi-Fi (excluding 6 GHz) ($Billion)	$0.55	$0.90	$1.14	$1.54	$2.38
Indirect impact ($Billion)	$2.10	$2.52	$2.66	$3.37	$4.16
Indirect/Direct multiplier	1.00	1.00	1.00	1.00	1.00
Indirect impact ($Million)	$549.84	$897.36	$1,137.24	$1,536.06	$2,379.53

Sources: PwC, ABI; Telecom Advisory Services analysis

Wider deployment of AR/VR solutions (accelerated effect due to 6 GHz)

Higher throughput enabled by the allocation of 6 GHz spectrum is expected to spur the adoption and use of AR/VR among enterprises, hence increasing the associated spillover effects. By relying on the ratio built from 5 GHz and 6 GHz AR/VR related products from above, we were able to isolate the specific economic contribution of the new spectrum allocation. Following a similar procedure as the one described above spillovers from AR/VR in the UK attributed to 6 GHz were calculated. They will account for $267 million in 2021 and are expected to reach $1.2 billion by 2025 (Table E-27).

Table E-27. United Kingdom: GDP contribution resulting from AR/VR spillovers due to 6 GHz (2021-2025)

Variable	2021	2022	2023	2024	2025
AR/VR total contribution to GDP ($Billion)	$6.30	$8.80	$11.80	$15.90	$22.30
Share attributed to 6 GHz (%)	24.58%	25.59%	26.64%	27.73%	28.87%
Portion of GDP contribution attributed to 6 GHz ($Billion)	$1.55	$2.25	$3.14	$4.41	$6.44
Direct impact (sales) attributed to 6 GHz ($Billion)	$0.32	$0.59	$0.94	$1.38	$2.34
Indirect impact ($Billion)	$1.23	$1.66	$2.20	$3.03	$4.10
Indirect/Direct multiplier	1.00	1.00	1.00	1.00	1.00
Indirect impact ($Million)	$266.70	$385.90	$561.09	$778.04	$1,240.71

Sources: PwC, ABI; Telecom Advisory Services analysis

E.5. Internet Service Providers

In addition to the economic value generated by the sources analyzed above, Wi-Fi will also contribute to either producer surplus or GDP of Internet Service Providers. This section will assess the economic value in three sources:

- Producer surplus of cellular operators resulting from CAPEX savings incurred in network deployment
- Revenues of Wi-Fi carriers offering service in public spaces
- Revenues of Wireless ISPs (this effect differs from the GDP impact of WISPs as a result of their deployment in rural and isolated areas analyzed in section E.3.5.)

E.5.1. Cellular network savings by off-loading traffic to Wi-Fi

The estimation of CAPEX savings starts by considering the GSMA Intelligence aggregate projected investment by wireless carriers in UK, which amounts to $31.6 billion between 2019 and 2025. Considering the total CAPEX required to deploy 5G in UK, and the incremental 5G coverage between 2021 and 2025 we are able to interpolate the 5G CAPEX for each year of the period considered. It is assumed that all the CAPEX invested during the period would be dedicated to 5G deployment.

Based on the simulation model developed to forecast the impact of Wi-Fi off-loading in 5G deployment, we estimate that the savings of deploying carrier-grade Wi-Fi complementing the rollout of 5G to accommodate future traffic growth would amount to 32.9% of CAPEX, while the OPEX savings are $2.82 for each dollar saved in CAPEX. This would result in a total producer surplus (adding CAPEX and OPEX savings) of $9.2 billion in 2021, descending to 4.8 billion in 2025, when 5G coverage will reach 83% (see Table E-28).

Table E-28. United Kingdom: Savings due to traffic off-loading (2021-2025)

Variable	2021	2022	2023	2024	2025
5G coverage	46%	58%	68%	76%	83%
CAPEX without saving ($Million)	$7,341.10	$6,809.46	$5,808.40	$4,677.26	$3,834.56
CAPEX reduction due to Wi-Fi off-loading ($Million)	$2,415.2	$2,240.3	$1,911.0	$1,538.8	$1,261.6
OPEX reduction due to Wi-Fi off-loading ($Million)	$6,810.9	$6,317.7	$5,388.9	$4,339.5	$3,557.6
Total Cost of Ownership ($Million)	$9,226	$8,558	$7,300	$5,878	$4,819

Sources: GSMA; Telecom Advisory Services analysis

The decline in savings over time is compensated by the increase in economic benefit under the 6 GHz spectrum allocation.

Enhanced capability for cellular off-loading if 6 GHz allocated

The complementarity between Wi-Fi and cellular networks for Wi-Fi 6E and 5G, adds further potential gains derived from the savings in capital and operating expenses required to accommodate exploding data traffic. The key objective is to estimate the savings in capital investment as a result of an increase in traffic offloading with Wi-Fi benefits from the additional spectrum allocated, particularly, due to the ability to leverage 160 MHz within single contiguous channels.

The estimation of CAPEX savings starts by considering the GSMA Intelligence aggregate investment estimates of 5G deployments. By relying on the geographic disaggregation of Oughton and Frias, we estimate that CAPEX can be split in urban, suburban and rural geographies. We conservatively assume that Wi-Fi 6 will not be critical in sustaining investment in urban areas, but that it will play a significant role beyond those geographies. Based on the cost advantage of carrier grade Wi-Fi, we assume that it will become effective for a portion of the suburban (approximately

15%) and rural network (approximately 5%) deployment. Therefore, this will yield yearly CAPEX savings of $395 million.

E.5.2. Wi-Fi carrier revenues

The value of Wi-Fi carriers includes the sum of revenues generated by paid public Wi-Fi access. In order to estimate this value, we start by calculating the number of commercial Wi-Fi hotspots in the United Kingdom. According to Cisco, in 2021 there will be 21.73 million public Wi-Fi hotspots in the country, although that figure includes home spots (such as the guest account service provided by cable operators). By subtracting the home spots from the public Wi-Fi estimates of Cisco, we estimated a total of 360,000 commercial Wi-Fi hotspots for 2021, which will increase reaching 440,000 in 2025. On the other hand, based on revenue per hotspot generated by Boingo in the United States, and adjusting the metric by PPP we estimated the value for the United Kingdom. Accordingly, this amounts to $184 million in 2021, gradually increasing to reach $208 million in 2025 (Table E-29).

Table E-29. United Kingdom: Revenues of Wi-Fi carriers (2021-2025)

Variable	2021	2022	2023	2024	2025
Public Wi-Fi hotspots (Million)	21.73	24.50	26.10	28.61	31.35
Home spots (Million)	21.37	23.43	25.70	28.18	30.91
Commercial Wi-Fi hotspots (Million)	0.36	1.07	0.40	0.42	0.44
Revenue per hotspot ($)	$513.41	$501.84	$490.54	$479.49	$468.69
Revenue ($Million)	$183.70	$534.88	$196.22	$202.37	$208.40

Sources: Cisco, Boingo, Telecom Advisory Services analysis

Increased revenues of Wi-Fi carriers in public places due to 6 GHz

The allocation of the 6 GHz spectrum band offers an opportunity for commercial Wi-Fi carriers to enhance their business. As Wi-Fi 6E developments will allow up to 1,500 connected devices per access point, Wi-Fi carriers will have the possibility of adding more clients without quality limitations due to congestion. By considering a conservative potential increase of 40% in the number of connected devices in public venues and weighting that figure by the gradual expansion of the latest technology, we expect commercial Wi-Fi carriers to increase their user base by 16% in 2025. If the revenue per hotspot increases in the same amount, that will yield an increase in overall revenues for the sector of an additional $33 million by 2025 (Table E-30).

Table E-30. United Kingdom: Revenues of Wi-Fi carriers due to 6 GHz (2021-2025)

Variable	2021	2022	2023	2024	2025
Potential increase in connected devices in public venues	40.00%	40.00%	40.00%	40.00%	40.00%
Traffic through the 6 GHz Channel (%)	0%	10%	20%	30%	40%
Increase in connected devices due to 6 GHz	0%	4%	8%	12%	16%
Revenue per hotspot if 6 GHz allocated ($)	$513.41	$521.92	$529.78	$537.03	$543.68
Revenue if 6 GHz allocated ($Million)	$0.00	$21.40	$15.70	$24.28	$33.34

Note: Given the lack of future growth rate in the number of devices connected in public venues, this estimate is driven by a conservative constant estimate of 40%.
Sources: Boingo, Telecom Advisory Services analysis

E.5.3. Wireless ISPs revenues

The 2021 GDP contribution related to the WISP industry was calculated as a function of the number of subscribers (100,000) and the ARPU (from U.S., adjusted by PPP), yielding a total of $53 million (Table E-31).

Table E-31. United Kingdom: WISP revenues (2021-2025)

Variable	2021	2022	2023	2024	2025
Subscribers (Million)	0.1	0.1	0.1	0.1	0.1
Revenues ($Million)	$53.27	$59.84	$62.01	$64.45	$67.54

Sources: UK WISPA; Telecom Advisory Services analysis

Increased revenues of WISPs due to 6 GHz

As described in section E.2.5, the allocation of 6 GHz spectrum will potentially increase the WISP user base by 4,579 subscribers in 2025, due to expanded coverage and better affordability. Thus, by assuming the same ARPU values as described above, the new subscriptions will amount to an additional $3 million in revenues in 2025 (Table E-32).

Table E-32. United Kingdom: WISP revenues due to 6 GHz (2021-2025)

Variable	2021	2022	2023	2024	2025
WISP annual ARPU ($)	$532.67	$598.38	$620.14	$644.46	$675.43
New subscribers if 6 GHz allocated (Million)	0	0.002	0.003	0.004	0.005
New revenue ($Million)	$0.00	$1.00	$1.67	$2.38	$3.09

Sources: UK WISPA; Telecom Advisory Services analysis

E.6. Wi-Fi ecosystem

The economic value generated by Wi-Fi within Wi-Fi ecosystem companies is calculated based on the following three sources:

- The producer surplus (i.e. margins) of residential Wi-Fi devices and equipment manufactured in the United Kingdom;
- The producer surplus of local firms providing products and services in the IoT ecosystem (hardware, software, and systems integration) in the United Kingdom; and
- The producer surplus of local firms providing products and services in the AR/VR ecosystem (hardware, software and content) in the United Kingdom.

E.6.1 Locally manufactured residential Wi-Fi devices and equipment

In section E.3.4 we calculated the producer surplus attributed to residential Wi-Fi devices and equipment, relying on Milgrom et al. (2011) assumption that consumer surplus could be approximated by that of the producers. As a result, we estimate a total economic value of $4.7 billion in 2021, which we expect to slightly increase to $5.2 billion in 2025 (Table E-33).

Table E-33. United Kingdom: Producer surplus from locally manufactured residential Wi-Fi devices and equipment (2021-2025)

Variable	2021	2022	2023	2024	2025
Total producer surplus ($Million)	$4,684.05	$5,037.82	$5,417.02	$5,349.81	$5,183.86

Sources: Consumer Technology Association; ABI Research; CS Markets; Telecom Advisory Services analysis

Locally manufactured Wi-Fi 6 devices and equipment for residential use

As mentioned above, devices for 6 GHz are expected to gradually replace those of prior generations. According to IDC, global shipments of consumer devices linked to 6 GHz spectrum (802.11ax) will represent 40% of the shipments of those from previous generations in 2025. Therefore, we expect the producer surplus attributed to 6 GHz devices to yield $2.1 billion in economic value by 2025 (see Table E-34).

Table E-34. United Kingdom: Producer surplus from locally manufactured residential Wi-Fi 6 devices and equipment (2021-2025)

Variable	2021	2022	2023	2024	2025
Consumer 6 GHz / no 6 GHz	3.76%	8.83%	18.59%	28.86%	40.30%
Producer surplus 6 GHz devices ($Million)	$176.35	$445.02	$1,006.78	$1,543.77	$2,088.89

Sources: IDC; Telecom Advisory Services analysis

E.6.2. Firms belonging to the IoT ecosystem

According to estimates from Statista and Bain & Co, we expect total industrial IoT revenue in the United Kingdom to amount $10 million in 2021. By relying on the percentage of hardware connectivity spending in IoT in Europe, we were able to split that figure into the two main segments: (i) hardware; and (ii) software, contents, and services. By weighting those amounts by the share of local production (26% for hardware, 90% for software and services) and the margins (39.44% and 77.46%, respectively), we can estimate the overall producer surplus. However, the share attributed to 6 GHz should be subtracted from the total economic value. To do so, we estimated a natural growth rate, by subtracting the corresponding share attributed to 6 GHz spectrum according to the growth rates indicated in E.6.1. Thus, we estimate a producer surplus not attributed to 6 GHz of $5.9 billion in 2021, expecting to reach $11.2 billion in 2025 (Table E-35).

Table E-35. United Kingdom: IoT ecosystem direct contribution (2021-2025)

Variable	2021	2022	2023	2024	2025
IoT revenue - Hardware ($billions)	$1.98	$2.46	$2.95	$3.48	$4.12
IoT revenue - Software, Contents, Services ($billions)	$8.45	$10.49	$12.59	$14.86	$17.58
Total Industrial IoT revenue in ($Billion)	$10.44	$12.95	$15.54	$18.34	$21.71
Local production (%) - Hardware	26%	26%	26%	26%	26%
Local production (%) - Software & Services	90%	90%	90%	90%	90%
Margins (%) - Hardware	39%	39%	39%	39%	39%
Margins (%) - Software & Services	77%	77%	77%	77%	77%
Margins - IoT Hardware revenue	$0.20	$0.25	$0.30	$0.36	$0.42
Margins - Software, contents and services IoT revenue	$5.89	$7.32	$8.78	$10.36	$12.26
Producer surplus ($Million)	$6,097.43	$7,568.55	$9,080.64	$10,715.38	$12,682.36
Growth rate (%)	27.60%	24.13%	19.98%	18.00%	18.36%
Growth rate not attributed to 6 GHz (%)	25.13%	21.35%	17.23%	15.53%	15.83%
Producer surplus not attributed to 6 GHz ($Million)	$5,875.96	$7,130.35	$8,358.97	$9,656.83	$11,185.69

Sources: Statista, Bain & Co, CSI, Telecom Advisory Services analysis

Wider deployment of Internet of Things under 6 GHz

Following the previous analysis, we were able to estimate which portion of IoT producer surplus growth can be attributed to the 6 GHz spectrum. As Table E-36 indicates, we expect the additional IoT surplus generated by 6 GHz to account for $1.5 billion in 2025.

Table E-36. United Kingdom: IoT direct contribution attributed to 6 GHz (2021-2025) ($Million)

Variable	2021	2022	2023	2024	2025
Producer surplus	$6,097.43	$7,568.55	$9,080.64	$10,715.38	$12,682.36
Producer surplus not attributed to 6 GHz	$5,875.96	$7,130.35	$8,358.97	$9,656.83	$11,185.69
Additional surplus due to 6 GHz	$221.47	$438.20	$721.67	$1,058.55	$1,496.67

Sources: Statista, Bain & Co, CSI, Telecom Advisory Services analysis

E.6.3. Firms belonging to the AR/VR ecosystem

Following a similar approach as in the case of IoT, we estimated the direct contribution of this ecosystem to the British economy. Starting with the local spending in AR/VR by category (hardware, software, and content), and apportioning those figures by the respective shares of local production and margins, we were able to estimate the total producer surplus. By relying on a ratio built from 6 GHz AR/VR related products, we were able to subtract the specific contribution attributed to 6 GHz from the surplus corresponding to current bands. Accordingly, we expect by 2021 a direct contribution from the AR/VR ecosystem of $262 million, increasing to reach $1.2 billion by 2025 (Table E-37).

Table E-37. United Kingdom: AR/VR ecosystem direct contribution (2021-2025)

Variable	2021	2022	2023	2024	2025
Spending in AR/VR - Hardware $Billion	$0.49	$0.79	$1.13	$1.55	$2.35
Spending in AR/VR - Software, Contents, Services ($Billion)	$0.82	$1.52	$2.40	$3.43	$5.77
Total Spending in AV/VR ($Billion)	$1.31	$2.31	$3.53	$4.97	$8.12
Share of local production - Hardware	26.11%	26.11%	26.11%	26.11%	26.11%
Share of local production - Software, Contents, Services	90.00%	90.00%	90.00%	90.00%	90.00%
Local production for local consumption - Hardware ($Billion)	$0.13	$0.21	$0.30	$0.40	$0.61
Local production for local consumption - Software, Contents, Services ($Billion)	$0.74	$1.37	$2.16	$3.09	$5.19
Local Producer Surplus - Hardware ($Billion)	$0.05	$0.08	$0.12	$0.16	$0.24
Local Producer Surplus - Software, Contents, Services ($Billion)	$0.57	$1.06	$1.67	$2.39	$4.02
Total Producer Surplus	$0.62	$1.14	$1.79	$2.55	$4.26
Share attributable to Wi-Fi (excluding 6 GHz)	42.02%	38.80%	32.18%	30.88%	29.32%
Producer Surplus attributed to Wi-Fi (not including 6 GHz) ($Million)	$261.73	$442.71	$576.20	$787.31	$1,249.93

Sources: PwC, ABI; Telecom Advisory Services analysis

Wider deployment of AR/VR solutions if 6 GHz allocated

By relying on a ratio built from 6 GHz AR/VR related products, we were able to isolate the specific economic contribution of the new spectrum allocation. Following an approach similar as that one described above, the direct contribution from AR/VR ecosystem in the United Kingdom attributed to 6 GHz in 2025 will yield $652 million.

Table E-38. United Kingdom: AR/VR direct contribution attributed to 6 GHz (2021-2025)

Variable	2021	2022	2023	2024	2025
Spending in AR/VR ($Billion)	$1.31	$2.31	$3.53	$4.97	$8.12
Share attributed to 6 GHz	24.58%	25.59%	26.64%	27.73%	28.87%
Spending in AR/VR attributed to 6 GHz ($Billion)	$0.32	$0.59	$0.94	$1.38	$2.34
Local production for local consumption 6 GHz ($Billion)	$0.21	$0.40	$0.65	$0.97	$1.68
Local Producer Surplus ($Million)	$126.95	$190.38	$284.28	$398.79	$651.73

Sources: PwC, ABI, Telecom Advisory Services analysis

E.7. Wi-Fi contribution to employment

The estimation of employment generated by Wi-Fi's economic value is calculated by relying on the total GDP contribution resulting from the effects analyzed above and using that as an input in the communications sector of an input-output matrix of the British economy. Table E-39 presents the GDP contribution, as sum of all GDP sources discussed above, enabled by Wi-Fi projected for the period 2021-2025.

Table E-39. United Kingdom: Wi-Fi enabled GDP contribution (2021-2025)

Year	GDP contribution enabled by Wi-Fi ($Million)		
	Attributed to current bands	Attributed to 6 GHz	Total
2021	$24,980	$847	$25,827
2022	$16,884	$1,755	$18,640
2023	$7,309	$1,842	$9,151
2024	$7,783	$2,597	$10,380
2025	$8,715	$3,459	$12,174

Sources: Telecom Advisory Services analysis

These inputs generate the following annual employment effects based on the input/output matrix for the British economy (Table E-40).

Table E-40. United Kingdom: Wi-Fi generated Annual Employment

Variable	2021			2025		
	Current bands	6 GHz	Total	Current bands	6 GHz	Total
Direct jobs	46,643	1,582	48,224	16,273	6,458	22,731
Indirect jobs	29,742	1,009	30,751	10,376	4,118	14,495
Induced jobs	15,759	0,534	16,293	5,498	2,182	7,680
Total	92,144	3,125	95,268	32,147	12,759	44,906

Sources: GTAP; Telecom Advisory Services analysis

According to the contribution to GDP, Wi-Fi will generate approximately 95,000 jobs in 2021 and is expected to create almost 45,000 in 2025. The reason that explains the decrease in jobs is related to the reduction in GDP contribution over the period, mainly related to the slowdown in the growth of M2M devices that reduces the contribution of IoT. While in other countries that effect is partially compensated by the progressive increase in return to speed contribution, this additional effect does not apply in the UK due to the reasons explained above, as cellular speeds are already as fast as Wi-Fi. Job estimates include direct jobs (those jobs created by the specific Wi-Fi contribution), indirect jobs (those jobs created by suppliers to the Wi-Fi sector) and induced jobs (those jobs created by spending of direct and indirect workers).

The sector breakdown of 2021 employment (including the additional jobs created by 6 GHz) is as follows (Table E-41).

Table E-41. United Kingdom: Sector Breakdown of Wi-Fi generated annual employment (2021)

Sector	Direct	Indirect	Induced	Total
Agriculture	0	0	80	80
Extractive industries	0	0	61	61
Manufacturing	0	2,228	116	2,343
Construction	0	3,552	0	3,552
Trade	0	1,783	2,246	4,030
Transportation	0	2,108	0	2,108
Communications	48,224	0	0	48,224
Financial Services	0	2,190	0	2,190
Business services	0	18,889	0	18,889
Other services	0	0	13,791	13,791
Total	48,224	30,751	16,293	95,268

Sources: GTAP; Telecom Advisory Services analysis

F. ECONOMIC VALUE OF WI-FI IN FRANCE

Wi-Fi has become a key component in the French telecommunications infrastructure. According to the Wiman site, there are 1,219,000 free public Wi-Fi access points, of which 418,000 are in Paris, 43,000 in Lyon, 29,000 in Nice, and 23,000 in Marseille. Eighty-seven percent of broadband homes are equipped with a Wi-Fi router to enable wireless connection of all home devices. Given the Wi-Fi access point density, hotspots have become a very important connectivity feature.

The increasing importance of Wi-Fi technology in the digital infrastructure ecosystem should have a significant contribution on its social and economic contribution. This section presents the results and calculations of the economic assessment.

F.1. Total economic value of Wi-Fi in France (2021-2025)

In the prior study of Wi-Fi's economic contribution[172], its value for 2021 was estimated at $55.2 billion. Before considering the additional effect of allocating the 6 GHz spectrum band for unlicensed use, the total economic value of Wi-Fi in France in 2021 will amount to $61.1 billion. The increase of $5.9 billion is mainly due to the development of four new sources of economic value:

- The increasing importance of free Wi-Fi;
- The increasing benefits of Wi-Fi technology broadband speed;
- A substantial boost to deployment of IoT technology;
- The growing adoption of AR/VR technology.

The total economic value in 2021 of $61.1 billion is broken down by $20.4 billion in consumer surplus, $28.0 billion in producer surplus, and $12.7 billion in a net contribution to GDP. Even before accounting for the acceleration effect resulting from the allocation of 500 MHz in the 6 GHz band, the 2025 forecast of economic value will reach $95.1 billion, composed of $31.7 billion in consumer surplus, $35.0 billion in producer surplus, and $28.5 billion in GDP contribution (see Table F-1).

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[172] Katz, R. and Callorda, F. (2018). *The Economic value of Wi-Fi: A Global View (2018 and 2023)*. New York: Telecom Advisory Services. October.

Table F-1. France: Economic value of Wi-Fi (Baseline Scenario)

Agent	Source	Economic Value ($Million)					
		2021	2022	2023	2024	2025	Category
1. Free Wi-Fi	1.1. Savings generated by free Wi-Fi traffic offered in public sites	$84	$77	$69	$62	$53	Consumer Surplus
	1.2. Deployment of free Wi-Fi in public sites	$866	$711	$555	$399	$243	GDP contribution
2.Residential Wi-Fi	2.1. Internet access for home usage of devices that lack a wired port	$2,573	$3,374	$4,422	$5,797	$7,606	Consumer Surplus
	2.2. Avoidance of investment in in-house wiring	$12,388	$12,965	$13,700	$14,391	$15,124	Consumer Surplus
	2.3. Benefit to consumers from speed increases	$1,574	$2,245	$3,029	$3,938	$4,971	Consumer Surplus
	2.4. Residential Wi-Fi devices and equipment deployed	$3,838	$3,930	$4,038	$3,977	$3,845	Consumer Surplus
	2.5. Bridging digital divide: use of Wi-Fi to increase coverage in rural and isolated areas	$163	$158	$155	$152	$148	GDP contribution
3. Enterprise Wi-Fi	3.1. Business Internet traffic transmitted through Wi-Fi	$1,707	$1,898	$2,111	$2,348	$2,611	Producer surplus
	3.2. Avoidance of enterprise inside wiring costs	$5,028	$5,028	$5,028	$5,028	$5,028	Producer surplus
	3.3. Return to speed: contribution to GDP derived from an increase in average mobile speed	$6,130	$9,061	$12,777	$17,461	$23,329	GDP contribution
	3.4. Wide deployment of IoT	$4,914	$3,603	$2,641	$2,678	$2,717	GDP contribution
	3.5. Deployment of AR/VR solutions	$528	$862	$1,092	$1,475	$1,849	GDP contribution
4. ISPs	4.1. CAPEX and OPEX savings due to cellular off-loading	$9,562	$6,829	$9,987	$11,165	$12,826	Producer surplus
	4.2. Revenues of service providers offering paid Wi-Fi access in public places	$74	$84	$95	$106	$120	GDP contribution
	4.3. Aggregated revenues of WISPs	$51	$57	$60	$62	$66	GDP contribution
5. Wi-Fi ecosystem	5.1. Locally manufactured residential Wi-Fi devices and equipment	$6,557	$6,876	$7,259	$7,169	$6,947	Producer surplus
	5.2. Locally manufactured Wi-Fi enterprise equipment	$0	$0	$0	$0	$0	Producer surplus
	5.3. Locally produced IoT products and services	$4,997	$5,366	$5,794	$6,261	$6,734	Producer surplus
	5.4. Locally produced of AR/VR solutions	$173	$292	$379	$517	$819	Producer surplus
Total		$61,207	$63,416	$73,191	$82,986	$95,036	

Source: Telecom Advisory Services analysis

In addition to the value generated from the unlicensed use of the 2.4 GHz and 5 GHz bands (referred to as the baseline scenario), the allocation of 500 MHz in the 6 GHz spectrum band for unlicensed use[173] and the deployment of Wi-Fi 6 and Wi-Fi 6E devices will trigger an additional boost in economic value, reaching $9 billion in 2025 (see Table F-2).

Table F-2. France: Economic value of Wi-Fi (only attributed to 6 GHz)

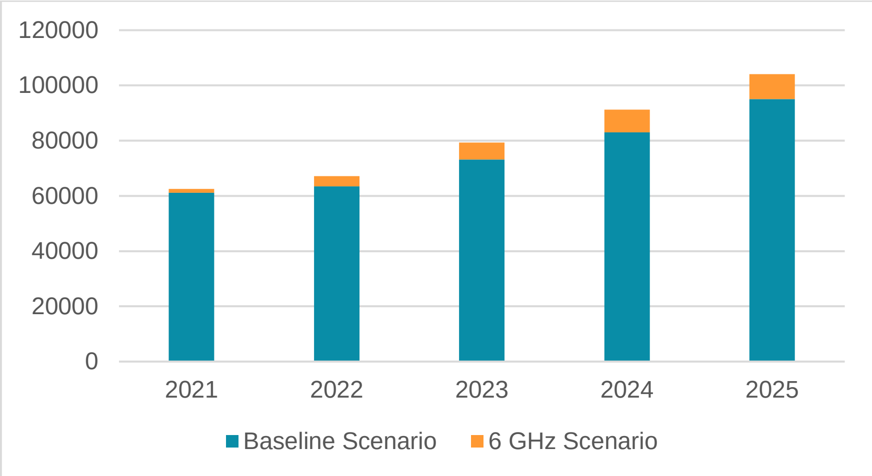
Agent	Source	Economic Value ($Million)					
		2021	2022	2023	2024	2025	Category
1. Free Wi-Fi	1.1. Savings generated by free Wi-Fi traffic offered in public sites	$0	$3	$8	$16	$28	Consumer Surplus
	1.2. Deployment of free Wi-Fi in public sites	$0	$67	$105	$113	$92	GDP contribution
	1.3. Benefit of faster free Wi-Fi with Wi-Fi 6E devices	$0	$24	$39	$44	$38	Consumer Surplus
2. Residential Wi-Fi	2.3. Benefit to consumers from speed increases	$0	$301	$521	$625	$442	Consumer Surplus
	2.4. Residential Wi-Fi devices and equipment deployed	$140	$337	$733	$1,124	$1,521	Consumer Surplus
	2.5. Bridging digital divide: use of Wi-Fi to increase coverage in rural and isolated areas	$0	$6	$10	$14	$17	GDP contribution
3. Enterprise Wi-Fi	3.1. Business Internet traffic transmitted through Wi-Fi	$0	$92	$117	$147	$140	Producer surplus
	3.3. Return to speed: contribution to GDP derived from an increase in average mobile speed	$0	$1,018	$1,761	$2,082	$1,416	GDP contribution
	3.4. Wide deployment of Internet of Things	$121	$235	$211	$214	$217	GDP contribution
	3.5. Deployment of AR/VR solutions	$256	$371	$539	$747	$964	GDP contribution
4. ISPs	4.1 CAPEX and OPEX savings due to cellular off-loading	$377	$377	$377	$377	$377	Producer surplus
	4.2. Revenues of service providers offering paid Wi-Fi access in public places	$0	$3	$8	$13	$19	GDP contribution
	4.3. Aggregated revenues of WISPs	$0	$1	$2	$2	$3	GDP contribution
5.Wi-Fi ecosystem	5.1. Locally manufactured residential Wi-Fi devices and equipment	$247	$607	$1,349	$2,069	$2,799	Producer surplus
	5.2. Locally manufactured Wi-Fi enterprise equipment	$0	$0	$0	$0	$0	Producer surplus
	5.3. Locally produced IoT products and services	$113	$170	$254	$352	$459	Producer surplus
	5.4. Locally produced of AR/VR solutions	$84	$126	$187	$262	$427	Producer surplus
Total		$1,338	$3,738	$6,221	$8,201	$8,959	

Source: Telecom Advisory Services analysis

[173] In response to a request from the European Commission to investigate spectrum between 5,925 to 6,425 MHz, the CEPT (has issued a technical report to the European Commission on the feasibility of Wi-Fi in the 6 GHz band.

Considering that by 2025 only 40% of Wi-Fi traffic will rely on 6 GHz channels, the accelerated effect derived from the new spectrum allocation and latest Wi-Fi technologies will still be far from reaching its maximum potential at this time. However, a visual depiction of the trend provides a perspective of the growing importance of Wi-Fi 6 in the overall economic value (see Graphic F-1)

Graphic F-1. France: Economic value of Wi-Fi (2021-2025) ($Thousand)



Source: Telecom Advisory Services analysis

If the French regulatory agency decides to allocate the upper part of the spectrum to unlicensed use, Wi-Fi economic value would increase significantly beyond the values presented in Table F-2.

By combining the baseline and the Wi-Fi 6 and 6 GHz scenarios, the overall economic value of Wi-Fi for France will yield $104 billion in 2025 (see Table F-3).

Table F-3. France: Total Economic Value of Wi-Fi (including Wi-Fi 6 and 6 GHz)

Agent	Source	Economic Value ($Million)					
		2021	2022	2023	2024	2025	Category
1. Free Wi-Fi	1.1. Savings to consumers of free Wi-Fi traffic offered in public sites	$84	$79	$77	$78	$82	Consumer Surplus
	1.2. Deployment of free Wi-Fi in public sites	$866	$778	$660	$512	$334	GDP contribution
	1.3. Benefit of faster free Wi-Fi with Wi-Fi 6E devices	$0	$24	$39	$44	$38	Consumer Surplus
2. Residential Wi-Fi	2.1. Internet access for home usage of devices that lack a wired port	$2,573	$3,374	$4,422	$5,797	$7,606	Consumer Surplus
	2.2. Avoidance of investment in in-house wiring	$12,388	$12,965	$13,700	$14,391	$15,124	Consumer Surplus
	2.3. Benefit to consumers from speed increases	$1,574	$2,546	$3,551	$4,563	$5,412	Consumer Surplus
	2.4. Residential Wi-Fi devices and equipment deployed	$3,978	$4,267	$4,771	$5,101	$5,366	Consumer Surplus

Agent	Source	Economic Value ($Million)					
		2021	2022	2023	2024	2025	Category
	2.5. Bridging digital divide: use of Wi-Fi to increase coverage in rural and isolated areas	$163	$165	$165	$166	$166	GDP contribution
3. Enterprise Wi-Fi	3.1. Business Internet traffic transmitted through Wi-Fi	$1,707	$1,990	$2,228	$2,495	$2,751	Producer surplus
	3.2. Avoidance of enterprise inside wiring costs	$5,028	$5,028	$5,028	$5,028	$5,028	Producer surplus
	3.3. Return to speed: contribution to GDP derived from an increase in average mobile speed	$6,130	$10,080	$14,538	$19,543	$24,744	GDP contribution
	3.4. Wide deployment of IoT	$5,034	$3,838	$2,851	$2,892	$2,933	GDP contribution
	3.5. Deployment of AR/VR solutions	$784	$1,233	$1,631	$2,223	$2,813	GDP contribution
4. ISPs	4.1 CAPEX and OPEX savings due to cellular off-loading	$9,939	$7,205	$10,364	$11,542	$13,203	Producer surplus
	4.2. Revenues of service providers offering paid Wi-Fi access in public places	$74	$87	$102	$119	$139	GDP contribution
	4.3. Aggregated revenues of WISPs	$51	$58	$61	$65	$69	GDP contribution
5. Wi-Fi ecosystem	5.1. Locally manufactured residential Wi-Fi devices and equipment	$6,804	$7,483	$8,608	$9,238	$9,746	Producer surplus
	5.2. Locally manufactured Wi-Fi enterprise equipment	$0	$0	$0	$0	$0	Producer surplus
	5.3. Locally produced IoT products and services	$5,110	$5,536	$6,048	$6,614	$7,192	Producer surplus
	5.4. Locally produced of AR/VR solutions	$257	$418	$566	$779	$1,247	Producer surplus
Total		$62,544	$67,154	$79,410	$91,190	$103,993	

Source: Telecom Advisory Services analysis

The following sections will present in detail the calculation of each source of value, disaggregating the economic contribution between the current spectrum allocation and the enhanced effect due to Wi-Fi 6 availability and the 6 GHz band.

F.2. Value from free Wi-Fi service

The economic value of free Wi-Fi service originates from three contribution sources:

- Savings to consumers by accessing the Internet in free Wi-Fi sites rather; than incurring cellular costs;
- The use of Wi-Fi to expand broadband coverage to the unserved population; and
- The return to speed of Wi-Fi compared to the use of cellular service.

F.2.1. Savings incurred by accessing free Wi-Fi in public sites

The economic value of free Wi-Fi is measured in terms of consumer surplus, calculated by estimating the benefit that flows to consumers as a result of savings incurred by not purchasing wireless broadband service. We begin by forecasting the traffic generated at free Wi-Fi access points. In order to isolate the effect from the increased capacity derived from the 6 GHz allocation, we calculate the portion of free Wi-Fi traffic attributed to current spectrum bands. For this, we relied on the assumption that current traffic levels are already producing congestion in most free Wi-Fi hotspots at times of peak demand. Thus, we assume that traffic per hotspot beyond 2021 will remain at 2020 levels (546.31 GB per year), although overall free traffic will continue growing as new hotspots will continue to be deployed (see Table F-4).

Table F-4. France: Total Free Wi-Fi Traffic projection (2021-2025)

Variable	2021	2022	2023	2024	2025
Free Wi-Fi traffic (Million GB Per year) - considering current trends	818.93	1,057.66	1,391.22	1,862.16	2,533.72
Free Wi-Fi hotspots (Million)	1.31	1.46	1.62	1.80	2.00
Traffic per hotspot - considering current trends	623.17	724.27	857.31	1,032.66	1,264.43
Traffic per hotspot - capped due to congestion	546.31	546.31	546.31	546.31	546.31
Total traffic (not attributed to 6 GHz) (Million $)	$717.93	$797.79	$886.53	$985.14	$1,094.73

Sources: Cisco; Wiman; Telecom Advisory Services analysis

We calculate consumer surplus by multiplying the total free traffic (not attributed to 6 GHz) by the difference between what the consumer would have to pay if she/he were to rely on a wireless carrier and the cost of offering free Wi-Fi (incurred by the retailer or public site). To do so, we calculated the average price per GB of wireless data transmitted by wideband networks by averaging the most economic "dollar per GB" plan of four major wireless carriers (see Table F-5).

Table F-5. France: Average Price Per Gigabyte (2020)

Carrier	Plan	Price per GB ($)
Bouygues Telecom	100 GB	$0.185
Orange	Play 120Go	$0.337
SFR (Altice)	120 GB	$0.482
Free Mobile (Iliad)	Internet 4G + 100 GB	$0.231

Sources: Websites of cellular operators; Telecom Advisory Services analysis

Historical data allowed for a projection of future prices per gigabyte. Based on this forecast, we expect the average price per GB will reach an estimated $0.19 in 2025. By relying on the total free Wi-Fi traffic not attributed to 6 GHz allocation shown in Table F-4 and the average price per cellular gigabyte minus the cost of provisioning Wi-Fi service, we calculated the consumer surplus of free Wi Fi traffic (see Table F-6).

Table F-6. France: Consumer Surplus of Free Wi-Fi Traffic (2021-2025)

Variable	2021	2022	2023	2024	2025
Total Free Traffic (not attributed to 6 GHz) (Million GB)	717.93	797.79	886.53	985.14	1094.73
Price per cellular gigabyte ($)	$0.29	$0.26	$0.24	$0.21	$0.19
Cost per Wi-Fi provisioning ($)	$0.18	$0.17	$0.16	$0.15	$0.14
Consumer surplus per GB ($)	$0.12	$0.10	$0.08	$0.06	$0.05
Total Consumer surplus ($Million)	$83.74	$76.79	$69.45	$61.69	$53.49

Sources: Cisco; Websites of cellular operators; Telecom Advisory Services analysis

As indicated in Table F-6, consumer surplus of free Wi-Fi traffic in 2021 will reach an estimated $84 million, decreasing to $53 million in 2025 due to the remaining congestion if additional spectrum in the 6 GHz spectrum band is not allocated to unlicensed use.

Enhanced free Wi-Fi traffic due to 6 GHz allocation

The allocation of the 6 GHz spectrum band and the technological advances implied by the Wi-Fi 6 standard will remove the above-mentioned bottlenecks. As a result, the traffic per hotspot will be able to continue growing at its natural rate as determined by the extrapolation of past recent trends. That being said, we must take into account that not all Wi-Fi traffic will benefit immediately from opening the 6 GHz band, as most current devices are not prepared to support the new standards. Thus, we expect the traffic through the 6 GHz channel to gradually increase until reaching a 40% of total free traffic by 2025.

Once computed, the additional traffic "above and beyond" the future previsions under current spectrum bands, we will follow a similar approach to calculate the consumer surplus, by multiplying it by the difference between what the consumer would have to pay if he were to utilize a wireless carrier and the cost of offering free Wi-Fi (Table F-7). As a result, we project an additional consumer surplus of $28 million from free Wi-Fi traffic attributed to 6 GHz.

Table F-7. France: Additional Consumer Surplus of Free Wi-Fi Traffic generated due to 6 GHz (2021-2025)

Variable	2021	2022	2023	2024	2025
Demand not satisfied due to congestion (Million GB)	101.00	259.87	504.68	877.02	1439.00
Traffic through the 6 GHz Channel (%)	0%	10%	20%	30%	40%
Total traffic (attributed to 6 GHz) (Million GB)	0.00	25.99	100.94	263.11	575.60
Consumer Surplus (attributed to 6 GHz) ($Million)	$0.00	$2.50	$7.91	$16.48	$28.13

Sources: Cisco; Telecom Advisory Services analysis

The additional surplus generated by the allocation of the 6 GHz spectrum band will mitigate the decreasing trend of consumer surplus derived from free Wi-Fi under the current spectrum allocation.

F.2.2. Free Wi-Fi to provide broadband to the unserved population

As explained in section B, free Wi-Fi in public sites can provide Internet access to the unserved population. Consumers that do not have broadband at home because they lack the economic means to acquire services can rely on free Wi-Fi to gain Internet access. The net result is that more people can be connected, which in turn enhances the economic contribution of broadband.

The estimation of this particular economic impact starts by calculating which portion of households that lack broadband service are already accessing Internet through free hotspots. We follow a conservative approach and assume that only 5% of unconnected households rely on free hotspots for accessing Internet. After calculating the increase in broadband penetration due to households relying on free Wi-Fi, we rely on the broadband impact coefficient calculated by Katz and Callorda (2018b) in their econometric models developed for Europe. As a result, the GDP contribution of this particular effect is expected to amount to $866 million in 2021 but declining to $243 million in 2025. The decline is due to the large, expected reduction in unconnected households during the period, and hence, on the households exclusively relying on free hotspots (see Table F-8).

Table F-8. France: GDP contribution due to households relying on Free Wi-Fi (2021-2025)

Variable	2021	2022	2023	2024	2025
Households without Internet	3,529,983	2,943,152	2,335,195	1,705,458	1,053,267
Households that do not buy broadband because access Internet free hotspots (%)	5%	5%	5%	5%	5%
Households served by Free Wi-Fi hot spots	176,499	147,158	116,760	85,273	52,663
Increase in national broadband penetration	0.7%	0.6%	0.5%	0.3%	0.2%
Impact of fixed broadband adoption in GDP	4.63%	4.63%	4.63%	4.63%	4.63%
Increase in the GDP due to the new broadband adoption (% GDP)	0.03%	0.03%	0.02%	0.02%	0.01%
GDP ($Billion)	$2,549.53	$2,585.00	$2,620.98	$2,658.51	$2,696.58
Total impact in GDP ($Million)	$865.80	$710.52	$554.88	$399.03	$242.66

Sources: Eurostat; IMF; Telecom Advisory Services analysis

Enhanced GDP contribution due to 6 GHz allocation

As stated above, Wi-Fi 6 technology enables supporting a high number of devices on a single access point. Accordingly, the improved throughput of free Wi-Fi hotspots under the 6 GHz allocation will allow the possibility of serving additional unconnected households. The potential universe of additional households that could be served under this effect is enormous, as most unconnected households usually identify that costs are their main barrier for accessing to connectivity and thus, may potentially be served by free hotspots as long as they are in proximity to the access point. However, evidence suggests that not many people rely exclusively on free Wi-Fi as their main source of Internet access, so we will follow again a conservative approach and assume that a further 5% of unconnected households will be served through free hotspots under the allocation of the 6 GHz band. On the other hand, we have also considered that the expansion of traffic through the new band will take place gradually, reaching 40% in 2025. All in all, we estimate that almost 20,000 additional households in France will be served in 2025 due to free hotspots operating under 6 GHz spectrum, yielding an additional GDP contribution of approximately $92 million (Table F-9).

Table F-9. France: GDP contribution due to households relying on Free Wi-Fi due to 6 GHz (2021-2025)

Variable	2021	2022	2023	2024	2025
Households without Internet (not served by free Wi-Fi and not new adopters of WISP)	3,353,483	2,793,557	2,214,563	1,614,827	993,731
Potential households that could be served through free Wi-Fi hotspots under increased capacity (% of those not connected)	5%	5%	5%	5%	5%
Traffic through the 6 GHz Channel (%)	0%	10%	20%	30%	40%
Additional households served by Free Wi-Fi hot spots with 6 GHz	0	13,968	22,146	24,222	19,875
Increase in national broadband penetration	0.00%	0.056%	0.09%	0.09%	0.07%
Increase in the GDP due to the new broadband adoption (% GDP)	0.00000%	0.00003%	0.00004%	0.00004%	0.00003%
Total impact in GDP ($Million)	$0.00	$67.44	$105.24	$113.35	$91.58

Sources: Eurostat; IMF; Telecom Advisory Services analysis

F.2.3. Benefit to consumers for enjoying higher speed from free Wi-Fi if 6 GHz band is allocated

When the 6 GHz band is adopted by free Wi-Fi access points it will deliver service at faster broadband speeds. Current speeds from free hotspots are quite modest. Thus, the expanded capabilities due to the allocation of 6 GHz spectrum band will enhance free Wi-Fi speed, and as a result, will increase consumer surplus. We assume that under the 6 GHz allocation, speed from free hotspots will be similar to the Wi-Fi speeds from mobile devices reported by Cisco. After calculating the average speed by considering the expected share of traffic through 6 GHz, we follow Nevo et al. (2016) and calculate the additional consumer surplus per household relying on free Wi-Fi. We expect the consumer surplus resulting from faster speed in free Wi-Fi sites to reach $38 million in 2025 (Table F-10).

Table F-10. France: Consumer surplus for enjoying higher speed from free Wi-Fi if 6 GHz band allocated (2021-2025)

Variable	2021	2022	2023	2024	2025
Free Wi-Fi mean speed with no 6 GHz (Mbps)	10.76	12.73	15.04	16.51	18.11
Wi-Fi Speeds from Mobile Device (Mbps)	78.97	115.86	170.00	249.43	365.98
Traffic through the 6 GHz Channel (%)	0.00%	10.00%	20.00%	30.00%	40.00%
Free Wi-Fi mean speed with 6 GHz (Mbps)	10.763	23.039	46.036	86.384	157.257
Demand for average download speed	71.60	73.91	76.12	76.70	77.24
New Demand for average download speed	71.60	86.47	99.37	110.52	120.64
Additional Monthly Consumer surplus	$0.00	$12.56	$23.25	$33.82	$43.40
Additional Yearly Consumer Surplus	$0.00	$150.69	$279.02	$405.79	$520.81
Households that rely on Free Wi-Fi	176,499	161,125	138,905	109,495	72,538
Consumer surplus ($Million)	$0	$24	$39	$44	$38

Sources: Rotten Wi-Fi; Nevo et al. (2016); Telecom Advisory Services analysis

F.3. Residential Wi-Fi

The economic value of Wi-Fi in consumer residences is the result of five factors:

- Provision of connectivity to the home network for devices that lack an Ethernet port;
- Cost avoidance of ethernet inside wiring;
- Consumer surplus resulting from faster broadband speeds relative to cellular networks;
- Consumer surplus derived from usage of home devices connected to the home network; and
- Provision of Internet access to consumers located in rural and isolated areas.

F.3.1. Home Internet access for devices that lack an Ethernet port

The underlying premise of this analysis is that in the absence of Wi Fi, users of devices lacking an Ethernet port would have to depend on the cellular network to gain Internet access. For this reason, estimating value would first measure the traffic generated by these devices at home and then multiply it by the average price charged by cellular carriers.

To estimate the traffic of smartphones and tablets, we relied on 2018 Cisco estimates for the period 2016-21 and extrapolated those growth rates to 2025. It must be said, however, that in 2019 Cisco adjusted its predictions upwards. However, we preferred to rely on the original figures to avoid incurring in the risk of overestimation. Thus, it may be possible that our previsions reported here are slightly downward biased. In addition, we have to consider that according to Cisco IBSG (2012), 43.12% of use time of devices that lack an Ethernet port occurs at home. Therefore, the portion of said traffic generated at home in France will reach 8,798 million gigabytes in 2021 (see Table F-11).

Table F-11. France: Total Mobile Internet Traffic (2021-2025) (million gigabytes)

Variable	2021	2022	2023	2024	2025
Total Annual traffic - Smartphones	16,289.4	24,085.8	35,553.7	52,435.7	77,344.8
Total Annual traffic - Tablets	4,115.8	5,635.5	7,716.4	10,565.6	14,467.0
Share of traffic at Home	43.12%	43.12%	43.12%	43.12%	43.12%
Total Traffic at Home - Smartphones	7,023.6	10,385.3	15,330.0	22,609.1	33,349.3
Total Traffic at Home - Tablets	1,774.6	2,429.9	3,327.1	4,555.7	6,237.8
Total Traffic at Home	8,798.2	12,815.2	18,657.1	27,164.7	39,587.2
Average Price per GB ($)	$0.29	$0.26	$0.24	$0.21	$0.19
Price per home traffic ($Million)	$2,572.84	$3,373.96	$4,422.41	$5,797.22	$7,606.20

Sources: Cisco; GSMA; Telecom Advisory Services analysis

If this traffic had to be transported by cellular networks, at the average price per GB estimated, it would result in costs of $2.6 billion in 2021 reaching $7.6 billion in 2025.

F.3.2. Avoidance of inside wiring investment

Residential Wi-Fi allows consumers to avoid paying for wiring to connect all home devices (printers, laptops, storage units, etc.). Considering that 90% of all connected French households will have Wi-Fi in 2021[174], and the wiring cost estimated for a household[175], the avoidance costs of inside wiring over 21.5 million households amounts to $12.4 billion. By 2025, almost all French connected households are expected to have adopted Wi-Fi, which results in savings of $15.1 billion (Table F-12).

Table F-12. France: Consumer surplus from avoidance of investment in in-house wiring (2021-2025)

Variable	2021	2022	2023	2024	2025
Total Wiring Cost	$575.00	$575.00	$575.00	$575.00	$575.00
Households with Internet	24,053,462	24,777,799	25,523,948	26,292,567	27,084,332
Households with Wi-Fi (%)	90%	91%	93%	95%	97%
Households with Internet and Wi-Fi	21,540,870	22,547,797	23,830,000	25,028,695	26,300,378
Inside Wiring Costs ($Million)	$12,388	$12,965	$13,700	$14,391	$15,124

Sources: Eurostat; Burger (2012); Telecom Advisory Services analysis.

F.3.3. Benefits derived from speed increase

As described before, consumer surplus is generated if users enjoy faster Internet speeds through Wi-Fi than from cellular networks. Thus, in addition to the benefits outlined above, the welfare of residential customers is expected to increase if they access the Internet through a combination of Wi-Fi and fixed broadband relative to cellular service. After weighting the broadband speeds with the percentage of traffic carried out through Wi-Fi routers at home, the average speed advantage of using Wi-Fi in comparison to cellular networks is calculated. By applying the willingness-

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[174] Extrapolation based on data from Burger, A. (2012) "Wi-Fi households to approach 800 million by 2016", Telecompetitor

[175] Interview with Roland Montagne, IDATE on August 1, 2018. The equivalent U.S. number is $660.

to-pay parameters defined in Nevo et al. (2016) to the speed differential, the expected consumer surplus will attain $1,574 million in 2021, increasing to $4,971 million in 2025.

Table F-13. France: Consumer surplus from faster speed in households (2021-2025)

Variable	2021	2022	2023	2024	2025
Average Speed in households if Wi-Fi traffic were carried through mobile networks (Mbps)	63.59	79.81	99.95	124.92	155.86
Average Speed in household with Wi-Fi (Mbps)	84.54	118.13	166.69	237.32	340.56
Demand for average download speed	109.83	112.75	115.49	118.05	120.47
New Demand for average download speed	115.96	121.04	126.12	131.17	136.16
Additional Monthly Consumer surplus	$6.13	$8.30	$10.63	$13.11	$15.70
Additional Yearly Consumer Surplus	$73.54	$99.55	$127.61	$157.34	$188.35
Households with Internet and Wi-Fi	21,407,581	22,547,797	23,737,272	25,028,695	26,390,378
Impact ($Million)	$1,574	$2,245	$3,029	$3,938	$4,971

Sources: Cisco; Eurostat; Nevo et al. (2016); Telecom Advisory Services analysis

Additional benefit to consumers from speed increase due to 6 GHz

The welfare of residential Wi-Fi customers is expected to receive further benefit from the 6 GHz allocation due to faster Internet service under Wi-Fi 6E. As previously described in section B, only households acquiring a 150 Mbps (or faster) fixed broadband service are affected by router bottlenecks, therefore limiting the speed delivered by the fixed network. After calculating the difference in average speed attributed to 6 GHz, the additional consumer surplus will yield $442 million in 2025 (see Table F-14).

Table F-14. France: Consumer surplus from faster speed in households if 6 GHz is allocated (2021-2025)

Variable	2021	2022	2023	2024	2025
Households that have connections over 150 Mbps (%)	31.04%	35.54%	40.70%	46.60%	53.35%
Percentage of household traffic that goes through Wi-Fi	60.63%	63.64%	66.54%	69.33%	71.98%
Traffic through the 6 GHz Channel (%)	0.00%	10.00%	20.00%	30.00%	40.00%
Share of traffic affected due to 6 GHz (%)	0.00%	2.26%	5.42%	9.69%	15.36%
Average speed with no 6 GHz (Mbps)	84.54	118.13	166.69	237.32	340.56
Average speed with 6 GHz (Mbps)	84.54	124.51	182.03	262.77	372.73
Demand for average download speed	115.96	121.04	126.12	131.17	136.16
New Demand for average download speed	115.96	122.16	127.95	133.25	137.97
Additional Yearly Consumer Surplus	$0.00	$13.34	$21.97	$24.98	$21.75
Households with Wi-Fi	21,407,581	22,547,797	23,737,272	25,028,695	26,390,378
Impact ($Million)	$0	$301	$521	$625	$442

Sources: OECD; Cisco; Nevo et al. (2016); Telecom Advisory Services analysis

F.3.4. Residential Wi-Fi devices and equipment

The consumer surplus derived from the adoption of residential Wi-Fi devices and equipment focuses on seven consumers products which are intrinsically linked to Wi-Fi: smart home devices and systems, such as Wi-Fi speakers and home security systems, home networking systems, Wi-Fi tablets, access points, external adapters, routers, and gateways. Two different approaches are used in these cases: one assuming that consumer surplus is roughly equal to producer surplus in six of the seven products (excluding tablets), and an assessment of tablets' willingness-to-pay.

The estimation of economic value in the first approach begins by compiling local sales in the six product categories in France[176]. After computing the sales in France, we applied the prorated margin estimated by CSI markets (39.44%) which yields an estimated producer surplus for these particular products of $3.7 billion in 2021. As mentioned above, it is assumed that the consumer surplus is of the same magnitude. This methodology was also used to calculate the consumer surplus up to 2023. However, the gradual adoption of Wi-Fi 6 devices is forecast to reduce the sales and economic value from the devices relying on the 2.4 GHz and 5 GHz spectrum bands. Non 6 GHz consumer devices shipments are expected by IDC to decrease by 1.2% in 2024 and 3.1% in 2025. Based on this estimate, we extrapolated the consumer surplus from non 6 GHz reliant residential Wi-Fi devices and equipment between 2021 and 2025.

In addition, we calculated the consumer surplus attributable to tablets bought by local consumers. Starting with CTA/Statista worldwide tablet revenue estimates, we

[176] Calculated by pro-rating data for the United States based on GDP.

interpolated the revenue figures for France (by prorating the country's share of global GDP), and extrapolated the evolution of local revenue till 2025 by considering Cisco estimates of tablet evolution for the period. We reviewed the data on tablet prices for the market leader (taking as a reference the Apple iPad 10.2 Inch 128 GB, as Apple has 50.4% of the French market share in tablets[177]) and for the rest of the market (taking as a reference a Samsung Wi-Fi tablet 128 GB), and assumed consumer willingness-to-pay levels in a similar percentage above prices as in the U.S. average. Combining all that information, we were able to estimate a consumer surplus attributable to tablets of $130 million in 2021, expected to reach $71 million in 2025.

In sum, overall consumer surplus for Wi-Fi enabled residential products is expected to yield $3.8 billion in 2021, remaining stable until 2025 (Table F-15).

Table F-15. France: Economic Value of Wi-Fi enabled consumer products (2021-2025)

Variable	2021	2022	2023	2024	2025
Consumer surplus (exc. Tablets) ($Million)	$3,708	$3,820	$3,943	$3,894	$3,774
Tablet consumer surplus ($Million)	$130	$110	$95	$82	$71
Total consumer surplus ($Million)	$3,838	$3,930	$4,038	$3,977	$3,845

Sources: Consumer Technology Association; ABI Research; CS Markets; IDC; Telecom Advisory Services analysis

Consumer surplus derived to Wi-Fi enabled residential equipment for 6 GHz

As commented before, devices for 6 GHz are expected to gradually replace those of former generations. According to IDC, global shipments of consumer devices linked to 6 GHz (802.11ax standard) will represent 40% of the shipments from previous generations. As a result, if the shipments ratio will reach 40% in 2025, we can expect that, at least, the consumer surplus derived from 6 GHz devices will represent an amount of 40% of that of the legacy technology of residential devices. As Table F-16 indicates, our estimates for consumer surplus attributed to 6 GHz residential devices amount to $1.5 billion in 2025.

Table F-16. France: Economic Value of Wi-Fi enabled consumer products for 6 GHz (2021-2025)

Variable	2021	2022	2023	2024	2025
Consumer surplus (ex. Tablets) ($Million)	$3,708	$3,820	$3,943	$3,894	$3,774
Consumer 6 GHz / no 6 GHz device ratio	3.76%	8.83%	18.59%	28.86%	40.30%
Consumer surplus 6 GHz devices ($Million)	$139.6	$337.4	$732.9	$1,123.8	$1,520.6

Sources: IDC; Telecom Advisory Services analysis

F.3.5. Bridging the digital divide: use of Wi-Fi to increase coverage in rural and isolated areas

Wi-Fi is an appropriate technology to offer Internet access in rural and isolated areas. Based on the data provided by Statista in subscriptions by technology ("other"

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[177] Source: Gs StatCounter

category), we can estimate at least 100,000 WISP subscriptions. The calculation of the Wi-Fi contribution to the reduction of the digital divide must subtract the direct impact of WISPs (Section 4.4.3.) to avoid double counting. On the other hand, we assume that 50% of WISP potential connections may be theoretically served by other technologies (i.e. satellite) covering the same isolated footprint. Thus, we can conservatively expect 50% of broadband subscriptions in remote locations exclusively attributed to WISPs. Once this is done, we calculate the impact on GDP by relying on the coefficient estimated by Katz and Callorda (2018b) through regression models that links increase in broadband penetration to economic growth. The contribution to GDP materializes through multiple effects: creation of new businesses, increasing productivity of existing enterprises, and growth of average income per household. We expect a GDP contribution of $164 million in 2021, which will decrease till reaching $148.5 million in 2025 (see Table F-17).

Table F-17. France: Estimation of GDP Contribution derived from reducing the digital divide (2021-2025)

Variable	2021	2022	2023	2024	2025
WISP subscribers	100,000	100,000	100,000	100,000	100,000
Additional broadband penetration due to WISP	0.32%	0.31%	0.31%	0.30%	0.29%
Impact of fixed broadband adoption in GDP	4.63%	4.63%	4.63%	4.63%	4.63%
GDP ($Billion)	$2,550	$2,585	$2,621	$2,659	$2,697
WISP TOTAL impact ($Billion)	$0.378	$0.374	$0.370	$0.366	$0.363
WISP Revenues ($Billion)	$0.05	$0.06	$0.06	$0.06	$0.07
Share that exist because WISP	50.00%	50.00%	50.00%	50.00%	50.00%
WISP spillovers on GDP ($Million)	$163.5	$158.3	$155.1	$152.0	$148.5

Sources: Statista, IMF; Telecom Advisory Services analysis

The decline in economic impact over time reflects a trend where WISP subscribers diminish as a percent of total broadband lines.

Economic impact of enhanced coverage and affordability due to 6 GHz

The allocation of the 6 GHz band to unlicensed use would allow WISPs to potentially increase their subscriber base within their same coverage footprint. Therefore, a first effect derived from the allocation of the new spectrum band is related to additional households served due to additional coverage. We will follow a cautious approach and consider that the expanded coverage will yield a gradual increase in WISP subscribers, from 2% in 2022 to 5% in 2025 over the figures projected without assuming the additional spectrum allocation. In addition, an increase of the user base would allow service providers to lower their operating costs. Thus, by assuming stability in prices, affordability would increase as GDP per capita grows as economic growth resumes. All in all, we can expect an overall increase in almost 6,900 WISP connections in 2025, contributing to an increase 0.02% in national broadband penetration. Considering the impact coefficient of broadband on the economy, which will yield a GDP contribution of $17.5 million.

Table F-18. France: GDP Contribution derived from reducing the digital divide due to 6 GHz (2021-2025)

Variable	2021	2022	2023	2024	2025
New subscribers due to expanded coverage (%)	0%	2%	3%	4%	5%
New subscribers due to expanded coverage	0	2,000	3,000	4,000	5,000
New WISP adoption after price decrease (% households)	0.46%	0.38%	0.37%	0.37%	0.37%
Traffic through the 6 GHz Channel (%)	0.00%	10.00%	20.00%	30.00%	40.00%
Increase in WISP connections due to lower prices (households that buy the service)	0	437	872	1,358	1,873
Overall increase in WISP connections due to 6 GHz	0	2,437	3,872	5,358	6,873
Increase in national broadband penetration	0.00%	0.01%	0.01%	0.02%	0.02%
Impact of fixed broadband adoption in GDP	4.63%	4.63%	4.63%	4.63%	4.63%
Increase in the GDP due to the new broadband adoption (% GDP)	0.000%	0.000%	0.001%	0.001%	0.001%
Total impact in GDP ($Million)	$0.00	$6.38	$10.03	$13.74	$17.45

Sources: Statista; IMF; Telecom Advisory Services analysis

F.4. Enterprise Wi-Fi

Beyond the impact on consumers, Wi-Fi also contributes significant economic value in the French enterprise segment. This section provides estimates in five areas:

- Support of business Internet traffic;
- Avoidance of campus and enterprise facilities inside wiring;
- Contribution to GDP resulting from Wi-Fi speed faster than cellular connections;
- Deployment of IoT solutions; and
- Implementation of business focused AR/VR use cases.

F.4.1. Business Internet traffic transmitted through Wi-Fi

Wi-Fi enterprise savings results from wireless traffic that is routed through Wi-Fi access points. Considering Cisco 2016-21 projections, we estimate that total business Internet traffic will reach 12.4 billion GB in 2021, of which 5.8 billion GB would have been transported through Wi-Fi access points. Considering the average price per GB transported by cellular (from Table F-5), savings from Wi-Fi will reach $1.7 billion, an addition to the producer surplus[178]. By 2025, this benefit will reach $2.6 billion (see Table F-19).

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[178] We acknowledge that enterprises are likely to negotiate wireless rates lower than those offered in the consumer market; however, data in this area is not available.

Table F-19. France: Savings in business wireless traffic (2021-2025)

Variable	2021	2022	2023	2024	2025
Share of Business Internet Traffic by Wi Fi	47.00%	48.07%	49.16%	50.28%	51.43%
Total Business Internet Traffic (Million GB)	12,419.3	15,000.1	18,117.3	21,882.1	26,429.4
Total Wi-Fi enterprise traffic (Million GB)	5,837.1	7,210.5	8,907.0	11,002.6	13,591.4
Average Price per GB	$0.29	$0.26	$0.24	$0.21	$0.19
Economic Impact ($Million)	$1,706.92	$1,898.36	$2,111.28	$2,348.07	$2,611.42

Sources: Cisco; Telecom Advisory Services analysis

Enhanced business Internet traffic transmitted through Wi-Fi due to 6 GHz

The deployment of the latest enterprise applications will generate an exponential growth in data traffic that will be handled by devices operating in unlicensed spectrum, through the combination of the existing bands and the 6 GHz band. In 2019, an updated Cisco traffic forecast based on the explosion of IoT and AR/VR applications, among other factors, increased total business Internet traffic forecast from the prior 2016-21 estimates from 2018. As in the other countries, we assume that part of the increase in traffic was driven by "natural" growth, while the remainder was triggered by Wi-Fi volumes stimulated by changes in 6 GHz. The sum of the difference due to broader Wi-Fi traffic between forecasts will reach $139.78 million in 2025 (see Table F-20).

Table F-20. France: Savings in business wireless traffic due to 6 GHz (2021-2025) ($Million)

Variable	2021	2022	2023	2024	2025
Total value of business Wi-Fi traffic 2016-21	$1,706.9	$1,898.4	$2,111.3	$2,348.1	$2,611.4
Total value of business Wi-Fi traffic 2017/22	$2,364.1	$2,747.8	$3,193.8	$3,712.2	$4,314.7
Difference between the 2 estimations	$657.2	$849.4	$1,082.5	$1,364.1	$1,703.2
Difference because natural growth	$615.7	$757.9	$965.8	$1,217.0	$1,519.6
Difference due to 6 GHz	$0.00	$91.57	$116.69	$147.05	$139.78

Sources: Cisco; Telecom Advisory Services analysis

F.4.2. Avoidance in enterprise building inside wiring

Similar to residential Wi-Fi savings due to capital investment avoidance in inside wiring, we assume that the total number of business establishments are equipped with Wi-Fi access points and multiply this value by a standard cost of deploying a CAT 6 network[179] (see Table F-21).

[179] The value for France was estimated in our previous study (Katz and Callorda, 2018), by multiplying the percent difference between a house and an office in the United States by the estimate for wiring a house in France.

Table F-21. France: Savings in business wiring CAPEX (2021-2025)

Variable	2021	2022	2023	2024	2025
Total Wiring Cost	$1,340.00	$1,340.00	$1,340.00	$1,340.00	$1,340.00
Number of Establishments	3,752,544	3,752,544	3,752,544	3,752,544	3,752,544
Establishments with Wi-Fi (%)	100%	100%	100%	100%	100%
Establishments with Wi-Fi	3,752,544	3,752,544	3,752,544	3,752,544	3,752,544
Inside Wiring Costs ($Million)	$5,028	$5,028	$5,028	$5,028	$5,028

Source: Telecom Advisory Services analysis

The wiring costs is constant across years because the total number of establishments (assumed to have full Wi-Fi penetration) and wiring costs remain constant over time.

F.4.3. Return to speed: contribution to GDP derived from an increase in average mobile speed

Since Wi-Fi accessibility allows, in general, for faster access to the Internet than cellular networks do, higher speeds have a positive contribution on the economy in terms of increased overall efficiency and innovation. This contribution is measured in terms of economic growth. As described in section E.3.3 for the case of consumer surplus, we begin by calculating the average broadband speed if cellular networks transported all Wi-Fi traffic, and compare it with the presence of Wi-Fi technology. Having calculated the speed increase percentage, we then apply this percentage to the coefficient derived from the model developed by Katz and Callorda (2019) to gauge the potential impact on GDP from Wi-Fi enhanced speed. Table E-22 indicates that the economic value of Wi-Fi in terms of increasing the speed of transporting wireless will account to $6.1 billion in 2021, before being increased to $23.3 billion in 2025 (see Table F-22).

Table F-22. France: Estimation of speed differential for total traffic (2021-2025)

Variable	2021	2022	2023	2024	2025
Average Download Speed if Wi-Fi traffic were carried through mobile networks (Mbps)	63.59	79.81	99.95	124.92	155.86
Average Speed with Wi-Fi (Mbps)	84.54	118.13	166.69	237.32	340.56
Speed increase (%)	33%	48%	67%	90%	119%
Impact of speed in GDP	0.73%	0.73%	0.73%	0.73%	0.73%
Increase in GDP	0.24%	0.35%	0.49%	0.66%	0.87%
GDP ($Billion)	$2,549.53	$2,585.00	$2,620.98	$2,658.51	$2,696.58
GDP increase ($Million)	$6,130	$9,061	$12,777	$17,461	$23,329

Sources: Cisco; Telecom Advisory Services analysis

Additional return to speed effect due to 6 GHz

As previously described, only those broadband connections above 150 Mbps will be affected due to current router bottlenecks, and hence, the speed experienced will not be equivalent to that delivered by the fixed network. Thus, the allocation of the 6 GHz band will remove those barriers, increasing broadband speed. After calculating the difference in average speed attributed to 6 GHz, we estimate that the additional GDP contribution will reach $1.4 billion in 2025 (Table F-23).

Table F-23. France: Estimation of speed differential due to 6 GHz (2021-2025)

Variable	2021	2022	2023	2024	2025
Mean speed with no 6 GHz (Mbps)	84.54	118.13	166.69	237.32	340.56
Mean speed with 6 GHz (Mbps)	84.54	124.51	182.03	262.77	365.05
Speed increase due to 6Ghz (%)	0%	5%	9%	11%	7%
Impact speed on GDP	0.73%	0.73%	0.73%	0.73%	0.73%
Increase in GDP (%)	0.00%	0.04%	0.07%	0.08%	0.05%
GDP increase ($Million)	$0	$1,018	$1,761	$2,082	$1,416

Sources: Cisco; Telecom Advisory Services analysis

The decline in 2025 GDP contribution is due to the fact that we conservatively assume that, in the short run, a portion of the speed increase could be handled by existing spectrum bands and is captured in the estimates of Table F-22. Over the time, the portion being handled by 6 GHz will increase.

F.4.4. IoT Deployment

IoT adoption has a contribution to GDP growth through the multiplicity of use cases that improve efficiency in processes such as preventive maintenance, production monitoring and the like. To estimate this, we rely on a coefficient of GDP impact calculated through an aggregate simple production function which estimates that a 10% rise in M2M connections results in annual increases in GDP of between 0.3% and 0.9%[180]. We will follow a conservative approach for France and assume a 0.3% GDP increase after a 10% increase in the M2M installed base.

Starting with a 2021 installed base of 25.2 million M2M devices in France, we estimate the growth between 2020 and 2021 that can be exclusively attributed to the allocation of additional spectrum to indoor Wi-Fi devices. By subtracting the growth in M2M attributed to 6 GHz, the IoT impact for 2021 according to the natural growth is forecast to reach $4.9 billion (see Table F-24).

Table F-24. France: GDP Contribution of IoT Deployment Boost (2021-2025)

Variable	2021	2022	2023	2024	2025
Connections, Cellular M2M	25,248,861	26,574,768	27,609,560	28,684,646	29,801,594
Growth Rate (%)	7.06%	5.25%	3.89%	3.89%	3.89%
Natural Growth Rate (%)	6.42%	4.65%	3.36%	3.36%	3.36%
Impact of 1% M2M Growth on GDP	3.00%	3.00%	3.00%	3.00%	3.00%
Impact on GDP (%)	0.19%	0.14%	0.10%	0.10%	0.10%
GDP ($Billion)	$2,550	$2,585	$2,621	$2,659	$2,697
Impact ($Million)	$4,913.80	$3,603.34	$2,640.65	$2,678.46	$2,716.82

Sources: GSMA Intelligence; Frontier Economics; IMF; Telecom Advisory Services analysis

It should be noted that the GDP impact of IoT declines due to a decreasing growth rate of M2M installed base.

[180] See Frontier Economics (2018)

Accelerated deployment of IoT due to 6 GHz

As described above, a share of the M2M growth can be attributed to IoT traffic shifting to the 6 GHz spectrum. According to the data in Table F-25, cumulative impact of enhanced IoT deployment driven by 6 GHz spectrum proposals will reach $217 million by 2025.

Table F-25. France: GDP Contribution of IoT Deployment Boost caused by 6 GHz (2021-2025)

Variable	2021	2022	2023	2024	2025
Growth due to 6 GHz (%)	0.63%	0.60%	0.54%	0.54%	0.54%
Level of development of new bands (%)	50%	100%	100%	100%	100%
Impact on GDP (%)	0.00%	0.01%	0.01%	0.01%	0.01%
Impact ($Million)	$120.57	$234.54	$210.55	$213.56	$216.62

Sources: GSMA Intelligence; Frontier Economics; IMF; Telecom Advisory Services analysis

F.4.5. Deployment of AR/VR solutions

The adoption of AR/VR among French businesses will have a spillover effect on productivity, thereby contributing to the growth of GDP. Estimating spillover effects of AR/VR is a not a trivial exercise considering the embryonic adoption of some of these use cases. Since the objective is to estimate the spillover effect of AR/VR sales by local firms in the domestic market, we will take as points of departure the estimate by PwC of the total GDP contribution of AR/VR for 2021 and 2022, and the sales of AR/VR components as estimated by ABI Research for Western Europe[181], which we will interpolate to France according to its weight in the GDP. The extrapolation of these two parameters allow estimating the indirect (spillover) contribution of AR/VR to the French economy for the period under analysis.

Starting values are reduced by the proportion that can be attributed to other technologies rather than Wi-Fi. After computing the resulting value, we subtracted the impact of the 6 GHz spectrum bands. To do so, we took as a reference a ratio of AR/VR product developments for each technology (built with data from ABI Research). Once the amount to be attributed in both GDP contribution and direct sales is estimated, the annual indirect to direct multiplier can be calculated. The lowest multiplier value is applied to sales of AR/VR in the local market to calculate the total spillovers. Accordingly, total spillover value of AR/VR in France in 2021 will account for $528 million and is expected to increase to $1.8 billion by 2025 (see Table F-26).

[181] See ABI Research, *Augmented and Mixed Reality Market Data: devices, use cases, verticals and value chain*. MD-ARMR-103, QTR 4 2019, and ABI Research, *Virtual Reality Market Data: devices, verticals, and value chain*. MD-VR-108, QTR 1 2020.

Table F-26. France: GDP contribution resulting from AR/VR spillovers (2021-2025)

Variable	2021	2022	2023	2024	2025
AR/VR total contribution to GDP ($Billion)	$5.00	$6.80	$8.90	$11.20	$14.10
Share attributed to Wi-Fi (excluding 6 GHz)	42.02%	38.80%	32.18%	30.88%	29.32%
Portion of GDP contribution attributed to Wi-Fi (excluding 6 GHz) ($Billion)	$2.10	$2.64	$2.86	$3.46	$4.13
Direct impact (sales) attributed to Wi-Fi (excluding 6 GHz) ($Billion)	$0.53	$0.86	$1.09	$1.48	$2.29
Indirect impact ($Billion)	$1.57	$1.78	$1.77	$1.98	$1.85
Indirect/Direct multiplier	1.00	1.00	1.00	1.00	0.81
Indirect impact ($Million)	$528.14	$861.94	$1,092.35	$1,475.42	$1,848.86

Sources: PwC, ABI; Telecom Advisory Services analysis

Wider deployment of AR/VR solutions (accelerated effect due to 6 GHz)

Higher throughput enabled by the allocation of the 6 GHz band is expected to spur the adoption and use of AR/VR among enterprises, hence increasing the associated spillover effects. By relying on the ratio built from 5 GHz and 6 GHz AR/VR related products from above, we were able to isolate the specific economic contribution of the new spectrum allocation. Following a similar procedure as that described above, spillovers from AR/VR in France attributed to 6 GHz were calculated. They will account for $256 million in 2021 and are expected to increase to $964 million by 2025 (Table F-27).

Table F-27. France: GDP contribution resulting from AR/VR spillovers due to 6 GHz (2021-2025)

Variable	2021	2022	2023	2024	2025
AR/VR total contribution to GDP ($Billion)	$5.00	$6.80	$8.90	$11.20	$14.10
Share attributed to 6 GHz (%)	24.58%	25.59%	26.64%	27.73%	28.87%
Portion of GDP contribution attributed to 6 GHz ($Billion)	$1.23	$1.74	$2.37	$3.11	$4.07
Direct impact (sales) attributed to 6 GHz ($Billion)	$0.31	$0.57	$0.90	$1.33	$2.25
Indirect impact ($Billion)	$0.92	$1.17	$1.47	$1.78	$1.82
Indirect/Direct multiplier	1.00	1.00	1.00	1.00	0.81
Indirect impact ($Million)	$256.17	$370.67	$538.94	$747.33	$964.02

Sources: PwC, ABI; Telecom Advisory Services analysis

E.5. Internet Service Providers

In addition to the economic value generated by the sources analyzed above, Wi-Fi will also contribute to either producer surplus or GDP of Internet Service Providers. This section will assess the economic value generated from three sources:

- Producer surplus of cellular operators resulting from CAPEX savings incurred in network deployment;
- Revenues of Wi-Fi carriers offering service in public spaces; and
- Revenues of Wireless ISPs (this effect differs from the GDP impact of WISPs as a result of their deployment in rural and isolated areas analyzed in section F.3.5.)

F.5.1. Cellular network savings by off-loading traffic to Wi-Fi

The estimation of CAPEX savings starts by considering the GSMA Intelligence aggregate projected investment by wireless carriers in France, which amounts to $32.1 billion between 2019 and 2025. Considering the total CAPEX required to deploy 5G in France, and the incremental 5G coverage between 2021 and 2025 we are able to interpolate the 5G CAPEX for each year of the period considered. It is assumed that all the CAPEX invested during the period would be dedicated to 5G deployment.

Based on the simulation model developed to forecast the impact of Wi-Fi off-loading in 5G deployment, we estimate that the savings of deploying carrier-grade Wi-Fi complementing the rollout of 5G to accommodate future traffic growth would amount to 32.9% of CAPEX, while the OPEX savings are $2.82 for each dollar saved in CAPEX. This would result in a total producer surplus (adding CAPEX and OPEX savings) of $9.6 billion in 2021, increasing to 12.8 billion in 2025, when 5G coverage will reach 62% (see Table F-28).

Table F-28. France: Savings due to traffic off-loading (2021-2025)

Variable	2021	2022	2023	2024	2025
5G coverage	20%	27%	37%	49%	62%
CAPEX without saving	$7,608.3	$5,433.4	$7,946.4	$8,884.0	$10,205.8
CAPEX reduction due to Wi-Fi off-loading	$2,503.1	$1,787.6	$2,614.4	$2,922.8	$3,357.7
OPEX reduction due to Wi-Fi off-loading	$7,058.8	$5,041.0	$7,372.5	$8,242.4	$9,468.8
Total Cost of Ownership ($Million)	$9,562	$6,829	$9,987	$11,165	$12,826

Sources: GSMA; Telecom Advisory Services analysis

Enhanced capability for cellular off-loading if 6 GHz allocated

The complementarity between Wi-Fi and cellular networks for Wi-Fi 6E and 5G, adds further potential gains derived from the savings in capital and operating expenses required to accommodate exploding data traffic. The key objective is to estimate the savings in capital investment as a result of an increase in traffic offloading with Wi-Fi benefits from the additional spectrum allocated, particularly, due to the ability to leverage 160 MHz within single contiguous channels.

The estimation of CAPEX savings starts by considering the GSMA Intelligence aggregate investment estimates of 5G deployments. By relying again on the geographic disaggregation of Oughton and Frias, we estimate that CAPEX can be split in urban, suburban, and rural geographies. We conservatively assume that Wi-Fi 6 will not be critical in sustaining investment in urban areas, but that it will play a significant role beyond those geographies. Based on the cost advantage of carrier grade Wi-Fi, we assume that it will become effective for a portion of the suburban (approximately 15%) and rural network (approximately 5%) deployment. Therefore, this will yield yearly CAPEX savings of $377 million between 2021 and 2025.

F.5.2. Wi-Fi carrier revenues

The economic value generated by Wi-Fi carriers is based on the revenues from public Wi-Fi access. In order to estimate this value, we start by calculating the number of commercial Wi-Fi hotspots in France. According to Cisco, in 2021 there will be 21.73 million public Wi-Fi hotspots in the country, although that figure includes home spots (such as the guest account service provided by cable operators). By subtracting the home spots from the public Wi-Fi estimates of Cisco, we estimated a total of 150,000 commercial Wi-Fi hotspots for 2021, which will increase to 260,000 in 2025. On the other hand, based on revenue per hotspot from Boingo in the United States, and adjusting the metric by PPP we estimated the value for France. Accordingly, total revenues generated by this sector in France amount to $74 million in 2021, gradually increasing to reach $120 million in 2025 (Table F-29).

Table F-29. France: Revenues of Wi-Fi carriers (2021-2025)

Variable	2021	2022	2023	2024	2025
Public Wi-Fi hotspots (Million)	24.70	27.45	30.50	33.89	37.66
Home spots (Million)	24.55	27.27	30.30	33.66	37.40
Commercial Wi-Fi hotspots (Million)	0.15	0.17	0.20	0.23	0.26
Revenue per hotspot ($)	$489.54	$481.12	$472.83	$464.69	$456.70
Revenue ($Million)	$74.44	$83.95	$94.57	$106.43	$119.68

Sources: Cisco; Boingo; Telecom Advisory Services analysis

Increased revenues of Wi-Fi carriers in public places due to 6 GHz

The allocation of the 6 GHz spectrum band offers an opportunity for commercial Wi-Fi carriers to grow their business. As Wi-Fi 6E developments will allow up to 1,500 connected devices per access point, Wi-Fi carriers will have the possibility of adding more clients without quality limitations due to congestion. By considering a conservative potential increase of 40% in the number of connected devices in public venues and weighting that value by the gradual expansion of the latest technology, we expect commercial Wi-Fi carriers in France to increase their user base by 16% in 2025. If the revenue per hotspot grows by the same amount, it will yield an increase in overall revenues for the sector of an additional $19 million by 2025 (Table F-30).

Table F-30. France: Revenues of Wi-Fi carriers due to 6 GHz (2021-2025)

Variable	2021	2022	2023	2024	2025
Potential increase in connected devices in public venues	40.00%	40.00%	40.00%	40.00%	40.00%
Traffic through the 6 GHz Channel (%)	0%	10%	20%	30%	40%
Increase in connected devices due to 6 GHz	0%	4%	8%	12%	16%
Revenue per hotspot if 6 GHz allocated ($)	$489.54	$500.36	$510.66	$520.46	$529.77
Revenue if 6 GHz allocated ($Million)	$0.00	$3.36	$7.57	$12.77	$19.15

Sources: Boingo; Telecom Advisory Services

F.5.3. Wireless ISPs revenues

The 2021 GDP contribution related to the WISP industry was calculated as a function of the number of subscribers (100,000) and the ARPU (from U.S., adjusted by PPP), yielding a total of $50.79 million for 2021, reaching $65.81 by 2025 (Table F-31).

Table F-31. France: WISP revenues (2021-2025)

Variable	2021	2022	2023	2024	2025
Subscribers (Million)	0.10	0.10	0.10	0.10	0.10
Revenues ($Million)	$50.79	$57.37	$59.78	$62.46	$65.81

Sources: Statista; Telecom Advisory Services analysis

Increased revenues of WISPs due to 6 GHz

As described in section E.2.5, the allocation of 6 GHz spectrum band will potentially increase the WISP user base by almost 5,000 subscribers in 2025, due to expanded coverage and better affordability. Thus, by assuming the same ARPU values as cited above, the new subscriptions will amount to an additional $3 million in revenues in 2025 (Table F-32).

Table F-32. France: WISP revenues due to 6 GHz (2021-2025)

Variable	2021	2022	2023	2024	2025
WISP annual ARPU ($)	$507.91	$573.67	$597.76	$624.57	$658.14
New subscribers if 6 GHz allocated (Million)	0.000	0.002	0.003	0.004	0.005
New revenue ($Million)	$0.00	$0.98	$1.62	$2.34	$3.17

Sources: Statista; Telecom Advisory Services analysis

F.6. Wi-Fi ecosystem

The economic value generated by Wi-Fi within Wi-Fi ecosystem companies in France is calculated based on the following three sources:

- The producer surplus (i.e. margins) of residential Wi-Fi devices and equipment manufactured in France;
- The producer surplus of French firms providing products and services in the IoT ecosystem (hardware, software and systems integration) in the country; and
- The producer surplus of French firms providing products and services in the AR/VR ecosystem (hardware, software and content).

F.6.1. Locally manufactured residential Wi-Fi devices and equipment

In section VI.2.4 we calculated the producer surplus attributed to residential Wi-Fi devices and equipment, relying on Milgrom et al. (2011) assumption that consumer surplus could be approximated by that of the producers. Thus, we estimate a total economic value of $6.5 billion in 2021, which we expect to slightly increase to $6.9 billion in 2025 (Table F-33).

Table F-33. France: Producer Surplus from locally manufactured residential Wi-Fi devices and equipment (2021-2025)

Variable	2021	2022	2023	2024	2025
Total producer surplus ($Million)	$6,557.36	$6,875.69	$7,259.22	$7,169.15	$6,946.76

Sources: Consumer Technology Association; ABI Research; CS Markets; Telecom Advisory Services analysis

Locally manufactured Wi-Fi 6 devices and equipment for residential use

As mentioned above, devices for 6 GHz are expected to gradually replace those of prior generations. According to IDC, global shipments of consumer devices linked to 6 GHz (802.11ax) will represent 40% of those from previous generations in 2025. Therefore, we expect the producer surplus attributed to 6 GHz devices to yield $2.8 billion in economic value by 2025 (see Table F-34).

Table F-34. France: Producer Surplus from locally manufactured residential Wi-Fi 6 devices and equipment (2021-2025)

Variable	2021	2022	2023	2024	2025
Consumer 6 GHz / no 6 GHz	3.76%	8.83%	18.59%	28.86%	40.30%
Producer surplus 6 GHz devices ($Million)	$246.88	$607.37	$1,349.16	$2,068.77	$2,799.27

Sources: IDC; Telecom Advisory Services analysis

F.6.2. Firms belonging to the IoT ecosystem

According to estimates from Statista and Bain & Co[182], we expect total industrial IoT revenue in France to amount $13 million in 2021. By relying on the percentage of hardware connectivity spending in IoT in Europe according to AT Kearney[183], we were able to split that value into two main segments: hardware; and software, contents, and services. By weighting those amounts by the share of local production (25% for hardware, 60% for software and services) and the assumed margins (39.44% and 77.46%, respectively), we estimate the overall producer surplus. However, the share attributed to 6 GHz developments should be subtracted from the total economic value. To do so, we estimate a natural growth rate, by subtracting the corresponding share attributed to 6 GHz according to the growth rates indicated in F-34. Thus, we estimate a producer surplus not attributed to 6 GHz of $5 billion in 2021, expecting to reach $6.7 billion in 2025 (Table F-35).

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[182] Source: Bain & Company (2018). "Bain & Company predicts the Internet of Things market will more than double to $520 billion by 2021" Press Release (August 8th)

[183] Source: icom (2016). "IoT & 5G Revolution. The Highway for the future of EU Services and Industry: Energy, Healthcare and manufacturing."

Table F-35. France: IoT ecosystem direct contribution (2021-2025)

Variable	2021	2022	2023	2024	2025
IoT revenue - Hardware ($billions)	$2.46	$2.66	$2.91	$3.18	$3.46
IoT revenue - Software, Contents, Services ($billions)	$10.48	$11.35	$12.40	$13.56	$14.75
Total Industrial IoT revenue in ($Billion)	$12.94	$14.02	$15.31	$16.75	$18.21
Local production (%) - Hardware	25%	25%	25%	25%	25%
Local production (%) - Software & Services	60%	60%	60%	60%	60%
Margins (%) - Hardware	39%	39%	39%	39%	39%
Margins (%) - Software & Services	77%	77%	77%	77%	77%
Margins - IoT Hardware revenue	$0.24	$0.26	$0.28	$0.31	$0.34
Margins - Software, contents and services IoT revenue	$4.87	$5.28	$5.76	$6.30	$6.85
Producer surplus ($Million)	$5,110.30	$5,535.93	$6,048.45	$6,613.87	$7,192.14
Growth rate (%)	8.04%	8.33%	9.26%	9.35%	8.74%
Growth rate not attributed to 6 GHz (%)	7.33%	7.37%	7.98%	8.06%	7.54%
Producer surplus not attributed to 6 GHz ($Million)	$4,997.49	$5,365.78	$5,794.22	$6,261.38	$6,733.53

Sources: Statista, Bain & Co, CSI, Telecom Advisory Services analysis

Wider deployment of Internet of Things under 6 GHz

Following the previous analysis, we were able to estimate which portion of IoT producer surplus growth that can be attributed to 6 GHz. As Table F-36 indicates, we expect the additional IoT surplus generated by 6 GHz to account for $459 million in 2025.

Table F-36. France: IoT direct contribution attributed to 6 GHz (2021-2025) ($Million)

Variable	2021	2022	2023	2024	2025
Producer surplus	$5,110.30	$5,535.93	$6,048.45	$6,613.87	$7,192.14
Producer surplus not attributed to 6 GHz	$4,997.49	$5,365.78	$5,794.22	$6,261.38	$6,733.53
Additional surplus due to 6 GHz	$112.82	$170.16	$254.23	$352.49	$458.61

Sources: Statista, Bain & Co, CSI, Telecom Advisory Services analysis

F.6.3. Firms belonging to the AR/VR ecosystem

Following a similar procedure as with the case of IoT, we were able to estimate the direct contribution of this ecosystem to the French economy. Starting with the local spending in AR/VR by category (hardware, software, and contents), and weighting those figures by the respective shares of local production and margins, we were able to estimate the total producer surplus. By relying on a ratio built from 5 GHz and 6 GHz AR/VR related products, we were able to subtract the specific contribution attributed to 6 GHz from the surplus corresponding to current bands. Then, we expect by 2021 a direct contribution from the AR/VR ecosystem of $173 million, which will increase to $819 million by 2025 (Table F-37).

Table F-37. France: AR/VR ecosystem direct contribution (2021-2025)

Variable	2021	2022	2023	2024	2025
Spending in AR/VR - Hardware $Billion	$0.47	$0.76	$1.09	$1.48	$2.25
Spending in AR/VR - Software, Contents, Services ($Billion)	$0.79	$1.46	$2.31	$3.29	$5.54
Total Spending in AV/VR ($Billion)	$1.26	$2.22	$3.39	$4.78	$7.79
Share of local production - Hardware	24.71%	24.71%	24.71%	24.71%	24.71%
Share of local production - Software, Contents, Services	60.00%	60.00%	60.00%	60.00%	60.00%
Local production for local consumption - Hardware ($Billion)	$0.12	$0.19	$0.27	$0.37	$0.56
Local production for local consumption - Software, Contents, Services ($Billion)	$0.47	$0.88	$1.38	$1.98	$3.32
Local Producer Surplus - Hardware ($Billion)	$0.05	$0.07	$0.11	$0.14	$0.22
Local Producer Surplus - Software, Contents, Services ($Billion)	$0.37	$0.68	$1.07	$1.53	$2.57
Total Producer Surplus	$0.41	$0.75	$1.18	$1.68	$2.79
Share attributable to Wi-Fi (excluding 6 GHz)	42.02%	38.80%	32.18%	30.88%	29.32%
Producer Surplus attributed to Wi-Fi (not including 6 GHz) ($Billion)	$173.26	$292.01	$379.06	$517.36	$819.44

Sources: PwC, ABI; Telecom Advisory Services analysis

Wider deployment of AR/VR solutions if 6 GHz allocated

By relying on a ratio calculated from the relationship between 5 GHz and 6 GHz AR/VR related products, we were able to isolate the specific economic contribution of the new spectrum allocation. Following an approach similar to the one described above, the direct contribution from AR/VR ecosystem in France attributed to 6 GHz in 2025 will yield $427 million.

Table F-38. France: AR/VR direct contribution attributed to 6 GHz (2021-2025)

Variable	2021	2022	2023	2024	2025
Spending in AR/VR ($Billion)	$1.26	$2.22	$3.39	$4.78	$7.79
Share attributed to 6 GHz	24.58%	25.59%	26.64%	27.73%	28.87%
Spending in AR/VR attributed to 6 GHz ($Billion)	$0.31	$0.57	$0.90	$1.33	$2.25
Local production for local consumption 6 GHz ($Billion)	$0.14	$0.27	$0.44	$0.65	$1.12
Local Producer Surplus ($Million)	$84.04	$125.57	$187.02	$262.05	$427.26

Sources: PwC, ABI; Telecom Advisory Services analysis

F.7. Wi-Fi contribution to employment

The estimation of employment generated by Wi-Fi's economic contribution is calculated by relying on the total GDP contribution resulting from the effects analyzed above and using that as an input in the communications sector of an input-output matrix of the French economy. Table F-39 presents the GDP contribution enabled by Wi-Fi, as the sum of all GDP sources discussed above, projected for the period 2021-2025.

Table F-39. France: Wi-Fi enabled GDP contribution (2021-2025)

Year	GDP contribution enabled by Wi-Fi ($Million)		
	Attributed to current bands	Attributed to 6 GHz	Total
2021	$12,726	$377	$13,103
2022	$14,537	$1,702	$16,238
2023	$17,374	$2,635	$20,009
2024	$22,335	$3,185	$25,520
2025	$28,471	$2,728	$31,199

Source: Telecom Advisory Services analysis

These inputs generate the following annual employment effects based on the input/output matrix for the French economy (Table F-40).

Table F-40. France: Wi-Fi generated Annual Employment

Variable	2021			2025		
	Current bands	6 GHz	Total	Current bands	6 GHz	Total
Direct jobs	16,580	491	17,071	37,093	3,554	40,647
Indirect jobs	13,282	393	13,675	29,714	2,847	32,561
Induced jobs	3,788	112	3,900	8,474	812	9,285
Total	33,650	996	34,646	75,280	7,212	82,493

Sources: GTAP; Telecom Advisory Services analysis

According to the contribution to GDP, Wi-Fi will generate approximately 35,000 jobs in 2021 and is expected to create over 82,000 in 2025. Job estimates include direct jobs (those jobs created by the specific Wi-Fi contribution), indirect jobs (those jobs created by suppliers to the Wi-Fi sector) and induced jobs (those jobs created by spending of direct and indirect workers).

The sector breakdown of 2021 employment (including the additional jobs created by 6 GHz) is as follows (Table F-41).

Table F-41. France: Sector Breakdown of Wi-Fi generated annual employment (2021)

Sector	Direct	Indirect	Induced	Total
Agriculture	0	0	43	43
Extractive industries	0	0	5	5
Manufacturing	0	958	94	1,052
Construction	0	331	0	331
Trade	0	1,006	1,212	2,218
Transportation	0	990	0	990
Communications	17,071	0	0	17,071
Financial Services	0	1,644	0	1,644
Business services	0	8,747	0	8,747
Other services	0	0	2,545	2,545
Total	17,071	13,675	3,900	34,646

Sources: GTAP; Telecom Advisory Services analysis

G. ECONOMIC VALUE OF WI-FI IN GERMANY

Wi-Fi has become a pervasive feature in the German telecommunications infrastructure. According to Wiman, there are 1,950,000 free Wi-Fi cites currently operating in the German territory (of which 95,000 are in Berlin, 68,000 are deployed in Hamburg, and 116,000 in Munich). Cisco estimates that there are 300,000 public commercial hot spots operating in the country. Given the Wi-Fi access point density, Wi-Fi has become a very important connectivity feature. According to Opensignal[184], German wireless users spend 71.4% of their communications time connected to Wi-Fi networks rather than relying on their cellular data connection. The important weight of Wi-Fi technology on the digital ecosystem should result in a significant social and economic contribution. This section presents the results and calculations of the economic assessment.

G.1. Total Economic Value of Wi-Fi in Germany (2021-2025)

Before considering the additional effect of allocating the 6 GHz spectrum band for unlicensed use, the total economic value of Wi-Fi in Germany in 2021 will amount to $132.6 billion. In our prior study, Wi-Fi's economic value for 2021 was estimated at $115.3 billion. The increase of $17.3 billion in the updated estimate is mostly due to four new sources of economic value:

- The increasing importance of free Wi-Fi as a platform to address the needs of the population that cannot acquire broadband service due to affordability barriers;
- The increasing benefits of Wi-Fi technology broadband speed;
- A substantial boost to deployment of IoT technology;
- The growing adoption of AR/VR technology.

The total economic value in 2021 is comprised of $62.5 billion in consumer surplus, $41.1 billion in producer surplus, and $29 billion in contribution to GDP. The 2025 forecast of economic value will reach $158 billion without considering the acceleration effect from Wi-Fi 6 and the allocation of the 6 GHz band (this is labeled the baseline scenario). The 2025 forecast of the baseline scenario will be composed of $82.1 billion in consumer surplus, $54.5 billion in producer surplus, and $21.4 billion in GDP contribution (see Table G-1).

[184] Khatri, H. and Fenwick, S. (2020). "Analyzing mobile experience during the coronavirus pandemic: Time on Wi-Fi". *Opensignal* (March 30).

Table G-1. Germany: Economic Value of Wi-Fi (Baseline Scenario)

Agent	Source	Economic Value ($Million)					
		2021	2022	2023	2024	2025	Category
1. Free Wi-Fi	1.1. Savings generated by free Wi-Fi traffic offered in public sites	$507	$521	$536	$550	$564	Consumer Surplus
	1.2. Deployment of free Wi-Fi in public sites	$356	$263	$227	$230	$233	GDP contribution
2. Residential Wi-Fi	2.1. Internet access for home usage of devices that lack a wired port	$10,137	$12,443	$15,188	$18,493	$22,543	Consumer Surplus
	2.2. Avoidance of investment in in-house wiring	$45,100	$47,050	$48,305	$51,131	$52,002	Consumer Surplus
	2.3. Benefit to consumers from speed increases	$1,343	$1,418	$1,475	$1,555	$1,570	Consumer Surplus
	2.4. Residential Wi-Fi devices and equipment deployed	$5,438	$5,569	$5,724	$5,639	$5,453	Consumer Surplus
	2.5. Bridging digital divide: use of Wi-Fi to increase coverage in rural and isolated areas	$205	$197	$191	$184	$178	GDP contribution
3. Enterprise Wi-Fi	3.1. Business Internet traffic transmitted through Wi-Fi	$7,153	$7,807	$8,521	$9,300	$10,150	Producer surplus
	3.2. Avoidance of enterprise inside wiring costs	$19,053	$19,053	$19,053	$19,053	$19,053	Producer surplus
	3.3. Return to speed: contribution to GDP derived from an increase in average mobile speed	$4,557	$4,718	$4,835	$4,904	$4,921	GDP contribution
	3.4. Wide deployment of IoT	$22,918	$16,830	$12,404	$12,549	$12,696	GDP contribution
	3.5. Deployment of AR/VR solutions	$748	$1,221	$1,547	$2,089	$3,237	GDP contribution
4. ISPs	4.1. CAPEX and OPEX savings due to cellular off-loading	$4,486	$6,898	$9,886	$11,352	$11,860	Producer surplus
	4.2. Revenues of service providers offering paid Wi-Fi access in public places	$150	$158	$151	$122	$53	GDP contribution
	4.3. Aggregated revenues of WISPs	$53	$60	$64	$68	$72	GDP contribution
5. Wi-Fi ecosystem	5.1. Locally manufactured residential Wi-Fi devices and equipment	$5,196	$5,457	$5,723	$5,652	$5,477	Producer surplus
	5.2. Locally manufactured Wi-Fi enterprise equipment	$0	$0	$0	$0	$0	Producer surplus
	5.3. Locally produced IoT products and services	$4,970	$5,351	$5,792	$6,271	$6,749	Producer surplus
	5.4. Locally produced of AR/VR solutions	$251	$422	$547	$746	$1,180	Producer surplus
Total		$132,621	$135,436	$140,169	$149,888	$157,991	

Source: Telecom Advisory Services analysis

In addition to the baseline scenario, the allocation of the 6 GHz spectrum band for unlicensed use and the deployment of Wi-Fi 6 and Wi-Fi 6E devices will trigger a growth of economic value, reaching $15.3 billion in 2025 (see Table G-2).

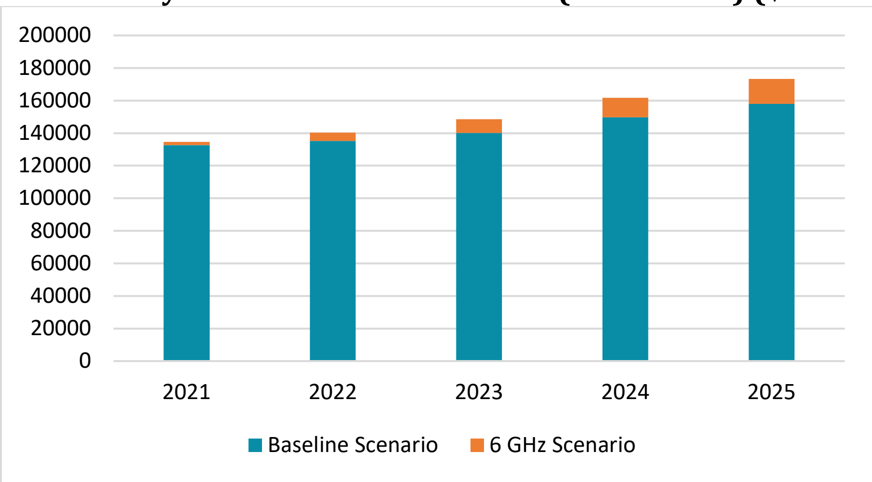
Table G-2. Germany: Economic Value of Wi-Fi (only attributed to 6 GHz)

Agent	Source	Economic Value ($Million)					
		2021	2022	2023	2024	2025	Category
1. Free Wi-Fi	1.1. Savings generated by free Wi-Fi traffic offered in public sites	$0	$0	$0	$0	$0	Consumer Surplus
	1.2. Deployment of free Wi-Fi in public sites	$0	$25	$43	$65	$88	GDP contribution
	1.3. Benefit of faster free Wi-Fi with Wi-Fi 6E devices	$0	$8	$15	$23	$31	Consumer Surplus
2. Residential Wi-Fi	2.3. Benefit to consumers from speed increases	$0	$348	$760	$1,243	$1,512	Consumer Surplus
	2.4. Residential Wi-Fi devices and equipment deployed	$198	$478	$1,038	$1,592	$2,153	Consumer Surplus
	2.5. Bridging digital divide: use of Wi-Fi to increase coverage in rural and isolated areas	$0	$8	$13	$17	$20	GDP contribution
3. Enterprise Wi-Fi	3.1. Business Internet traffic transmitted through Wi-Fi	$0	$367	$394	$423	$397	Producer surplus
	3.3. Return to speed: contribution to GDP derived from an increase in average mobile speed	$0	$1,089	$2,396	$3,857	$4,726	GDP contribution
	3.4. Wide deployment of Internet of Things	$562	$1,095	$989	$1,001	$1,012	GDP contribution
	3.5. Deployment of AR/VR solutions	$363	$525	$763	$1,058	$1,688	GDP contribution
4. ISPs	4.1 CAPEX and OPEX savings due to cellular off-loading	$356	$356	$356	$356	$356	Producer surplus
	4.2. Revenues of service providers offering paid Wi-Fi access in public places	$0	$6	$12	$15	$9	GDP contribution
	4.3. Aggregated revenues of WISPs	$0	$1	$2	$3	$3	GDP contribution
5. Wi-Fi ecosystem	5.1. Locally manufactured residential Wi-Fi devices and equipment	$196	$482	$1,064	$1,631	$2,207	Producer surplus
	5.2. Locally manufactured Wi-Fi enterprise equipment	$0	$0	$0	$0	$0	Producer surplus
	5.3. Locally produced IoT products and services	$115	$175	$262	$363	$472	Producer surplus
	5.4. Locally produced of AR/VR solutions	$122	$182	$270	$378	$615	Producer surplus
Total		$1,912	$5,145	$8,377	$12,025	$15,289	

Source: Telecom Advisory Services analysis

Considering that we forecast that by 2025 only 40% of Wi-Fi traffic will rely on 6 GHz channels, the accelerated effect derived from the new spectrum allocation and latest Wi-Fi technologies will still be far from reaching its maximum potential at this time. If the German regulatory agency decides to allocate the upper part of the spectrum to unlicensed use, Wi-Fi economic value would increase significantly beyond the values presented in Table F-2. A visual depiction of the trend provides a perspective of the growing importance of Wi-Fi 6 in the overall economic value (see Graphic G-1).

Graphic G-1. Germany: Economic Value of Wi-Fi (2021-2025) ($Thousand)



Source: Telecom Advisory Services analysis

By combining the baseline and the Wi-Fi 6 and 6 GHz scenarios, the overall economic value of Wi-Fi for Germany will yield $173.3 billion in 2025 (see Table G-3).

Table G-3. Germany: Total Economic Value of Wi-Fi (including Wi-Fi 6 and 6 GHz)

Agent	Source	Economic Value ($Million)					
		2021	2022	2023	2024	2025	Category
1. Free Wi-Fi	1.1. Savings to consumers of free Wi-Fi traffic offered in public sites	$507	$521	$536	$550	$564	Consumer Surplus
	1.2. Deployment of free Wi-Fi in public sites	$356	$288	$271	$295	$321	GDP contribution
	1.3. Benefit of faster free Wi-Fi with Wi-Fi 6E devices	$0	$8	$15	$23	$31	Consumer Surplus
2. Residential Wi-Fi	2.1. Internet access for home usage of devices that lack a wired port	$10,137	$12,393	$15,188	$18,493	$22,543	Consumer Surplus
	2.2. Avoidance of investment in in-house wiring	$45,100	$47,050	$48,305	$51,131	$52,002	Consumer Surplus
	2.3. Benefit to consumers from speed increases	$1,343	$1,766	$2,235	$2,798	$3,083	Consumer Surplus
	2.4. Residential Wi-Fi devices and equipment deployed	$5,636	$6,047	$6,762	$7,230	$7,606	Consumer Surplus
	2.5. Bridging digital divide: use of Wi-Fi to increase coverage in rural and isolated areas	$213	$221	$228	$235	$240	GDP contribution
3. Enterpris	3.1. Business Internet traffic transmitted through Wi-Fi	$7,153	$8,174	$8,914	$9,722	$10,547	Producer surplus

Agent	Source	Economic Value ($Million)					
		2021	2022	2023	2024	2025	Category
	3.2. Avoidance of enterprise inside wiring costs	$19,053	$19,053	$19,053	$19,053	$19,053	Producer surplus
	3.3. Return to speed: contribution to GDP derived from an increase in average mobile speed	$4,557	$5,807	$7,231	$8,761	$9,647	GDP contribution
	3.4. Wide deployment of IoT	$23,480	$17,926	$13,393	$13,550	$13,708	GDP contribution
	3.5. Deployment of AR/VR solutions	$1,111	$1,746	$2,310	$3,148	$4,924	GDP contribution
4. ISPs	4.1 CAPEX and OPEX savings due to cellular off-loading	$4,842	$7,253	$10,242	$11,708	$12,215	Producer surplus
	4.2. Revenues of service providers offering paid Wi-Fi access in public places	$150	$164	$164	$136	$62	GDP contribution
	4.3. Aggregated revenues of WISPs	$53	$61	$66	$70	$76	GDP contribution
5. Wi-Fi ecosystem	5.1. Locally manufactured residential Wi-Fi devices and equipment	$5,391	$5,939	$6,787	$7,283	$7,684	Producer surplus
	5.2. Locally manufactured Wi-Fi enterprise equipment	0	0	0	0	0	Producer surplus
	5.3. Locally produced IoT products and services	$5,086	$5,526	$6,054	$6,634	$7,221	Producer surplus
	5.4. Locally produced of AR/VR solutions	$373	$604	$817	$1,124	$1,795	Producer surplus
		$134,541	$140,547	$148,571	$161,944	$173,322	

Source: Telecom Advisory Services analysis

The following sections will present in detail the calculation of each source of value, disaggregating the economic contribution under the current spectrum allocation and the enhanced effect due to the allocation of the lower portion of the 6 GHz band.

G.2. Value from free Wi-Fi service

The economic value of free Wi-Fi service is generated through three contribution sources:

- Savings to consumers by accessing the Internet in free Wi-Fi sites rather than incurring cellular costs
- The use of Wi-Fi to expand broadband coverage to the unserved population
- The return to speed of Wi-Fi compared to the use of cellular service

G.2.1. Savings incurred by accessing free Wi-Fi in public sites

The economic value of free Wi-Fi is measured in terms of consumer surplus, that is, by estimating the benefit that flows to consumers as a result of the savings in wireless broadband service acquisition. We start by quantifying the mobile Internet traffic. Given that the traffic per hotspot is decreasing and will continue to do so up to 2025, we will not consider for Germany a free Wi-Fi site congestion bottleneck as was done in most countries under study (Table G-4).

Table G-4. Germany: Total Free Wi-Fi Traffic projection (2021-2025)

Variable	2021	2022	2023	2024	2025
Free Wi-Fi traffic (million GB Per year) - considering current trends	813.75	993.38	1,223.91	1,523.36	1,918.35
Free Wi-Fi hotspots (Million)	2.51	3.39	4.57	6.17	8.34
Traffic per hotspot - considering current trends	324.46	293.34	267.66	246.73	230.11
Traffic per hotspot - capped due to congestion	324.46	293.34	267.66	246.73	230.11
Total traffic (not attributed to 6 GHz) (Million GB)	$813.75	$993.38	$1,223.91	$1,523.36	$1,918.35

Sources: Cisco; Wiman; Telecom Advisory Services analysis

We calculate consumer surplus by multiplying the total free traffic by the difference between what the consumer would have to pay if she/he were to rely on a wireless carrier and the cost of offering free Wi-Fi (incurred by the retailer or public site). To do so, the estimate of the average price per GB of wireless data transmitted by wideband networks was calculated by averaging the most economic "dollar per GB" plan of four major wireless carriers (see Table G-5).

Table G-5. Germany: Average Price Per Gigabyte (2020)

Carrier	Plan	Price per GB ($)
O2 (Telefonica)	120 GB LTE	$0.43
Vodafone	Red Tarife 45	$1.93
Telekom (Deutsche Telekom)	Confort Data L	$2.25

Sources: Operator websites; Telecom Advisory Services analysis

Historical data allowed for a projection of future prices per gigabyte. Based on these prices, we expect the average price per GB will reach an estimated $0.89 in 2025. By relying on the total free Wi-Fi traffic allocation shown in Table G-4 and the average price per cellular gigabyte minus the cost of provisioning Wi-Fi service, we calculated the consumer surplus of free Wi-Fi traffic (see Table G-6).

Table G-6. Germany: Consumer Surplus of Free Wi-Fi Traffic (2021-2025)

Variable	2021	2022	2023	2024	2025
Total Free Traffic (not attributed to 6 GHz) (Million GB)	813.75	993.38	1223.91	1523.36	1918.35
Price per cellular gigabyte ($)	$1.35	$1.22	$1.10	$0.99	$0.89
Cost per Wi-Fi provisioning ($)	$0.73	$0.69	$0.66	$0.63	$0.60
Consumer surplus per gigabyte ($)	$0.62	$0.52	$0.44	$0.36	$0.29
Total Consumer surplus ($Million)	$506.99	$521.04	$535.64	$550.17	$563.86

Sources: Cisco; Websites of cellular operators; Telecom Advisory Services analysis

As indicated in Table VII-6, consumer surplus of free Wi-Fi traffic in 2021 would reach an estimated $507 million, increasing to $564 million in 2025.

Enhanced free Wi-Fi traffic due to 6 GHz allocation

Given that the traffic per hotspot is decreasing, we will not consider for Germany a congestion bottleneck as in other countries. Thus, we will not attribute additional economic effect to the 6 GHz band for free Wi-Fi traffic.

G.2.2. Free Wi-Fi to provide broadband to the unserved population

As explained in section B, deployment of free Wi-Fi provides Internet access to the unserved population. Consumers that do not have broadband at home because they lack the economic means to acquire services can rely on free Wi-Fi to gain Internet access. As a result, through Wi-Fi sites more people can be connected, which in turn enhances the economic contribution of broadband.

The calculation of this economic impact starts by calculating which portion of households that lack broadband service are already accessing Internet through free hotspots. We follow a conservative approach and assume that only 5% of unconnected German households rely on free hotspots for accessing Internet. After calculating the increase in broadband penetration due to households relying on free Wi-Fi, we rely on the broadband impact coefficient from Katz and Callorda (2018b), estimated for Europe. As a result, the GDP contribution of this particular effect is expected to amount to $356 million in 2021, reaching $233 million in 2025.

Table G-7. Germany: GDP contribution due to households relying on Free Wi-Fi (2021-2025)

Variable	2021	2022	2023	2024	2025
Households without Internet	1,527,235	1,124,754	962,139	960,706	959,275
Households that don't buy because access Internet free hotspots (%)	5%	5%	5%	5%	5%
Households served by Free Wi-Fi hot spots	76,362	56,238	48,107	48,035	47,964
Increase in national broadband penetration	0.2%	0.2%	0.1%	0.1%	0.1%
Impact of fixed broadband adoption in GDP	4.63%	4.63%	4.63%	4.63%	4.63%
Increase in the GDP due to the new broadband adoption (% GDP)	0.01%	0.01%	0.01%	0.01%	0.01%
GDP ($Billion)	$3,737.14	$3,787.07	$3,833.84	$3,878.58	$3,923.84
Total impact in GDP ($Million)	$356.24	$263.42	$227.47	$230.13	$232.81

Sources: Eurostat; ITU; Telecom Advisory Services analysis

Enhanced GDP contribution due to 6 GHz allocation

As stated above, Wi-Fi 6 technology enables supporting a high number of devices on a single access point. Accordingly, the improved throughput of free Wi-Fi hotspots under the 6 GHz allocation will allow the possibility of serving additional unconnected households with consistent quality performance.

The potential universe of additional households that could be served under this effect is enormous, as most unconnected households usually identify that costs are their main barrier for accessing to connectivity and thus, may potentially be served by free hotspots as long as they are in proximity to the access point. However, evidence suggests that not many people rely exclusively on free Wi-Fi as their main source of Internet access, so we will follow again a conservative approach and assume that a further 5% of unconnected households will be served through free hotspots under the allocation of the 6 GHz band. On the other hand, we have also considered that the expansion of traffic through the new band will take place gradually, reaching 40% in 2025. All in all, we estimate that additional 18,091 households will be served in 2025 due to free hotspots operating under 6 GHz spectrum, yielding an additional GDP contribution of approximately $88 million (Table G-8).

Table G-8. Germany: GDP contribution due to households relying on Free Wi-Fi due to 6 GHz (2021-2025)

Variable	2021	2022	2023	2024	2025
Households without Internet (not served by free Wi-Fi and not new adopters of WISP)	1,450,873	1,065,961	909,990	907,170	904,560
Potential households that could be served through free Wi-Fi hotspots under increased capacity (% of those not connected)	5%	5%	5%	5%	5%
Traffic through the 6 GHz Channel (%)	0%	10%	20%	30%	40%
Additional households served by Free Wi-Fi hot spots with 6 GHz	0	5,330	9,100	13,608	18,091
Increase in national broadband penetration	0	0.01%	0.02%	0.04%	0.05%
Increase in the GDP due to the new broadband adoption (% GDP)	0.00000%	0.00001%	0.00001%	0.00002%	0.00002%
Total impact in GDP ($Million)	$0.00	$24.96	$43.03	$65.19	$87.81

Sources: Eurostat; ITU; Telecom Advisory Services analysis

G.2.3. Benefit to consumers for enjoying higher speed from free Wi-Fi if 6 GHz band is allocated

When the 6 GHz band is adopted by free Wi-Fi access points it will deliver service at faster broadband speeds. Current speeds from free hotspots are quite modest. Thus, the expanded capabilities due to the allocation of 6 GHz spectrum band will enhance free Wi-Fi speed, and as a result, will increase consumer surplus. We assume that under the 6 GHz allocation, speed from free hotspots will be similar to the Wi-Fi speeds from mobile devices reported by Cisco. After calculating the average speed by considering the expected share of traffic through 6 GHz, we follow Nevo et al. (2016) and calculate the additional consumer surplus per household relying on free Wi-Fi. We expect the consumer surplus resulting from faster speed in free Wi-Fi sites to reach $31 million in 2025 (Table G-9).

Table G-9. Germany: Consumer surplus for enjoying higher speed from free Wi-Fi if 6 GHz band allocated (2021-2025)

Variable	2021	2022	2023	2024	2025
Free Wi-Fi mean speed with no 6 GHz (Mbps)	9.97	10.30	10.64	10.99	11.34
Wi-Fi Speeds from Mobile Device (Mbps)	63.17	78.28	97.00	120.20	148.94
Traffic through the 6 GHz Channel (%)	0.00%	10.00%	20.00%	30.00%	40.00%
Free Wi-Fi mean speed with 6 GHz (Mbps)	9.973	17.098	27.910	43.749	66.385
Demand for average download speed	72.55	73.05	73.55	74.05	74.54
New Demand for average download speed	72.55	84.33	94.96	104.62	113.52
Additional Monthly Consumer surplus	$0.00	$11.28	$21.41	$30.58	$38.97
Additional Yearly Consumer Surplus	$0.00	$135.35	$256.87	$366.90	$467.69
Households that rely on Free Wi-Fi	76,362	61,568	57,207	61,643	66,055
Consumer surplus ($Million)	$0	$8	$15	$23	$31

Sources: Travel Triangle; Nevo et al. (2016); Telecom Advisory Services analysis

G.3. Residential Wi-Fi

The economic value of Wi-Fi in consumer residences is the result of five factors:

- Provision of connectivity to the home network for devices that lack an Ethernet port;
- Cost avoidance of ethernet inside wiring;
- Consumer surplus resulting from faster broadband speeds relative to cellular networks;
- Consumer surplus derived from usage of home devices connected to the home network; and
- Provision of Internet access to consumers located in rural and isolated areas.

G.3.1. Home Internet access for devices that lack an Ethernet port

The underlying premise of this analysis is that in the absence of Wi-Fi, users of devices lacking an Ethernet port would have to depend on the cellular network to gain Internet access. For this reason, estimating value would first measure the traffic generated by these devices at home and then multiply it by the average price charged by cellular carriers.

To estimate the traffic of smartphones and tablets, we relied on 2018 Cisco estimates for the period 2016-21 and extrapolated those growth rates to 2025. It must be said, however, that in 2019 Cisco adjusted its predictions upwards. However, we preferred to rely on the original figures to avoid incurring in the risk of overestimation. Thus, it may be possible that our previsions reported here are slightly downward biased. In addition, we have to consider that according to Cisco IBSG (2012), 43.12% of use time of devices that lack an Ethernet port occurs at home. Therefore, the portion of said traffic generated at home will reach 7,490 million gigabytes in 2021 (see Table G-10).

Table G-10. Germany: Total Mobile Internet Traffic (2021-2025) (million gigabytes)

Variable	2021	2022	2023	2024	2025
Total Annual traffic - Smartphones	11,430.8	15,913.8	21,946.2	30,134.2	41,412.5
Total Annual traffic - Tablets	5,939.7	7,768.4	10,159.9	13,287.8	17,378.6
Share of traffic at Home	43.12%	43.12%	43.12%	43.12%	43.12%
Total Traffic at Home - Smartphones	4,928.7	6,861.7	9,462.7	12,993.2	17,856.1
Total Traffic at Home - Tablets	2,561.1	3,349.5	4,380.7	5,729.4	7,493.3
Total Traffic at Home	7,489.8	10,211.2	13,843.4	18,722.6	25,349.4
Average Price per GB ($)	$1.35	$1.22	$1.10	$0.99	$0.89
Price per home traffic ($Million)	$10,137.38	$12,443.22	$15,187.92	$18,493.49	$22,543.42

Sources: Cisco; GSMA; Telecom Advisory Services analysis

If this traffic had to be transported by cellular networks, at the average price per GB, it would result in costs of $10 billion in 2021 reaching $22.5 billion in 2025.

G.3.2. Avoidance of inside wiring investment

Residential Wi-Fi allows consumers to avoid paying for wiring to connect all home devices (printers, laptops, storage units, etc.). Considering that 88% of connected households will have Wi-Fi in 2021[185], and the wiring cost estimated for households[186], the avoidance costs of inside wiring over 32.5 million households yields a total of $45 billion. By 2025, all connected households are expected to have adopted Wi-Fi, so the savings would have reached $52 billion (Table G-11).

Table G-11. Germany: Consumer surplus from avoidance of investment in in-house wiring (2021-2025)

Variable	2021	2022	2023	2024	2025
Total Wiring Cost	$1,390	$1,390	$1,390	$1,390	$1,390
Households with Internet	37,073,198	37,418,196	37,523,414	37,467,535	37,411,740
Households with Wi-Fi (%)	88%	90%	93%	98%	100%
Households with Internet and Wi-Fi	32,450,000	33,850,000	34,751,808	36,730,000	37,411,740
Inside Wiring Costs ($Million)	$45,100	$47,050	$48,305	$51,131	$52,002

Sources: Eurostat; Burger (2012); Telecom Advisory Services analysis

G.3.3. Benefits derived from speed increase

As described before, consumer surplus increases if users enjoy faster Internet speeds. Thus, the welfare of residential Wi-Fi customers is expected to benefit from faster services than those provided by cellular networks. After weighting the corresponding broadband speeds with the percentage of traffic carried out through Wi-Fi at home, we calculated the average speed advantage of using Wi-Fi in comparison to cellular networks. By applying the parameters determined in Nevo et

[185] Extrapolated from Burger, A. (2012) "Wi-Fi households to approach 800 million by 2016", Telecompetitor.

[186] Our sources indicate two price points for wiring a residence with CAT 5 wire in Germany: € 2,500 and € 1,200. We opted for the lower estimate, although it is important to note the significant difference with U.S. prices.

al. (2016), the expected consumer surplus will yield $1.3 billion in 2021, reaching $1.6 billion in 2025.

Table G-12. Germany: Consumer surplus from faster speed in households (2021-2025)

Variable	2021	2022	2023	2024	2025
Average Speed in households if Wi-Fi traffic were carried through mobile networks (Mbps)	60.10	72.08	86.79	104.92	127.38
Average Speed in household with Wi-Fi (Mbps)	70.14	84.38	101.78	123.10	149.27
Demand for average download speed	112.64	116.35	120.13	123.98	127.89
New Demand for average download speed	116.08	119.86	123.67	127.51	131.39
Additional Monthly Consumer surplus	$3.45	$3.51	$3.54	$3.53	$3.50
Additional Yearly Consumer Surplus	$41.37	$42.08	$42.44	$42.41	$41.97
Households with Internet and Wi-Fi	32,453,094	33,704,730	34,751,808	36,662,562	37,411,740
Impact ($Million)	$1,343	$1,418	$1,475	$1,555	$1,570

Sources: Cisco; Eurostat; Burger (2012); Nevo et al. (2016); Telecom Advisory Services analysis

Additional benefit to consumers from speed increase due to 6 GHz

The welfare of residential Wi-Fi customers is expected to receive further benefit from the 6 GHz allocation due to faster Internet service under Wi-Fi 6E. As previously described in section B, only households acquiring a 150 Mbps (or faster) fixed broadband line will be affected due to current router bottlenecks, and hence, the speed experienced will not be equivalent to that delivered by the fixed network. After calculating the difference in average speed attributed to 6 GHz, the additional consumer surplus will yield $1.5 billion in 2025.

Table G-13. Germany: Consumer surplus from faster speed in households if 6 GHz allocated (2021-2025)

Variable	2021	2022	2023	2024	2025
Households that have connections over 150 Mbps (%)	17.12%	19.60%	22.44%	25.70%	29.42%
Percentage of household traffic that goes through Wi-Fi	51.75%	53.75%	55.74%	57.71%	59.66%
Traffic through the 6 GHz Channel (%)	0.00%	10.00%	20.00%	30.00%	40.00%
Share of traffic affected due to 6 GHz (%)	0.00%	1.05%	2.50%	4.45%	7.02%
Average speed with no 6 GHz (Mbps)	70.14	84.38	101.78	123.10	149.27
Average speed with 6 GHz (Mbps)	70.14	87.70	110.49	139.87	173.89
Demand for average download speed	116.08	119.86	123.67	127.51	131.39
New Demand for average download speed	116.08	120.72	125.49	130.34	134.76
Additional Yearly Consumer Surplus	$0.00	$10.32	$21.87	$33.91	$40.42
Households with Wi-Fi	32,453,094	33,704,730	34,751,808	36,662,562	37,411,740
Impact ($Million)	$0	$348	$760	$1,243	$1,512

Sources: OECD; Cisco; Nevo et al. (2016); Telecom Advisory Services analysis

G.3.4. Residential Wi-Fi devices and equipment

The consumer surplus derived from the adoption of residential Wi-Fi devices and equipment focuses on seven consumers products which are intrinsically linked to Wi-Fi: smart home devices and systems such as Wi-Fi speakers and home security systems, home networking systems, Wi-Fi tablets, access points, external adapters, routers, and gateways. Two different approaches are used in these cases: one assuming that consumer surplus is roughly equal to producer surplus in six of the seven products (excluding tablets), and an assessment of tablets' willingness-to-pay.

The estimation of economic value in the first approach begins by compiling local sales in the six product categories in Germany[187]. After computing the sales in Germany, we applied the prorated margin estimated by CSI markets (39.44%) which yields an estimated producer surplus for these particular products of $5.3 billion in 2021. As mentioned above, it is assumed that the consumer surplus is of the same magnitude. This methodology was also used to calculate the consumer surplus up to 2023. However, the gradual adoption of Wi-Fi 6 devices is forecast to reduce the sales and economic value from the devices relying on the 2.4 GHz and 5 GHz spectrum bands. Non 6 GHz consumer devices shipments are expected by IDC to decrease by 1.2% in 2024 and 3.1% in 2025. Based on this estimate, we extrapolated the consumer surplus from non 6 GHz reliant residential Wi-Fi devices and equipment between 2021 and 2025.

In addition, we calculated the consumer surplus attributable to tablets bought by local consumers. Starting with CTA/Statista worldwide tablet revenue estimates, we interpolated the revenue figures for Germany (by prorating the country's share on global GDP), and extrapolated the evolution of local revenue till 2025 by considering Cisco estimates of tablet evolution for the period. We reviewed the data on tablet prices for the market leader (taking as a reference the Apple iPad 10.2 Inch 128 GB, as Apple has 44.4% of the German market share in tablets[188]) and for the rest of the market (taking as a reference a Samsung Wi-Fi tablet 128 GB), and assumed consumer willingness-to-pay levels in a similar percentage above prices as in the U.S. average. Combining all that information, we were able to estimate a consumer surplus attributable to tablets of $187 million in 2021, expected to reach $108 million in 2025.

In sum, overall consumer surplus for Wi-Fi enabled residential products is expected to yield $5.4 billion in 2021, reaching $5.5 billion in 2025 (Table G-14).

[187] Calculated by prorating data for the United States based on GDP.
[188] Source: Gs StatCounter

Table G-14. Germany: Economic Value of Wi-Fi enabled consumer products (2021-2025)

Variable	2021	2022	2023	2024	2025
Consumer surplus (exc. Tablets) ($Million)	$5,252	$5,410	$5,585	$5,515	$5,344
Tablet consumer surplus ($Million)	$187	$160	$140	$123	$108
Total consumer surplus ($Million)	$5,438	$5,569	$5,724	$5,639	$5,453

Sources: Consumer Technology Association; ABI Research; CS Markets; IDC; Telecom Advisory Services analysis

Consumer surplus derived to Wi-Fi enabled residential equipment for 6 GHz

As commented before, devices for 6 GHz are expected to gradually replace those of former generations. According to IDC, global shipments of consumer devices linked to 6 GHz (802.11ax standard) will represent 40% of the shipments from previous generations. As a result, if the shipments ratio reaches 40% in 2025, we can expect that, at least, the consumer surplus derived from 6 GHz devices will represent an amount of 40% of that of former technology residential devices. As Table G-15 indicates, our estimates for consumer surplus attributed to 6 GHz residential devices amount to $2.2 billion in 2025.

Table G-15. Germany: Economic Value of Wi-Fi enabled consumer products for 6 GHz (2021-2025)

Variable	2021	2022	2023	2024	2025
Consumer surplus (ex. Tablets) ($Million)	$5,252	$5,410	$5,585	$5,515	$5,344
Consumer 6 GHz / no 6 GHz device ratio	3.76%	8.83%	18.59%	28.86%	40.30%
Consumer surplus 6 GHz devices ($Million)	$197.7	$477.9	$1,037.9	$1,591.5	$2,153.5

Sources: IDC; Telecom Advisory Services analysis

G.3.5. Bridging the digital divide: use of Wi-Fi to increase coverage in rural and isolated areas

Wi-Fi is an appropriate technology to offer Internet access in rural and isolated areas. Based on the data provided by Bundesnetzagentur on subscriptions by technology, we can estimate approximately 100,000 WISP subscriptions. The calculation of the Wi-Fi contribution to the reduction of the digital divide must subtract the direct impact of WISPs (Section G.4.3.) to avoid double counting. On the other hand, we assume that 50% of WISP potential connections may be theoretically served by other technologies (i.e. satellite) covering the same isolated footprint. Thus, we can conservatively expect 50% of broadband subscriptions in remote locations exclusively attributed to WISPs. Once this is done, we calculate the impact on GDP by relying on the coefficient estimated by Katz and Callorda (2018b) through regression models that links increase in broadband penetration to economic growth. The contribution to GDP materializes through multiple effects: creation of new businesses, increasing productivity of existing enterprises, and growth of average income per household. We expect a GDP contribution of $205 million in 2021, which will turn into $178 million 2025 (see Table G-16).

Table G-16. Germany: Estimation of GDP Contribution derived from reducing the digital divide (2021-2025)

Variable	2021	2022	2023	2024	2025
WISP subscribers	100,000	100,000	100,000	100,000	100,000
Additional broadband penetration due to WISP	0.27%	0.26%	0.25%	0.24%	0.24%
Impact of fixed broadband adoption in GDP	4.63%	4.63%	4.63%	4.63%	4.63%
GDP ($Billion)	$3,737	$3,787	$3,834	$3,879	$3,924
WISP total impact ($Billion)	$0.46	$0.45	$0.45	$0.44	$0.43
WISP Revenues ($Billion)	$0.05	$0.06	$0.06	$0.07	$0.07
Share that exist because WISP	50.00%	50.00%	50.00%	50.00%	50.00%
WISP spillovers on GDP ($Million)	$204.96	$196.82	$190.67	$184.26	$177.52

Sources: Bundesnetzagentur; IMF; Telecom Advisory Services analysis

The decline in value is the result of capping the number of WISP subscriptions in the context of growing broadband lines.

Economic impact of enhanced coverage and affordability due to 6 GHz

The allocation of the 6 GHz band to unlicensed use would allow WISPs to potentially increase their subscriber base within their same coverage footprint. Therefore, a first effect derived from the allocation of the new spectrum band is related to additional households served due to additional coverage. We will follow a cautious approach and consider that the expanded coverage will yield a gradual increase on WISP subscribers, from 2% in 2022 to 5% in 2025 over the figures projected without assuming the additional spectrum allocation. In addition, an increase of the user base would allow service providers to lower their operating costs. Thus, by assuming stability in prices, affordability would increase as GDP per capita grows as economic growth resumes. All in all, we can expect an overall increase in 6,752 WISP connections in 2025, contributing to an increase 0.02% in national broadband penetration. Considering the impact coefficient of broadband on the economy, which will yield $20 million in GDP contribution.

Table G-17. Germany: GDP Contribution derived from reducing the digital divide due to 6 GHz (2021-2025)

Variable	2021	2022	2023	2024	2025
New subscribers due to expanded coverage (%)	0%	2%	3%	4%	5%
New subscribers due to expanded coverage	0	2,000	3,000	4,000	5,000
New WISP adoption after price decrease (% households)	0.32%	0.27%	0.27%	0.27%	0.27%
Traffic through the 6 GHz Channel (%)	0.00%	10.00%	20.00%	30.00%	40.00%
Increase in WISP connections due to lower prices (households that buy the service)	0	556	1,042	1,500	1,752
Overall increase in WISP connections due to 6 GHz	0	2,556	4,042	5,500	6,752
Increase in national broadband penetration	0.00%	0.01%	0.01%	0.01%	0.02%
Impact of fixed broadband adoption in GDP	4.63%	4.63%	4.63%	4.63%	4.63%
Increase in the GDP due to the new broadband adoption (% GDP)	0.000%	0.000%	0.001%	0.001%	0.001%
Total impact in GDP ($Million)	0.00	8.12	12.60	16.79	20.20

Sources: Bundesnetzagentur; IMF; Telecom Advisory Services analysis

G.4. Enterprise Wi-Fi

Beyond the impact on consumers, Wi-Fi also contributes significant economic value in the German enterprise segment. This section provides estimates in five areas:

- Support of business Internet traffic;
- Avoidance of campus and enterprise facilities inside wiring;
- Contribution to GDP resulting from Wi-Fi speed faster than cellular connections;
- Deployment of IoT solutions; and
- Implementation of business focused AR/VR use cases.

G.4.1. Business Internet traffic transmitted through Wi-Fi

Wi-Fi enterprise savings results from wireless traffic that is routed through Wi-Fi access points. Considering Cisco 2016-21 projections, we estimate that total business Internet traffic will reach 11.4 billion GB in 2021, of which 5.3 billion GB would have been transported through Wi-Fi access points. Considering the average price per GB transported by cellular (from Table VII-5), savings from Wi-Fi will reach $7.2 billion, an addition to the producer surplus[189]. By 2025, this benefit will reach $10.2 billion (see Table G-18).

Table G-18. Germany: Savings in business wireless traffic (2021-2025)

Variable	2021	2022	2023	2024	2025
Share of Business Internet Traffic by Wi Fi	46.00%	47.30%	48.64%	50.02%	51.44%
Total Business Internet Traffic (Million GB)	11,488.2	13,543.1	15,965.5	18,821.2	22,187.8
Total Wi-Fi enterprise traffic (Million GB)	5,284.6	6,406.4	7,766.4	9,415.1	1,141.4
Average Price per GB	$1.35	$1.22	$1.10	$0.99	$0.89
Economic Impact ($Million)	$7,152.63	$7,806.74	$8,520.66	$9,299.88	$10,150.36

Sources: Cisco; Telecom Advisory Services analysis

Enhanced business Internet traffic transmitted through Wi-Fi due to 6 GHz

The deployment of the latest enterprise applications will generate an exponential growth in data traffic that will be handled by devices operating in unlicensed spectrum, through the combination of the existing bands and the 6 GHz band. In 2019, an updated Cisco traffic forecast based on the explosion of IoT and AR/VR applications, among other factors, increased total business Internet traffic previsions from the previous 2016-21 estimates from 2018. As in the case of the U.S., we assume that part of the growth was driven by "natural" growth, and another portion was triggered by Wi-Fi traffic stimulated by changes in 6 GHz. The sum of the difference due to broader Wi-Fi traffic will reach $397 million in 2025 (see Table G-19).

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[189] We acknowledge that enterprises are likely to negotiate wireless rates lower than those offered in the consumer market; however, data in this area is not available.

Table G-19. Germany: Savings in business wireless traffic due to 6 GHz (2021-2025)

Variable	2021	2022	2023	2024	2025
Total value of business Wi-Fi traffic 2016-21 ($Million)	$7,152.63	$7,806.74	$8,520.66	$9,299.88	$10,150.36
Total value of business Wi-Fi traffic 2017/22 ($Million)	$10,323.9	$11,210.7	$12,173.8	$13,219.6	$14,355.2
Difference between the 2 estimations ($Million)	$3,171.2	$3,404.0	$3,653.1	$3,919.7	$4,204.9
Difference because natural growth ($Million)	$2,970.9	$3,037.0	$3,259.3	$3,497.2	$3,751.6
Difference due to 6 GHz ($Million)	$0.00	$366.96	$393.81	$422.55	$396.73

Sources: Cisco; Telecom Advisory Services analysis

G.4.2. Avoidance in enterprise building inside wiring

Similar to residential Wi-Fi savings due to capital investment avoidance in inside wiring, we assume that the total number of business establishments are equipped with Wi-Fi access points and multiply this value by a standard cost of deploying a CAT 6 network (although in this case, the cost is $6,639 per building[190]) (see Table G-20).

Table G-20. Germany: Savings in business wiring CAPEX (2021-2025)

Variable	2021	2022	2023	2024	2025
Total Wiring Cost	$6,639	$6,639	$6,639	$6,639	$6,639
Number of Establishments	2,869,925	2,869,925	2,869,925	2,869,925	2,869,925
Establishments with Wi-Fi (%)	100%	100%	100%	100%	100%
Establishments with Wi-Fi	2,869,925	2,869,925	2,869,925	2,869,925	2,869,925
Inside Wiring Costs ($Million)	$19,053	$19,053	$19,053	$19,053	$19,053

Sources: Trading Economics; Telecom Advisory Services analysis

G.4.3. Return to speed: contribution to GDP derived from an increase in average mobile speed

Since Wi-Fi accessibility allows, in general, faster access to the Internet than cellular networks do, higher speeds have a positive contribution on the economy in terms of increased overall efficiency and innovation. This contribution is measured in terms of economic growth. As described in section VII.2.3 for the case of consumer surplus, we start with the quantification of the average broadband speed if cellular networks transported all Wi-Fi traffic, and compare it with the presence of Wi-Fi technology (see Table G-21).

[190] The cost of deploying inside telecommunication wiring was calculated by multiplying the percent difference between a house and an office in the United States by the high-end estimate for wiring a house in Germany, which results in $6,639.

Table G-21. Germany: Estimation of speed differential for total traffic (2021-2025)

Variable	2021	2022	2023	2024	2025
Average Download Speed if Wi-Fi traffic were carried through mobile networks (Mbps)	60.10	72.08	86.79	104.92	127.38
Average Speed with Wi-Fi (Mbps)	70.14	84.38	101.78	123.10	149.27
Speed increase (%)	17%	17%	17%	17%	17%
Impact of speed in GDP	0.73%	0.73%	0.73%	0.73%	0.73%
Increase in GDP	0.12%	0.12%	0.13%	0.13%	0.13%
GDP ($Billion)	$3,737.14	$3,787.07	$3,833.84	$3,878.58	$3,923.84
GDP increase ($Million)	$4,557	$4,718	$4,835	$4,904	$4,921

Sources: Cisco; IMF; Telecom Advisory Services analysis

Having calculated the speed increase percentage, we then apply this percentage to the coefficient derived from the model developed by Katz and Callorda (2019) to gauge the potential impact on GDP from Wi-Fi enhanced speed. Table G-21 indicates that the economic value of Wi-Fi in terms of increasing the speed of transporting wireless will account to $4.6 billion in 2021, reaching $4.9 billion in 2025.

Return to Speed additional effect due to 6 GHz

As previously described, only those broadband connections above 150 Mbps will be affected due to current router bottlenecks, and hence, the speed experienced will not be equivalent to that delivered by the fixed network. Thus, the allocation of the 6 GHz band will remove those barriers, increasing broadband speed. After calculating the difference in average speed attributed to 6 GHz, the additional GDP contribution will yield $4.7 billion in 2025 (Table G-22).

Table G-22. Germany: Estimation of speed differential due to 6 GHz (2021-2025)

Variable	2021	2022	2023	2024	2025
Mean speed with no 6 GHz (Mbps)	70.14	84.38	101.78	123.10	149.27
Mean speed with 6 GHz (Mbps)	70.14	87.70	110.49	139.87	173.89
Speed increase due to 6Ghz (%)	0%	4%	9%	14%	16%
Impact speed on GDP	0.73%	0.73%	0.73%	0.73%	0.73%
Increase in GDP (%)	0.00%	0.03%	0.06%	0.10%	0.12%
GDP increase ($Million)	$0	$1,089	$2,396	$3,857	$4,726

Sources: Cisco; IMF; Telecom Advisory Services analysis

G.4.4. IoT deployment

IoT adoption has a contribution to GDP growth through the multiplicity of use cases that improve efficiency in processes such as preventive maintenance, production monitoring and the like. To estimate this, we rely on a coefficient of GDP impact calculated through an aggregate simple production function which estimates that a 10% rise in M2M connections results in annual increases in GDP of between 0.3% and 0.9%[191]. Given the strength of the industrial and technological sector in Germany, we assume a 0.9% GDP increase after a 10% raise in M2M.

[191] See Frontier Economics (2018)

Starting with a 2021 installed base of 24.88 million M2M devices, we estimate the growth between 2020 and 2021 that can be exclusively attributed to the allocation of additional spectrum to indoor Wi-Fi devices. Thus, by subtracting the growth in M2M attributed to 6 GHz, it is estimated that the IoT impact for 2021 according to the natural growth would reach $23 billion (see Table G-23).

Table G-23. Germany: GDP Contribution of IoT Deployment Boost (2021-2025)

Variable	2021	2022	2023	2024	2025
Connections, Cellular M2M	24,878,519	26,266,943	27,361,830	28,502,355	29,690,421
Growth Rate (%)	7.48%	5.58%	4.17%	4.17%	4.17%
Natural Growth Rate (%)	6.81%	4.94%	3.60%	3.60%	3.60%
Impact of 1% M2M Growth on GDP	9.00%	9.00%	9.00%	9.00%	9.00%
Impact on GDP (%)	0.61%	0.44%	0.32%	0.32%	0.32%
GDP ($Billion)	$3,737	$3,787	$3,834	$3,879	$3,924
Impact ($Million)	$22,917.66	$16,830.43	$12,404.45	$12,549.21	$12,695.66

Sources: GSMA Intelligence; Frontier Economics; IMF; Telecom Advisory Services analysis

Accelerated effect of IoT due to 6 GHz

As described above, a share of the M2M growth can be attributed to 6 GHz developments. According to the data in Table G-24, cumulative impact of enhanced IoT deployment driven by 6 GHz spectrum proposals will reach $1 billion by 2025.

Table G-24. Germany: GDP Contribution of IoT Deployment Boost caused by 6 GHz (2021-2025)

Variable	2021	2022	2023	2024	2025
Growth due to 6 GHz (%)	0.67%	0.64%	0.57%	0.57%	0.57%
Level of development of new bands (%)	50%	100%	100%	100%	100%
Impact on GDP (%)	0.02%	0.03%	0.03%	0.03%	0.03%
Impact ($Million)	$562.34	$1,095.49	$989.05	$1,000.59	$1,012.27

Sources: GSMA Intelligence; Frontier Economics; IMF; Telecom Advisory Services analysis

G.4.5. Deployment of AR/VR solutions

The adoption of AR/VR among German business will in turn have a spillover effect on productivity, thereby contributing to the growth of GDP. Estimating spillover effects of AR/VR is a not a trivial exercise considering the embryonic adoption of some of these use cases. Since the objective is to estimate the spillover effect of AR/VR sales by local firms in the domestic market, we will take as points of departure the estimate by PwC of the total GDP contribution of AR/VR for 2021 and 2022, and the sales of AR/VR components as estimated by ABI research. The extrapolation of these two parameters allow estimating the indirect (spillover) contribution of AR/VR to the local economy for the period under analysis.

Starting values are reduced by the proportion that can be attributed to the impact of the 6 GHz spectrum bands. To do so, we took as a reference a ratio of AR/VR product developments according to each technology. Once the amount to be attributed in both GDP contribution and direct sales is estimated, the annual indirect to direct multiplier can be calculated. The lowest multiplier value is applied to sales of AR/VR in the local market to calculate the total spillovers (see Table G-25). Total spillover value of AR/VR in Germany in 2021 will account for $748 million and is expected to increase by 2025 to $3.2 billion.

Table G-25. Germany: GDP contribution resulting from AR/VR spillovers (2021-2025)

Variable	2021	2022	2023	2024	2025
AR/VR total contribution to GDP ($Billion)	$9.80	$13.90	$19.30	$27.70	$41.70
Share attributed to Wi-Fi (excluding 6 GHz)	42.02%	38.80%	32.18%	30.88%	29.32%
Portion of GDP contribution attributed to Wi-Fi (excluding 6 GHz) ($Billion)	$4.12	$5.39	$6.21	$8.55	$12.23
Direct impact (sales) attributed to Wi-Fi (excluding 6 GHz) ($Billion)	$0.75	$1.22	$1.55	$2.09	$3.24
Indirect impact ($Billion)	$3.37	$4.17	$4.66	$6.46	$8.99
Indirect/Direct multiplier	1.00	1.00	1.00	1.00	1.00
Indirect impact ($Million)	$747.93	$1,220.65	$1,546.95	$2,089.45	$3,236.79

Sources: PwC, ABI; Telecom Advisory Services analysis

Wider deployment of AR/VR solutions (accelerated effect due to 6 GHz)

Higher throughput enabled by the allocation of the 6 GHz band is expected to spur the adoption and use of AR/VR among enterprises, hence increasing the associated spillover effects. By relying on the ratio built from 5 GHz and 6 GHz AR/VR related products, we were able to isolate the specific economic contribution of the new spectrum allocation. Following a similar procedure as that described above, spillovers from AR/VR in Germany attributed to 6 GHz in 2021 will account for $363 million and are expected to increase by 2025 to $1.7 billion (Table G-26).

Table G-26. Germany: GDP contribution resulting from AR/VR spillovers due to 6 GHz (2021-2025)

Variable	2021	2022	2023	2024	2025
AR/VR total contribution to GDP ($Billion)	$9.80	$13.90	$19.30	$27.70	$41.70
Share attributed to 6 GHz (%)	24.58%	25.59%	26.64%	27.73%	28.87%
Portion of GDP contribution attributed to 6 GHz ($Billion)	$2.41	$3.56	$5.14	$7.68	$12.04
Direct impact (sales) attributed to 6 GHz ($Billion)	$0.44	$0.80	$1.28	$1.88	$3.19
Indirect impact ($Billion)	$1.97	$2.75	$3.86	$5.81	$8.85
Indirect/Direct multiplier	1.00	1.00	1.00	1.00	1.00
Indirect impact ($Million)	$362.78	$524.93	$763.23	$1,058.34	$1,687.70

Sources: PwC, ABI; Telecom Advisory Services analysis

G.5. Internet Service Providers

In addition to the economic value generated by the sources analyzed above, Wi-Fi will also contribute to either producer surplus or GDP of Internet Service Providers. This section will assess the economic value in three sources:

- Producer surplus of cellular operators resulting from CAPEX savings incurred in network deployment

- Revenues of Wi-Fi carriers offering service in public spaces
- Revenues of Wireless ISPs (this effect differs from the GDP impact of WISPs as a result of their deployment in rural and isolated areas analyzed in section G.3.5.)

G.5.1. Cellular network savings by off-loading traffic to Wi-Fi

The estimation of CAPEX savings starts by considering the GSMA Intelligence aggregate projected investment by wireless carriers in Germany, which amounts to $30.5 billion between 2019 and 2025. Considering the total CAPEX required to deploy 5G in Germany, and the incremental 5G coverage between 2021 and 2025 we are able to interpolate the 5G CAPEX for each year of the period considered. It is assumed that all the CAPEX invested during the period would be dedicated to 5G deployment.

Based on the simulation model developed to forecast the impact of Wi-Fi off-loading in 5G deployment, we estimate that the savings of deploying carrier-grade Wi-Fi complementing the rollout of 5G to accommodate future traffic growth would amount to 32.9% of CAPEX, while the OPEX savings are $2.82 for each dollar saved in CAPEX. This would result in a total producer surplus (adding CAPEX and OPEX savings) of $4.5 billion in 2021, increasing to 11.9 billion in 2025, when 5G coverage will reach 90% (see Table G-27).

Table G-27. Germany: Savings due to traffic off-loading (2021-2025)

Variable	2021	2022	2023	2024	2025
5G coverage	27%	38%	53%	71%	90%
CAPEX without saving	$3,569.64	$5,488.26	$7,866.34	$9,032.66	$9,436.58
CAPEX reduction due to Wi-Fi off-loading	$1,174.4	$1,805.6	$2,588.0	$2,971.7	$3,104.6
OPEX reduction due to Wi-Fi off-loading	$3,311.8	$5,091.9	$7,298.2	$8,380.3	$8,755.1
Total Cost of Ownership ($Million)	$4,486	$6,898	$9,886	$11,352	$11,860

Sources: GSMA; Telecom Advisory Services analysis

Enhanced capability for cellular off-loading if 6 GHz allocated

The complementarity between Wi-Fi and cellular networks for Wi-Fi 6E and 5G, adds further potential gains derived from the savings in capital and operating expenses required to accommodate exploding data traffic. The key objective is to estimate the savings in capital investment as a result of an increase in traffic offloading with Wi-Fi benefits from the additional spectrum allocated, particularly, due to the ability to leverage 160 MHz within single contiguous channels. The estimation of CAPEX savings starts by considering the GSMA Intelligence aggregate investment estimates of 5G deployments. By relying again on the geographic disaggregation of Oughton and Frias, we estimate that CAPEX can be split in urban, suburban and rural geographies. We conservatively assume that Wi-Fi 6 will not be critical in sustaining investment in urban areas, but that it will play a significant role beyond those geographies. Based on the cost advantage of carrier grade Wi-Fi, we assume that it will become effective for a portion of the suburban (approximately 15%) and rural network (approximately 5%) deployment. Therefore, this will yield yearly CAPEX savings of $356 million.

G.5.2. Wi-Fi carrier revenues

The value of Wi-Fi carriers includes the sum of revenues through paid public Wi-Fi access. In order to estimate those aggregated revenues, we start by calculating the number of commercial Wi-Fi hotspots in Germany. According to Cisco, in 2021 there will be almost 21 million public Wi-Fi hotspots in the country, although that figure includes home spots (such as the guest account service provided by cable operators). By subtracting the home spots from the public Wi-Fi estimates of Cisco, we calculated a total of 300,000 commercial Wi-Fi hotspots for 2021, which will decrease till reaching 110,000 in 2025. On the other hand, based on revenue figures per hotspot from Boingo for the U.S., by adjusting by PPP we were able to estimate a figure for the case of Germany. Then, we estimate total revenues generated by this sector in Germany: $150 million in 2021, gradually decreasing to reach $53 million in 2025 (Table G-28).

Table G-28. Germany: Revenues of Wi-Fi carriers (2021-2025)

Variable	2021	2022	2023	2024	2025
Public Wi-Fi hotspots (Million)	21.17	28.59	38.60	52.12	70.38
Home spots (Million)	20.88	28.28	38.30	51.88	70.27
Commercial Wi-Fi hotspots (Million)	0.30	0.31	0.30	0.24	0.11
Revenue per hotspot ($)	$507.66	$506.17	$504.68	$503.20	$501.73
Revenue ($Million)	$150.41	$157.55	$151.41	$121.85	$53.32

Sources: Cisco, Boingo, Telecom Advisory Services

Increased revenues of Wi-Fi carriers in public places due to 6 GHz

The allocation of the 6 GHz spectrum band offers an opportunity for commercial Wi-Fi carriers to enhance their business. As Wi-Fi 6E developments will allow up to 1,500 connected devices per access point, Wi-Fi carriers will have the possibility of adding more clients without quality limitations due to congestion. By considering a conservative potential increase of 40% in the number of connected devices in public venues and weighting that figure by the gradual expansion of the latest technology, we expect commercial Wi-Fi carriers to increase their user base by 16% in 2025. If the revenue per hotspot increases in the same amount, that will yield an increase in overall revenues for the sector of an additional $8.5 million by 2025 (Table G-29).

Table G-29. Germany: Revenues of Wi-Fi carriers due to 6 GHz (2021-2025)

Variable	2021	2022	2023	2024	2025
Potential increase in connected devices in public venues	40.00%	40.00%	40.00%	40.00%	40.00%
Traffic through the 6 GHz Channel (%)	0%	10%	20%	30%	40%
Increase in connected devices due to 6 GHz	0%	4%	8%	12%	16%
Revenue per hotspot if 6 GHz allocated ($)	$507.66	$526.41	$545.06	$563.59	$582.00
Revenue if 6 GHz allocated ($Million)	$0.00	$6.30	$12.11	$14.62	$8.53

Sources: Boingo; Telecom Advisory Services analysis

G.5.3. Wireless ISPs revenues

The 2021 GDP contribution related to the WISP industry was calculated as a function of the number of subscribers (100,000) and the ARPU (from U.S., adjusted by PPP), yielding a total of $53 million (Table G-30).

Table G-30. Germany: WISP revenues (2021-2025)

Variable	2021	2022	2023	2024	2025
Subscribers (Million)	0.10	0.10	0.10	0.10	0.10
Revenues ($Million)	$52.67	$60.35	$63.80	$67.63	$72.30

Sources: Bundesnetzagentur, Telecom Advisory Services analysis

Increased revenues of WISPs due to 6 GHz

As described in section G.2.5, the allocation of 6 GHz spectrum band will potentially increase the WISP user base in 5,000 subscribers by 2025, due to expanded coverage and better affordability. Thus, by assuming the same ARPU values as described above, the new subscriptions will amount to an additional $3.4 million in revenues in 2025 (Table G-31).

Table G-31. Germany: WISP revenues due to 6 GHz (2021-2025)

Variable	2021	2022	2023	2024	2025
WISP annual ARPU ($)	$526.71	$603.54	$638.02	$676.33	$723.03
New subscribers if 6 GHz allocated (Million)	0.000	0.002	0.003	0.004	0.005
New revenue ($Million)	$0.00	$1.08	$1.81	$2.60	$3.42

Sources: Bundesnetzagentur, Telecom Advisory Services analysis

G.6. Wi-Fi ecosystem

The economic value generated by Wi-Fi within Wi-Fi ecosystem companies in Germany is generated from the following three sources:

- The producer surplus (i.e. margins) of residential Wi-Fi devices and equipment manufactured in Germany;
- The producer surplus of local firms providing products and services in the IoT ecosystem (hardware, software and systems integration) in Germany; and
- The producer surplus of local firms providing products and services in the AR/VR ecosystem (hardware, software and content) in Germany.

G.6.1 Locally manufactured residential Wi-Fi devices and equipment

In section G.3.4 we calculated the producer surplus attributed to residential Wi-Fi devices and equipment, relying on Milgrom et al. (2011) assumption that consumer surplus could be approximated by that of the producers. We estimate a total economic value of $5.2 billion in 2021, which we expect to slightly increase to $5.5 billion in 2025 (Table G-32).

Table G-32. Germany: Producer Surplus from locally manufactured residential Wi-Fi devices and equipment (2021-2025)

Variable	2021	2022	2023	2024	2025
Total producer surplus ($Million)	$5,195.71	$5,456.79	$5,722.97	$5,651.96	$5,476.64

Sources: Consumer Technology Association; ABI Research; CS Markets; Telecom Advisory Services analysis

Locally manufactured Wi-Fi 6 devices and equipment for residential use

As mentioned above, devices for 6 GHz are expected to gradually replace those of prior generations. According to IDC, global shipments of consumer devices linked to 6 GHz (802.11ax) will represent 40% of the shipments of those from previous generations in 2025. Therefore, we expect the producer surplus attributed to 6 GHz devices to yield $2.2 billion by 2025.

Table G-33. Germany: Producer Surplus from locally manufactured residential Wi-Fi 6 devices and equipment (2021-2025)

Variable	2021	2022	2023	2024	2025
Consumer 6 GHz / no 6 GHz	3.76%	8.83%	18.59%	28.86%	40.30%
Producer surplus 6 GHz devices ($Million)	$195.61	$482.03	$1,063.64	$1,630.96	$2,206.87

Sources: IDC; Telecom Advisory Services analysis

G.6.2. Firms belonging to the IoT ecosystem

According to estimates from Statista and Bain & Co, we expect total industrial IoT revenue in Germany to amount $12.75 million in 2021. By relying on the percentage of hardware connectivity spending in IoT in Europe, we were able to split that figure into two main segments: hardware; and software, contents, and services. By weighting those amounts by the share of local production (30% for hardware, 60% for software and services) and the assumed margins (39.44% and 77.46%, respectively), we can estimate the overall producer surplus. However, to that economic value we should extract the share attributed to 6 GHz developments. To do so, we estimated a natural growth rate, by subtracting the corresponding share attributed to 6 GHz according to the growth rates indicated in Table G-33. Thus, we estimate a producer surplus not attributed to 6 GHz of $4.97 billion in 2021, expected to reach $6.75 billion in 2025 (Table G-34).

Table G-34. Germany: IoT ecosystem direct contribution (2021-2025)

Variable	2021	2022	2023	2024	2025
IoT revenue - Hardware ($billions)	$2.42	$2.63	$2.88	$3.16	$3.44
IoT revenue - Software, Contents, Services ($billions)	$10.33	$11.22	$12.29	$13.47	$14.66
Total Industrial IoT revenue in ($Billion)	$12.75	$13.85	$15.18	$16.63	$18.10
Local production (%) - Hardware	30%	30%	30%	30%	30%
Local production (%) - Software & Services	60%	60%	60%	60%	60%
Margins (%) - Hardware	39%	39%	39%	39%	39%
Margins (%) - Software & Services	77%	77%	77%	77%	77%
Margins - IoT Hardware revenue	$0.29	$0.31	$0.34	$0.37	$0.41
Margins - Software, contents and services IoT revenue	$4.80	$5.22	$5.71	$6.26	$6.81
Producer surplus ($Million)	$5,085.50	$5,526.31	$6,053.88	$6,634.21	$7,220.74
Growth rate (%)	8.48%	8.67%	9.55%	9.59%	8.84%
Growth rate not attributed to 6 GHz (%)	7.72%	7.67%	8.23%	8.27%	7.63%
Producer surplus not attributed to 6 GHz ($Million)	$4,970.12	$5,351.30	$5,791.90	$6,270.75	$6,748.90

Sources: Statista, Bain & Co, CSI, Telecom Advisory Services analysis

Wider deployment of Internet of Things under 6 GHz

Following the previous analysis, we were able to estimate which portion of IoT producer surplus growth can be attributed to 6 GHz. As Table G-35 indicates, we expect the additional IoT surplus generated by 6 GHz to account for $472 million in 2025.

Table G-35. Germany: IoT direct contribution attributed to 6 GHz (2021-2025)

Variable	2021	2022	2023	2024	2025
Producer surplus ($Million)	$5,085.50	$5,526.31	$6,053.88	$6,634.21	$7,220.74
Producer surplus not attributable to 6 GHz ($Million)	$4,970.12	$5,351.30	$5,791.90	$6,270.75	$6,748.90
Additional surplus due to 6 GHz ($Million)	$115.39	$175.01	$261.98	$363.46	$471.84

Sources: Statista, Bain & Co, CSI, Telecom Advisory Services analysis

G.6.3. Firms belonging to the AR/VR ecosystem

Following a similar procedure as with the case of IoT, we can estimate the direct contribution of this ecosystem to the German economy. Starting with the local spending in AR/VR by category (hardware, software, and contents), and weighting those figures by the respective shares of local production and margins, we were able to estimate the total producer surplus. By relying on a ratio built from 5 GHz and 6 GHz AR/VR related products, we were able to subtract the specific contribution attributed to 6 GHz from the surplus corresponding to current bands. Then, we expect by 2021 a direct contribution from the AR/VR ecosystem of $251 million, which will increase until reaching $1.2 billion by 2025 (Table G-36).

Table G-36. Germany: AR/VR ecosystem direct contribution (2021-2025)

Variable	2021	2022	2023	2024	2025
Spending in AR/VR - Hardware $Billion	$0.66	$1.08	$1.54	$2.10	$3.19
Spending in AR/VR - Software, Contents, Services ($Billion)	$1.12	$2.07	$3.27	$4.66	$7.85
Total Spending in AV/VR ($Billion)	$1.78	$3.15	$4.81	$6.77	$11.04
Share of local production - Hardware	29.96%	29.96%	29.96%	29.96%	29.96%
Share of local production - Software, Contents, Services	60.00%	60.00%	60.00%	60.00%	60.00%
Local production for local consumption - Hardware ($Billion)	$0.20	$0.32	$0.46	$0.63	$0.96
Local production for local consumption - Software, Contents, Services ($Billion)	$0.67	$1.24	$1.96	$2.80	$4.71
Local Producer Surplus - Hardware ($Billion)	$0.08	$0.13	$0.18	$0.25	$0.38
Local Producer Surplus - Software, Contents, Services ($Billion)	$0.52	$0.96	$1.52	$2.17	$3.65
Total Producer Surplus	$0.60	$1.09	$1.70	$2.42	$4.02
Share attributable to Wi-Fi (excluding 6 GHz)	42.02%	38.80%	32.18%	30.88%	29.32%
Producer Surplus attributed to Wi-Fi (not including 6 GHz) ($Million)	$251.13	$422.20	$547.08	$746.11	$1,179.84

Sources: PwC, ABI; Telecom Advisory Services analysis

Wider deployment of AR/VR solutions if 6 GHz allocated

By relying on a ratio built from 5 GHz and 6 GHz AR/VR related products, we were able to isolate the specific economic contribution of the new spectrum allocation. Following a similar procedure as that described above, the direct contribution from AR/VR ecosystem in Germany attributed to 6 GHz in 2025 will yield $615 million.

Table G-37. Germany: AR/VR direct contribution attributed to 6 GHz (2021-2025)

Variable	2021	2022	2023	2024	2025
Spending in AR/VR ($Billion)	$1.78	$3.15	$4.81	$6.77	$11.04
Share attributed to 6 GHz	24.58%	25.59%	26.64%	27.73%	28.87%
Spending in AR/VR attributed to 6 GHz ($Billion)	$0.44	$0.80	$1.28	$1.88	$3.19
Local production for local consumption 6 GHz ($Billion)	$0.21	$0.40	$0.65	$0.95	$1.64
Local Producer Surplus ($Million)	$121.81	$181.56	$269.92	$377.92	$615.18

Sources: PwC, ABI; Telecom Advisory Services analysis

G.7. Wi-Fi contribution to employment

The estimation of employment generated is calculated by relying on the total GDP contribution resulting from the effects analyzed above and using that as an input in the communications sector of an input-output matrix of the German economy. Table G-38 presents the GDP contribution enabled by Wi-Fi projected for the period 2021-2025.

Table G-38. Germany: Wi-Fi enabled GDP contribution (2021-2025)

Year	GDP contribution enabled by Wi-Fi ($Million)		
	Attributed to current bands	Attributed to 6 GHz	Total
2021	$28,987	$925	$29,912
2022	$23,447	$2,750	$26,198
2023	$19,420	$4,217	$23,637
2024	$20,146	$6,015	$26,161
2025	$21,390	$7,546	$28,935

Source: Telecom Advisory Services analysis

These inputs generate the following annual employment effects based on the input/output matrix for the German economy (Table G-39).

Table G-39. Germany: Wi-Fi generated Annual Employment

Variable	2021			2025		
	Current bands	6 GHz	Total	Current bands	6 GHz	Total
Direct jobs	48,428	1,546	49,974	35,736	12,606	48,343
Indirect jobs	31,205	0,996	32,201	23,027	8,123	31,150
Induced jobs	10,460	0,334	10,794	7,719	2,723	10,442
Total	90,094	2,875	92,969	66,482	23,452	89,934

Sources: GTAP; Telecom Advisory Services analysis

According to the contribution to GDP, Wi-Fi will generate approximately 93,000 jobs in 2021 and is expected to generate almost 90,000 in 2025. Job estimates include direct jobs (those jobs created by the specific Wi-Fi contribution), indirect jobs (those jobs created by suppliers to the Wi-Fi sector) and induced jobs (those jobs created by spending of direct and indirect workers).

The sector breakdown of 2021 employment (including the additional jobs created by 6 GHz) is as follows (Table G-40).

Table G-40. Germany: Sector Breakdown of Wi-Fi generated annual employment (2021)

Sector	Direct	Indirect	Induced	Total
Agriculture	0	0	38	38
Extractive industries	0	0	34	34
Manufacturing	0	2,414	53	2,467
Construction	0	4,642	0	4,642
Trade	0	2,046	2,461	4,506
Transportation	0	1,898	0	1,898
Communications	49,974	0	0	49,974
Financial Services	0	1.694	0	1,694
Business services	0	19,508	0	19,508
Other services	0	0	8,209	8,209
Total	49,974	32,201	10,794	92,969

Sources: GTAP; Telecom Advisory Services analysis

H. ECONOMIC VALUE OF WI-FI IN SPAIN

Wi-Fi has become a pervasive feature in the Spanish telecommunications landscape. The Cisco Annual Internet Report Highlights Tool 2018-2023 estimates for 2018 point to the existence of 200,000 public commercial hot spots in Spain, while the Wiman site estimates that there are currently 986,000 free Wi-Fi hotspots. In addition, 87% of broadband households are equipped with a Wi-Fi router. According to OpenSignal[192], after the outbreak of COVID-19 Spanish wireless users currently spend 73.1% of their communications time connected to Wi-Fi networks rather than relying on their cellular data connection. The important deployment and use of Wi-Fi technology in Spain should result in a significant social and economic contribution. This section presents the results and calculations of the economic assessment.

H.1. Total Economic Value of Wi-Fi in Spain (2021-2025)

Before considering the additional effect of allocating the 6 GHz spectrum band for unlicensed use (baseline scenario), the total economic value of Wi-Fi in Spain in 2021 will amount to $39.7 billion. This amount is comprised of $15.8 billion in consumer surplus, $16.3 billion in producer surplus, and $7.7 billion in contribution to GDP. On the other hand, the 2025 forecast of economic value will reach $49.6 billion forecast of the baseline scenario, composed of $27.3 billion in consumer surplus, $11.7 billion in producer surplus, and $10.6 billion in GDP contribution (see Table H-1).

Table H-1. Spain: Economic Value of Wi-Fi (Baseline Scenario)

Agent	Source	Economic Value ($Million)					
		2021	2022	2023	2024	2025	Category
1. Free Wi-Fi	1.1. Savings generated by free Wi-Fi traffic offered in public sites	$204	$208	$214	$219	$221	Consumer Surplus
	1.2. Deployment of free Wi-Fi in public sites	$77	$78	$79	$81	$82	GDP contribution
2. Residential Wi-Fi	2.1. Internet access for home usage of devices that lack a wired port	$5,757	$7,393	$9,512	$12,250	$15,777	Consumer Surplus
	2.2. Avoidance of investment in in-house wiring	$6,590	$6,646	$6,831	$6,980	$7,133	Consumer Surplus
	2.3. Benefit to consumers from speed increases	$1,258	$1,464	$1,687	$1,928	$2,186	Consumer Surplus
	2.4. Residential Wi-Fi devices and equipment deployed	$1,971	$2,018	$2,074	$2,043	$1,976	Consumer Surplus
	2.5. Bridging digital divide: use of Wi-Fi to increase coverage in rural and isolated areas	$124	$146	$171	$201	$235	GDP contribution
3. Ent erp	3.1. Business Internet traffic transmitted through Wi-Fi	$3,711	$4,069	$4,461	$4,892	$5,364	Producer surplus

[192] Khatri, H. and Fenwick, S. (2020). "Analyzing mobile experience during the coronavirus pandemic: Time on Wi-Fi". *Opensignal* (March 30).

Agent	Source	Economic Value ($Million)					
		2021	2022	2023	2024	2025	Category
	3.2. Avoidance of enterprise inside wiring costs	$4,104	$4,086	$4,068	$4,050	$4,032	Producer surplus
	3.3. Return to speed: contribution to GDP derived from an increase in average mobile speed	$4,468	$5,332	$6,311	$7,408	$8,635	GDP contribution
	3.4. Wide deployment of IoT	$2,639	$1,049	$1,040	$1,056	$1,073	GDP contribution
	3.5. Deployment of AR/VR solutions	$204	$204	$230	$361	$393	GDP contribution
4. ISPs	4.1. CAPEX and OPEX savings due to cellular off-loading	$6,656	$4,747	$2,976	$1,006	$0	Producer surplus
	4.2. Revenues of service providers offering paid Wi-Fi access in public places	$118	$112	$85	$117	$160	GDP contribution
	4.3. Aggregated revenues of WISPs	$20	$24	$29	$35	$41	GDP contribution
5. Wi-Fi ecosystem	5.1. Locally manufactured residential Wi-Fi devices and equipment	$0	$0	$0	$0	$0	Producer surplus
	5.2. Locally manufactured Wi-Fi enterprise equipment	$0	$0	$0	$0	$0	Producer surplus
	5.3. Locally produced IoT products and services	$1,780	$1,875	$1,887	$1,849	$1,887	Producer surplus
	5.4. Locally produced of AR/VR solutions	$87	$148	$192	$262	$415	Producer surplus
Total		$39,768	$39,599	$41,847	$44,738	$49,610	

Source: Telecom Advisory Services analysis

The allocation of 500 MHz in the 6 GHz spectrum band for unlicensed use and the deployment of Wi-Fi 6 and Wi-Fi 6E devices will trigger an additional growth of economic value, reaching $4.5 billion in 2025 (see Table H-2).

Table H-2. Spain: Economic Value of Wi-Fi (only attributed to 6 GHz)

Agent	Source	Economic Value ($Million)					
		2021	2022	2023	2024	2025	Category
1. Free Wi-Fi	1.1. Savings generated by free Wi-Fi traffic offered in public sites	$0	$0	$0	$0	$0	Consumer Surplus
	1.2. Deployment of free Wi-Fi in public sites	$0	$7	$15	$23	$30	GDP contribution
	1.3. Benefit of faster free Wi-Fi with Wi-Fi 6E devices	$0	$3	$5	$9	$12	Consumer Surplus
2. Residential Wi-Fi	2.3. Benefit to consumers from speed increases	$0	$308	$543	$695	$619	Consumer Surplus
	2.4. Residential Wi-Fi devices and equipment deployed	$72	$173	$376	$577	$781	Consumer Surplus
	2.5. Bridging digital divide: use of Wi-Fi to increase coverage in rural and isolated areas	$0	$5	$10	$17	$25	GDP contribution
3. Enterpris	3.1. Business Internet traffic transmitted through Wi-Fi	$0	$124	$162	$208	$212	Producer surplus

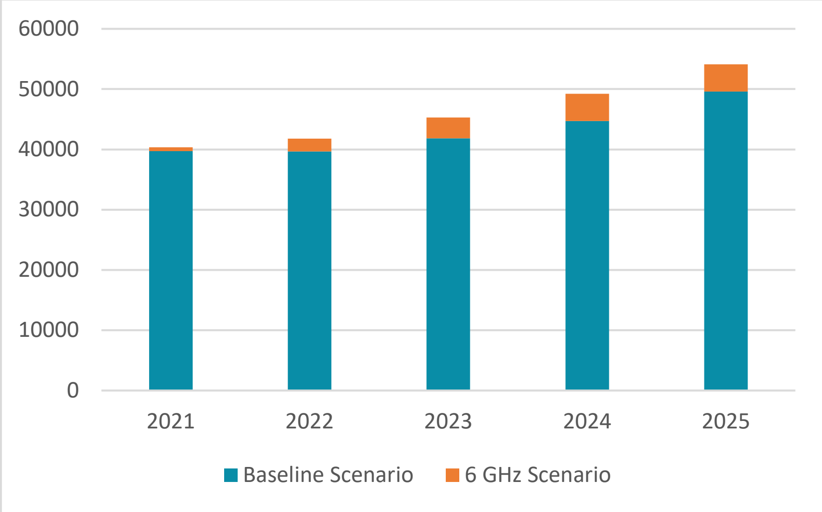
Agent	Source	Economic Value ($Million)					
		2021	2022	2023	2024	2025	Category
	3.3. Return to speed: contribution to GDP derived from an increase in average mobile speed	$0	$935	$1,701	$2,207	$1,930	GDP contribution
	3.4. Wide deployment of Internet of Things	$65	$68	$83	$84	$86	GDP contribution
	3.5. Deployment of AR/VR solutions	$99	$88	$113	$183	$205	GDP contribution
4. ISPs	4.1 CAPEX and OPEX savings due to cellular off-loading	$304	$304	$304	$304	$304	Producer surplus
	4.2. Revenues of service providers offering paid Wi-Fi access in public places	$0	$4	$7	$14	$26	GDP contribution
	4.3. Aggregated revenues of WISPs	$0	$0	$1	$1	$2	GDP contribution
5. Wi-Fi ecosystem	5.1. Locally manufactured residential Wi-Fi devices and equipment	$0	$0	$0	$0	$0	Producer surplus
	5.2. Locally manufactured Wi-Fi enterprise equipment	$0	$0	$0	$0	$0	Producer surplus
	5.3. Locally produced IoT products and services	$41	$56	$58	$51	$58	Producer surplus
	5.4. Locally produced of AR/VR solutions	$42	$63	$95	$133	$217	Producer surplus
Total		$623	$2,138	$3,473	$4,506	$4,507	

Source: Telecom Advisory Services analysis

Considering that it is assumed that by 2025 only 40% of Wi-Fi traffic will rely on the 6 GHz spectrum, the accelerated effect derived from the new spectrum allocation and latest Wi-Fi technologies will still be far from reaching its maximum potential at this time. If the French regulatory agency decides to allocate the upper part of the spectrum to unlicensed use, Wi-Fi economic value would increase significantly beyond the values presented in Table H-2.

A visual depiction of the trend provides a perspective of the growing importance of Wi-Fi 6 in driving the overall economic value (see Graphic H-1)

Graphic H-1. Spain: Economic Value of Wi-Fi (2021-2025) ($Thousand)



Source: Telecom Advisory Services analysis

By combining the baseline and the Wi-Fi 6 and 6 GHz scenarios, the overall economic value of Wi-Fi for Spain will yield $54.1 billion in 2025 (see Table H-3).

Table H-3. Spain: Total Economic Value of Wi-Fi (including Wi-Fi 6 and 6 GHz)

Agent	Source	Economic Value ($Million)					
		2021	2022	2023	2024	2025	Category
1. Free Wi-Fi	1.1. Savings to consumers of free Wi-Fi traffic offered in public sites	$204	$208	$214	$219	$221	Consumer Surplus
	1.2. Deployment of free Wi-Fi in public sites	$77	$85	$94	$103	$112	GDP contribution
	1.3. Benefit of faster free Wi-Fi with Wi-Fi 6E devices	$0	$3	$5	$9	$12	Consumer Surplus
2. Residential Wi-Fi	2.1. Internet access for home usage of devices that lack a wired port	$5,757	$7,393	$9,512	$12,250	$15,777	Consumer Surplus
	2.2. Avoidance of investment in in-house wiring	$6,656	$6,646	$6,831	$6,980	$7,133	Consumer Surplus
	2.3. Benefit to consumers from speed increases	$1,258	$1,772	$2,230	$2,623	$2,805	Consumer Surplus
	2.4. Residential Wi-Fi devices and equipment deployed	$2,043	$2,192	$2,451	$2,620	$2,756	Consumer Surplus
	2.5. Bridging digital divide: use of Wi-Fi to increase coverage in rural and isolated areas	$124	$151	$181	$217	$260	GDP contribution
3. Enterprise Wi-Fi	3.1. Business Internet traffic transmitted through Wi-Fi	$3,711	$4,193	$4,624	$5,100	$5,576	Producer surplus
	3.2. Avoidance of enterprise inside wiring costs	$4,104	$4,086	$4,068	$4,050	$4,032	Producer surplus
	3.3. Return to speed: contribution to GDP derived from an increase in average mobile speed	$4,468	$6,267	$8,012	$9,615	$10,565	GDP contribution
	3.4. Wide deployment of IoT	$2,704	$1,117	$1,122	$1,140	$1,158	GDP contribution

Agent	Source	Economic Value ($Million)					
		2021	2022	2023	2024	2025	Category
	3.5. Deployment of AR/VR solutions	$303	$292	$343	$544	$598	GDP contribution
4. ISPs	4.1 CAPEX and OPEX savings due to cellular off-loading	$6,960	$5,051	$3,280	$1,310	$304	Producer surplus
	4.2. Revenues of service providers offering paid Wi-Fi access in public places	$118	$117	$92	$131	$186	GDP contribution
	4.3. Aggregated revenues of WISPs	$20	$25	$30	$36	$43	GDP contribution
5.Wi-Fi ecosystem	5.1. Locally manufactured residential Wi-Fi devices and equipment	$0	$0	$0	$0	$0	Producer surplus
	5.2. Locally manufactured Wi-Fi enterprise equipment	$0	$0	$0	$0	$0	Producer surplus
	5.3. Locally produced IoT products and services	$1,821	$1,931	$1,945	$1,900	$1,946	Producer surplus
	5.4. Locally produced of AR/VR solutions	130	211	287	395	632	Producer surplus
Total		$40,458	$41,740	$45,321	$49,242	$54,116	

Source: Telecom Advisory Services analysis

The following sections will present in detail the calculation of each source of value, disaggregating the economic contribution under the current spectrum allocation and the enhanced effect due to Wi-Fi 6 availability and the 6 GHz band.

H.2. Value from free Wi-Fi service

The economic value of free Wi-Fi service originates from three contribution sources:

- Savings to consumers by accessing the Internet in free Wi-Fi sites rather than incurring cellular costs;
- The use of Wi-Fi to expand broadband coverage to the unserved population; and
- The return to speed of Wi-Fi compared to the use of cellular service.

H.2.1. Savings incurred by accessing free Wi-Fi in public sites

The economic value of free Wi-Fi is measured in terms of consumer surplus, calculated by estimating the benefit that flows to consumers as a result of the savings by not relying on cellular service. We begin by forecasting the traffic generated at free Wi-Fi access points. Given that the traffic per hotspot is decreasing and will continue to do so until 2025, we will not consider that Spanish free Wi-Fi sites undergo a congestion bottleneck as is the case in other countries (Table H-4).

Table H-4. Spain: Total Free Wi-Fi Traffic projection (2021-2025)

Variable	2021	2022	2023	2024	2025
Free Wi-Fi traffic (million GB Per year) - considering current trends	604.30	762.72	982.67	1290.49	1723.11
Free Wi-Fi hotspots (Million)	1.34	1.84	2.53	3.48	4.79
Traffic per hotspot - considering current trends	451.95	414.59	388.22	370.54	359.59
Traffic per hotspot - capped due to congestion	451.95	414.59	388.22	370.54	359.59
Total traffic (not attributed to 6 GHz) (Million GB)	604.30	762.72	982.67	1290.49	1723.11

Sources: Cisco; Wiman; Telecom Advisory Services analysis

We calculate consumer surplus by multiplying the total free traffic by the difference between what the consumer would have to pay if she/he were to rely on a wireless carrier and the cost of offering free Wi-Fi (incurred by the retailer or public site). To do so, we needed an estimate of the average price per GB of wireless data transmitted by wideband networks, which we calculated by averaging the most economic "dollar per GB" plan of four major wireless carriers (see Table H-5).

Table H-5. Spain: Average Price Per Gigabyte (2020)

Carrier	Plan	Price per GB ($)
Vodafone	Heavy Yuser	$0.925
Orange	Go Flexible	$0.288
Yoigo (Masmovil)	40 GB	$0.925
Movistar (Telefonica)	Contrato XL	$1.923

Sources: Operator websites; Telecom Advisory Services analysis

Historical data allowed for a projection of future prices per gigabyte. Based on these prices, we expect the average price per GB will reach an estimated $0.60 in 2025. By relying on the total free Wi-Fi traffic allocation shown in Table H-10 and the average price per cellular gigabyte minus the cost of provisioning Wi-Fi service, we calculated the consumer surplus of free Wi-Fi traffic (see Table H-6).

Table H-6. Spain: Consumer Surplus of Free Wi-Fi Traffic (2021-2025)

Variable	2021	2022	2023	2024	2025
Total Free Traffic (not attributed to 6 GHz) (Million GB)	604.30	762.72	982.67	1290.49	1723.11
Price per cellular gigabyte ($)	$0.91	$0.82	$0.74	$0.67	$0.60
Cost per Wi-Fi provisioning ($)	$0.58	$0.55	$0.52	$0.50	$0.47
Consumer surplus per gigabyte ($)	$0.34	$0.27	$0.22	$0.17	$0.13
Total Consumer surplus ($Million)	$203.73	$208.21	$214.13	$219.28	$220.58

Sources: Cisco; Websites of cellular operators; Telecom Advisory Services analysis

As indicated in Table H-6, consumer surplus of free Wi-Fi traffic in 2021 would reach an estimated $204 million, increasing to $221 million in 2025.

Enhanced free Wi-Fi traffic due to 6 GHz allocation

Given that the traffic per hotspot is decreasing, we do not consider a congestion bottleneck in Spanish free Wi-Fi sites as is the case in other countries. Thus, we will not attribute additional economic effect to the 6 GHz band for free Wi-Fi traffic.

H.2.2. Free Wi-Fi to provide broadband to the unserved population

As explained in section B, the deployment of free Wi-Fi provides Internet access to the population unserved by commercial broadband. Consumers that do not have broadband at home because they lack the economic means to acquire service can rely on free Wi-Fi to gain Internet access. As a result of this possibility, more people can be connected, which in turn enhances the economic contribution of broadband.

The calculation of this economic impact starts by calculating which portion of households that lack broadband service are already accessing Internet through free hotspots. We follow a conservative approach and assume that only 5% of unconnected households rely on free hotspots for accessing Internet. After calculating the increase in broadband penetration due to households relying on free Wi-Fi, we rely on the broadband impact coefficient from Katz and Callorda (2018b), estimated for Europe. The GDP contribution of this particular effect is expected to amount to $77 million in 2021, reaching $82 million in 2025 (see Table H-7).

Table H-7. Spain: GDP contribution due to households relying on Free Wi-Fi (2021-2025)

Variable	2021	2022	2023	2024	2025
Households without Internet	411,825	412,952	414,083	415,217	416,354
Households that don't buy because access Internet free hotspots (%)	5%	5%	5%	5%	5%
Households served by Free Wi-Fi hot spots	20,591	20,648	20,704	20,761	20,818
Increase in national broadband penetration	0.1%	0.1%	0.1%	0.1%	0.1%
Impact of fixed broadband adoption in GDP	4.63%	4.63%	4.63%	4.63%	4.63%
Increase in the GDP due to the new broadband adoption (% GDP)	0.01%	0.01%	0.01%	0.01%	0.01%
GDP ($Billion)	$1,292.26	$1,313.85	$1,335.50	$1,356.76	$1,378.36
Total impact in GDP ($Million)	$76.67	$77.96	$79.24	$80.50	$81.78

Sources: Eurostat; ITU; IMF; Telecom Advisory Services analysis

Enhanced GDP contribution due to 6 GHz allocation

As stated above, Wi-Fi 6 technology enables supporting a high number of devices on a single access point. Accordingly, the improved throughput of free Wi-Fi hotspots under the 6 GHz spectrum allocation will allow the possibility of serving additional unconnected households.

The potential universe of additional households that could be served under this effect is significant, as most unconnected households usually identify that costs are their main barrier for accessing to connectivity and thus, may potentially be served by free hotspots as long as they are in proximity to an access point. However, evidence suggests that not many people rely exclusively on free Wi-Fi as their main source of Internet access, so we follow again a conservative approach and assume that a further 5% of unconnected households will be served through free hotspots under the allocation of the 6 GHz band. On the other hand, we have also considered that traffic growth through the new band will take place gradually, reaching 40% in 2025. In consequence, we estimate that additional 7,700 households will be served in 2025 due to free hotspots operating under 6 GHz spectrum, yielding an additional GDP contribution of approximately $30 million (Table H-8).

Table H-8. Spain: GDP contribution due to households relying on Free Wi-Fi due to 6 GHz (2021-2025)

Variable	2021	2022	2023	2024	2025
Households without Internet (not served by free Wi-Fi and not new adopters of WISP)	391,233	390,080	389,132	387,531	384,895
Potential households that could be served through free Wi-Fi hotspots under increased capacity (% of those not connected)	5%	5%	5%	5%	5%
Traffic through the 6 GHz Channel (%)	0%	10%	20%	30%	40%
Additional households served by Free Wi-Fi hot spots with 6 GHz	0	1,950	3,891	5,813	7,698
Increase in national broadband penetration	0.00%	0.01%	0.02%	0.04%	0.05%
Increase in the GDP due to the new broadband adoption (% GDP)	0.000%	0.001%	0.001%	0.002%	0.002%
Total impact in GDP ($Million)	$0.00	$7.36	$14.89	$22.54	$30.24

Sources: Eurostat; ITU; IMF; Telecom Advisory Services analysis

H.2.3. Benefit to consumers for enjoying higher speed from free Wi-Fi if 6 GHz band is allocated

When the 6 GHz band is adopted by free Wi-Fi access points it will deliver service at faster broadband speeds. Current speeds from free hotspots in Spain are quite modest[193]. Thus, the expanded capabilities due to the allocation of 6 GHz spectrum band will enhance free Wi-Fi speed, and as a result, will increase consumer surplus. We assume that under the 6 GHz allocation, speed from free hotspots will be similar to the Wi-Fi speeds from mobile devices reported by Cisco. After calculating the average speed by considering the expected share of traffic through 6 GHz, we follow Nevo et al. (2016) and calculate the additional consumer surplus per household relying on free Wi-Fi. We expect the consumer surplus resulting from faster speed in free Wi-Fi sites to reach $12 million in 2025 (Table H-9).

Table H-9. Spain: Consumer surplus for enjoying higher speed from free Wi-Fi if 6 GHz band allocated (2021-2025)

Variable	2021	2022	2023	2024	2025
Free Wi-Fi mean speed with no 6 GHz (Mbps)	14.85	16.43	18.17	18.66	19.15
Wi-Fi Speeds from Mobile Device (Mbps)	98.47	129.00	169.00	221.40	290.04
Traffic through the 6 GHz Channel (%)	0.00%	10.00%	20.00%	30.00%	40.00%
Free Wi-Fi mean speed with 6 GHz (Mbps)	14.854	27.688	48.339	79.477	127.504
Demand for average download speed	69.02	70.61	72.19	72.35	72.52
New Demand for average download speed	69.02	80.44	90.53	99.41	107.75
Additional Monthly Consumer surplus	$0.00	$9.83	$18.34	$27.05	$35.23
Additional Yearly Consumer Surplus	$0.00	$117.94	$220.10	$324.63	$422.76
Households that rely on Free Wi-Fi	20,591	22,598	24,595	26,574	28,516
Consumer surplus ($Million)	$0	$3	$5	$9	$12

Sources: Cisco; Rotten Wi-Fi; Nevo et al. (2016); Telecom Advisory Services analysis

[193] Given the lack of reliable data on free Wi-Fi speed in Spain, we made an estimation based on United States data, applying the percentage difference in fixed broadband speed between both countries. As a result, we estimate free Wi-Fi speed in Spain to be 13.4 Mbps in 2020.

H.3. Residential Wi-Fi

The economic value of Wi-Fi in consumer residences is the result of five factors:

- Provision of connectivity to the home network for devices that lack an Ethernet port;
- Cost avoidance of ethernet inside wiring;
- Consumer surplus resulting from faster broadband speeds relative to cellular networks;
- Consumer surplus derived from usage of home devices connected to the home network; and
- Provision of Internet access to consumers located in rural and isolated areas.

H.3.1. Home Internet access for devices that lack an Ethernet port

The underlying premise of this analysis is that in the absence of Wi-Fi, users of devices lacking an Ethernet port would have to depend on the cellular network to gain Internet access. For this reason, estimating value would first measure the traffic generated by these devices at home and then multiply it by the average price charged by cellular carriers.

To estimate the traffic of smartphones and tablets, we relied on the 2018 Cisco Annual Internet Report Highlights Tool 2018-2023 estimates for the period 2016-21 and extrapolated the growth rates to 2025. In addition, we considered that, according to Cisco IBSG (2012), 43.12% of use time of devices that lack an Ethernet port occurs at home. Therefore, the portion of said traffic generated at home will reach 6,298 million gigabytes in 2021 (see Table H-10).

Table H-10. Spain: Total Mobile Internet Traffic (2021-2025) (million gigabytes)

Variable	2021	2022	2023	2024	2025
Total Annual traffic - Smartphones	10,226.8	14,868.0	21,644.7	31,519.2	45,842.7
Total Annual traffic - Tablets	4,380.3	5,966.3	8,126.4	11,068.7	15,076.3
Share of traffic at Home	43.12%	43.12%	43.12%	43.12%	43.12%
Total Traffic at Home -Smartphones	4,409.6	6,410.8	9,332.7	13,590.4	19,766.3
Total Traffic at Home - Tablets	1,888.7	2,572.5	3,503.9	4,772.6	6,500.6
Total Traffic at Home	6,298.3	8,983.2	12,836.6	18,362.9	26,266.9
Average Price per GB ($)	$0.91	$0.82	$0.74	$0.67	$0.60
Price per home traffic ($Million)	$5,757.48	$7,393.41	$9,511.75	$12,250.40	$15,776.69

Sources: Cisco; GSMA; Telecom Advisory Services analysis

If this traffic had to be transported by cellular networks, at the average price per GB estimated above (Table H-5), it would amount to $5.8 billion in 2021 reaching $15.8 billion in 2025.

H.3.2. Avoidance of inside wiring investment

Residential Wi-Fi allows consumers to avoid paying for inside wiring to connect all home devices (printers, laptops, storage units, etc.). Considering that 90% of connected Spanish households will have Wi-Fi in 2021[194], and the wiring cost estimated for households (based on U.S. data, adjusted by PPP), the avoidance costs of inside wiring over 14.5 million households yields a total of $6.66 billion. By 2025, almost all connected households are expected to have adopted Wi-Fi, resulting in savings would of $7.1 billion (Table H-11).

Table H-11. Spain: Consumer surplus from avoidance of investment in in-house wiring (2021-2025)

Variable	2021	2022	2023	2024	2025
Total Wiring Cost	$458.90	$456.86	$454.83	$452.81	$450.81
Households with Internet	16,061,164	16,105,140	16,149,237	16,193,454	16,237,792
Households with Wi-Fi (%)	90%	91%	93%	95%	97%
Households with Internet and Wi-Fi	14,510,000	14,655,678	15,018,790	15,415,042	15,821,748
Inside Wiring Costs ($Million)	$6,660	$6,696	$6,831	$6,980	$7,133

Sources: Eurostat; Telecom Advisory Services analysis

H.3.3. Benefits derived from speed increase

As described before, consumer surplus increases if users enjoy faster Internet speeds. Thus, the welfare of residential Wi-Fi customers is expected to benefit from faster service than those provided by cellular networks. After weighting the corresponding broadband speeds with the percentage of traffic carried out through Wi-Fi at home, we calculated the average speed advantage of using Wi-Fi versus relying on cellular networks. By applying the parameters of willingness-to-pay for broadband speed determined in Nevo et al. (2016), the expected consumer surplus will amount to $1.3 billion in 2021, reaching $2.2 billion in 2025.

Table H-12. Spain: Consumer surplus from faster speed in households (2021-2025)

Variable	2021	2022	2023	2024	2025
Average Speed in households if Wi-Fi traffic were carried through mobile networks (Mbps)	73.05	88.10	106.44	128.83	156.21
Average Speed in household with Wi-Fi (Mbps)	107.64	137.08	175.34	225.19	290.26
Demand for average download speed	99.15	102.24	105.33	108.42	111.52
New Demand for average download speed	106.48	110.56	114.69	118.85	123.04
Additional Monthly Consumer surplus	$7.33	$8.33	$9.36	$10.42	$11.51
Additional Yearly Consumer Surplus	$88.01	$99.90	$112.30	$125.09	$138.16
Households with Internet and Wi-Fi	14,294,436	14,655,678	15,018,790	15,415,042	15,821,748
Impact ($Million)	$1,258	$1,464	$1,687	$1,928	$2,186

Sources: Eurostat; Cisco; Nevo et al. (2016); Telecom Advisory Services analysis

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[194] Assuming similar levels as France.

Additional benefit to consumers from speed increase due to 6 GHz

The welfare of residential Wi-Fi customers is expected to receive an additional benefit from the 6 GHz spectrum allocation due to faster Internet service under Wi-Fi 6E. As described in Chapter B, only households acquiring a 150 Mbps (or faster) fixed broadband line will benefit from this effects since due to current router bottleneck, the speed experienced at the device level will not be equivalent to that delivered by the fixed network. A large portion of households in Spain already acquire fixed broadband service with speeds faster than 150 Mbps, due to the early roll-out of fiber-optics deployments by local incumbent Telefónica. We estimated the percentage of households with connectivity over 150 Mbps based on data from the CNMC, the Spanish regulatory agency, and the OECD. After calculating the difference in average speed attributed to 6 GHz, the additional consumer surplus will yield $619 million in 2025.

Table H-13. Spain: Consumer surplus from faster speed in households if 6 GHz allocated (2021-2025)

Variable	2021	2022	2023	2024	2025
Households that have connections over 150 Mbps (%)	66.64%	70.82%	75.26%	79.98%	85.00%
Percentage of household traffic that goes through Wi-Fi	69.47%	71.79%	74.01%	76.10%	78.08%
Traffic through the 6 GHz Channel (%)	0.00%	10.00%	20.00%	30.00%	40.00%
Share of traffic affected due to 6 GHz (%)	0.00%	5.08%	11.14%	18.26%	26.55%
Average speed with no 6 GHz (Mbps)	107.64	137.08	175.34	225.19	290.26
Average speed with 6 GHz (Mbps)	107.64	150.45	205.94	275.37	345.94
Demand for average download speed	106.48	110.56	114.69	118.85	123.04
New Demand for average download speed	106.48	112.31	117.70	122.60	126.30
Additional Yearly Consumer Surplus	$0.00	$21.03	$36.19	$45.06	$39.13
Households with Wi-Fi	14,294,436	14,655,678	15,018,790	15,415,042	15,821,748
Impact ($Million)	$0	$308	$543	$695	$619

Sources: CNMC; OECD, Cisco; Eurostat; Nevo et al. (2016); Telecom Advisory Services analysis

H.3.4. Residential Wi-Fi devices and equipment

The consumer surplus derived from the adoption of residential Wi-Fi devices and equipment focuses on seven consumers products which are intrinsically linked to Wi-Fi: smart home devices and systems such as Wi-Fi speakers and home security systems, home networking systems, Wi-Fi tablets, access points, external adapters, routers, and gateways. Two different approaches are used in these cases: one assuming that consumer surplus is roughly equal to producer surplus in six of the seven products (excluding tablets), and an assessment of tablets' willingness-to-pay.

The estimation of economic value in the first approach begins by compiling local sales in the six product categories in Spain[195]. After computing the sales in Spain, we applied the prorated margin estimated by CSI markets (39.44%) which yields an estimated producer surplus for these particular products of $2 billion in 2021. As mentioned above, it is assumed that the consumer surplus is of the same magnitude. This methodology was also used to calculate the consumer surplus up to 2023. However, the gradual adoption of Wi-Fi 6 devices is forecast to reduce the sales and economic value from the devices relying on the 2.4 GHz and 5 GHz spectrum bands. Non 6 GHz consumer devices shipments are expected by IDC to decrease by 1.2% in 2024 and 3.1% in 2025. Based on this estimate, we extrapolated the consumer surplus from non 6 GHz reliant residential Wi-Fi devices and equipment between 2021 and 2025.

Starting with CTA/Statista worldwide tablet revenue estimates, we interpolated the revenue figures for Spain (by weighting by the country's share of global GDP), and extrapolated the evolution of local revenue till 2025 by considering Cisco estimates of tablet evolution for the period. We reviewed the data on tablet prices for the market leader (taking as a reference the Apple iPad 10.2 Inch 128 GB, as Apple has 43.9% of the Spanish market share in tablets[196]) and for the rest of the market (taking as a reference a Samsung Wi-Fi tablet 128 GB), and assumed consumer willingness-to-pay levels in a similar percentage above prices as in the U.S. average. Combining all that information, we were able to estimate a consumer surplus attributable to tablets of $67 million in 2021, expected to reach $38 million in 2025

In sum, overall consumer surplus for Wi-Fi enabled residential products is expected to amount to $2 billion in 2021 and remain stable till 2025 (Table H-14).

Table H-14. Spain: Economic Value of Wi-Fi enabled consumer products (2021-2025)

Variable	2021	2022	2023	2024	2025
Consumer surplus (ex. tablets) ($Million)	1,904	1,961	2,025	1,999	1,937
Tablet consumer surplus ($Million)	$67	$57	$50	$44	$38
Total consumer surplus ($Million)	1,971	2,018	2,074	2,043	1,976

Source: Telecom Advisory Services analysis

Consumer surplus derived to Wi-Fi enabled residential equipment for 6 GHz

As discussed above, sales of residential Wi-Fi devices and equipment operating in the 6 GHz band are expected to gradually replace those of former generations. According to IDC, global shipments of consumer devices operating in the 6 GHz (802.11ax standard) will represent 40% of sales from prior generations. As a result, if the shipments ratio reaches 40% in 2025, we can expect that, at least, the consumer surplus derived from 6 GHz devices will represent 40% of that of former technology residential devices. As a result, our estimates for consumer surplus attributed to 6 GHz residential devices amount to $781 million in 2025 (see Table H-15).

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[195] Calculated by prorating data for the United States based on GDP.
[196] Source: Gs StatCounter

Table H-15. Spain: Economic Value of Wi-Fi enabled consumer products attributable to 6 GHz (2021-2025)

Variable	2021	2022	2023	2024	2025
Ratio consumer 6 GHz / no 6 GHz	3.76%	8.83%	18.59%	28.86%	40.30%
Total consumer surplus ($Million) – 6 GHz	$71.68	$173.23	$376.26	$576.95	$780.68

Sources: IDC; Telecom Advisory Services analysis

H.3.5. Bridging the digital divide: use of Wi-Fi to increase coverage in rural and isolated areas

Wi-Fi is an appropriate technology to offer Internet access in rural and isolated areas. The calculation of the Wi-Fi contribution to the reduction of the digital divide must subtract the direct impact of WISPs (Section H.5.3.) to avoid double counting. On the other hand, we assume that 50% of WISP potential connections may be theoretically served by other technologies (i.e. satellite) covering the same isolated footprint[197]. Thus, we can conservatively expect 50% of broadband subscriptions in remote locations exclusively attributed to WISPs. Once this is done, we calculate the impact on GDP by relying on the coefficient estimated by Katz and Callorda (2018b) through regression models that links increase in broadband penetration to economic growth. The contribution to GDP materializes through multiple effects: creation of new businesses, increasing productivity of existing enterprises, and growth of average income per household. We expect a GDP contribution of $124 million in 2021, which will increase to $235 in 2025 (see Table H-16).

Table H-16. Spain: Estimation of GDP Contribution derived from reducing the digital divide (2021-2025)

Variable	2021	2022	2023	2024	2025
WISP subscribers	74,904	89,483	106,900	127,707	152,565
Additional broadband penetration due to WISP	0.45%	0.52%	0.60%	0.69%	0.80%
Impact of fixed broadband adoption in GDP	4.63%	4.63%	4.63%	4.63%	4.63%
GDP ($Billion)	$1,292	$1,314	$1,336	$1,357	$1,378
WISP TOTAL impact ($Billion)	$0.269	$0.316	$0.371	$0.436	$0.512
WISP Revenues ($Billion)	$0.02	$0.02	$0.03	$0.03	$0.04
Share that exist because WISP	50.00%	50.00%	50.00%	50.00%	50.00%
WISP spillovers on GDP ($Million)	$124.30	$145.84	$171.08	$200.55	$235.10

Sources: CNMC, IMF; Telecom Advisory Services analysis

Economic impact of enhanced coverage and affordability due to 6 GHz

The allocation of the 6 GHz band to unlicensed use would allow WISPs to potentially increase their subscriber base within their same coverage footprint. Therefore, a first effect derived from the allocation of the new spectrum band is related to additional households served due to additional coverage. We will follow a cautious approach and consider that the expanded coverage will yield a gradual increase on WISP subscribers, from 2% in 2022 to 5% in 2025 over the figures projected without assuming the additional spectrum allocation. In addition, an increase of the user base would allow service providers to lower their operating costs. Thus, by assuming stability in prices, affordability would increase as GDP per capita grows as economic growth resumes. All in all, we can expect an overall increase in almost

[197] Assuming similar levels as those estimated for France and Germany

10,600 WISP connections in 2025, contributing to an increase 0.06% in national broadband penetration. Considering the impact coefficient of broadband on the economy, which will yield $25 million of GDP contribution.

Table H-17. Spain: GDP Contribution derived from reducing the digital divide due to 6 GHz (2021-2025)

Variable	2021	2022	2023	2024	2025
New subscribers due to expanded coverage (%)	0%	2%	3%	4%	5%
New subscribers due to expanded coverage	0	1,790	3,207	5,108	7,628
New WISP adoption after price decrease (% households)	1%	1%	1%	1%	1%
Traffic through the 6 GHz Channel (%)	0.00%	10.00%	20.00%	30.00%	40.00%
Increase in WISP connections due to lower prices (households that buy the service)	0	435	1,040	1,817	3,012
Overall increase in WISP connections due to 6 GHz	0	2,225	4,247	6,925	10,641
Increase in national broadband penetration	0.00%	0.01%	0.03%	0.04%	0.06%
Impact of fixed broadband adoption in GDP	4.63%	4.63%	4.63%	4.63%	4.63%
Increase in the GDP due to the new broadband adoption (% GDP)	0.000%	0.001%	0.001%	0.002%	0.003%
Total impact in GDP ($Million)	$0.00	$5.50	$10.32	$16.54	$24.97

Sources: CNMC; IMF; Telecom Advisory Services analysis

H.4. Enterprise Wi-Fi

Beyond the impact on consumers, Wi-Fi also contributes significant economic value in the Spanish enterprise segment. This section provides estimates in five areas:

- Support of business Internet traffic;
- Avoidance of campus and enterprise facilities inside wiring;
- Contribution to GDP resulting from Wi-Fi speed faster than cellular connections;
- Deployment of IoT solutions; and
- Implementation of business focused AR/VR use cases.

H.4.1. Business Internet traffic transmitted through Wi-Fi

Wi-Fi enterprise savings results from wireless traffic that is routed through Wi-Fi access points. Considering Cisco 2016-21 projections, we estimate that total business Internet traffic will reach 7.1 billion GB in 2021, of which 4.1 billion GB would have been transported through Wi-Fi access points. Considering the average price per GB transported by cellular (from Table H-5), savings from Wi-Fi will reach $3.7 billion, an addition to the producer surplus[198]. By 2025, this benefit will reach $5.4 billion (see Table H-18).

[198] We acknowledge that enterprises are likely to negotiate wireless rates lower than those offered in the consumer market; however, data in this area is not available.

Table H-18. Spain: Savings in business wireless traffic (2021-2025)

Variable	2021	2022	2023	2024	2025
Share of Business Internet Traffic by Wi Fi	57.00%	57.62%	58.25%	58.88%	59.52%
Total Business Internet Traffic (Million GB)	7,121.9	8,580.2	10,337.2	12,453.9	15,004.0
Total GB Wi-Fi enterprise traffic (Million GB)	4,059.5	4,943.9	6,021.0	7,332.8	8,930.3
Average Price per GB	$0.91	$0.82	$0.74	$0.67	$0.60
Economic Impact ($Million)	$3,710.93	$4,068.94	$4,461.48	$4,891.88	$5,363.81

Sources: Cisco; Telecom Advisory Services analysis

Enhanced business Internet traffic transmitted through Wi-Fi due to 6 GHz

The deployment of the latest enterprise applications will generate an exponential growth in data traffic that will be handled by devices operating in unlicensed spectrum, through the combination of the existing bands and the 6 GHz band. In 2019, an updated Cisco traffic forecast based on the explosion of IoT and AR/VR applications, among other factors, increased total business Internet traffic previsions from the previous 2016-21 estimates from 2018. As in the case of the U.S., we assume that part of the growth was driven by "natural" growth, and another portion was triggered by Wi-Fi traffic stimulated by changes in 6 GHz. The sum of the difference due to broader Wi-Fi traffic will reach $212 million in 2025 (see Table H-19).

Table H-19. Spain: Savings in business wireless traffic due to 6 GHz (2021-2025) ($Million)

Variable	2021	2022	2023	2024	2025
Total value of business Wi-Fi traffic 2016-21	$3,710.93	$4,068.94	$4,461.48	$4,891.88	$5,363.81
Total value of business Wi-Fi traffic 2017/22	$4,561.1	$5,216.1	$5,965.2	$6,821.9	$7,801.6
Difference between the 2 estimations	$850.1	$1,147.2	$1,503.7	$1,930.0	$2,437.8
Difference because natural growth	$796.4	$1,023.5	$1,341.6	$1,721.9	$2,175.0
Difference due to 6 GHz	$0.00	$123.67	$162.10	$208.05	$212.20

Sources: Cisco; Telecom Advisory Services analysis

H.4.2. Avoidance in enterprise building inside wiring

Similar to residential Wi-Fi savings due to capital investment avoidance in inside wiring, we assume that the total number of business establishments are equipped with Wi-Fi access points and multiply this value by a standard cost of deploying a CAT 6 network (from U.S., adjusted by PPP) (see Table H-20).

Table H-20. Spain: Savings in business wiring CAPEX (2021-2025)

Variable	2021	2022	2023	2024	2025
Total Wiring Cost	$1,529.66	$1,522.87	$1,516.11	$1,509.38	$1,502.68
Number of Establishments	2,682,905	2,682,905	2,682,905	2,682,905	2,682,905
Establishments with Wi-Fi (%)	100%	100%	100%	100%	100%
Establishments with Wi-Fi	2,682,905	2,682,905	2,682,905	2,682,905	2,682,905
Inside Wiring Costs ($Million)	$4,104	$4,086	$4,068	$4,050	$4,032

Sources: Eurostat; Telecom Advisory Services analysis

The wiring costs remain constant across years because the total number of establishments (assumed to have full Wi-Fi penetration) and wiring costs remain constant over time.

H.4.3. Return to speed: contribution to GDP derived from an increase in average mobile speed

Since Wi-Fi accessibility allows, in general, faster access to the Internet than cellular networks do, higher speeds have a positive contribution on the economy in terms of increased overall efficiency and innovation. This contribution is measured in terms of economic growth. As described in Section H.5.3 for the case of consumer surplus, we start with the quantification of the average broadband speed if cellular networks transported all Wi-Fi traffic, and compare it with the presence of Wi-Fi technology (see Table H-21).

Table H-21. Spain: Estimation of speed differential for total traffic (2021-2025)

Variable	2021	2022	2023	2024	2025
Average Download Speed if Wi-Fi traffic carried through mobile networks (Mbps)	73.05	88.10	106.44	128.83	156.21
Average Speed with Wi-Fi (Mbps)	107.64	137.08	175.34	225.19	290.26
Speed increase (%)	47%	56%	65%	75%	86%
Impact of speed in GDP	0.73%	0.73%	0.73%	0.73%	0.73%
Increase in GDP	0.35%	0.41%	0.47%	0.55%	0.63%
GDP ($Billion)	$1,292.26	$1,313.85	$1,335.50	$1,356.76	$1,378.36
GDP increase ($Million)	$4,468	$5,332	$6,311	$7,408	$8,635

Sources: Cisco; IMF; Telecom Advisory Services analysis

Having calculated the speed increase percentage, we then apply this percentage to the coefficient derived from the model developed by Katz and Callorda (2019) to gauge the potential impact on GDP from Wi-Fi enhanced speed. Table H-21 indicates that the economic value of Wi-Fi in terms of increasing the speed of transporting wireless will account to $4.5 billion in 2021, before increasing to $8.6 billion in 2025.

Return to Speed additional effect due to 6 GHz

As previously described, only those broadband connections above 150 Mbps will be affected due to current router bottlenecks, and hence, the speed experienced will not be equivalent to that delivered by the fixed network. Thus, the allocation of the 6 GHz band will remove those barriers, increasing broadband speed. After calculating the difference in average speed attributed to 6 GHz, the additional GDP contribution will yield $1.9 billion in 2025 (Table H-22).

Table H-22. Spain: Estimation of speed differential due to 6 GHz (2021-2025)

Variable	2021	2022	2023	2024	2025
Mean speed with no 6 GHz (Mbps)	107.64	137.08	175.34	225.19	290.26
Mean speed with 6 GHz (Mbps)	107.64	150.45	205.94	275.37	345.94
Speed increase due to 6Ghz (%)	0%	10%	17%	22%	19%
Impact speed on GDP	0.73%	0.73%	0.73%	0.73%	0.73%
Increase in GDP (%)	0.00%	0.07%	0.13%	0.16%	0.14%
GDP increase ($Million)	$0	$935	$1,701	$2,207	$1,930

Sources: Cisco; IMF; Telecom Advisory Services analysis

H.4.4. IoT Deployment

IoT adoption has a contribution to GDP growth through the multiplicity of use cases that improve efficiency in processes such as preventive maintenance, production monitoring and the like. To estimate this, we rely on a coefficient of GDP impact calculated through an aggregate simple production function which estimates that a 10% rise in M2M connections results in annual increases in GDP of between 0.3% and 0.9%[199]. Following a conservative approach, we relied on the lower-bound of that interval and assumed a 0.3% GDP increase after a 10% increase in M2M.

Starting with a 2021 installed base of 9.1 million M2M devices, we estimate the growth that can be exclusively attributed to the allocation of additional spectrum to indoor Wi-Fi devices. Thus, by subtracting the growth in M2M attributed to 6 GHz, it is estimated that the IoT impact for 2021 according to the natural growth would reach $2.6 billion (see Table H-23).

Table H-23. Spain: GDP Contribution of IoT Deployment Boost (2021-2025)

Variable	2021	2022	2023	2024	2025
Connections, Cellular M2M	9,065,973	9,338,710	9,619,652	9,909,046	10,207,145
Growth Rate (%)	7.47%	3.01%	3.01%	3.01%	3.01%
Natural Growth Rate (%)	6.81%	2.66%	2.59%	2.59%	2.59%
Impact of 1% M2M Growth on GDP	3.00%	3.00%	3.00%	3.00%	3.00%
Impact on GDP (%)	0.20%	0.08%	0.08%	0.08%	0.08%
GDP ($Billion)	$1,292	$1,314	$1,336	$1,357	$1,378
Impact ($Million)	$2,638.81	$1,049.18	$1,039.53	$1,056.08	$1,072.89

Sources: GSMA Intelligence; Frontier Economics; IMF; Telecom Advisory Services analysis

Accelerated effect of IoT due to 6 GHz

As described above, a share of the M2M growth can be attributed to 6 GHz developments. According to the data in Table H-24, cumulative impact of enhanced IoT deployment driven by 6 GHz spectrum proposals will reach $86 million by 2025.

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199 See Frontier Economics (2018)

Table H-24. Spain: GDP Contribution of IoT Deployment Boost caused by 6 GHz (2021-2025)

Variable	2021	2022	2023	2024	2025
Growth due to 6 GHz (%)	0.67%	0.35%	0.41%	0.41%	0.41%
Level of development of new bands (%)	50%	100%	100%	100%	100%
Impact on GDP (%)	0.01%	0.01%	0.01%	0.01%	0.01%
Impact ($Million)	$64.75	$68.29	$82.89	$84.20	$85.55

Sources: GSMA Intelligence; Frontier Economics; IMF; Telecom Advisory Services analysis

H.4.5. Deployment of AR/VR solutions

The adoption of AR/VR among Spanish businesses will in turn have a spillover effect on productivity, thereby contributing to the growth of GDP. Estimating spillover effects of AR/VR is a not a trivial exercise considering the embryonic adoption of some of these use cases. Since the objective is to estimate the spillover effect of AR/VR sales by local firms in the domestic market, we will take as points of departure the estimate by PwC of the total GDP contribution of AR/VR for 2021 and 2022, and the sales of AR/VR components as estimated by ABI Research. The extrapolation of these two parameters allow estimating the indirect (spillover) contribution of AR/VR to the local economy for the period under analysis.

Starting values are reduced by the proportion that can be attributed to the impact of the 6 GHz spectrum bands. To do so, we took as a reference a ratio of AR/VR product developments according to each technology. Once the amount to be attributed in both GDP contribution and direct sales is estimated, the annual indirect to direct multiplier can be calculated. The lowest multiplier value is applied to sales of AR/VR in the local market to calculate the total spillovers (see Table H-25). Total spillover value of AR/VR in Spain in 2021 will account for $204 million and is expected to increase by 2025 to $393 million.

Table H-25. Spain: GDP contribution resulting from AR/VR spillovers (2021-2025)

Variable	2021	2022	2023	2024	2025
AR/VR total contribution to GDP ($Billion)	$1.13	$1.67	$2.46	$3.62	$5.34
Share attributed to Wi-Fi (excluding 6 GHz)	42.02%	38.80%	32.18%	30.88%	29.32%
Portion of GDP contribution attributed to Wi-Fi (excluding 6 GHz) ($Billion)	$0.48	$0.65	$0.79	$1.12	$1.57
Direct impact (sales) attributed to Wi-Fi (excluding 6 GHz) ($Billion)	$0.27	$0.44	$0.56	$0.76	$1.17
Indirect impact ($Billion)	$0.20	$0.20	$0.23	$0.36	$0.39
Indirect/Direct multiplier	0.75	0.46	0.41	0.48	0.33
Indirect impact ($Million)	$203.99	$204.32	$229.97	$361.40	$392.88

Sources: PwC, ABI; Telecom Advisory Services analysis

Wider deployment of AR/VR solutions (accelerated effect due to 6 GHz)

Higher throughput enabled by the allocation of the 6 GHz band is expected to spur the adoption and use of AR/VR among enterprises, hence increasing the associated spillover effects. By relying on the ratio built from 5 GHz and 6 GHz AR/VR related products, we were able to isolate the specific economic contribution of the new spectrum allocation. Following a similar procedure as that described above, spillovers from AR/VR in Spain attributed to 6 GHz in 2021 will account for $99 million and are expected to increase by 2025 to $205 million (Table H-26).

Table H-26. Spain: GDP contribution resulting from AR/VR spillovers due to 6 GHz (2021-2025)

Variable	2021	2022	2023	2024	2025
AR/VR total contribution to GDP ($Billion)	$1.13	$1.67	$2.46	$3.62	$5.34
Share attributed to 6 GHz (%)	24.58%	25.59%	26.64%	27.73%	28.87%
Portion of GDP contribution attributed to 6 GHz ($Billion)	$0.28	$0.43	$0.65	$1.00	$1.54
Direct impact (sales) attributed to 6 GHz ($Billion)	$0.16	$0.29	$0.46	$0.68	$1.16
Indirect impact ($Billion)	$0.12	$0.13	$0.19	$0.32	$0.39
Indirect/Direct multiplier	0.75	0.46	0.41	0.48	0.33
Indirect impact ($Million)	$98.94	$87.86	$113.46	$183.05	$204.85

Sources: PwC, ABI; Telecom Advisory Services analysis

H.5. Internet Service Providers

In addition to the economic value generated by the sources analyzed above, Wi-Fi will also contribute to either producer surplus or GDP of Internet Service Providers. This section will assess the economic value in three sources:

- Producer surplus of cellular operators resulting from CAPEX savings incurred in network deployment
- Revenues of Wi-Fi carriers offering service in public spaces
- Revenues of Wireless ISPs (this effect differs from the GDP impact of WISPs as a result of their deployment in rural and isolated areas analyzed in section H.3.5.)

H.5.1. Cellular network savings by off-loading traffic to Wi-Fi

The estimation of CAPEX savings starts by considering the GSMA Intelligence aggregate projected investment by wireless carriers in Spain, which amounts to $22.2 billion between 2019 and 2025. Considering the total CAPEX required to deploy 5G in Spain, and the incremental 5G coverage between 2021 and 2025 we are able to interpolate the 5G CAPEX for each year of the period considered. It is assumed that all the CAPEX invested during the period would be dedicated to 5G deployment.

Based on the simulation model developed to forecast the impact of Wi-Fi off-loading in 5G deployment, we estimate that the savings of deploying carrier-grade Wi-Fi complementing the rollout of 5G to accommodate future traffic growth would amount to 32.9% of CAPEX, while the OPEX savings are $2.82 for each dollar saved in CAPEX. This would result in a total producer surplus (adding CAPEX and OPEX savings) of $6.7 billion in 2021, decreasing to $1 billion in 2024, when 5G coverage will reach 81% (see Table H-27).

Table H-27. Spain: Savings due to traffic off-loading (2021-2025)

Variable	2021	2022	2023	2024	2025
5G coverage	64%	73%	79%	81%	81%
CAPEX without saving	$5,296.0	$3,777.0	$2,368.3	$800.3	$0.0
CAPEX reduction due to Wi-Fi off-loading	$1,742.4	$1,242.6	$779.2	$263.3	$0.0
OPEX reduction due to Wi-Fi off-loading	$4,913.5	$3,504.2	$2,197.2	$742.5	$0.0
Total Cost of Ownership ($Million)	$6,656	$4,747	$2,976	$1,006	$0

Sources: GSMA; Telecom Advisory Services analysis

The decline in savings over time is compensated by the increase in economic benefit under the 6 GHz spectrum allocation.

Enhanced capability for cellular off-loading if 6 GHz allocated

The complementarity between Wi-Fi and cellular networks for Wi-Fi 6E and 5G, adds further potential gains derived from the savings in capital and operating expenses required to accommodate exploding data traffic. The key objective is to estimate the savings in capital investment as a result of an increase in traffic offloading with Wi-Fi benefits from the additional spectrum allocated, particularly, due to the ability to leverage 160 MHz within single contiguous channels. The estimation of CAPEX savings starts by considering the GSMA Intelligence aggregate investment estimates of 5G deployments. By relying again on the geographic disaggregation of Oughton and Frias, we estimate that CAPEX can be split in urban, suburban, and rural geographies. To estimate the percentage of population living in urban areas (over 1 million inhabitants), we considered those living in the metropolitan areas of Madrid, Barcelona, Sevilla and Valencia (according to data provided by the INE). The percentage of rural population was obtained from Fundación BBVA, while the remaining share of the population was classified in the suburban group. We conservatively assume that Wi-Fi 6 will not be critical in sustaining investment in urban areas, but that it will play a significant role beyond those geographies. Based on the cost advantage of carrier grade Wi-Fi, we assume that it will become effective for a portion of the suburban (approximately 15%) and rural network (approximately 5%) deployment. Therefore, this will yield yearly CAPEX savings of $304 million.

H.5.2. Wi-Fi carrier revenues

The value of Wi-Fi carriers includes the sum of revenues through paid public Wi-Fi access. In order to estimate those aggregated revenues, we start by calculating the number of commercial Wi-Fi hotspots in Spain. According to Cisco, in 2021 there will be 7.55 million public Wi-Fi hotspots in the country, although that figure includes home spots (such as the guest account service provided by cable operators). By subtracting the home spots from the public Wi-Fi estimates of Cisco, we calculated a total of 270,000 commercial Wi-Fi hotspots for 2021, which will increase until reaching 380,000 in 2025. On the other hand, based on revenue figures per hotspot from Boingo for the U.S., by adjusting by PPP we were able to estimate a figure for the case of Spain. Then, we estimate total revenues generated by this sector in Spain: $118 million in 2021, gradually increasing to reach $160 million in 2025 (Table H-28).

Table H-28. Spain: Revenues of Wi-Fi carriers (2021-2025)

Variable	2021	2022	2023	2024	2025
Public Wi-Fi hotspots (Million)	7.55	10.39	14.30	19.68	27.07
Home spots (Million)	7.28	10.13	14.10	19.40	26.69
Commercial Wi-Fi hotspots (Million)	0.27	0.26	0.20	0.28	0.38
Revenue per hotspot ($)	$430.22	$428.31	$426.41	$424.52	$422.64
Revenue ($Million)	$118.15	$112.34	$85.28	$116.82	$160.02

Sources: Cisco, Boingo, Telecom Advisory Services analysis

Increased revenues of Wi-Fi carriers in public places due to 6 GHz

The allocation of the 6 GHz spectrum band offers an opportunity for commercial Wi-Fi carriers to enhance their business. As Wi-Fi 6E developments will allow up to 1,500 connected devices per access point, Wi-Fi carriers will have the possibility of adding more clients without quality limitations due to congestion. By considering a conservative potential increase of 40% in the number of connected devices in public venues and weighting that figure by the gradual expansion of the latest technology, we expect commercial Wi-Fi carriers to increase their user base by 16% in 2025. If the revenue per hotspot increases in the same amount, that will yield an increase in overall revenues for the sector of an additional $26 million by 2025 (Table H-29).

Table H-29. Spain: Revenues of Wi-Fi carriers due to 6 GHz (2021-2025)

Variable	2021	2022	2023	2024	2025
Potential increase in connected devices in public venues	40.00%	40.00%	40.00%	40.00%	40.00%
Traffic through the 6 GHz Channel (%)	0%	10%	20%	30%	40%
Increase in connected devices due to 6 GHz	0%	4%	8%	12%	16%
Revenue per hotspot if 6 GHz allocated ($)	$430.22	$445.44	$460.52	$475.46	$490.26
Revenue if 6 GHz allocated ($Million)	$0.00	$4.49	$6.82	$14.02	$25.60

Sources: Boingo; Telecom Advisory Services analysis

H.5.3. Wireless ISPs revenues

The 2021 GDP contribution related to the WISP industry was calculated as a function of the number of subscribers and the ARPU (from CNMC data), yielding a total of $20 million (Table H-30).

Table H-30. Spain: WISP revenues (2021-2025)

Variable	2021	2022	2023	2024	2025
Subscribers (Million)	0.07	0.09	0.11	0.13	0.15
Revenues ($Million)	$20.29	$24.23	$28.95	$34.59	$41.32

Sources: CNMC; Telecom Advisory Services

Increased revenues of WISPs due to 6 GHz

As described in Section H.2.5, the allocation of 6 GHz spectrum band will potentially increase the WISP user base in 7,000 subscribers by 2025, due to expanded coverage and better affordability. Thus, by assuming the same ARPU values as described above, the new subscriptions will amount to an additional $2 million in revenues in 2025 (Table H-31).

Table H-31. Spain: WISP revenues due to 6 GHz (2021-2025)

Variable	2021	2022	2023	2024	2025
WISP annual ARPU ($)	$270.83	$270.83	$270.83	$270.83	$270.83
New subscribers if 6 GHz allocated (Million)	0.000	0.002	0.003	0.005	0.007
New revenue ($Million)	$0.00	$0.42	$0.81	$1.31	$2.02

Sources: CNMC; Telecom Advisory Services analysis

H.6. Wi-Fi ecosystem

The economic value generated by Wi-Fi within Wi-Fi ecosystem companies in Spain is generated from the following two sources:

- The producer surplus of local firms providing products and services in the IoT ecosystem (hardware, software and systems integration) in Spain; and
- The producer surplus of local firms providing products and services in the AR/VR ecosystem (hardware, software and content) in Spain.

H.6.1. Firms belonging to the IoT ecosystem

According to estimates interpolated from Bain & Co, we expect total industrial IoT revenue in Spain to amount $4.7 million in 2021. By relying on the percentage of hardware connectivity spending in IoT in Europe, we were able to split that figure into two main segments: hardware; and software, contents, and services. By weighting those amounts by the share of local production (21% for hardware, 60% for software and services) and the assumed margins (39.44% and 77.46%, respectively), we can estimate the overall producer surplus. However, to that economic value we should extract the share attributed to 6 GHz developments. To do so, we estimated a natural growth rate, by subtracting the corresponding share attributed to 6 GHz according to the growth rates indicated in 3.4. Thus, we estimate a producer surplus not attributed to 6 GHz of $1.8 billion in 2021, expected to reach $1.9 billion in 2025 (Table H-32).

Table H-32. Spain: IoT ecosystem direct contribution (2021-2025)

Variable	2021	2022	2023	2024	2025
IoT revenue - Hardware ($billions)	$0.88	$0.94	$0.94	$0.92	$0.94
IoT revenue - Software, Contents, Services ($billions)	$3.76	$3.99	$4.02	$3.93	$4.02
Total Industrial IoT revenue in ($Billion)	$4.65	$4.93	$4.96	$4.85	$4.96
Local production (%) - Hardware	21%	21%	21%	21%	21%
Local production (%) - Software & Services	60%	60%	60%	60%	60%
Margins (%) - Hardware	39%	39%	39%	39%	39%
Margins (%) - Software & Services	77%	77%	77%	77%	77%
Margins - IoT Hardware revenue	$0.07	$0.08	$0.08	$0.08	$0.08
Margins - Software, contents and services IoT revenue	$1.75	$1.85	$1.87	$1.82	$1.87
Producer surplus ($Million)	$1,821.42	$1,931.08	$1,945.23	$1,899.86	$1,945.95
Growth rate (%)	8.47%	6.02%	0.73%	-2.33%	2.43%
Growth rate not attributed to 6 GHz (%)	7.71%	5.33%	0.63%	-2.01%	2.09%
Producer surplus not attributed to 6 GHz ($Million)	$1,780.09	$1,874.91	$1,886.77	$1,848.81	$1,887.49

Sources: Statista, Bain & Co, CSI, Telecom Advisory Services analysis

Wider deployment of Internet of Things under 6 GHz

Following the previous analysis, we were able to estimate which portion of IoT producer surplus growth can be attributed to 6 GHz. As Table H-33 indicates, we expect the additional IoT surplus generated by 6 GHz to account for $59 million in 2025.

Table H-33. Spain: IoT direct contribution attributed to 6 GHz (2021-2025)

Variable	2021	2022	2023	2024	2025
Producer surplus ($Million)	$1,821.42	$1,931.08	$1,945.23	$1,899.86	$1,945.95
Producer surplus not attributed to 6 GHz ($Million)	$1,780.09	$1,874.91	$1,886.77	$1,848.81	$1,887.49
Additional surplus due to 6 GHz ($Million)	$41.33	$56.16	$58.47	$51.05	$58.46

Sources: Statista, Bain & Co, CSI, Telecom Advisory Services analysis

H.6.2. Firms belonging to the AR/VR ecosystem

Following a similar procedure as with the case of IoT, we can estimate the direct contribution of this ecosystem to the Spanish economy. Starting with the local spending in AR/VR by category (hardware, software, and contents), and weighting those figures by the respective shares of local production and margins, we were able to estimate the total producer surplus. By relying on a ratio built from 5 GHz and 6 GHz AR/VR related products, we were able to subtract the specific contribution attributed to 6 GHz from the surplus corresponding to current bands. Then, we expect by 2021 a direct contribution from the AR/VR ecosystem of $87 million, which will increase until reaching $416 million by 2025 (Table H-34).

Table H-34. Spain: AR/VR ecosystem direct contribution (2021-2025)

Variable	2021	2022	2023	2024	2025
Spending in AR/VR - Hardware $Billion	$0.24	$0.39	$0.56	$0.76	$1.16
Spending in AR/VR - Software, Contents, Services ($Billion)	$0.41	$0.75	$1.18	$1.69	$2.84
Total Spending in AV/VR ($Billion)	$0.65	$1.14	$1.74	$2.45	$4.00
Share of local production - Hardware	20.83%	20.83%	20.83%	20.83%	20.83%
Share of local production - Software, Contents, Services	60.00%	60.00%	60.00%	60.00%	60.00%
Local production for local consumption - Hardware ($Billion)	$0.05	$0.08	$0.12	$0.16	$0.24
Local production for local consumption - Software, Contents, Services ($Billion)	$0.24	$0.45	$0.71	$1.01	$1.71
Local Producer Surplus - Hardware ($Billion)	$0.02	$0.03	$0.05	$0.06	$0.10
Local Producer Surplus - Software, Contents, Services ($Billion)	$0.19	$0.35	$0.55	$0.79	$1.32
Total Producer Surplus	$0.21	$0.38	$0.60	$0.85	$1.42
Share attributable to Wi-Fi (excluding 6 GHz)	42.02%	38.80%	32.18%	30.88%	29.32%
Producer Surplus attributed to Wi-Fi (not including 6 GHz) ($Million)	$87.41	$147.59	$191.85	$262.01	$415.50

Sources: PwC, ABI; Telecom Advisory Services analysis

Wider deployment of AR/VR solutions if 6 GHz allocated

By relying on a ratio built from 5 GHz and 6 GHz AR/VR related products, we were able to isolate the specific economic contribution of the new spectrum allocation. Following a similar procedure as that described above, the direct contribution from AR/VR ecosystem in Spain attributed to 6 GHz in 2025 will yield $217 million.

Table H-35. Spain: AR/VR direct contribution attributed to 6 GHz (2021-2025)

Variable	2021	2022	2023	2024	2025
Spending in AR/VR ($Billion)	$0.65	$1.14	$1.74	$2.45	$4.00
Share attributed to 6 GHz	24.58%	25.59%	26.64%	27.73%	28.87%
Spending in AR/VR attributed to 6 GHz ($Billion)	$0.16	$0.29	$0.46	$0.68	$1.16
Local production for local consumption 6 GHz ($Billion)	$0.07	$0.14	$0.22	$0.33	$0.56
Local Producer Surplus ($Million)	$42.40	$63.47	$94.66	$132.71	$216.64

Sources: PwC, ABI; Telecom Advisory Services analysis

H.7. Wi-Fi contribution to employment

The estimation of employment generated is calculated by relying on the total GDP contribution resulting from the effects analyzed above and using that as an input in the communications sector of an input-output matrix of the Spanish economy. Table H-36 presents the GDP contribution enabled by Wi-Fi projected for the period 2021-2025.

Table H-36. Spain: Wi-Fi enabled GDP contribution (2021-2025)

Year	GDP contribution enabled by Wi-Fi ($Million)		
	Attributed to current bands	Attributed to 6 GHz	Total
2021	$7,650	$164	$7,814
2022	$6,946	$1,109	$8,055
2023	$7,945	$1,930	$9,875
2024	$9,258	$2,529	$11,787
2025	$10,619	$2,303	$12,922

Source: Telecom Advisory Services analysis

These inputs generate the following annual employment effects based on the input/output matrix for the Spanish economy (Table H-37).

Table H-37. Spain: Wi-Fi generated Annual Employment

Variable	2021			2025		
	Current bands	6 GHz	Total	Current bands	6 GHz	Total
Direct jobs	19,121	409	19,531	26,542	5,757	32,299
Indirect jobs	9,717	208	9,925	13,488	2,926	16,414
Induced jobs	3,372	72	3,445	4,681	1,015	5,696
Total	32,211	689	32,900	44,711	9,698	54,409

Sources: GTAP; Telecom Advisory Services analysis

According to the contribution to GDP, Wi-Fi will generate approximately 33,000 jobs in 2021 and is expected to generate over 54,000 in 2025. Job estimates include direct jobs (those jobs created by the specific Wi-Fi contribution), indirect jobs (those jobs created by suppliers to the Wi-Fi sector) and induced jobs (those jobs created by spending of direct and indirect workers).

The sector breakdown of 2021 employment (including the additional jobs created by 6 GHz) is as follows (Table H-38).

Table H-38. Spain: Sector Breakdown of Wi-Fi generated annual employment (2021)

Sector	Direct	Indirect	Induced	Total
Agriculture	0	0	72	72
Extractive industries	0	0	5	5
Manufacturing	0	902	62	964
Construction	0	418	0	418
Trade	0	808	1,049	1,858
Transportation	0	430	0	430
Communications	19,531	0	0	19,531
Financial Services	0	518	0	518
Business services	0	6,849	0	6,849
Other services	0	0	2,256	2,256
Total	19,531	9,925	3,445	32,900

Sources: GTAP; Telecom Advisory Services analysis

I. ECONOMIC VALUE OF WI-FI IN POLAND

Wi-Fi has become a critical component of Poland's telecommunications infrastructure. According to an interpolation from Cisco Annual Internet Report Highlights Tool 2018-2023 for Europe, we estimate there were 3,100,000 public Wi-Fi access points operating in the Polish territory in 2018, while Wiman estimates that there are currently 13,813 free Wi-Fi access points. Given the Wi-Fi access point density in the city-state, hotspots have become a very important connectivity feature. This section presents the results and calculations of the economic assessment.

I.1. Total Economic Value of Wi-Fi in Poland (2021-2025)

Before considering the additional effect of allocating the 6 GHz spectrum band for unlicensed use, the total economic value of Wi-Fi in Poland in 2021 will amount to $15.9 billion. The total economic value in 2021 is comprised of $5.5 billion in consumer surplus, $7.4 billion in producer surplus, and $3 billion in contribution to GDP. The 2025 forecast of economic value will reach $15.9 billion without considering the acceleration effect from Wi-Fi 6 and the allocation of the 6 GHz band. The 2025 forecast of the baseline scenario will be composed of $7.3 billion in consumer surplus, $6.5 billion in producer surplus, and $2 billion in GDP contribution (see Table I-1).

Table I-1. Poland: Economic Value of Wi-Fi (Baseline Scenario)

Agent	Source	Economic Value ($Million)					
		2021	2022	2023	2024	2025	Category
1. Free Wi-Fi	1.1. Savings generated by free Wi-Fi traffic offered in public sites	$33	$31	$29	$27	$24	Consumer Surplus
	1.2. Deployment of free Wi-Fi in public sites	$208	$187	$165	$143	$120	GDP contribution
2. Residential Wi-Fi	2.1. Internet access for home usage of devices that lack a wired port	$994	$1,165	$1,361	$1,588	$1,852	Consumer Surplus
	2.2. Avoidance of investment in in-house wiring	$3,474	$3,580	$3,895	$4,029	$4,378	Consumer Surplus
	2.3. Benefit to consumers from speed increases	$157	$176	$195	$214	$234	Consumer Surplus
	2.4. Residential Wi-Fi devices and equipment deployed	$839	$861	$886	$873	$845	Consumer Surplus
	2.5. Bridging digital divide: use of Wi-Fi to increase coverage in rural and isolated areas	$992	$896	$810	$732	$661	GDP contribution
3. Enterprise Wi-Fi	3.1. Business Internet traffic transmitted through Wi-Fi	$544	$577	$612	$649	$689	Producer surplus
	3.2. Avoidance of enterprise inside wiring costs	$2,229	$2,334	$2,443	$2,558	$2,679	Producer surplus
	3.3. Return to speed: contribution to GDP derived from an increase in average mobile speed	$412	$447	$480	$512	$542	GDP contribution
	3.4. Wide deployment of IoT	$1,202	$482	$481	$493	$506	GDP contribution

Agent	Source	Economic Value ($Million)					
		2021	2022	2023	2024	2025	Category
	3.5. Deployment of AR/VR solutions	$89	$120	$124	$159	$106	GDP contribution
4. ISPs	4.1. CAPEX and OPEX savings due to cellular off-loading	$3,195	$3,028	$2,459	$1,353	$231	Producer surplus
	4.2. Revenues of service providers offering paid Wi-Fi access in public places	$31	$31	$30	$26	$21	GDP contribution
	4.3. Aggregated revenues of WISPs	$84	$76	$68	$61	$55	GDP contribution
5. Wi-Fi ecosystem	5.1. Locally manufactured residential Wi-Fi devices and equipment	$0	$0	$0	$0	$0	Producer surplus
	5.2. Locally manufactured Wi-Fi enterprise equipment	$0	$0	$0	$0	$0	Producer surplus
	5.3. Locally produced IoT products and services	$1,352	$1,615	$1,921	$2,285	$2,717	Producer surplus
	5.4. Locally produced of AR/VR solutions	$30	$53	$72	$107	$195	Producer surplus
Total		$15,865	$15,659	$16,031	$15,809	$15,855	

Source: Telecom Advisory Services analysis

In addition to the baseline scenario, the allocation of the 6 GHz spectrum band for unlicensed use and the deployment of Wi-Fi 6 and Wi-Fi 6E devices will trigger a growth of economic value, reaching $5.7 billion in 2025 (see Table I-2).

Table I-2. Poland: Economic Value of Wi-Fi (only attributed to 6 GHz)

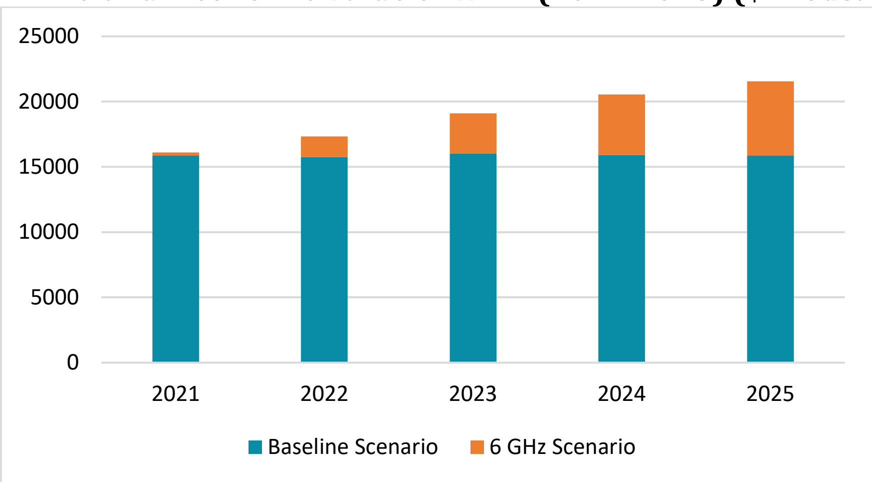
Agent	Source	Economic Value ($Million)					
		2021	2022	2023	2024	2025	Category
1. Free Wi-Fi	1.1. Savings generated by free Wi-Fi traffic offered in public sites	$0	$0	$0	$1	$1	Consumer Surplus
	1.2. Deployment of free Wi-Fi in public sites	$0	$18	$31	$40	$44	GDP contribution
	1.3. Benefit of faster free Wi-Fi with Wi-Fi 6E devices	$0	$2	$4	$6	$7	Consumer Surplus
2. Residential Wi-Fi	2.3. Benefit to consumers from speed increases	$0	$313	$636	$960	$1,166	Consumer Surplus
	2.4. Residential Wi-Fi devices and equipment deployed	$30	$74	$160	$245	$332	Consumer Surplus
	2.5. Bridging digital divide: use of Wi-Fi to increase coverage in rural and isolated areas	$0	$40	$60	$76	$87	GDP contribution
3. Enterprise Wi-Fi	3.1. Business Internet traffic transmitted through Wi-Fi	$0	$20	$25	$31	$34	Producer surplus
	3.3. Return to speed: contribution to GDP derived from an increase in average mobile speed	$0	$826	$1,765	$2,778	$3,383	GDP contribution
	3.4. Wide deployment of Internet of Things	$29	$31	$38	$39	$40	GDP contribution
	3.5. Deployment of AR/VR solutions	$43	$52	$61	$81	$55	GDP contribution

Agent	Source	Economic Value ($Million)					
		2021	2022	2023	2024	2025	Category
4. ISPs	4.1 CAPEX and OPEX savings due to cellular off-loading	$88	$88	$88	$88	$88	Producer surplus
	4.2. Revenues of service providers offering paid Wi-Fi access in public places	$0	$1	$2	$3	$3	GDP contribution
	4.3. Aggregated revenues of WISPs	$0	$2	$2	$3	$3	GDP contribution
5. Wi-Fi ecosystem	5.1. Locally manufactured residential Wi-Fi devices and equipment	$0	$0	$0	$0	$0	Producer surplus
	5.2. Locally manufactured Wi-Fi enterprise equipment	$0	$0	$0	$0	$0	Producer surplus
	5.3. Locally produced IoT products and services	$40	$83	$150	$241	$363	Producer surplus
	5.4. Locally produced of AR/VR solutions	$15	$23	$36	$54	$101	Producer surplus
Total		$245	$1,573	$3,058	$4,646	$5,707	

Source: Telecom Advisory Services analysis

Considering that we forecast that by 2025 only 40% of Wi-Fi traffic will rely on 6 GHz channels, the accelerated effect derived from the new spectrum allocation and latest Wi-Fi technologies will still be far from reaching its maximum potential at this time. If the Polish regulatory agency decides to allocate the upper part of the spectrum to unlicensed use, Wi-Fi economic value would increase significantly beyond the values presented in Table I-2. However, a visual depiction of the trend provides a perspective of the growing importance of Wi-Fi 6 in the overall economic value (see Graphic I-1)

Graphic I-1. Poland: Economic Value of Wi-Fi (2021-2025) ($Thousand)



Source: Telecom Advisory Services analysis

By combining the baseline and the Wi-Fi 6 and 6 GHz scenarios, the overall economic value of Wi-Fi for Poland will yield $20.2 billion in 2025 (see Table I-3).

Table I-3. Poland: Total Economic Value of Wi-Fi (including Wi-Fi 6 and 6 GHz)

Agent	Source	Economic Value ($Million)					
		2021	2022	2023	2024	2025	Category
1. Free Wi-Fi	1.1. Savings to consumers of free Wi-Fi traffic offered in public sites	$33	$31	$30	$27	$25	Consumer Surplus
	1.2. Deployment of free Wi-Fi in public sites	$208	$204	$196	$183	$164	GDP contribution
	1.3. Benefit of faster free Wi-Fi with Wi-Fi 6E devices	$0	$2	$4	$6	$7	Consumer Surplus
2. Residential Wi-Fi	2.1. Internet access for home usage of devices that lack a wired port	$994	$1,165	$1,361	$1,588	$1,852	Consumer Surplus
	2.2. Avoidance of investment in in-house wiring	$3,474	$3,580	$3,895	$4,029	$4,378	Consumer Surplus
	2.3. Benefit to consumers from speed increases	$157	$488	$830	$1,175	$1,400	Consumer Surplus
	2.4. Residential Wi-Fi devices and equipment deployed	$870	$934	$1,046	$1,118	$1,177	Consumer Surplus
	2.5. Bridging digital divide: use of Wi-Fi to increase coverage in rural and isolated areas	$992	$936	$870	$808	$748	GDP contribution
3. Enterprise Wi-Fi	3.1. Business Internet traffic transmitted through Wi-Fi	$544	$597	$637	$681	$722	Producer surplus
	3.2. Avoidance of enterprise inside wiring costs	$2,229	$2,334	$2,443	$2,558	$2,679	Producer surplus
	3.3. Return to speed: contribution to GDP derived from an increase in average mobile speed	$412	$1,272	$2,245	$3,290	$3,925	GDP contribution
	3.4. Wide deployment of IoT	$1,232	$513	$520	$533	$546	GDP contribution
	3.5. Deployment of AR/VR solutions	$132	$172	$185	$240	$161	GDP contribution
4. ISPs	4.1 CAPEX and OPEX savings due to cellular off-loading	$3,283	$3,116	$2,547	$1,441	$319	Producer surplus
	4.2. Revenues of service providers offering paid Wi-Fi access in public places	$31	$32	$32	$30	$24	GDP contribution
	4.3. Aggregated revenues of WISPs	$84	$77	$71	$64	$59	GDP contribution
5. Wi-Fi ecosystem	5.1. Locally manufactured residential Wi-Fi devices and equipment	$0	$0	$0	$0	$0	Producer surplus
	5.2. Locally manufactured Wi-Fi enterprise equipment	$0	$0	$0	$0	$0	Producer surplus
	5.3. Locally produced IoT products and services	$1,392	$1,698	$2,071	$2,526	$3,081	Producer surplus
	5.4. Locally produced of AR/VR solutions	$45	$76	$108	$161	$296	Producer surplus
Total		$16,112	$17,227	$19,091	$20,458	$21,563	

Source: Telecom Advisory Services analysis

The following sections will present in detail the calculation of each source of value, disaggregating the economic contribution under current the spectrum ecosystem and the enhanced effect due to Wi-Fi 6 availability and the 6 GHz band.

I.2. Value from free Wi-Fi service

The economic value of free Wi-Fi service originates from three contribution sources:

- Savings to consumers by accessing the Internet in free Wi-Fi sites rather than incurring cellular costs
- The use of Wi-Fi to expand broadband coverage to the unserved population
- The return to speed of Wi-Fi compared to the use of cellular service

I.2.1. Savings incurred by accessing free Wi-Fi in public sites

Free Wi-Fi offered in retail shops, libraries, schools, coffee shops, city halls, and corporate guest accounts allows consumers to save money that would otherwise be spent purchasing cellular service. In addition, free hotspots provide access to the Internet for consumers that cannot afford to purchase broadband service. This last effect has been particularly important in the ongoing pandemic, allowing households to access the Internet for telecommuting and continuing education.

The economic value of free Wi-Fi is measured in terms of consumer surplus, which is by estimating the benefit that flows to consumers as a result of the savings in wireless broadband service acquisition. We start by quantifying the mobile Internet traffic. In order to isolate the effect from the increased capacity derived from the 6 GHz allocation, we calculate the portion of free Wi-Fi traffic attributed to current spectrum bands. For this, we relied on the assumption than current traffic levels are already producing congestion in most free Wi-Fi hotspots at times of peak demand. Thus, we assume that traffic per hotspot beyond 2021 will remain at 2020 levels, although overall free traffic will continue growing as new hotspots will continue to be deployed.

Table I-4. Poland: Total Free Wi-Fi Traffic projection (2021-2025)

Variable	2021	2022	2023	2024	2025
Free Wi-Fi traffic (million GB Per year) - considering current trends	419.70	502.64	605.96	734.95	897.89
Free Wi-Fi hotspots (Million)	0.35	0.41	0.48	0.57	0.67
Traffic per hotspot - considering current trends	1195.50	1220.02	1253.32	1295.31	1348.47
Traffic per hotspot - capped due to congestion	1174.32	1174.32	1174.32	1174.32	1174.32
Total traffic (not attributed to 6 GHz) (Million GB)	412.27	483.81	567.77	666.30	781.93

Sources: Cisco; Wiman; Telecom Advisory Services analysis

We calculate consumer surplus by multiplying the total free traffic (not attributed to 6 GHz) by the difference between what the consumer would have to pay if she/he were to rely on a wireless carrier and the cost of offering free Wi-Fi (incurred by the retailer or public site). To do so, we needed an estimate of the average price per GB of wireless data transmitted by wideband networks, which we calculated by averaging the most economic "dollar per GB" plan of four major wireless carriers (see Table I-5).

Table I-5. Poland: Average Price Per Gigabyte (2020)

Carrier	Plan	Price per GB ($)
Plus (Cyfrowy Polsat)	70 PLN	$0.184
Play (P4)	Only L	$0.281
T-Mobile (Deutsche Telekom)	Internet 50	$0.210
Orange	Mobile Plan 75	$0.281

Sources: Websites of cellular operators; Telecom Advisory Services analysis

Historical data allowed for a projection of future prices per gigabyte. Based on these prices, we expect the average price per GB will reach an estimated $0.14 in 2025. By relying on the total free Wi-Fi traffic not attributed to 6 GHz allocation shown in Table I-10 and the average price per cellular gigabyte minus the cost of provisioning Wi-Fi service, we calculated the consumer surplus of free Wi-Fi traffic (see Table I-6).

Table I-6. Poland: Consumer Surplus of Free Wi-Fi Traffic (2021-2025)

Variable	2021	2022	2023	2024	2025
Total Free Traffic (not attributed to 6 GHz) (Million GB)	412.27	483.81	567.77	666.30	781.93
Price per cellular gigabyte ($)	$0.22	$0.19	$0.17	$0.16	$0.14
Cost per Wi-Fi provisioning ($)	$0.14	$0.13	$0.12	$0.12	$0.11
Consumer surplus per gigabyte ($)	$0.08	$0.06	$0.05	$0.04	$0.03
Total Consumer surplus ($Million)	$32.72	$31.09	$29.13	$26.65	$23.56

Sources: Cisco; Websites of cellular operators; Telecom Advisory Services analysis

As indicated in Table I-6, consumer surplus of free Wi-Fi traffic in 2021 would reach an estimated $32.7 million, decreasing to $23.6 million in 2025 due to congestion created if we do not consider the 6 GHz spectrum band.

Enhanced free Wi-Fi traffic due to 6 GHz allocation

The allocation of the 6 GHz spectrum band and the technological advances provided by the Wi-Fi 6 standard will remove the above-mentioned bottlenecks causing congestion. As a result, the traffic per hotspot will be able to continue growing at its natural rate as determined by the extrapolation of past recent trends. That being said, we must take into account that not all Wi-Fi traffic will benefit immediately from opening the 6 GHz band, as most current devices are not prepared to support the new standards. Thus, we expect the traffic through the 6 GHz channel to gradually increase until reaching a 40% of total free traffic by 2025.

Once computed the additional traffic "above and beyond" the future previsions under current spectrum bands, we will follow a similar approach to calculate the consumer surplus, by multiplying it by the difference between what the consumer would have to pay if he were to utilize a wireless carrier and the cost of offering free Wi-Fi (Table I-7). As a result, we project an additional consumer surplus of $1.4 million from free Wi-Fi traffic attributed to 6 GHz.

Table I-7. Poland: Additional Consumer Surplus of Free Wi-Fi Traffic generated due to 6 GHz (2021-2025)

Variable	2021	2022	2023	2024	2025
Demand not satisfied due to congestion (Million GB)	7.44	18.83	38.19	68.65	115.96
Traffic through the 6 GHz Channel (%)	0%	10%	20%	30%	40%
Total traffic (attributed to 6 GHz) (Million GB)	0.00	1.88	7.64	20.59	46.38
Consumer Surplus (attributed to 6 GHz) ($Million)	$0.00	$0.12	$0.39	$0.82	$1.40

Sources: Cisco; Telecom Advisory Services analysis

The additional surplus generated by the allocation of the 6 GHz spectrum band will mitigate the decreasing trend of consumer surplus derived from free Wi-Fi.

I.2.2. Free Wi-Fi to provide broadband to the unserved population

As explained in section B, deployment of free Wi-Fi provides Internet access to the unserved population. Consumers that do not have broadband at home because they lack the economic means to acquire services can rely on free Wi-Fi to gain Internet access. As a result, more people can be connected, which in turn enhances the economic contribution of broadband.

The calculation of this economic impact starts by calculating which portion of households that lack broadband service are already accessing Internet through free hotspots. We follow a conservative approach and assume that only 5% of unconnected households rely on free hotspots for accessing Internet. After calculating the increase in broadband penetration due to households relying on free Wi-Fi, we rely on the broadband impact coefficient from Katz and Callorda (2018b), for Europe. As a result, the GDP contribution of this particular effect is expected to amount to $208 million in 2021, reaching $120 million in 2025.

Table I-8. Poland: GDP contribution due to households relying on Free Wi-Fi (2021-2025)

Variable	2021	2022	2023	2024	2025
Households without Internet	1,930,354	1,734,360	1,532,158	1,323,591	1,108,500
Households that don't buy because access Internet free hotspots (%)	5%	5%	5%	5%	5%
Households served by Free Wi-Fi hot spots	96,518	86,718	76,608	66,180	55,425
Increase in national broadband penetration	0.8%	0.7%	0.6%	0.5%	0.4%
Impact of fixed broadband adoption in GDP	4.63%	4.63%	4.63%	4.63%	4.63%
Increase in the GDP due to the new broadband adoption (% GDP)	0.04%	0.03%	0.03%	0.02%	0.02%
GDP ($Billion)	$588.65	$603.52	$618.53	$633.91	$649.68
Total impact in GDP ($Million)	$207.56	$186.84	$165.31	$143.02	$119.96

Sources: Poland Census; Eurostat; IMF; Telecom Advisory Services analysis

Enhanced GDP contribution due to 6 GHz allocation

As stated above, Wi-Fi 6 technology enables supporting a high number of devices on a single access point. Accordingly, the improved throughput of free Wi-Fi hotspots under the 6 GHz allocation will allow the possibility of serving additional unconnected households.

The potential universe of additional households that could be served under this effect is enormous, as most unconnected households usually identify that costs are their main barrier for accessing to connectivity and thus, may potentially be served by free hotspots as long as they are in proximity to the access point. However, evidence suggests that not many people rely exclusively on free Wi-Fi as their main source of Internet access, so we will follow again a conservative approach and assume that a further 5% of unconnected households will be served through free hotspots under the allocation of the 6 GHz band. On the other hand, we have also considered that the expansion of traffic through the new band will take place gradually, reaching 40% in 2025. All in all, we estimate that additional 20,332 households will be served in 2025 due to free hotspots operating under 6 GHz spectrum, yielding an additional GDP contribution of approximately $44 million (Table I-9).

Table I-9. Poland: GDP contribution due to households relying on Free Wi-Fi due to 6 GHz (2021-2025)

Variable	2021	2022	2023	2024	2025
Households without Internet (not served by free Wi-Fi and not new adopters of WISP)	1,833,837	1,630,799	1,430,293	1,225,431	1,016,594
Potential households that could be served through free Wi-Fi hotspots under increased capacity (% of those not connected)	5%	5%	5%	5%	5%
Traffic through the 6 GHz Channel (%)	0%	10%	20%	30%	40%
Additional households served by Free Wi-Fi hot spots with 6 GHz	0	8,154	14,303	18,381	20,332
Increase in national broadband penetration	0	0.06%	0.11%	0.14%	0.15%
Increase in the GDP due to the new broadband adoption (% GDP)	0	0.00%	0.00%	0.01%	0.01%
Total impact in GDP ($Million)	$0	$17.57	$30.86	$39.72	$44.01

Sources: Poland Census; Eurostat; IMF; Telecom Advisory Services analysis

I.2.3. Benefit to consumers for enjoying higher speed from free Wi-Fi if 6 GHz band is allocated

When the 6 GHz band is adopted by free Wi-Fi access points, it will deliver service at faster broadband speeds. Current speeds from free hotspots are quite modest[200]. Thus, the expanded capabilities due to the allocation of 6 GHz spectrum band will enhance free Wi-Fi speed, and as a result, will increase consumer surplus. We assume that under the 6 GHz allocation, speed from free hotspots will be similar to the Wi-Fi speeds from mobile devices reported by Cisco. After calculating the average speed by considering the expected share of traffic through 6 GHz, we follow Nevo et al. (2016) and calculate the additional consumer surplus per household relying on free Wi-Fi. We expect the consumer surplus resulting from faster speed in free Wi-Fi sites to reach $7 million in 2025 (Table I-10).

[200] Given the lack of reliable data on free Wi-Fi speed in Poland, we made an estimation based on U.S. data, and applying the percentual differential between both countries in terms of fixed broadband speed. Then, we estimate free Wi-Fi speed in Poland to reach 9.2 Mbps in 2020.

Table I-10. Poland: Consumer surplus for enjoying higher speed from free Wi-Fi if 6 GHz band allocated (2021-2025)

Variable	2021	2022	2023	2024	2025
Free Wi-Fi mean speed with no 6 GHz (Mbps)	11.24	13.81	16.95	19.32	22.01
Wi-Fi Speeds from Mobile Device (Mbps)	32.60	38.30	45.00	52.87	62.12
Traffic through the 6 GHz Channel (%)	0.00%	10.00%	20.00%	30.00%	40.00%
Free Wi-Fi mean speed with 6 GHz (Mbps)	11.242	16.255	22.562	29.384	38.056
Demand for average download speed	42.81	45.97	49.20	51.52	53.89
New Demand for average download speed	42.81	48.07	52.92	57.04	61.18
Additional Monthly Consumer surplus	0.00	2.10	3.72	5.52	7.30
Additional Yearly Consumer Surplus	0	25.20	44.64	66.29	87.57
Households that rely on Free Wi-Fi	96,518	94,872	90,911	84,561	75,757
Consumer surplus ($Million)	$0	$2	$4	$6	$7

Sources: Cisco; Rotten Wi-Fi; Nevo et al. (2016); Telecom Advisory Services analysis

I.3. Residential Wi-Fi

The economic value of Wi-Fi in consumer residences is the result of five factors:

- Provision of connectivity to the home network for devices that lack an Ethernet port;
- Cost avoidance of ethernet inside wiring;
- Consumer surplus resulting from faster broadband speeds relative to cellular networks;
- Consumer surplus derived from usage of home devices connected to the home network; and
- Provision of Internet access to consumers located in rural and isolated areas.

I.3.1. Home Internet access for devices that lack an Ethernet port

The underlying premise of this analysis is that in the absence of Wi-Fi, users of devices lacking an Ethernet port would have to depend on the cellular network to gain Internet access. For this reason, estimating value would first measure the traffic generated by these devices at home and then multiply it by the average price charged by cellular carriers.

To estimate the traffic of smartphones and tablets, we relied on 2018 Cisco estimates for the period 2016-21 and extrapolated those growth rates to 2025. It must be said, however, that in 2019 Cisco adjusted its predictions upwards. However, we preferred to rely on the original figures to avoid incurring in the risk of overestimation. Thus, it may be possible that our previsions reported here are slightly downward biased. In addition, we have to consider that according to Cisco IBSG (2012), 43.12% of use time of devices that lack an Ethernet port occurs at home. Therefore, the portion of said traffic generated at home will reach 4,619 million gigabytes in 2021 (see Table I-11).

Table I-11. Poland: Total Mobile Internet Traffic (2021-2025) (Million gigabytes)

Variable	2021	2022	2023	2024	2025
Total Annual traffic – Smartphones	8,448.2	11,128.7	14,609.5	19,111.9	24,996.3
Total Annual traffic - Tablets	2,264.7	2,811.1	3,489.4	4,331.2	5,376.2
Share of traffic at Home	43.12%	43.12%	43.12%	43.12%	43.12%
Total Traffic at Home - Smartphones	3,642.7	4,798.5	6,299.3	8,240.6	10,777.8
Total Traffic at Home - Tablets	976.5	1,212.1	1,504.5	1,867.5	2,318.1
Total Traffic at Home	4,619.2	6,010.6	7,803.8	10,108.1	13,096.0
Average Price per GB ($)	$0.22	$0.19	$0.17	$0.16	$0.14
Price per home traffic ($Million)	$994.08	$1,164.58	$1,361.33	$1,587.54	$1,851.78

Sources: Cisco; GSMA Intelligence; Telecom Advisory Services analysis

If this traffic had to be transported by cellular networks, at the average price per GB estimated, it would result in costs of $994 million in 2021, before reaching $1.9 billion in 2025.

I.3.2. Avoidance of inside wiring investment

Residential Wi-Fi allows consumers to avoid paying for wiring to connect all home devices (printers, laptops, storage units, etc.). Considering that 89% of connected households will have Wi-Fi in 2021[201], and the wiring cost estimated for households[202], the avoidance costs of inside wiring over 11.27 million households yields a total of $3.474 billion. By 2025, almost all connected households are expected to have adopted Wi-Fi, so the savings would have reached $4.378 billion (Table I-12).

Table I-12. Poland: Consumer surplus from avoidance of investment in in-house wiring (2021-2025)

Variable	2021	2022	2023	2024	2025
Total Wiring Cost	$308.16	$311.91	$315.70	$319.54	$323.42
Households with Internet	12,668,294	12,963,608	13,265,806	13,575,049	13,891,500
Households with Wi-Fi (%)	89%	89%	93%	93%	97%
Households with Internet and Wi-Fi	11,274,782	11,480,000	12,337,200	12,610,000	13,535,572
Inside Wiring Costs ($Million)	$3,474	$3,580	$3,895	$4,029	$4,378

Sources: Eurostat; Telecom Advisory Services analysis

I.3.3. Benefits derived from speed increase

As described before, consumer surplus increases if users enjoy faster Internet speeds. Thus, the welfare of residential Wi-Fi customers is expected to benefit from faster services than those provided by cellular networks. After weighting the corresponding broadband speeds with the percentage of traffic carried out through

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[201] Assumed equal to France.

[202] We took as a reference the value from United States and adjusted it for Poland considering the differences in PPP between both countries.

Wi-Fi at home, we calculated the average speed advantage of using Wi-Fi in comparison to cellular networks. By applying the parameters determined in Nevo et al. (2016), the expected consumer surplus will yield $157 million in 2021, increasing to $234 million in 2025.

Table I-13. Poland: Consumer surplus from faster speed in households (2021-2025)

Variable	2021	2022	2023	2024	2025
Average Speed in households if Wi-Fi traffic were carried through mobile networks (Mbps)	44.77	55.16	67.97	83.76	103.26
Average Speed in household with Wi-Fi (Mbps)	49.06	60.75	75.19	93.03	115.05
Demand for average download speed	60.36	63.78	67.27	70.84	74.49
New Demand for average download speed	61.52	65.02	68.58	72.22	75.93
Additional Monthly Consumer surplus	$1.16	$1.24	$1.31	$1.38	$1.44
Additional Yearly Consumer Surplus	$13.95	$14.90	$15.78	$16.58	$17.30
Households with Internet and Wi-Fi	11,274,782	11,796,883	12,337,200	12,922,502	13,535,572
Impact ($Million)	$157	$176	$195	$214	$234

Sources: Cisco; Nevo et al. (2016); Eurostat; Telecom Advisory Services analysis

Additional benefit to consumers from speed increase due to 6 GHz

The welfare of residential Wi-Fi customers is expected to receive further benefit from the 6 GHz allocation due to faster Internet service under Wi-Fi 6E. As previously described in section B, only households acquiring a 150 Mbps (or faster) fixed broadband line will be affected due to current router bottlenecks, and hence, the speed experienced will not be equivalent to that delivered by the fixed network. After calculating the difference in average speed attributed to 6 GHz, the additional consumer surplus will yield $1.2 billion in 2025.

Table I-14. Poland: Consumer surplus from faster speed in households if 6 GHz allocated (2021-2025)

Variable	2021	2022	2023	2024	2025
Households that have connections over 150 Mbps (%)	38.49%	44.07%	50.46%	57.77%	66.15%
Percentage of household traffic that goes through Wi-Fi	74.54%	76.16%	77.70%	79.17%	80.58%
Traffic through the 6 GHz Channel (%)	0.00%	10.00%	20.00%	30.00%	40.00%
Share of traffic affected due to 6 GHz (%)	0.00%	3.36%	7.84%	13.72%	21.32%
Average speed with no 6 GHz (Mbps)	49.06	60.75	75.19	93.03	115.05
Average speed with 6 GHz (Mbps)	49.06	72.14	104.58	148.87	197.12
Demand for average download speed	61.52	65.02	68.58	72.22	75.93
New Demand for average download speed	61.52	67.23	72.88	78.42	83.11
Additional Yearly Consumer Surplus	$0.00	$26.50	$51.52	$74.32	$86.14
Households with Wi-Fi	11,274,782	11,796,883	12,337,200	12,922,502	13,535,572
Impact ($Million)	$0	$313	$636	$960	$1,166

Sources: OECD; Eurostat; Cisco; Nevo et al. (2016); Telecom Advisory Services analysis

I.3.4. Residential Wi-Fi devices and equipment

The consumer surplus derived from the adoption of residential Wi-Fi devices and equipment focuses on seven consumers products which are intrinsically linked to Wi-Fi: smart home devices and systems such as Wi-Fi speakers and home security systems, home networking systems, Wi-Fi tablets, access points, external adapters, routers, and gateways. Two different approaches are used in these cases: one assuming that consumer surplus is roughly equal to producer surplus in six of the seven products (excluding tablets), and an assessment of tablets' willingness-to-pay.

The estimation of economic value in the first approach begins by compiling local sales in the six product categories in Poland[203]. After computing the sales in Poland, we applied the prorated margin estimated by CSI markets (39.44%) which yields an estimated producer surplus for these particular products of $809 million in 2021. As mentioned above, it is assumed that the consumer surplus is of the same magnitude. This methodology was also used to calculate the consumer surplus up to 2023. However, the gradual adoption of Wi-Fi 6 devices is forecast to reduce the sales and economic value from the devices relying on the 2.4 GHz and 5 GHz spectrum bands. Non 6 GHz consumer devices shipments are expected by IDC to decrease by 1.2% in 2024 and 3.1% in 2025. Based on this estimate, we extrapolated the consumer surplus from non 6 GHz reliant residential Wi-Fi devices and equipment between 2021 and 2025.

Starting with CTA/Statista worldwide tablet revenue estimates, we interpolated the revenue figures for Poland (by weighting by the country's share on global GDP), and extrapolated the evolution of local revenue till 2025 by considering Cisco estimates of tablet evolution for the period. We reviewed the data on tablet prices for the market leader (taking as a reference the Samsung Wi-Fi tablet 128GB, as Samsung has 32.6% of the Poland market share in tablets[204]) and for the rest of the market (taking as a reference the Apple iPad 10.2 Inch 128 GB), and assumed consumer willingness-to-pay levels in a similar percentage above prices as in the U.S. average. Combining all that information, we were able to estimate a consumer surplus attributable to tablets of $31 million in 2021, expected to reach $23 million in 2025 (Table I-15).

Table I-15. Poland: Economic Value of Wi-Fi enabled consumer products (2021-2025)

Variable	2021	2022	2023	2024	2025
Consumer surplus (exc. tablets) ($Million)	$809	$833	$860	$849	$823
Tablet consumer surplus ($Million)	$31	$28	$26	$24	$23
Total consumer surplus ($Million)	$839	$861	$886	$873	$845

Source: Telecom Advisory Services analysis

[203] Calculated by prorating data for the United States based on GDP.
[204] Source: Gs StatCounter

Consumer surplus derived to Wi-Fi enabled residential equipment for 6 GHz

As discussed above, sales of residential Wi-Fi devices and equipment operating in the 6 GHz band are expected to gradually replace those of former generations. According to IDC, global shipments of consumer devices operating in the 6 GHz (802.11ax standard) will represent 40% of sales from prior generations. As a result, if the shipments ratio reaches 40% in 2025, we can expect that, at least, the consumer surplus derived from 6 GHz devices will represent 40% of that of former technology residential devices. As a result, our estimates for consumer surplus attributed to 6 GHz residential devices amount to $332 million in 2025 (see Table I-16).

Table I-16. Poland: Economic Value of Wi-Fi enabled consumer products attributable to 6 GHz (2021-2025)

Variable	2021	2022	2023	2024	2025
Ratio consumer 6 GHz / no 6 GHz	3.76%	8.83%	18.59%	28.86%	40.30%
Total consumer surplus ($Million) – 6 GHz	$30.45	$73.58	$159.82	$245.07	$331.60

Sources: IDC; Telecom Advisory Services analysis

I.3.5. Bridging the digital divide: use of Wi-Fi to increase coverage in rural and isolated areas

Wi-Fi is an appropriate technology to offer Internet access in rural and isolated areas. Based on the data provided by UKE in subscriptions by technology, we can estimate 620,000 WISP subscriptions in 2021. The calculation of the Wi-Fi contribution to the reduction of the digital divide must subtract the direct impact of WISPs (Section 4.4.3.) to avoid double counting. On the other hand, we assume that 50% of WISP potential connections may be theoretically served by other technologies (i.e. satellite) covering the same isolated footprint[205]. Thus, we can conservatively expect 50% of broadband subscriptions in remote locations exclusively attributed to WISPs. Once this is done, we calculate the impact on GDP by relying on the coefficient estimated by Katz and Callorda (2018b) through regression models that links increase in broadband penetration to economic growth. The contribution to GDP materializes through multiple effects: creation of new businesses, increasing productivity of existing enterprises, and growth of average income per household. We expect a GDP contribution of $992 million in 2021, which will decrease till $661 million in 2025 (see Table I-17).

[205] Assuming similar levels as those estimated for France and Germany

Table I-17. Poland: Estimation of GDP Contribution derived from reducing the digital divide (2021-2025)

Variable	2021	2022	2023	2024	2025
WISP subscribers	616,734	555,061	499,555	449,599	404,639
Additional broadband penetration due to WISP	7.59%	6.69%	5.90%	5.27%	4.58%
Impact of fixed broadband adoption in GDP	4.63%	4.63%	4.63%	4.63%	4.63%
GDP ($Billion)	$589	$604	$619	$634	$650
WISP TOTAL impact ($Billion)	$2.1	$1.9	$1.7	$1.5	$1.4
WISP Revenues ($Billion)	$0.08	$0.08	$0.07	$0.06	$0.06
Share that exist because WISP	50.00%	50.00%	50.00%	50.00%	50.00%
WISP spillovers on GDP ($Million)	$991.5	$896.3	$809.9	$731.9	$661.4

Sources: UKE, IMF; Telecom Advisory Services analysis

Economic impact of enhanced coverage and affordability due to 6 GHz

The allocation of the 6 GHz band to unlicensed use would allow WISPs to potentially increase their subscriber base within their same coverage footprint. Therefore, a first effect derived from the allocation of the new spectrum band is related to additional households served due to additional coverage. We will follow a cautious approach and consider that the expanded coverage will yield a gradual increase on WISP subscribers, from 2% in 2022 to 5% in 2025 over the figures projected without assuming the additional spectrum allocation. In addition, an increase of the user base would allow service providers to lower their operating costs. Thus, by assuming stability in prices, affordability would increase as GDP per capita grows as economic growth resumes. All in all, we can expect an overall increase in almost 36,500 WISP connections in 2025, contributing to an increase 0.24% in national broadband penetration. Considering the impact coefficient of broadband on the economy, which will yield a GDP contribution equivalent to $87 million.

Table I-18. Poland: GDP Contribution derived from reducing the digital divide due to 6 GHz (2021-2025)

Variable	2021	2022	2023	2024	2025
New subscribers due to expanded coverage (%)	0%	2%	3%	4%	5%
New subscribers due to expanded coverage	0.00	11,101	14,987	17,984	20,232
New WISP adoption after price decrease (% households)	5%	4%	4%	3%	3%
Traffic through the 6 GHz Channel (%)	0.00%	10.00%	20.00%	30.00%	40.00%
Increase in WISP connections due to lower prices (households that buy the service)	0.00	5,742	10,270	13,996	16,249
Overall increase in WISP connections due to 6 GHz	0.00	16,844	25,256	31,980	36,481
Increase in national broadband penetration	0.00%	0.11%	0.17%	0.21%	0.24%
Impact of fixed broadband adoption in GDP	4.63%	4.63%	4.63%	4.63%	4.63%
Increase in the GDP due to the new broadband adoption (% GDP)	0.00%	0.01%	0.01%	0.02%	0.02%
Total impact in GDP ($Million)	0.0	39.7	59.7	75.9	87.0

Sources: UKE; IMF; Telecom Advisory Services analysis

I.4. Enterprise Wi-Fi

Beyond the impact on consumers, Wi-Fi also contributes significant economic value in the Polish enterprise segment. This section provides estimates in five areas:

- Support of business Internet traffic;
- Avoidance of campus and enterprise facilities inside wiring;
- Contribution to GDP resulting from Wi-Fi speed faster than cellular connections;
- Deployment of IoT solutions; and
- Implementation of business focused AR/VR use cases.

I.4.1. Business Internet traffic transmitted through Wi-Fi

Wi-Fi enterprise savings results from wireless traffic that is routed through Wi-Fi access points. Considering Cisco 2016-21 projections, we estimate that total business Internet traffic will reach 4.3 billion GB in 2021, of which 2.5 billion GB would have been transported through Wi-Fi access points. Considering the average price per GB transported by cellular (from Table IX-5), savings from Wi-Fi will reach $544 million, an addition to the producer surplus[206]. By 2025, this benefit will reach $689 million (see Table I-19).

Table I-19. Poland: Savings in business wireless traffic (2021-2025)

Variable	2021	2022	2023	2024	2025
Share of Business Internet Traffic by Wi Fi	58.80%	59.00%	59.20%	59.40%	59.61%
Total Business Internet Traffic (Million GB)	4,300.6	5,049.4	5,928.6	6,960.9	8,173.0
Total Wi-Fi enterprise traffic (Million GB)	2,528.7	2,979.2	3,510.0	4,135.1	4,871.8
Average Price per GB	$0.22	$0.19	$0.17	$0.16	$0.14
Economic Impact ($Million)	$544.19	$577.23	$612.27	$649.44	$688.87

Sources: Cisco; Telecom Advisory Services analysis

Enhanced business Internet traffic transmitted through Wi-Fi due to 6 GHz

The deployment of the latest enterprise applications will generate an exponential growth in data traffic that will be handled by devices operating in unlicensed spectrum, through the combination of the existing bands and the 6 GHz band. In 2019, an updated Cisco traffic forecast based on the explosion of IoT and AR/VR applications, among other factors, increased total business Internet traffic previsions from the previous 2016-21 estimates from 2018. As in the case of the U.S., we assume that part of the growth was driven by "natural" growth, and another portion was triggered by Wi-Fi traffic stimulated by changes in 6 GHz. The sum of the difference due to broader Wi-Fi traffic will reach $33.5 million in 2025 (see Table I-20).

[206] We acknowledge that enterprises are likely to negotiate wireless rates lower than those offered in the consumer market; however, data in this area is not available.

Table I-20. Poland: Savings in business wireless traffic due to 6 GHz (2021-2025)

Variable	2021	2022	2023	2024	2025
Total value of business Wi-Fi traffic 2016-21 ($Million)	$544.3	$577.2	$612.3	$649.4	$688.9
Total value of business Wi-Fi traffic 2017/22 ($Million)	$687.3	$762.4	$845.6	$937.9	$1,040.2
Difference between the 2 estimations ($Million)	$143.2	$185.1	$233.3	$288.4	$351.4
Difference because natural growth ($Million)	$134.1	$165.2	$208.2	$257.3	$313.5
Difference due to 6 GHz ($Million)	$0.00	$19.96	$25.15	$31.09	$33.52

Sources: Cisco; Telecom Advisory Services analysis

I.4.2. Avoidance in enterprise building inside wiring

Similar to residential Wi-Fi savings due to capital investment avoidance in inside wiring, we assume that the total number of business establishments are equipped with Wi-Fi access points and multiply this value by a standard cost of deploying a CAT 6 network (from U.S., adjusted by PPP) (see Table I-21).

Table I-21. Poland: Savings in business wiring CAPEX (2021-2025)

Variable	2021	2022	2023	2024	2025
Total Wiring Cost	$1,027.21	$1,039.69	$1,052.33	$1,065.13	$1,078.07
Number of Establishments	2,169,934	2,244,657	2,321,954	2,401,912	2,484,623
Establishments with Wi-Fi (%)	100%	100%	100%	100%	100%
Establishments with Wi-Fi	2,169,934	2,244,657	2,321,954	2,401,912	2,484,623
Inside Wiring Costs ($Million)	$2,229	$2,334	$2,443	$2,558	$2,679

Sources: Eurostat; Telecom Advisory Services analysis

I.4.3. Return to speed: contribution to GDP derived from an increase in average mobile speed

Since Wi-Fi accessibility allows, in general, faster access to the Internet than cellular networks do, higher speeds have a positive contribution on the economy in terms of increased overall efficiency and innovation. This contribution is measured in terms of economic growth. As described in section I.2.3 for the case of consumer surplus, we start with the quantification of the average broadband speed if cellular networks transported all Wi-Fi traffic, and compare it with the presence of Wi-Fi technology (see Table I-22).

Table I-22. Poland: Estimation of speed differential for total traffic (2021-2025)

Variable	2021	2022	2023	2024	2025
Average Download Speed if Wi-Fi traffic were carried through mobile networks (Mbps)	44.77	55.16	67.97	83.76	103.26
Average Speed with Wi-Fi (Mbps)	49.06	60.75	75.19	93.03	115.05
Speed increase (%)	10%	10%	11%	11%	11%
Impact of speed in GDP	0.73%	0.73%	0.73%	0.73%	0.73%
Increase in GDP	0.07%	0.07%	0.08%	0.08%	0.08%
GDP ($Billion)	$588.65	$603.52	$618.53	$633.91	$649.68
GDP increase ($Million)	$412	$447	$480	$512	$542

Sources: Cisco; IMF; Telecom Advisory Services analysis

Having calculated the speed increase percentage, we then apply this percentage to the coefficient derived from the model developed by Katz and Callorda (2019) to gauge the potential impact on GDP from Wi-Fi enhanced speed. Table I-22 indicates that the economic value of Wi-Fi in terms of increasing the speed of transporting wireless will account to $412 million in 2021, before being increased to $542 billion in 2025.

Return to Speed additional effect due to 6 GHz

As previously described, only those broadband connections above 150 Mbps will be affected due to current router bottlenecks, and hence, the speed experienced will not be equivalent to that delivered by the fixed network. Thus, the allocation of the 6 GHz band will remove those barriers, increasing broadband speed. After calculating the difference in average speed attributed to 6 GHz, the additional GDP contribution will yield $3.4 billion in 2025 (Table I-23).

Table I-23. Poland: Estimation of speed differential due to 6 GHz (2021-2025)

Variable	2021	2022	2023	2024	2025
Mean speed with no 6 GHz (Mbps)	49.06	60.75	75.19	93.03	115.05
Mean speed with 6 GHz (Mbps)	49.06	72.14	104.58	148.87	197.12
Speed increase due to 6Ghz (%)	0%	19%	39%	60%	71%
Impact speed on GDP	0.73%	0.73%	0.73%	0.73%	0.73%
Increase in GDP (%)	0.00%	0.14%	0.29%	0.44%	0.52%
GDP increase ($Million)	$0	$826	$1,765	$2,778	$3,383

Sources: Cisco; IMF; Telecom Advisory Services analysis

I.4.4. IoT deployment

IoT adoption has a contribution to GDP growth through the multiplicity of use cases that improve efficiency in processes such as preventive maintenance, production monitoring and the like. To estimate this, we rely on a coefficient of GDP impact calculated through an aggregate simple production function which estimates that a 10% rise in M2M connections results in annual increases in GDP of between 0.3% and 0.9%[207]. Following a conservative approach, for Poland we assume a 0.3% GDP increase after a 10% raise in M2M.

Starting with a 2021 installed base of 7.6 million M2M devices, we estimate the growth that can be exclusively attributed to the allocation of additional spectrum to indoor Wi-Fi devices. Thus, by subtracting the growth in M2M attributed to 6 GHz, it is estimated that the IoT impact for 2021 according to the natural growth would reach $1.2 billion (see Table I-24).

[207] See Frontier Economics (2018)

Table I-24. Poland: GDP Contribution of IoT Deployment Boost (2021-2025)

Variable	2021	2022	2023	2024	2025
Connections, Cellular M2M	7,562,465	7,789,972	8,024,323	8,265,725	8,514,388
Growth Rate (%)	7.47%	3.01%	3.01%	3.01%	3.01%
Natural Growth Rate (%)	6.81%	2.66%	2.59%	2.59%	2.59%
Impact of 1% M2M Growth on GDP	3.00%	3.00%	3.00%	3.00%	3.00%
Impact on GDP (%)	0.20%	0.08%	0.08%	0.08%	0.08%
/GDP ($Billion)	$589	$604	$619	$634	$650
Impact ($Million)	$1,202.03	$481.94	$481.45	$493.43	$505.70

Sources: GSMA Intelligence; Frontier Economics; IMF; Telecom Advisory Services analysis

Accelerated effect of IoT due to 6 GHz

As described above, a share of the M2M growth can be attributed to 6 GHz developments. According to the data in Table I-25, cumulative impact of enhanced IoT deployment driven by 6 GHz spectrum proposals will reach $40 million by 2025.

Table I-25. Poland: GDP Contribution of IoT Deployment Boost caused by 6 GHz (2021-2025)

Variable	2021	2022	2023	2024	2025
Growth due to 6 GHz (%)	0.67%	0.35%	0.41%	0.41%	0.41%
Level of development of new bands (%)	50%	100%	100%	100%	100%
Impact on GDP (%)	0.01%	0.01%	0.01%	0.01%	0.01%
Impact ($Million)	$29.49	$31.37	$38.39	$39.34	$40.32

Sources: GSMA Intelligence; Frontier Economics; IMF; Telecom Advisory Services analysis

I.4.5. Deployment of AR/VR solutions

The adoption of AR/VR among Polish businesses will in turn have a spillover effect on productivity, thereby contributing to the growth of GDP. Estimating spillover effects of AR/VR is a not a trivial exercise considering the embryonic adoption of some of these use cases. Since the objective is to estimate the spillover effect of AR/VR sales by local firms in the domestic market, we will take as points of departure the estimate by PwC of the total GDP contribution of AR/VR for 2021 and 2022, and the sales of AR/VR components as estimated by IDC. The extrapolation of these two parameters allow estimating the indirect (spillover) contribution of AR/VR to the local economy for the period under analysis.

Starting values are reduced by the proportion that can be attributed to the impact of the 6 GHz spectrum bands. To do so, we took as a reference a ratio of AR/VR product developments according to each technology. Once the amount to be attributed in both GDP contribution and direct sales is estimated, the annual indirect to direct multiplier can be calculated. The lowest multiplier value is applied to sales of AR/VR in the local market to calculate the total spillovers (see Table I-26). Total spillover value of AR/VR in Poland in 2021 will account for $89 million and is expected to increase by 2025 to $106 million.

Table I-26. Poland: GDP contribution resulting from AR/VR spillovers (2021-2025)

Variable	2021	2022	2023	2024	2025
AR/VR total contribution to GDP ($Billion)	$0.48	$0.71	$1.04	$1.54	$2.27
Share attributed to Wi-Fi (excluding 6 GHz)	42.02%	38.80%	32.18%	30.88%	29.32%
Portion of GDP contribution attributed to Wi-Fi (excluding 6 GHz) ($Billion)	$0.20	$0.27	$0.34	$0.48	$0.67
Direct impact (sales) attributed to Wi-Fi (excluding 6 GHz) ($Billion)	$0.09	$0.15	$0.21	$0.32	$0.56
Indirect impact ($Billion)	$0.11	$0.12	$0.12	$0.16	$0.11
Indirect/Direct multiplier	1.00	0.78	0.59	0.50	0.19
Indirect impact ($Million)	$88.93	$120.03	$124.17	$159.33	$105.69

Sources: PwC, ABI; Telecom Advisory Services analysis

Wider deployment of AR/VR solutions (accelerated effect due to 6 GHz)

Higher throughput enabled by the allocation of the 6 GHz band is expected to spur the adoption and use of AR/VR among enterprises, hence increasing the associated spillover effects. By relying on the ratio built from 5 GHz and 6 GHz AR/VR related products, we were able to isolate the specific economic contribution of the new spectrum allocation. Following a similar procedure as that described above, spillovers from AR/VR in Poland attributed to 6 GHz in 2021 will account for $43 million and are expected to increase by 2025 to $55 million (Table I-27).

Table I-27. Poland: GDP contribution resulting from AR/VR spillovers due to 6 GHz (2021-2025)

Variable	2021	2022	2023	2024	2025
AR/VR total contribution to GDP ($Billion)	$0.48	$0.71	$1.04	$1.54	$2.27
Share attributed to 6 GHz (%)	24.58%	25.59%	26.64%	27.73%	28.87%
Portion of GDP contribution attributed to 6 GHz ($Billion)	$0.12	$0.18	$0.28	$0.43	$0.66
Direct impact (sales) attributed to 6 GHz ($Billion)	$0.05	$0.10	$0.18	$0.28	$0.55
Indirect impact ($Billion)	$0.07	$0.08	$0.10	$0.14	$0.10
Indirect/Direct multiplier	1.00	0.78	0.59	0.50	0.19
Indirect impact ($Million)	$43.14	$51.62	$61.26	$80.71	$55.11

Sources: PwC, ABI; Telecom Advisory Services analysis

I.5. Internet Service Providers

In addition to the economic value generated by the sources analyzed above, Wi-Fi will also contribute to either producer surplus or GDP of Internet Service Providers. This section will assess the economic value in three sources:

- Producer surplus of cellular operators resulting from CAPEX savings incurred in network deployment
- Revenues of Wi-Fi carriers offering service in public spaces
- Revenues of Wireless ISPs (this effect differs from the GDP impact of WISPs as a result of their deployment in rural and isolated areas analyzed in section I.3.5.)

I.5.1. Cellular network savings by off-loading traffic to Wi-Fi

The estimation of CAPEX savings starts by considering the GSMA Intelligence aggregate projected investment by wireless carriers in Poland, which amounts to $8.3 billion between 2019 and 2025. Considering the total CAPEX required to deploy 5G in Poland, and the incremental 5G coverage between 2021 and 2025 we are able to interpolate the 5G CAPEX for each year of the period considered. It is assumed that all the CAPEX invested during the period would be dedicated to 5G deployment.

Based on the simulation model developed to forecast the impact of Wi-Fi off-loading in 5G deployment, we estimate that the savings of deploying carrier-grade Wi-Fi complementing the rollout of 5G to accommodate future traffic growth would amount to 32.9% of CAPEX, while the OPEX savings are $2.82 for each dollar saved in CAPEX. This would result in a total producer surplus (adding CAPEX and OPEX savings) of $3.2 billion in 2021, descending to $231 million in 2025, when 5G coverage will reach 61% (see Table I-28).

Table I-28. Poland: Savings due to traffic off-loading (2021-2025)

Variable	2021	2022	2023	2024	2025
5G coverage	33%	45%	55%	60%	61%
CAPEX without saving ($Million)	$2,542.51	$2,409.22	$1,956.86	$1,076.38	$183.77
CAPEX reduction due to Wi-Fi off-loading ($Million)	$836.5	$792.6	$643.8	$354.1	$60.5
OPEX reduction due to Wi-Fi off-loading ($Million)	$2,358.9	$2,235.2	$1,815.5	$998.6	$170.5
Total Cost of Ownership ($Million)	$3,195	$3,028	$2,459	$1,353	$231

Sources: GSMA; Telecom Advisory Services analysis

The decline in savings over time is compensated by the increase in economic benefit under the 6 GHz spectrum allocation.

Enhanced capability for cellular off-loading if 6 GHz allocated

The complementarity between Wi-Fi and cellular networks for Wi-Fi 6E and 5G, adds further potential gains derived from the savings in capital and operating expenses required to accommodate exploding data traffic. The key objective is to estimate the savings in capital investment as a result of an increase in traffic offloading with Wi-Fi benefits from the additional spectrum allocated, particularly, due to the ability to leverage 160 MHz within single contiguous channels.

The estimation of CAPEX savings starts by considering the GSMA Intelligence aggregate investment estimates of 5G deployments. By relying again on the geographic disaggregation of Oughton and Frias, we estimate that CAPEX can be split in urban, suburban and rural geographies. To estimate the percentage of population living in urban areas (over 1 million inhabitants), we considered those living in the metropolitan areas of Warsaw, Katowice, Krakow, Lodz, Tricity, Poznan, and Wroclaw. The percentage of rural population was obtained from Trading Economics, while the remaining share of the population was classified in the suburban group. We conservatively assume that Wi-Fi 6 will not be critical in sustaining investment in urban areas, but that it will play a significant role beyond those geographies. Based on the cost advantage of carrier grade Wi-Fi, we assume that it will become effective for a portion of the suburban (approximately 15%) and rural network (approximately 5%) deployment. Therefore, this will yield yearly CAPEX savings of $88 million.

I.5.2. Wi-Fi carrier revenues

The value of Wi-Fi carriers includes the sum of revenues through paid public Wi-Fi access. In order to estimate those aggregated revenues, we start by calculating the number of commercial Wi-Fi hotspots in Poland. According to Cisco, in 2021 there will be 5 million public Wi-Fi hotspots in the country, although that figure includes home spots (such as the guest account service provided by cable operators). By subtracting the home spots from the public Wi-Fi estimates of Cisco, we calculated a total of 110,000 commercial Wi-Fi hotspots for 2021, which will decrease till reaching 70,000 in 2025. On the other hand, based on revenue figures per hotspot from Boingo for the U.S., by adjusting by PPP we were able to estimate a figure for the case of Poland. Then, we estimate total revenues generated by this sector in Poland: $31 million in 2021, gradually reducing to reach $21 million in 2025 (Table I-29).

Table I-29. Poland: Revenues of Wi-Fi carriers (2021-2025)

Variable	2021	2022	2023	2024	2025
Public Wi-Fi hotspots (Million)	5.01	5.88	6.90	8.10	9.50
Home spots (Million)	4.90	5.77	6.80	8.01	9.43
Commercial Wi-Fi hotspots (Million)	0.11	0.11	0.10	0.09	0.07
Revenue per hotspot ($)	$288.91	$292.42	$295.97	$299.57	$303.21
Revenue ($Million)	$31.32	$31.07	$29.60	$26.44	$21.02

Sources: Cisco, Boingo, Telecom Advisory Services

Increased revenues of Wi-Fi carriers in public places due to 6 GHz

The allocation of the 6 GHz spectrum band offers an opportunity for commercial Wi-Fi carriers to enhance their business. As Wi-Fi 6E developments will allow up to 1,500 connected devices per access point, Wi-Fi carriers will have the possibility of adding more clients without quality limitations due to congestion. By considering a conservative potential increase of 40% in the number of connected devices in public venues and weighting that figure by the gradual expansion of the latest technology, we expect commercial Wi-Fi carriers to increase their user base by 16% in 2025. If the revenue per hotspot increases in the same amount, that will yield an increase in overall revenues for the sector of an additional $3.4 million by 2025 (Table I-30).

Table I-30. Poland: Revenues of Wi-Fi carriers due to 6 GHz (2021-2025)

Variable	2021	2022	2023	2024	2025
Potential increase in connected devices in public venues	40.00%	40.00%	40.00%	40.00%	40.00%
Traffic through the 6 GHz Channel (%)	0%	10%	20%	30%	40%
Increase in connected devices due to 6 GHz	0%	4%	8%	12%	16%
Revenue per hotspot if 6 GHz allocated ($)	$288.91	$304.11	$319.65	$335.52	$351.73
Revenue if 6 GHz allocated ($Million)	$0.00	$1.24	$2.37	$3.17	$3.36

Sources: Boingo; Telecom Advisory Services

I.5.3. Wireless ISPs revenues

The 2021 GDP contribution related to the WISP industry was calculated as a function of the number of subscribers (620,000) and the ARPU (data from UKE), yielding a total of $84 million (Table I-31).

Table I-31. Poland: WISP revenues (2021-2025)

Variable	2021	2022	2023	2024	2025
Subscribers (Million)	0.62	0.56	0.50	0.45	0.40
Revenues ($Million)	$84.24	$75.82	$68.23	$61.41	$55.27

Sources: UKE, Telecom Advisory Services

Increased revenues of WISPs due to 6 GHz

As described above, the allocation of 6 GHz spectrum band will potentially increase the WISP user base in 30,000 subscribers by 2025, due to expanded coverage and better affordability. Thus, by assuming the same ARPU values as described above, the new subscriptions will amount to an additional $3.5 million in revenues in 2025 (Table I-32).

Table I-32. Poland: WISP revenues due to 6 GHz (2021-2025)

Variable	2021	2022	2023	2024	2025
WISP annual ARPU ($)	$136.59	$136.59	$136.59	$136.59	$136.59
New subscribers if 6 GHz allocated (Million)	0.00	0.01	0.02	0.02	0.03
New revenue ($Million)	$0.00	$1.61	$2.41	$3.06	$3.49

Sources: UKE; Telecom Advisory Services

I.6. Wi-Fi ecosystem

The economic value generated by Wi-Fi within Wi-Fi ecosystem companies in Poland is generated from the following two sources:

- The producer surplus of local firms providing products and services in the IoT ecosystem (hardware, software and systems integration) in Poland; and
- The producer surplus of local firms providing products and services in the AR/VR ecosystem (hardware, software and content) in Poland.

I.6.3. Firms belonging to the IoT ecosystem

According to an interpolation from Bain & Co data, we expect total industrial IoT revenue in Poland to amount $3.5 million in 2021. By relying on the percentage of hardware connectivity spending in IoT in Europe, we were able to split that figure into two main segments: hardware; and software, contents, and services. By weighting those amounts by the share of local production (27% for hardware, 60% for software and services) and the assumed margins (39.44% and 77.46%, respectively), we can estimate the overall producer surplus. However, to that economic value we should extract the share attributed to 6 GHz developments. To do so, we estimated a natural growth rate, by subtracting the corresponding share attributed to 6 GHz according to the growth rates indicated in Table I-24. Thus, we estimate a producer surplus not attributed to 6 GHz of $1.35 billion in 2021, expected to reach $2.7 billion in 2025 (Table I-33).

Table I-33. Poland: IoT ecosystem direct contribution (2021-2025)

Variable	2021	2022	2023	2024	2025
IoT revenue - Hardware ($billions)	$0.67	$0.81	$0.99	$1.21	$1.48
IoT revenue - Software, Contents, Services ($billions)	$2.84	$3.47	$4.23	$5.16	$6.29
Total Industrial IoT revenue in ($Billion)	$3.51	$4.28	$5.22	$6.37	$7.77
Local production (%) - Hardware	27%	27%	27%	27%	27%
Local production (%) - Software & Services	60%	60%	60%	60%	60%
Margins (%) - Hardware	39%	39%	39%	39%	39%
Margins (%) - Software & Services	77%	77%	77%	77%	77%
Margins - IoT Hardware revenue	$0.07	$0.09	$0.10	$0.13	$0.16
Margins - Software, contents and services IoT revenue	$1.32	$1.61	$1.97	$2.40	$2.92
Producer surplus ($Million)	$1,392.28	$1,698.09	$2,071.07	$2,525.97	$3,080.79
Growth rate (%)	10.64%	21.96%	21.96%	21.96%	21.96%
Growth rate not attributed to 6 GHz (%)	9.69%	19.43%	18.94%	18.94%	18.94%
Producer surplus not attributed to 6 GHz ($Million)	$1,352.08	$1,614.85	$1,920.76	$2,284.62	$2,717.41

Sources: Statista, Bain & Co, CSI, Telecom Advisory Services analysis

Wider deployment of Internet of Things under 6 GHz

Following the previous analysis, we were able to estimate which portion of IoT producer surplus growth can be attributed to 6 GHz. As Table I-34 indicates, we expect the additional IoT surplus generated by 6 GHz to account for $363 million in 2025.

Table I-34. Poland: IoT direct contribution attributed to 6 GHz (2021-2025) ($Million)

Variable	2021	2022	2023	2024	2025
Producer surplus	$1,392.28	$1,698.09	$2,071.07	$2,525.97	$3,080.79
Producer surplus not attributable to 6 GHz	$1,352.08	$1,614.85	$1,920.76	$2,284.62	$2,717.41
Additional surplus due to 6 GHz	$40.21	$83.24	$150.31	$241.35	$363.38

Sources: Statista, Bain & Co, CSI, Telecom Advisory Services analysis

I.6.4. Firms belonging to the AR/VR ecosystem

Following a similar procedure as with the case of IoT, we can estimate the direct contribution of this ecosystem to the local economy. Starting with the local spending in AR/VR by category (hardware, software, and contents), and weighting those figures by the respective shares of local production and margins, we were able to estimate the total producer surplus. By relying on a ratio built from 5 GHz and 6 GHz AR/VR related products, we were able to subtract the specific contribution attributed to 6 GHz from the surplus corresponding to current bands. Then, we expect by 2021 a direct contribution from the AR/VR ecosystem of $30 million, which will increase until reaching $195 million by 2025 (Table I-35).

Table I-35. Poland: AR/VR ecosystem direct contribution (2021-2025)

Variable	2021	2022	2023	2024	2025
Spending in AR/VR - Hardware $Billion	$0.07	$0.13	$0.23	$0.36	$0.62
Spending in AR/VR - Software, Contents, Services ($Billion)	$0.14	$0.26	$0.43	$0.66	$1.29
Total Spending in AV/VR ($Billion)	$0.21	$0.40	$0.66	$1.02	$1.91
Share of local production - Hardware	26.78%	26.78%	26.78%	26.78%	26.78%
Share of local production - Software, Contents, Services	60.00%	60.00%	60.00%	60.00%	60.00%
Local production for local consumption - Hardware ($Billion)	$0.02	$0.04	$0.06	$0.10	$0.17
Local production for local consumption - Software, Contents, Services ($Billion)	$0.08	$0.16	$0.26	$0.40	$0.77
Local Producer Surplus - Hardware ($Billion)	$0.01	$0.01	$0.02	$0.04	$0.07
Local Producer Surplus - Software, Contents, Services ($Billion)	$0.06	$0.12	$0.20	$0.31	$0.60
Total Producer Surplus	$0.07	$0.14	$0.22	$0.35	$0.66
Share attributable to Wi-Fi (excluding 6 GHz)	42.02%	38.80%	32.18%	30.88%	29.32%
Producer Surplus attributed to Wi-Fi (not including 6 GHz) ($Million)	$30.10	$53.10	$72.31	$106.67	$194.66

Sources: PwC, ABI; Telecom Advisory Services analysis

Wider deployment of AR/VR solutions if 6 GHz allocated

By relying on a ratio built from 5 GHz and 6 GHz AR/VR related products, we were able to isolate the specific economic contribution of the new spectrum allocation. Following a similar procedure as that described above, the direct contribution from AR/VR ecosystem in Poland attributed to 6 GHz in 2025 will yield $101.5 million.

Table I-36. Poland: AR/VR direct contribution attributed to 6 GHz (2021-2025)

Variable	2021	2022	2023	2024	2025
Spending in AR/VR ($Billion)	$0.21	$0.40	$0.66	$1.02	$1.91
Share attributed to 6 GHz	24.58%	25.59%	26.64%	27.73%	28.87%
Spending in AR/VR attributed to 6 GHz ($Billion)	$0.05	$0.10	$0.18	$0.28	$0.55
Local production for local consumption 6 GHz ($Billion)	$0.03	$0.05	$0.09	$0.14	$0.27
Local Producer Surplus ($Million)	$14.60	$22.84	$35.68	$54.03	$101.50

Sources: PwC, ABI; Telecom Advisory Services analysis

I.7. Wi-Fi contribution to employment

The estimation of employment generated is calculated by relying on the total GDP contribution resulting from the effects analyzed above and using that as an input in the communications sector of an input-output matrix of the Polish economy. Table I-37 presents the GDP contribution enabled by Wi-Fi projected for the period 2021-2025.

Table I-37. Poland: Wi-Fi enabled GDP contribution (2021-2025)

Year	GDP contribution enabled by Wi-Fi ($Million)		
	Attributed to current bands	Attributed to 6 GHz	Total
2021	$3,017	$73	$3,090
2022	$2,239	$969	$3,208
2023	$2,159	$1,960	$4,119
2024	$2,127	$3,020	$5,147
2025	$2,011	$3,616	$5,627

Source: Telecom Advisory Services analysis

These inputs generate the following annual employment effects based on the input/output matrix for the Poland economy (Table I-38).

Table I-38. Poland: Wi-Fi generated Annual Employment

Variable	2021			2025		
	Current bands	6 GHz	Total	Current bands	6 GHz	Total
Direct jobs	15,208	0,366	15,574	10,134	18,226	28,360
Indirect jobs	9,064	0,218	9,282	6,040	10,863	16,903
Induced jobs	4,541	0,109	4,650	3,026	5,442	8,468
Total	28,812	0,694	29,506	19,199	34,531	53,730

Sources: GTAP; Telecom Advisory Services analysis

According to the contribution to GDP, Wi-Fi will generate approximately 29,500 jobs in 2021 and is expected to generate over 53,000 in 2025. Job estimates include direct jobs (those jobs created by the specific Wi-Fi contribution), indirect jobs (those jobs created by suppliers to the Wi-Fi sector) and induced jobs (those jobs created by spending of direct and indirect workers).

The sector breakdown of 2021 employment (including the additional jobs created by 6 GHz) is as follows (Table I-39).

Table I-39. Poland: Sector Breakdown of Wi-Fi generated annual employment (2021)

Sector	Direct	Indirect	Induced	Total
Agriculture	0	0	66	66
Extractive industries	0	0	225	225
Manufacturing	0	1,471	44	1,515
Construction	0	1,164	0	1,164
Trade	0	874	985	1,859
Transportation	0	649	0	649
Communications	15,574	0	0	15,574
Financial Services	0	474	0	474
Business services	0	4,651	0	4,651
Other services	0	0	3,330	3,330
Total	15,574	9,282	4,650	29,506

Sources: GTAP; Telecom Advisory Services analysis

J. ECONOMIC VALUE OF WI-FI IN JAPAN

Wi-Fi has become a significant component of Japan's telecommunications infrastructure. According to the Cisco Annual Internet Report Highlights Tool 2018-2023, there were 400,000 paid Wi-Fi access points operating in Japanese territory in 2018, while Wiman reports the activity of 1,223,000 free Wi-Fi sites in the country (485,000 in Tokyo, 238,000 in Yokohama, and 132,000 in Osaka). Given Wi-Fi's access point density, hotspots have become a very important connectivity feature. According to Opensignal[208], Japanese wireless users spend 62.6% of their communications time connected to Wi-Fi networks rather than relying on their cellular data connection. The increasing importance of Wi-Fi technology in the digital infrastructure ecosystem should have a significant social and economic contribution. This section presents the results and calculations of the economic assessment.

J.1. Total Economic Value of Wi-Fi in Japan (2021-2025)

In the prior study of Wi-Fi's economic contribution[209], Wi-Fi economic value in Japan for 2021 was estimated at $213.7 billion. An update of this study that accounts for changes in deployment indicates an increase of 14.6%. Before considering the additional effect of allocating the 6 GHz spectrum band for unlicensed use, the total economic value of Wi-Fi in Japan in 2021 will amount to $245.7 billion. The increase of $32.0 billion is due to the development of four new sources of economic value:

- The increasing importance of free Wi-Fi;
- The contribution of Wi-Fi technology to improving broadband speed;
- A substantial boost to deployment of IoT technology; and
- The growing adoption of AR/VR technology use cases.

The total economic value in 2021 of $245.7 billion is broken down as follows: $90.2 billion in consumer surplus, $96.9 billion in producer surplus, and $58.5 billion in a net contribution to the GDP. Even before accounting for the acceleration effect resulting from the allocation of the 6 GHz band, the 2025 forecast of economic value will reach $296.2 billion, comprised of $143.6 billion in consumer surplus, $110.7 billion in producer surplus, and $41.9 billion in GDP contribution (see Table J-1).

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[208] Khatri, H. and Fenwick, S. (2020). "Analyzing mobile experience during the coronavirus pandemic: Time on Wi-Fi". *Opensignal* (March 30).

[209] Katz, R. and Callorda, F. (2018). *The Economic value of Wi-Fi: A Global View (2018 and 2023)*. New York: Telecom Advisory Services. October.

Table J-1. Japan: Economic Value of Wi-Fi (Baseline Scenario)

Agent	Source	Economic Value ($Million)					
		2021	2022	2023	2024	2025	Category
1. Free Wi-Fi	1.1. Savings generated by free Wi-Fi traffic offered in public sites	$907	$925	$930	$914	$867	Consumer Surplus
	1.2. Deployment of free Wi-Fi in public sites	$204	$205	$206	$207	$208	GDP contribution
2. Residential Wi-Fi	2.1. Internet access for home usage of devices that lack a wired port	$50,103	$59,355	$70,302	$83,084	$97,934	Consumer Surplus
	2.2. Avoidance of investment in in-house wiring	$29,591	$30,972	$32,329	$32,122	$31,867	Consumer Surplus
	2.3. Benefit to consumers from speed increases	$2,413	$3,193	$4,097	$4,897	$5,743	Consumer Surplus
	2.4. Residential Wi-Fi devices and equipment deployed	$7,190	$7,372	$7,581	$7,471	$7,227	Consumer Surplus
	2.5. Bridging digital divide: use of Wi-Fi to increase coverage in rural and isolated areas	$18	$17	$17	$17	$16	GDP contribution
3. Enterprise Wi-Fi	3.1. Business Internet traffic transmitted through Wi-Fi	$26,299	$29,719	$33,584	$37,952	$42,887	Producer surplus
	3.2. Avoidance of enterprise inside wiring costs	$11,885	$11,735	$11,586	$11,439	$11,294	Producer surplus
	3.3. Return to speed: contribution to GDP derived from an increase in average mobile speed	$6,506	$8,454	$10,708	$13,304	$16,279	GDP contribution
	3.4. Wide deployment of IoT	$50,625	$34,201	$20,943	$21,049	$21,155	GDP contribution
	3.5. Deployment of AR/VR solutions	$860	$1,372	$1,800	$2,566	$4,072	GDP contribution
4. ISPs	4.1. CAPEX and OPEX savings due to cellular off-loading	$36,422	$33,065	$16,698	$18,770	$18,004	Producer surplus
	4.2. Revenues of service providers offering paid Wi-Fi access in public places	$286	$287	$273	$234	$159	GDP contribution
	4.3. Aggregated revenues of WISPs	$6	$7	$7	$7	$8	GDP contribution
5. Wi-Fi ecosystem	5.1. Locally manufactured residential Wi-Fi devices and equipment	$6,212	$6,437	$6,660	$6,578	$6,374	Producer surplus
	5.2. Locally manufactured Wi-Fi enterprise equipment	$1,373	$1,432	$1,515	$1,477	$1,332	Producer surplus
	5.3. Locally produced IoT products and services	$14,298	$17,077	$20,312	$24,160	$28,737	Producer surplus
	5.4. Locally produced of AR/VR solutions	$457	$722	$931	$1,292	$2,084	Producer surplus
Total		$245,655	$246,547	$240,479	$267,540	$296,247	

Source: Telecom Advisory Services analysis

In addition to the value generated from the unlicensed use of the 2.4 GHz and 5 GHz bands (referred to as the baseline scenario), the allocation of the 6 GHz spectrum band for unlicensed use and the deployment of Wi-Fi 6 and Wi-Fi 6E devices will trigger an additional boost in economic value, reaching $28.8 billion in 2025 (see Table J-2).

Table J-2. Japan: Economic Value of Wi-Fi (only attributed to 6 GHz)

Agent	Source	Economic Value ($Million)					
		2021	2022	2023	2024	2025	Category
1. Free Wi-Fi	1.1. Savings generated by free Wi-Fi traffic offered in public sites	$0	$7	$23	$47	$78	Consumer Surplus
	1.2. Deployment of free Wi-Fi in public sites	$0	$19	$39	$59	$79	GDP contribution
	1.3. Benefit of faster free Wi-Fi with Wi-Fi 6E devices	$0	$2	$4	$6	$9	Consumer Surplus
2. Residential Wi-Fi	2.3. Benefit to consumers from speed increases	$0	$449	$999	$1,539	$2,051	Consumer Surplus
	2.4. Residential Wi-Fi devices and equipment deployed	$261	$631	$1,372	$2,103	$2,846	Consumer Surplus
	2.5. Bridging digital divide: use of Wi-Fi to increase coverage in rural and isolated areas	$0	$4	$7	$9	$11	GDP contribution
3. Enterprise Wi-Fi	3.1. Business Internet traffic transmitted through Wi-Fi	$0	$0	$0	$0	$0	Producer surplus
	3.3. Return to speed: contribution to GDP derived from an increase in average mobile speed	$0	$1,086	$2,363	$3,749	$5,146	GDP contribution
	3.4. Wide deployment of Internet of Things	$2,484	$4,452	$3,340	$3,357	$3,373	GDP contribution
	3.5. Deployment of AR/VR solutions	$503	$905	$1,490	$2,305	$4,009	GDP contribution
4. ISPs	4.1 CAPEX and OPEX savings due to cellular off-loading	$1,123	$1,123	$1,123	$1,123	$1,123	Producer surplus
	4.2. Revenues of service providers offering paid Wi-Fi access in public places	$0	$11	$22	$28	$25	GDP contribution
	4.3. Aggregated revenues of WISPs	$0	$0	$0	$0	$0	GDP contribution
5. Wi-Fi ecosystem	5.1. Locally manufactured residential Wi-Fi devices and equipment	$234	$569	$1,238	$1,898	$2,568	Producer surplus
	5.2. Locally manufactured Wi-Fi enterprise equipment	$116	$313	$638	$1,057	$1,537	Producer surplus
	5.3. Locally produced IoT products and services	$425	$880	$1,590	$2,552	$3,843	Producer surplus
	5.4. Locally produced of AR/VR solutions	$267	$476	$771	$1,160	$2,052	Producer surplus
Total		$5,413	$10,927	$15,019	$20,992	$28,750	

Source: Telecom Advisory Services analysis

Considering that by 2025 only 40% of Wi-Fi traffic will rely on the 6 GHz channels, the accelerated effect derived from the new spectrum allocation and latest Wi-Fi technologies will still be far from reaching its maximum potential at this time.

By combining the baseline and the Wi-Fi 6 and 6 GHz scenarios, the overall economic value of Wi-Fi for Japan will reach $325 billion in 2025 (see Table J-3).

Table J-3. Japan: Total Economic Value of Wi-Fi (including Wi-Fi 6 and 6 GHz)

Agent	Source	Economic Value ($Million)					
		2021	2022	2023	2024	2025	Category
1. Free Wi-Fi	1.1. Savings to consumers of free Wi-Fi traffic offered in public sites	$907	$933	$953	$961	$945	Consumer Surplus
	1.2. Deployment of free Wi-Fi in public sites	$204	$224	$245	$266	$287	GDP contribution
	1.3. Benefit of faster free Wi-Fi with Wi-Fi 6E devices	$0	$2	$4	$6	$9	Consumer Surplus
2. Residential Wi-Fi	2.1. Internet access for home usage of devices that lack a wired port	$50,103	$59,355	$70,302	$83,084	$97,934	Consumer Surplus
	2.2. Avoidance of investment in in-house wiring	$29,591	$30,972	$32,329	$32,122	$31,867	Consumer Surplus
	2.3. Benefit to consumers from speed increases	$2,413	$3,642	$5,096	$6,437	$7,794	Consumer Surplus
	2.4. Residential Wi-Fi devices and equipment deployed	$7,455	$8,003	$8,953	$9,574	$10,073	Consumer Surplus
	2.5. Bridging digital divide: use of Wi-Fi to increase coverage in rural and isolated areas	$18	$22	$24	$26	$27	GDP contribution
3. Enterprise Wi-Fi	3.1. Business Internet traffic transmitted through Wi-Fi	$26,299	$29,719	$33,584	$37,952	$42,887	Producer surplus
	3.2. Avoidance of enterprise inside wiring costs	$11,885	$11,735	$11,586	$11,439	$11,294	Producer surplus
	3.3. Return to speed: contribution to GDP derived from an increase in average mobile speed	$6,506	$9,541	$13,071	$17,053	$21,426	GDP contribution
	3.4. Wide deployment of IoT	$53,109	$38,653	$24,283	$24,405	$24,528	GDP contribution
	3.5. Deployment of AR/VR solutions	$1,363	$2,277	$3,291	$4,871	$8,081	GDP contribution
4. ISPs	4.1 CAPEX and OPEX savings due to cellular off-loading	$37,544	$34,188	$17,821	$19,893	$19,126	Producer surplus
	4.2. Revenues of service providers offering paid Wi-Fi access in public places	$286	$299	$295	$262	$184	GDP contribution
	4.3. Aggregated revenues of WISPs	$6	$7	$7	$8	$8	GDP contribution
5. Wi-Fi ecosystem	5.1. Locally manufactured residential Wi-Fi devices and equipment	$6,446	$7,006	$7,898	$8,476	$8,942	Producer surplus
	5.2. Locally manufactured Wi-Fi enterprise equipment	$1,489	$1,745	$2,153	$2,534	$2,869	Producer surplus
	5.3. Locally produced IoT products and services	$14,724	$17,958	$21,902	$26,712	$32,580	Producer surplus
	5.4. Locally produced of AR/VR solutions	$724	$1,199	$1,702	$2,452	$4,136	Producer surplus
Total		$251,072	$257,480	$255,499	$288,533	$324,997	

Source: Telecom Advisory Services analysis

The following sections will present in detail the calculation of each source of value, disaggregating the economic contribution between the current spectrum allocation and the enhanced effect due to Wi-Fi 6 availability and the 6 GHz band.

J.2. Value from free Wi-Fi service

The economic value of free Wi-Fi service primarily originates through two contribution sources:

- Savings to consumers by accessing the Internet in free Wi-Fi sites rather than incurring cellular costs; and
- Provision of Internet service to broadband unserved households.

J.2.1. Savings incurred by accessing free Wi-Fi in public sites

The economic value of free Wi-Fi is first measured in terms of consumer surplus, calculated by estimating the benefit that flows to consumers as a result of savings incurred by not relying on cellular service. We begin by forecasting the traffic generated at free Wi-Fi access points. In order to isolate the effect from the increased capacity derived from the 6 GHz allocation, we calculate the portion of free Wi-Fi traffic attributed only to the reliance on current spectrum bands. For this, we assumed that current traffic levels at free Wi-Fi access points is congested at times of peak demand. Thus, we assume that, if the 6 GHz spectrum is not allocated to Wi-Fi use, traffic per hotspot beyond 2021 will remain at 2020 levels (1,183 GB per year). That said, overall free traffic will continue growing as new hotspots continue to be deployed (see Table J-4).

Table J-4. Japan: Total Free Wi-Fi Traffic projection (2021-2025)

Variable	2021	2022	2023	2024	2025
Free Wi-Fi traffic (Million GB Per year) - considering current trends	1,896.97	2,477.69	3,249.53	4,270.25	5,619.83
Free Wi-Fi hotspots (Million)	1.54	1.94	2.44	3.08	3.88
Traffic per hotspot - considering current trends	1,231.57	1,277.18	1,329.94	1,387.62	1,449.93
Traffic per hotspot - capped due to congestion	1,183.09	1,183.09	1,183.09	1,183.09	1,183.09
Total traffic (not attributed to 6 GHz) (Million GB)	1,822.29	2,295.15	2,890.72	3,640.83	4,585.58

Sources: Cisco Annual Internet Report Highlights Tool 2018-2023; Wiman; Telecom Advisory Services analysis

We calculate consumer surplus by multiplying the total free traffic (not attributed to 6 GHz) by the difference between what the consumer would have to pay if she/he were to rely on a wireless carrier and the cost of offering free Wi-Fi (incurred by the retailer or public site). To do so, we needed an estimate of the average price per GB of wireless data transmitted by wideband networks, which we calculated by averaging the most economic "dollar per GB" plan of four major wireless carriers in Japan[210] (see Table J-5).

[210] The average is calculated by prorating every price per GB by the carrier's market share.

Table J-5. Japan: Average Price Per Gigabyte (2020)

Carrier	Plan	Price per GB ($)
KDDI	30/30 (V) (30 GB)	$2.41
NTT DOCOMO	5G Gigaho	$0.69
SoftBank	Ultra Giga	$1.18

Note: The average price per GB is converted to U.S. dollars in order to calculate total economic value.
Sources: Operator websites; Telecom Advisory Services analysis

Historical cellular price per gigabyte data was used to project future prices. Based on these prices, we forecast that the average price per GB will reach $0.89 in 2025 from $1.35 in 2021. By relying on the total free Wi-Fi traffic not attributed to 6 GHz allocation shown in Table J-4 and the average price per cellular gigabyte minus the cost of provisioning Wi-Fi service, we calculated the consumer surplus of free Wi-Fi traffic (see Table J-6).

Table J-6. Japan: Consumer Surplus of Free Wi-Fi Traffic (2021-2025)

Variable	2021	2022	2023	2024	2025
Total Free Traffic (not attributed to 6 GHz) (Million GB)	1,822.29	2,295.15	2,890.72	3,640.83	4,585.58
Price per cellular gigabyte ($)	$1.35	$1.22	$1.09	$0.99	$0.89
Cost per Wi-Fi provisioning ($)	$0.85	$0.81	$0.77	$0.73	$0.70
Consumer surplus per gigabyte ($)	$0.50	$0.40	$0.32	$0.25	$0.19
Total Consumer surplus ($Million)	$907.22	$925.19	$930.18	$913.55	$866.83

Sources: Websites of cellular operators; Telecom Advisory Services analysis

As indicated in Table J-6, consumer surplus of free Wi-Fi traffic in 2021 would reach an estimated $907.2 million, decreasing to $866.83 million in 2025 due to the decline in cellular prices coupled with traffic reduction caused by site congestion if the 6 GHz spectrum is not allocated.

Enhanced free Wi-Fi traffic due to 6 GHz allocation

The allocation of the 6 GHz spectrum band coupled with the technological advances provided by the Wi-Fi 6 standard will remove the above-mentioned bottlenecks causing congestion. As a result, the traffic per hotspot will be able to continue growing at its natural rate as determined by the extrapolation of past trends. That being said, we must take into account that not all Wi-Fi traffic will benefit immediately from opening the 6 GHz band, as most current devices are not prepared to operate in the new standards. We expect the traffic through the 6 GHz channel to gradually increase until reaching a 40% of total free traffic by 2025.

Once computed the additional traffic "above and beyond" the future previsions under current spectrum bands, we will follow a similar approach to calculate the consumer surplus, by multiplying it by the difference between what the consumer would have to pay if he were to utilize a wireless carrier and the cost of offering free Wi-Fi (see Table J-7). As a result, we project for 2025 an additional consumer surplus of $78 million from free Wi-Fi traffic attributed to 6 GHz.

Table J-7. Japan: Additional Consumer Surplus of Free Wi-Fi Traffic generated due to 6 GHz (2021-2025)

Variable	2021	2022	2023	2024	2025
Demand not satisfied due to congestion (Million GB)	74.68	182.53	358.81	629.42	1034.25
Traffic through the 6 GHz Channel (%)	0%	10%	20%	30%	40%
Total traffic (attributed to 6 GHz) (Million GB)	0.00	18.25	71.76	188.83	413.70
Consumer Surplus (attributed to 6 GHz) ($Million)	$0.00	$7.36	$23.09	$47.38	$78.20

Source: Telecom Advisory Services analysis

The additional surplus generated by the allocation of the 6 GHz spectrum band will mitigate the decreasing trend of consumer surplus derived from free Wi-Fi under the current spectrum allocation.

J.2.2. Free Wi-Fi to provide broadband to the unserved population

As explained in Chapter II, free Wi-Fi in public sites can provide Internet access to the unserved population. Consumers that do not have broadband at home because they lack the economic means to acquire services can rely on free Wi-Fi to gain Internet access. The net result is that more people can be connected, which in turn enhances the economic contribution of broadband.

The estimation of this particular economic impact starts by calculating the portion of households that lack home broadband service but are already accessing Internet through free hotspots in Japan. Total households' evolution was estimated from data reported by the Japanese census, while the percentage of home Internet adoption was extrapolated from the data estimated by Knoema, a data analysis firm. We capped the extrapolated trend of connected households, by assuming that 0.5% will remain unconnected until 2025. We follow a conservative approach and assume that only 5% of unconnected households rely on free hotspots for accessing Internet. After calculating the increase in broadband penetration due to households relying on free Wi-Fi, we apply the broadband impact coefficient calculated by Katz and Callorda (2018b) in their econometric models developed for Asia-Pacific. As a result, the GDP contribution of this particular effect is expected to amount to $203.9 million in 2021, reaching $208.1 million in 2025 (see Table J-8).

Table J-8. Japan: GDP contribution due to households relying on Free Wi-Fi (2021-2025)

Variable	2021	2022	2023	2024	2025
Households without Internet	276,518	278,095	279,681	281,276	282,880
Households that don't buy because access Internet free hotspots (%)	5%	5%	5%	5%	5%
Households served by Free Wi-Fi hot spots	13,826	13,905	13,984	14,064	14,144
Increase in national broadband penetration	0.025%	0.025%	0.025%	0.025%	0.025%
Impact of fixed broadband adoption in GDP	16.32%	16.32%	16.32%	16.32%	16.32%
Increase in the GDP due to the new broadband adoption (% GDP)	0.004%	0.004%	0.004%	0.004%	0.004%
GDP ($Billion)	$4,972.05	$4,998.00	$5,023.04	$5,048.31	$5,073.70
Total impact in GDP ($Million)	$203.88	$204.94	$205.97	$207.01	$208.05

Sources: Japan Census; Knoema; Telecom Advisory Services analysis

Enhanced GDP contribution due to 6 GHz allocation

As stated above, Wi-Fi 6 technology operating in the 6 GHz band supports a higher number of devices per access point than Wi-Fi sites relying on the 2.4 GHz and 5 GHz bands. Accordingly, the improved throughput of free Wi-Fi hotspots under the 6 GHz allocation will allow the possibility of serving additional unconnected households. The potential universe of additional users that could be served under this effect is significant, as most unconnected households usually identify that costs are their main barrier for accessing to connectivity and thus, may potentially be served by free hotspots as long as they are in proximity to the access point. However, evidence suggests that not many people undergoing the affordability barrier rely exclusively on free Wi-Fi as their main source of Internet access[211], so we follow again a conservative approach and assume that a further 5% of unconnected households will be served through free hotspots under the allocation of the 6 GHz band. On the other hand, we have also considered that the expansion of traffic through the new band will take place gradually, reaching 40% in 2025. All in all, we estimate that additional 5,362 households in Japan will be served by free hotspots operating under 6 GHz spectrum in 2025, yielding an additional GDP contribution of approximately $79 million (Table J-9).

Table J-9. Japan: GDP contribution due to households relying on Free Wi-Fi due to 6 GHz (2021-2025)

Variable	2021	2022	2023	2024	2025
Households without Internet (not served by free Wi-Fi and not new adopters of WISP)	262,692	263,953	265,322	266,696	268,103
Potential households that could be served through free Wi-Fi hotspots under increased capacity (% of those not connected)	5%	5%	5%	5%	5%
Traffic through the 6 GHz Channel (%)	0%	10%	20%	30%	40%
Additional households served by Free Wi-Fi hot spots with 6 GHz	0	1,320	2,653	4,000	5,362
Increase in national broadband penetration	0	0.002%	0.005%	0.007%	0.010%
Increase in the GDP due to the new broadband adoption (% GDP)	0	0.000%	0.001%	0.001%	0.002%
Total impact in GDP ($Million)	$0.00	$19.45	$39.08	$58.88	$78.87

Sources: Japan Census; Knoema; Telecom Advisory Services analysis

J.2.3. Benefit to consumers for enjoying higher speed from free Wi-Fi if 6 GHz band is allocated

When the 6 GHz band is adopted by free Wi-Fi access points it will deliver service at faster broadband speeds. Current speeds from free hotspots are quite modest[212]. However, the expanded capabilities due to the allocation of 6 GHz spectrum band will enhance free Wi-Fi speed, and as a result, will increase consumer surplus. We assume that under the 6 GHz allocation, speed from free hotspots will be similar to the Wi-Fi speeds from mobile devices reported by Cisco. After calculating the

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[211] They tend to also use broadband service provided at work or at an educational institution.
[212] Given the lack of reliable data on free Wi-Fi speed in Japan, we made an estimation based on U.S. data, and applying the percentage difference between both countries in terms of fixed broadband speed. Thus, we estimate free Wi-Fi speed in Japan to reach 15 Mbps in 2020.

average speed by considering the expected share of traffic through 6 GHz, we follow Nevo et al. (2016) and calculate the additional consumer surplus per household relying on free Wi-Fi. We expect the consumer surplus resulting from faster speed in free Wi-Fi sites to reach $9 million in 2025 (Table J-10).

Table J-10. Japan: Consumer surplus for enjoying higher speed from free Wi-Fi if 6 GHz band allocated (2021-2025)

Variable	2021	2022	2023	2024	2025
Free Wi-Fi mean speed with no 6 GHz (Mbps)	15.69	16.43	17.22	16.74	16.27
Wi-Fi Speeds from Mobile Device (Mbps)	75.15	92.96	115.00	142.26	175.98
Traffic through the 6 GHz Channel (%)	0.00%	10.00%	20.00%	30.00%	40.00%
Free Wi-Fi mean speed with 6 GHz (Mbps)	15.69	24.09	36.77	54.39	80.16
Demand for average download speed	91.25	91.15	91.03	89.13	87.27
New Demand for average download speed	91.25	100.44	109.23	117.01	124.47
Additional Monthly Consumer surplus	$0.00	$9.30	$18.20	$27.88	$37.21
Additional Yearly Consumer Surplus	$0.00	$111.54	$218.40	$334.57	$446.49
Households that rely on Free Wi-Fi	13,826	15,225	16,637	18,064	19,506
Consumer surplus ($Million)	$0	$2	$4	$6	$9

Note: Demand for average download speed is the redefined curve based on faster speed service enabled by 6 GHz spectrum.
Sources: Rotten Wi-Fi; Cisco; Nevo et al. (2016); Telecom Advisory Services analysis

J.3. Residential Wi-Fi

The economic value of Wi-Fi in the consumer residential market is driven by five factors:

- Provision of connectivity to the home network for devices that lack an Ethernet port;
- Cost avoidance of ethernet inside wiring;
- Consumer surplus resulting from faster broadband speeds relative to cellular networks;
- Consumer surplus derived from usage of home devices connected to the home network; and
- Provision of Internet access to consumers located in rural and isolated areas.

J.3.1. Home Internet access for devices that lack an Ethernet port

The underlying premise of this analysis is that in the absence of Wi-Fi, users of devices lacking an Ethernet port would have to depend on the cellular network to gain Internet access. For this reason, estimating value would first measure the traffic generated by these devices at home and then multiply it by the average price charged by cellular carriers.

To estimate the traffic of smartphones and tablets, we relied on 2018 Cisco estimates for the period 2016-21 and extrapolated those growth rates to 2025. In addition, we considered, following Cisco IBSG (2012), that 43.12% of use time of devices that lack an Ethernet port occurs at home. Therefore, the portion of said traffic generated at home in Japan will reach 37,116 million gigabytes in 2021 (see Table J-11).

Table J-11. Japan: Total Mobile Internet Traffic (2021-2025) (Million gigabytes)

Variable	2021	2022	2023	2024	2025
Total Annual traffic - Smartphones	62,585.9	81,019.9	104,753.0	134,856.6	172,720.5
Total Annual traffic - Tablets	23,495.2	32,245.9	44,255.8	60,738.6	83,360.3
Share of traffic at Home	43.12%	43.12%	43.12%	43.12%	43.12%
Total Traffic at Home - Smartphones	26,985.6	34,933.9	45,167.1	58,147.1	74,473.2
Total Traffic at Home - Tablets	10,130.6	13,903.7	19,082.1	26,189.1	35,943.1
Total Traffic at Home	37,116.3	48,837.7	64,249.2	84,336.2	110,416.3
Average Price per GB ($)	$1.35	$1.22	$1.09	$0.99	$0.89
Price per home traffic ($Million)	$50,103.44	$59,355.00	$70,302.28	$83,083.50	$97,933.83

Note: The share of home traffic is conservatively assumed to remain constant.
Sources: Cisco; GSMA; Telecom Advisory Services analysis

If this traffic had to be transported by cellular networks, at the average price per GB estimated above (Table J-5), it would result in costs of $50.1 billion in 2021 reaching $97.9 billion in 2025.

J.3.2. Avoidance of inside wiring investment

Residential Wi-Fi allows consumers to avoid paying for wiring to connect all home devices (printers, laptops, external storage drives, etc.). Considering that 90% of connected Japanese households will have Wi-Fi in 2021[213], and the wiring cost estimated per household[214], the avoidance costs of inside wiring over 55 million households yields a total of $29.6 billion. By 2025, all connected households are expected to have adopted Wi-Fi. Therefore, the savings from inside wiring avoidance would have reached $31.87 billion (Table J-12).

Table J-12. Japan: Consumer surplus from avoidance of investment in in-house wiring (2021-2025)

Variable	2021	2022	2023	2024	2025
Total Wiring Cost	$597.84	$589.74	$581.75	$573.87	$566.09
Households with Internet	55,027,124	55,340,906	55,656,478	55,973,849	56,293,030
Households with Wi-Fi (%)	90%	95%	100%	100%	100%
Households with Internet and Wi-Fi	49,496,486	52,517,691	55,571,743	55,973,849	56,293,030
Inside Wiring Costs ($Million)	$29,591	$30,972	$32,329	$32,122	$31,867

Sources: Japanese Census; Watkins (2012); Telecom Advisory Services analysis

213 Extrapolation based on data from Watkins (2012).
214 We estimate for Japan a similar value as in the U.S., adjusted by the PPP difference.

J.3.3. Benefits derived from speed increase

As described before, consumer surplus increases if users enjoy faster Internet speeds. Thus, the welfare of residential customers accessing fixed broadband via Wi-Fi is expected to increase as a result of speeds faster than those provided by cellular networks. After weighting the corresponding broadband speeds with the percentage of traffic carried out through Wi-Fi at home, we calculated the average speed advantage of using Wi-Fi in comparison to cellular networks. By applying the parameters determined in Nevo et al. (2016), the expected consumer surplus will amount to $2.4 billion in 2021, reaching $5.7 billion in 2025.

Table J-13. Japan: Consumer surplus from faster speed in households (2021-2025)

Variable	2021	2022	2023	2024	2025
Average Speed in households if Wi-Fi traffic were carried through mobile networks (Mbps)	83.91	95.04	107.60	121.77	137.77
Average Speed in household with Wi-Fi (Mbps)	98.95	117.06	139.02	165.73	198.33
Demand for average download speed	132.58	133.81	134.98	136.08	137.11
New Demand for average download speed	136.65	138.88	141.12	143.37	145.61
Additional Monthly Consumer surplus	$4.06	$5.07	$6.14	$7.29	$8.50
Additional Yearly Consumer Surplus	$48.76	$60.80	$73.73	$87.49	$102.02
Households with Internet and Wi-Fi	49,496,486	52,517,691	55,571,743	55,973,849	56,293,030
Impact ($Million)	$2,413	$3,193	$4,097	$4,897	$5,743

Sources: Cisco; Nevo et al. (2016); Telecom Advisory Services analysis

Additional benefit to consumers from speed increase due to 6 GHz

The well-being of residential Wi-Fi customers is expected to receive further benefit from the 6 GHz allocation due to faster Internet service under Wi-Fi 6E. As previously described in Chapter B, households acquiring a 150 Mbps (or faster) fixed broadband line will receive a benefit since they are considered to be undergoing current router bottlenecks[215]. To assess the percentage of Japanese households with connections above 150 Mbps, we relied on Cisco projections for local connections over 100 Mbps and the estimated OECD share of connections within that segment than can be assumed to provide faster than 150 Mbps connectivity. After calculating the difference in average speed attributed to 6 GHz, the additional consumer surplus will yield $2.1 billion in 2025 (see table J-14).

[215] See our analysis in Katz, R. (2020). *Assessing the economic value of unlicensed use in the 5.9 GHz and 6 GHz bands*. Washington, DC: Wi-Fi Forward (April), pp. 24-28.

Table J-14. Japan: Consumer surplus from faster speed in households if 6 GHz allocated (2021-2025)

Variable	2021	2022	2023	2024	2025
Households that have connections over 150 Mbps (%)	17.33%	19.63%	22.23%	25.18%	28.53%
Percentage of household traffic that goes through Wi-Fi	60.69%	62.76%	64.78%	66.76%	68.68%
Traffic through the 6 GHz Channel (%)	0.00%	10.00%	20.00%	30.00%	40.00%
Share of traffic affected due to 6 GHz (%)	0.00%	1.23%	2.88%	5.04%	7.84%
Average speed with no 6 GHz (Mbps)	98.95	117.06	139.02	165.73	198.33
Average speed with 6 GHz (Mbps)	98.95	120.55	147.98	182.59	225.89
Demand for average download speed	136.65	138.88	141.12	143.37	145.61
New Demand for aver. download speed	136.65	139.59	142.62	145.66	148.65
Additional Yearly Consumer Surplus	$0.00	$8.56	$17.97	$27.50	$36.43
Households with Wi-Fi	49,496,486	52,517,691	55,571,743	55,973,849	56,293,030
Impact ($Million)	$0	$449	$999	$1,539	$2,051

Sources: OECD; Cisco; Nevo et al. (2016); Telecom Advisory Services analysis

J.3.4. Residential Wi-Fi devices and equipment

The consumer surplus derived from the adoption of residential Wi-Fi devices and equipment focuses on seven consumers products which are intrinsically linked to Wi-Fi: smart home devices and systems such as Wi-Fi speakers and home security systems, home networking systems, Wi-Fi tablets, access points, external adapters, routers, and gateways. Two different approaches are used in this case: one assuming that consumer surplus is roughly equal to producer surplus in six of the seven products (excluding tablets), and an assessment of tablets' willingness-to-pay.

The estimation of economic value in the first approach begins by compiling local sales in the six product categories in Japan[216]. After computing the sales in Japan, we applied the prorated margin estimated by CSI markets (39.44%) which yields an estimated producer surplus for these particular products of $6.9 billion in 2021. As mentioned above, it is assumed that the consumer surplus is of the same magnitude. This methodology was also used to calculate the consumer surplus up to 2023. However, the gradual adoption of Wi-Fi 6 devices is forecast to reduce the sales and economic value from the devices relying on the 2.4 GHz and 5 GHz spectrum bands. Non 6 GHz consumer devices shipments are expected by IDC to decrease by 1.2% in 2024 and 3.1% in 2025. Based on this estimate, we extrapolated the consumer surplus from non 6 GHz reliant residential Wi-Fi devices and equipment between 2021 and 2025.

In addition, we calculated the consumer surplus attributable to tablets bought by local consumers. Starting with CTA/Statista worldwide tablet revenue estimates, we

[216] Calculated by prorating data for the United States based on GDP.

interpolated the revenue figures for Japan (by weighting by the country's share of global GDP), and extrapolated the evolution of local revenue until 2025 by considering Cisco estimates of tablet evolution for the period. We reviewed the data on tablet prices for the market leader (taking as a reference the Apple iPad 10.2 Inch 128 GB, as Apple has 70% of the local market share in tablets[217]) and for the rest of the market (taking as a reference a Samsung Wi-Fi tablet 128 GB), and assumed consumer willingness-to-pay levels in a similar percentage above prices as in the U.S. average. Based on that information, we were able to estimate a consumer surplus attributable to tablets of $254 million in 2021, expected to decline to $165 million in 2025.

In sum, overall consumer surplus for Wi-Fi enabled residential products is expected to yield $7.2 billion in 2021, remaining relatively stable until 2025 (Table J-15).

Table J-15. Japan: Economic Value of Wi-Fi enabled consumer products (2021-2025)

Variable	2021	2022	2023	2024	2025
Consumer surplus (ex. Tablets) ($Million)	$6,940	$7,148	$7,380	$7,288	$7,062
Consumer surplus (Tablets) ($Million)	$254	$223	$201	$183	$165
Total consumer surplus ($Million)	$7,194	$7,372	$7,581	$7,471	$7,227

Sources: Consumer Technology Association; ABI Research; CS Markets; IDC; Gs StatCounter; Telecom Advisory Services analysis

Consumer surplus derived from Wi-Fi enabled residential equipment for 6 GHz

As discussed above, sales of residential Wi-Fi devices and equipment operating in the 6 GHz band are expected to gradually replace those of former generations. According to IDC, global shipments of consumer devices operating in the 6 GHz (802.11ax standard) will represent 40% of sales from prior generations. As a result, if the shipments ratio attains 40% in 2025, we can expect that, at least, the consumer surplus derived from 6 GHz devices will represent 40% of that of former technology residential devices. As a result, our estimates for consumer surplus attributed to 6 GHz residential devices amount to $2.8 billion in 2025 (see Table J-16).

Table J-16. Japan: Economic Value of Wi-Fi enabled consumer products for 6 GHz (2021-2025)

Variable	2021	2022	2023	2024	2025
Consumer surplus (ex. Tablets) ($Million)	$6,940	$7,148	$7,380	$7,288	$7,062
Consumer 6 GHz / no 6 GHz device ratio	3.76%	8.83%	18.59%	28.86%	40.30%
Consumer surplus 6 GHz devices ($Million)	$261	$631	$1,372	$2,103	$2,846

Sources: IDC; Telecom Advisory Services analysis

J.3.5. Bridging the digital divide: use of Wi-Fi to increase coverage in rural and isolated areas

Wi-Fi is an appropriate technology to offer Internet access in rural and isolated areas. The incremental number of lines supported by Wireless Internet Service

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[217] Source: Gs StatCounter

Providers (WISPs) represents an increase in penetration, which in turn contributes to the national GDP.

According to Statista, there were approximately 10,000 fixed wireless connections in Japan in 2018. In order to estimate Wi-Fi's contribution, we assume that 90% of WISP potential connections may be theoretically served by other technologies (i.e. satellite) covering the same isolated footprint. Thus, we can conservatively expect 10% of broadband subscriptions in remote locations to be exclusively served by WISPs. With this value, we calculate the impact on GDP by relying on the coefficient estimated by Katz and Callorda (2018b) through regression models that links increase in broadband penetration to economic growth in Asia Pacific. However, the calculation of Wi-Fi contribution to GDP must subtract the direct impact of WISPs sales (estimated below in Section J.5.3.) to avoid double counting. As a result, by reducing the digital divide and increasing broadband penetration, we estimate a GDP contribution of $17.8 million in 2021, which will slightly decrease by 2025 to $16.5 million (see Table J-17).

Table J-17. Japan: Estimation of GDP Contribution derived from reducing the digital divide (2021-2025)

Variable	2021	2022	2023	2024	2025
WISP subscribers	10,000	10,000	10,000	10,000	10,000
Additional broadband penetration due to WISP	0.02%	0.02%	0.02%	0.02%	0.02%
Impact of fixed broadband adoption in GDP	16.32%	16.32%	16.32%	16.32%	16.32%
GDP ($Billion)	$4,972	$4,998	$5,023	$5,048	$5,074
WISP TOTAL impact ($Million)	$0.184	$0.181	$0.178	$0.175	$0.173
WISP Revenues ($Million)	$0.01	$0.01	$0.01	$0.01	$0.01
Share that exist because WISP	10.00%	10.00%	10.00%	10.00%	10.00%
WISP spillovers on GDP ($Million)	$17.79	$17.43	$17.11	$16.80	$16.49

Sources: Statista; Telecom Advisory Services analysis

The contribution to GDP materializes through multiple effects: creation of new businesses, increasing productivity of existing enterprises (especially small), and the growth of average income per household.

Economic impact of enhanced coverage and affordability due to 6 GHz

The allocation of the 6 GHz band to unlicensed use would allow WISPs to potentially increase their subscriber base within their same coverage footprint. Therefore, a first effect derived from the allocation of the new spectrum band is related to additional households served due to additional coverage. We will follow a cautious approach and consider that the expanded coverage will yield a gradual increase on WISP subscribers, from 2% in 2022 to 5% in 2025 over the values projected above. In addition, an increase of the user base would allow service providers to lower their operating costs. Thus, by assuming stability in prices, affordability would increase as GDP per capita grows in a context of economic growth resumption. All in all, we can expect an overall increase in 632 WISP connections in 2025, contributing to an increase 0.001% in national broadband penetration. Considering the impact coefficient of broadband on the economy, which will yield $10.9 millions in GDP contribution.

Table J-18. Japan: GDP Contribution derived from reducing the digital divide due to 6 GHz (2021-2025)

Variable	2021	2022	2023	2024	2025
New subscribers due to expanded coverage (%)	0%	2%	3%	4%	5%
New subscribers due to expanded coverage	0	200	300	400	500
New WISP adoption after price decrease (% households)	0.020%	0.019%	0.019%	0.018%	0.018%
Traffic through the 6 GHz Channel (%)	0.00%	10.00%	20.00%	30.00%	40.00%
Increase in WISP connections due to lower prices (households that buy the service)	0	37	75	116	132
Overall increase in WISP connections due to 6 GHz	0	237	375	516	632
Increase in national broadband penetration	0.000%	0.000%	0.001%	0.001%	0.001%
Impact of fixed broadband adoption in GDP	16.32%	16.32%	16.32%	16.32%	16.32%
Increase in the GDP due to the new broadband adoption (% GDP)	0.0000%	0.0001%	0.0001%	0.0002%	0.0002%
Total impact in GDP ($Million)	$0.000	$4.284	$6.681	$9.049	$10.905

Source: Telecom Advisory Services analysis

J.4. Enterprise Wi-Fi

Beyond the impact on consumers, Wi-Fi also contributes significant economic value to the Japanese enterprise segment. This section provides estimates in five areas:

- Support of business Internet traffic;
- Avoidance of campus and enterprise facilities inside wiring;
- Contribution to GDP resulting from Wi-Fi speed faster than cellular connections;
- Deployment of IoT solutions; and
- Implementation of business focused AR/VR use cases.

J.4.1. Business Internet traffic transmitted through Wi-Fi

Wi-Fi enterprise savings results from wireless traffic that is routed through Wi-Fi access points rather than being transported through cellular networks. Based on Cisco 2016-21 projections for Japan, we estimate that total business Internet traffic will reach 34.8 billion GB in 2021, of which 19.5 billion GB would have been transported through Wi-Fi access points. Considering the average price per GB transported by cellular, savings from Wi-Fi will reach $26.3 billion, an addition to the producer surplus. By 2025, this benefit will reach $42.9 billion (see Table J-19).

Table J-19. Japan: Savings in business wireless traffic (2021-2025)

Variable	2021	2022	2023	2024	2025
Share of Business Internet Traffic by Wi Fi	56.00%	57.28%	58.60%	59.94%	61.31%
Total Business Internet Traffic (Million GB)	34,789.2	42,687.5	52,378.8	64,270.4	78,861.8
Total Wi-Fi enterprise traffic (Million GB)	19,482.0	24,453	30,692.4	38,523.9	48,353.6
Average Price per GB	$1.35	$1.22	$1.09	$0.99	$0.89
Economic Impact ($Million)	$26,298.82	$29,719.02	$33,584.01	$37,951.66	$42,887.32

Sources: Cisco; Telecom Advisory Services analysis

Enhanced business Internet traffic transmitted through Wi-Fi due to 6 GHz

The deployment of the latest enterprise applications will generate an exponential growth in data traffic that will be handled by devices operating in unlicensed spectrum as well, through the combination of the existing bands and the 6 GHz band. In 2019, updated Cisco traffic forecast increased the worldwide forecast for business Internet traffic with respect to the prior 2016-21 estimates from 2018. We assume that part of the forecast increase was driven by "natural" growth, while the remainder was triggered by Wi-Fi traffic stimulated by shifting traffic to the 6 GHz band. However, in the specific case of Japan, Cisco updated forecasts do not foresee an increase in business traffic in comparison with prior estimates. Then, and following a consistent approach as in the case of the other countries, we will not attribute a specific economic value of business traffic increase due to 6 GHz.

J.4.2. Avoidance in enterprise building inside wiring

Similar to residential Wi-Fi savings due to capital investment avoidance in inside wiring, we assume that the total number of business establishments in Japan are equipped with Wi-Fi access points and multiply this value by a standard cost of deploying a CAT 6 network in business establishments (although in this case, the cost is higher than for households) (see Table J-20).

Table J-20. Japan: Savings in business wiring CAPEX (2021-2025)

Variable	2021	2022	2023	2024	2025
Total Wiring Cost	$1,992.80	$1,965.80	$1,939.17	$1,912.89	$1,886.97
Number of Establishments	5,963,998	5,969,331	5,974,668	5,980,011	5,985,359
Establishments with Wi-Fi (%)	100%	100%	100%	100%	100%
Establishments with Wi-Fi	5,963,998	5,969,331	5,974,668	5,980,011	5,985,359
Inside Wiring Costs ($Million)	$11,885	$11,735	$11,586	$11,439	$11,294

Sources: Japanese Economic Census for Business Activity; Telecom Advisory Services analysis

J.4.3. Return to speed: contribution to GDP derived from an increase in average mobile speed

Since Wi-Fi accessibility allows, in general, faster access to the Internet than cellular networks do, higher speeds have a positive economic contribution in terms of increased overall efficiency and innovation, that translates into economic growth. As described in section J.3.3 for the case of consumer surplus, we begin with the quantification of the average broadband speed if cellular networks transported all Wi-Fi traffic, and compare it with the performance of Wi-Fi technology. Having calculated the percentage of speed increase, we then apply it to the coefficient derived from the model developed by Katz and Callorda (2019) to gauge the potential impact on GDP from Wi-Fi enhanced speed (see Table J-21).

Table J-21. Japan: Estimation of speed differential for total traffic (2021-2025)

Variable	2021	2022	2023	2024	2025
Average Download Speed if Wi-Fi traffic were carried through mobile networks (Mbps)	83.91	95.04	107.60	121.77	137.77
Average Speed with Wi-Fi (Mbps)	98.95	117.06	139.02	165.73	198.33
Speed increase (%)	18%	23%	29%	36%	44%
Impact of speed in GDP	0.73%	0.73%	0.73%	0.73%	0.73%
Increase in GDP	0.13%	0.17%	0.21%	0.26%	0.32%
GDP ($Billion)	$4,972.05	$4,998.00	$5,023.04	$5,048.31	$5,073.70
GDP increase ($Million)	$6,506	$8,454	$10,708	$13,304	$16,279

Sources: Cisco; Telecom Advisory Services analysis

As Table J-21 indicates, the economic value of Wi-Fi in terms of increasing the wireless speed will account to $6.5 billion in 2021, before being increased to $16.3 billion in 2025.

Additional return to speed effect due to 6 GHz

As previously described, only those broadband connections above 150 Mbps will be affected due to current router bottlenecks, and hence, the speed experienced will not be equivalent to that delivered by the fixed network. The allocation of spectrum in the 6 GHz band will remove those barriers, increasing broadband speed. After calculating the difference in average speed attributed to the allocation of 6 GHz spectrum, the additional GDP contribution will amount to $5.1 billion in 2025 (Table J-22).

Table J-22. Japan: Estimation of speed differential due to 6 GHz (2021-2025)

Variable	2021	2022	2023	2024	2025
Mean speed with no 6 GHz (Mbps)	98.95	117.06	139.02	165.73	198.33
Mean speed with 6 GHz (Mbps)	98.95	120.55	147.98	182.59	225.89
Speed increase due to 6Ghz (%)	0%	3%	6%	10%	14%
Impact speed on GDP	0.73%	0.73%	0.73%	0.73%	0.73%
Increase in GDP (%)	0.00%	0.02%	0.05%	0.07%	0.10%
GDP increase ($Million)	$0	$1,086	$2,363	$3,749	$5,146

Sources: Cisco; Telecom Advisory Services analysis

J.4.4. IoT deployment

IoT adoption has a contribution to GDP growth through the multiplicity of use cases that improve efficiency in processes, such as preventive maintenance, production monitoring and the like. To estimate this impact, we rely on a coefficient of GDP impact of IoT calculated through an aggregate simple production function which estimates that a 10% rise in M2M (Machine to Machine) connections results in annual increases in GDP of between 0.3% and 0.9%[218]. Given the strength of the industrial and technological sector in Japan, we assume a 0.9% GDP increase after a 10% increase in the M2M installed base.

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[218] See Frontier Economics (2018).

Starting with a 2021 installed base of 35 million M2M devices in Japan, we estimate the growth that can be exclusively attributed to the allocation of additional spectrum to indoor Wi-Fi devices. By subtracting the growth in M2M attributed to 6 GHz, the IoT impact for 2021 is estimated to reach $50.6 billion (see Table J-23).

Table J-23. Japan: GDP Contribution of IoT Deployment Boost (2021-2025)

Variable	2021	2022	2023	2024	2025
Connections, Cellular M2M	35,308,836	38,342,956	40,402,542	42,572,758	44,859,548
Growth Rate (%)	12.42%	8.59%	5.37%	5.37%	5.37%
Natural Growth Rate (%)	11.31%	7.60%	4.63%	4.63%	4.63%
Impact of 1% M2M Growth on GDP	9.00%	9.00%	9.00%	9.00%	9.00%
Impact on GDP (%)	1.02%	0.68%	0.42%	0.42%	0.42%
GDP ($Billion)	$4,972	$4,998	$5,023	$5,048	$5,074
Impact ($Million)	$50,624.70	$34,201.14	$20,943.31	$21,048.66	$21,154.53

Sources: GSMA Intelligence; Frontier Economics; Telecom Advisory Services analysis

It should be noted that the GDP impact of IoT declines due to a decreasing growth rate of M2M installed base.

Accelerated effect of IoT due to 6 GHz

As described above, a share of the M2M growth can be attributed to IoT traffic shifting to the 6 GHz spectrum. According to the data in Table J-24, the impact of enhanced IoT deployment driven by 6 GHz spectrum proposals will reach $3.4 billion by 2025.

Table J-24. Japan: GDP Contribution of IoT Deployment Boost caused by 6 GHz (2021-2025)

Variable	2021	2022	2023	2024	2025
Growth due to 6 GHz (%)	1.11%	0.99%	0.74%	0.74%	0.74%
Level of development of new bands (%)	50%	100%	100%	100%	100%
Impact on GDP (%)	0.05%	0.09%	0.07%	0.07%	0.07%
Impact ($Million)	$2,484.41	$4,452.31	$3,339.76	$3,356.56	$3,373.44

Sources: GSMA Intelligence; Frontier Economics; Telecom Advisory Services analysis

J.4.5. Deployment of AR/VR solutions

The adoption of AR/VR among Japanese businesses will have a spillover effect on productivity, thereby contributing to the growth of GDP. Estimating spillover effects of AR/VR is a not a trivial exercise considering the embryonic adoption of some of the use cases based on this technology. Since the objective is to estimate the spillover effect of AR/VR sales in Japan, we consider the estimate by PwC of the total GDP contribution of AR/VR for 2021 and 2022[219], and the sales of AR/VR components as estimated by ABI Research[220]. The extrapolation of these two

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[219] See PWC (2019). *Seeing is believing how virtual reality and augmented reality are transforming business and the economy.*

[220] See ABI Research, *Augmented and Mixed Reality Market Data: devices, use cases, verticals and value chain*. MD-ARMR-103, QTR 4 2019, and ABI Research, *Virtual Reality Market Data: devices, verticals, and value chain*. MD-VR-108, QTR 1 2020.

parameters allows estimating the indirect (spillover) contribution of AR/VR to Japan's economy for the period under analysis.

Starting values are reduced by the proportion that can be attributed to other technologies rather than Wi-Fi. After computing the resulting value, we subtracted the impact of the 6 GHz spectrum bands. To do so, we took as a reference a ratio of AR/VR product developments for each technology (built with data from ABI Research). Once the amounts to be attributed to GDP contribution and direct sales were estimated, the annual indirect to direct multiplier can be calculated. The lowest multiplier value is applied to sales of AR/VR in the local market to calculate the total spillovers. Accordingly, total spillover value of AR/VR in Japan in 2021 will account for $860 million and is expected to increase by 2025 to $4.1 billion (see Table J-25).

Table J-25. Japan: GDP contribution resulting from AR/VR spillovers (2021-2025)

Variable	2021	2022	2023	2024	2025
AR/VR total contribution to GDP ($Billion)	$9.63	$14.19	$20.93	$30.85	$45.48
Share attributed to Wi-Fi (excluding 6 GHz)	42.02%	38.80%	32.18%	30.88%	29.32%
Portion of GDP contribution attributed to Wi-Fi (excluding 6 GHz) ($Billion)	$4.05	$5.51	$6.73	$9.53	$13.34
Direct impact (sales) attributed to Wi-Fi (excluding 6 GHz) ($Billion)	$0.86	$1.37	$1.80	$2.57	$4.07
Indirect impact ($Billion)	$3.19	$4.13	$4.93	$6.96	$9.26
Indirect/Direct multiplier	1.00	1.00	1.00	1.00	1.00
Indirect impact ($Million)	$860.24	$1,372.37	$1,800.28	$2,566.50	$4,071.61

Sources: PwC, ABI; Telecom Advisory Services analysis

Wider deployment of AR/VR solutions (accelerated effect due to 6 GHz)

Higher throughput enabled by the allocation of 6 GHz spectrum is expected to spur the adoption and use of AR/VR among enterprises, hence increasing the associated spillover effects. By relying on the ratio built from 5 GHz and 6 GHz AR/VR related products, we were able to isolate the specific economic contribution of the new spectrum allocation. Following a similar procedure as the one described above, spillovers from AR/VR in Japan attributed to 6 GHz were calculated. They will account for $503 million in 2021 and are expected to reach $4 billion by 2025 (Table J-26).

Table J-26. Japan: GDP contribution resulting from AR/VR spillovers due to 6 GHz (2021-2025)

Variable	2021	2022	2023	2024	2025
AR/VR total contribution to GDP ($Billion)	$9.63	$14.19	$20.93	$30.85	$45.48
Share attributed to 6 GHz (%)	24.58%	25.59%	26.64%	27.73%	28.87%
Portion of GDP contribution attributed to 6 GHz ($Billion)	$2.37	$3.63	$5.57	$8.56	$13.13
Direct impact (sales) attributed to 6 GHz ($Billion)	$0.50	$0.90	$1.49	$2.30	$4.01
Indirect impact ($Billion)	$1.86	$2.73	$4.08	$6.25	$9.12
Indirect/Direct multiplier	1.00	1.00	1.00	1.00	1.00
Indirect impact ($Million)	$503.16	$904.99	$1,490.43	$2,304.88	$4,009.06

Sources: PwC, ABI; Telecom Advisory Services analysis

J.5. Internet Service Providers

In addition to the economic value generated by the sources analyzed above, Wi-Fi will also contribute to either producer surplus or GDP of Internet Service Providers. This section will assess the economic value in three sources:

- Producer surplus of cellular operators resulting from CAPEX savings incurred in network deployment
- Revenues of Wi-Fi carriers offering service in public spaces
- Revenues of Wireless ISPs (this effect differs from the GDP impact of WISPs as a result of their deployment in rural and isolated areas analyzed in section J.3.5.)

J.5.1. Cellular network savings by off-loading traffic to Wi-Fi

The estimation of CAPEX savings starts by considering the GSMA Intelligence aggregate investment estimates of 5G deployments. It is assumed that all the CAPEX invested during the period would be dedicated to 5G deployment. In this context, Wi-Fi becomes a key enabler of 5G services. The upcoming flexible, radio-neutral 5G environment will be intrinsically supported by the next wave of 802.11 Wi-Fi standards (802.11n/ac, 802.11ax, WiGig), and short-range wireless technologies operating in unlicensed bands. Considering that the total CAPEX required to deploy 5G in Japan, and the growth in 5G coverage between 2021 and 2025 as reported in GSMA Intelligence, we are able to calculate the 5G CAPEX for each year of the period under consideration. Once this is estimated, the savings incurred by Wi-Fi is estimated by calculating the capital spending reduction ratio from Table J-36.

Based on the simulation model developed to estimate the impact of Wi-Fi off-loading in 5G deployment, we estimate that the savings of deploying carrier-grade Wi-Fi complementing the rollout of 5G to accommodate future traffic growth would amount to 32.9% of CAPEX, while the OPEX savings are $2.82 for each dollar saved in CAPEX. The estimation of CAPEX savings starts by considering the GSMA Intelligence aggregate investment estimates of 5G deployments in Japan, which amount to $99.50 billion between 2019 and 2025. It is assumed that all the CAPEX invested during the period would be dedicated to 5G deployment. Considering the total CAPEX required to deploy 5G in the country, and the incremental 5G coverage between 2021 and 2025, we are able to interpolate the 5G CAPEX for each year of the period considered. Assuming that this amount already reflects the savings incurred by relying on Wi-Fi sites, this would result in a total producer surplus (adding CAPEX and OPEX savings) of $36.4 billion in 2021, and $18 billion in 2025, when the value of Wi-Fi will shift to the 6 GHz band (see Table J-27).

Table J-27. Japan: Savings due to traffic off-loading (2021-2025)

Variable	2021	2022	2023	2024	2025
5G coverage	48%	64%	72%	81%	90%
CAPEX without saving ($Million)	$28,980.06	$26,309.54	$13,286.65	$14,935.12	$14,325.18
CAPEX reduction due to Wi-Fi off-loading ($Million)	$9,534.4	$8,655.8	$4,371.3	$4,913.7	$4,713.0
OPEX reduction due to Wi-Fi off-loading ($Million)	$26,887.1	$24,409.5	$12,327.1	$13,856.5	$13,290.6
Total Cost of Ownership ($Million)	$36,422	$33,065	$16,698	$18,770	$18,004

Sources: GSMA; Telecom Advisory Services analysis

The decline in savings over time is compensated by the increase in economic benefit under the 6 GHz spectrum allocation.

Enhanced capability for cellular off-loading if 6 GHz allocated

The complementarity between Wi-Fi and cellular networks for Wi-Fi 6E and 5G, adds further potential gains derived from the savings in capital and operating expenses required to accommodate exploding data traffic. The key objective is to estimate the savings in capital investment as a result of an increase in traffic offloading with Wi-Fi benefits from the additional spectrum allocated, particularly, due to the ability to leverage 160 MHz within single contiguous channels.

The estimation of CAPEX savings starts by considering the GSMA Intelligence aggregate investment estimates of 5G deployments. By relying on the geographic disaggregation of Oughton and Frias, we estimate that CAPEX can be split in urban, suburban, and rural geographies. To estimate the percentage of population living in areas over 1 million inhabitants, we considered those living in the metropolitan areas of Kantō, Keihanshin, Chūkyō, Fukuoka-Kitakyushu, Shizuoka-Hamamatsu, Sapporo, Sendai, Hiroshima, Utsunomiya, Okayama, Kumamoto, Niigata, and Kagoshima. The percentage of rural population was obtained from Statista, while the remaining share of the population was classified in the suburban group (see Table J-28).

Table J-28. Japan: 5G CAPEX estimated by geographical breakdown

Geography	Japan		
	Population Breakdown (%)	5G CAPEX ($Billion)	5G CAPEX (%)
Urban (cities>1 Million)	69.8%	$7.62	7.66%
Suburban	21.6%	$10.18	10.22%
Rural	8.6%	$81.75	82.12%
Total	100%	$99.55	100%

Sources: Oughton and Frias (2016); GSMA; Telecom Advisory Services analysis

We conservatively assume that Wi-Fi 6 will not be critical in sustaining investment in urban areas, but that it will play a significant role beyond those geographies. Based on the cost advantage of carrier grade Wi-Fi, we assume that it will become effective for a portion of the suburban (approximately 15%) and rural network (approximately 5%) deployment. Therefore, this will yield yearly CAPEX savings of $1.1 billion.

J.5.2. Wi-Fi carrier revenues

The value of Wi-Fi carriers includes the sum of revenues generated by paid public Wi-Fi access. In order to estimate this value, we start by calculating the number of commercial Wi-Fi hotspots in Japan. According to Cisco, in 2021 there will be 24.77 million public Wi-Fi hotspots in the country, although that figure includes home spots (such as the guest account service provided by cable operators). By subtracting the home spots from the public Wi-Fi estimates of Cisco, we estimated a total of 510,000 commercial Wi-Fi hotspots for 2021, which will decrease, reaching 300,000 in 2025. On the other hand, based on revenue per hotspot generated by Boingo in the United States, and adjusting the metric by PPP we estimated the value for Japan. Accordingly, this amounts to $285.8 million in 2021, gradually decreasing to reach $158.8 million in 2025 (Table J-29).

Table J-29. Japan: Revenues of Wi-Fi carriers (2021-2025)

Variable	2021	2022	2023	2024	2025
Public Wi-Fi hotspots (Million)	24.77	31.20	39.30	49.50	62.34
Home spots (Million)	24.26	30.68	38.80	49.06	62.04
Commercial Wi-Fi hotspots (Million)	0.51	0.52	0.50	0.43	0.30
Revenue per hotspot ($)	$560.48	$552.89	$545.40	$538.01	$530.72
Revenue ($Million)	$285.82	$287.43	$272.70	$233.51	$158.76

Sources: Cisco, Boingo, Telecom Advisory Services

Increased revenues of Wi-Fi carriers in public places due to 6 GHz

The allocation of the 6 GHz spectrum band offers an opportunity for commercial Wi-Fi carriers to enhance their business. As Wi-Fi 6E developments will allow up to 1,500 connected devices per access point, Wi-Fi carriers will have the possibility of adding more clients without quality limitations due to congestion. By considering a conservative potential increase of 40% in the number of connected devices in public venues and weighting that figure by the gradual expansion of the latest technology, we expect commercial Wi-Fi carriers to increase their user base by 16% in 2025. If the revenue per hotspot increases in the same amount, that will yield an increase in overall revenues for the sector of an additional $25 million by 2025 (Table J-30).

Table J-30. Japan: Revenues of Wi-Fi carriers due to 6 GHz (2021-2025)

Variable	2021	2022	2023	2024	2025
Potential increase in connected devices in public venues	40.00%	40.00%	40.00%	40.00%	40.00%
Traffic through the 6 GHz Channel (%)	0%	10%	20%	30%	40%
Increase in connected devices due to 6 GHz	0%	4%	8%	12%	16%
Revenue per hotspot if 6 GHz allocated ($)	$560.48	$575.00	$589.03	$602.57	$615.63
Revenue if 6 GHz allocated ($Million)	$0.00	$11.50	$21.82	$28.02	$25.40

Sources: Boingo, Telecom Advisory Services

J.5.3. Wireless ISPs revenues

The 2021 GDP contribution related to the WISP industry was calculated as a function of the number of subscribers (10,000) and the ARPU (from U.S., adjusted by PPP), yielding a total of $5.8 million (Table J-31).

Table J-31. Japan: WISP revenues (2021-2025)

Variable	2021	2022	2023	2024	2025
Subscribers (Million)	0.01	0.01	0.01	0.01	0.01
Revenues ($Million)	$5.82	$6.59	$6.89	$7.23	$7.65

Sources: Statista, Telecom Advisory Services

Increased revenues of WISPs due to 6 GHz

As described in section J.2.5, the allocation of 6 GHz spectrum will potentially increase the WISP user base by 632 subscribers in 2025, due to expanded coverage and better affordability. Thus, by assuming the same ARPU values as described above, the new subscriptions will amount to an additional $480 thousand in revenues in 2025 (Table J-32).

Table J-32. Japan: WISP revenues due to 6 GHz (2021-2025)

Variable	2021	2022	2023	2024	2025
WISP annual ARPU ($)	$581.51	$659.25	$689.49	$723.11	$764.81
New subscribers if 6 GHz allocated (Million)	0.0000	0.0002	0.0004	0.0005	0.0006
New revenue ($Million)	$0.00	$0.16	$0.26	$0.37	$0.48

Source: Telecom Advisory Services

J.6. Wi-Fi ecosystem

The economic value generated by Wi-Fi within Wi-Fi ecosystem companies in Japan is generated from the following three sources:

- The producer surplus (i.e. margins) of residential Wi-Fi devices and equipment manufactured in Japan;
- The producer surplus of local firms providing products and services in the IoT ecosystem (hardware, software and systems integration) in Japan; and
- The producer surplus of local firms providing products and services in the AR/VR ecosystem (hardware, software and content) in Japan.

J.6.1 Locally manufactured residential Wi-Fi devices and equipment

In section J.2.4 we calculated the producer surplus attributed to residential Wi-Fi devices and equipment, relying on Milgrom et al. (2011) assumption that consumer surplus could be approximated by that of the producers. As a result, we estimate a total economic value of $6.2 billion in 2021, which we expect to slightly increase to $6.4 billion in 2025 (Table J-33).

Table J-33. Japan: Producer Surplus from locally manufactured residential Wi-Fi devices and equipment (2021-2025)

Variable	2021	2022	2023	2024	2025
Total producer surplus ($Million)	$6,212.39	$6,437.48	$6,660.20	$6,577.57	$6,373.53

Sources: Consumer Technology Association; ABI Research; CS Markets; Telecom Advisory Services analysis

Locally manufactured Wi-Fi 6 devices and equipment for residential use

As mentioned above, devices for 6 GHz are expected to gradually replace those of prior generations. According to IDC, global shipments of consumer devices linked to 6 GHz spectrum (802.11ax) will represent 40% of the shipments of those from previous generations in 2025. Therefore, we expect the producer surplus attributed to 6 GHz devices to yield $2.6 billion in economic value by 2025 (see Table J-34).

Table J-34. Japan: Producer Surplus from locally manufactured residential Wi-Fi 6 devices and equipment (2021-2025)

Variable	2021	2022	2023	2024	2025
Consumer 6 GHz / no 6 GHz	3.76%	8.83%	18.59%	28.86%	40.30%
Producer surplus 6 GHz devices ($Million)	$233.89	$568.66	$1,237.83	$1,898.06	$2,568.28

Sources: IDC; Telecom Advisory Services analysis

J.6.2 Locally manufactured enterprise Wi-Fi devices and equipment

Of the revenues of Japanese manufacturers, the prorated margin estimated by CSI markets is 39.44%, which yields a producer surplus for local manufacturers of enterprise products of $686.5 million. Following again Milgrom et al. (2011) in their assumption that consumer value for enterprises[221] is of the same magnitude as producer value, total economic value in 2021 will amount to $1.4 billion (see Table J-35). That value is expected to decrease by 2025 due to the replacement of current devices by those specific for 6 GHz.

Table J-35. Japan: Producer Surplus from locally manufactured enterprise Wi-Fi devices and equipment (2021-2025)

Variable	2021	2022	2023	2024	2025
Total producer surplus ($Million)	$1,373.04	$1,431.85	$1,514.53	$1,477.39	$1,331.96

Sources: Consumer Technology Association; ABI Research; CS Markets; Telecom Advisory Services analysis

Locally manufactured Wi-Fi 6 devices and equipment for enterprisers

In total, global shipments for industrial devices for 6 GHz will account for 115% of those attributed to previous generations in 2025. Thus, by applying the corresponding ratios, we expect the producer surplus linked to enterprise 6 GHz devices to yield $1.5 billion by 2025.

Table J-36. Japan: Economic Value of Wi-Fi 6 enabled enterprise equipment (2021-2025)

Variable	2021	2022	2023	2024	2025
Ratio 6 GHz / no 6 GHz	8.45%	21.87%	42.15%	71.53%	115.38%
Producer surplus 6 GHz devices ($Million)	$115.98	$313.18	$638.42	$1,056.73	$1,536.85

Sources: IDC Telecom Advisory Services analysis

[221] The enterprise surplus is considered here as a producer surplus for companies that benefit from Wi-Fi technology.

J.6.3. Firms belonging to the IoT ecosystem

According to estimates from Statista and Bain & Co, we expect total industrial IoT revenue in Japan to amount $30 million in 2021. By relying on the percentage of hardware connectivity spending in IoT in the Asia-Pacific region, we were able to split that figure into the two main segments: (i) hardware; and (ii) software, contents, and services. By weighting those amounts by the share of local production (36% for hardware, 90% for software and services) and the margins (39.44% and 77.46%, respectively), we can estimate the overall producer surplus. However, the share attributed to 6 GHz should be subtracted from the total economic value. To do so, we estimated a natural growth rate, by subtracting the corresponding share attributed to 6 GHz spectrum according to the growth rates indicated in Section J.6.2. J.3.4. Thus, we estimate a producer surplus not attributed to 6 GHz of $14.3 billion in 2021, expected to reach $28.7 billion in 2025 (Table J-37).

Table J-37. Japan: IoT ecosystem direct contribution (2021-2025)

Variable	2021	2022	2023	2024	2025
IoT revenue - Hardware ($billions)	$11.30	$13.78	$16.81	$20.50	$25.00
IoT revenue - Software, Contents, Services ($billions)	$18.83	$22.97	$28.01	$34.17	$41.67
Total Industrial IoT revenue in ($Billion)	$30.13	$36.75	$44.82	$54.67	$66.68
Local production (%) - Hardware	36%	36%	36%	36%	36%
Local production (%) - Software & Services	90%	90%	90%	90%	90%
Margins (%) - Hardware	39%	39%	39%	39%	39%
Margins (%) - Software & Services	77%	77%	77%	77%	77%
Margins - IoT Hardware revenue	$1.59	$1.94	$2.37	$2.89	$3.53
Margins - Software, contents and services IoT revenue	$13.13	$16.01	$19.53	$23.82	$29.05
Producer surplus ($Million)	$14,723.54	$17,957.50	$21,901.80	$26,712.45	$32,579.74
Growth rate (%)	10.64%	21.96%	21.96%	21.96%	21.96%
Growth rate not attributed to 6 GHz (%)	9.69%	19.43%	18.94%	18.94%	18.94%
Producer surplus not attributed to 6 GHz ($Million)	$14,298.35	$17,077.18	$20,312.24	$24,160.13	$28,736.96

Sources: Statista, Bain & Co, CSI, Telecom Advisory Services analysis

Wider deployment of Internet of Things under 6 GHz

Following the previous analysis, we were able to estimate which portion of IoT producer surplus growth can be attributed to the 6 GHz spectrum. As Table J-38 indicates, we expect the additional IoT surplus generated by 6 GHz to account for $3.8 billion in 2025.

Table J-38. Japan: IoT direct contribution attributed to 6 GHz (2021-2025)

Variable	2021	2022	2023	2024	2025
Producer surplus ($Million)	$14,723.54	$17,957.50	$21,901.80	$26,712.45	$32,579.74
Producer surplus not attributed to 6 GHz ($Million)	$14,298.35	$17,077.18	$20,312.24	$24,160.13	$28,736.96
Additional surplus due to 6 GHz ($Million)	$425.18	$880.32	$1,589.57	$2,552.32	$3,842.78

Sources: Statista, Bain & Co, CSI, Telecom Advisory Services analysis

J.6.4. Firms belonging to the AR/VR ecosystem

Following a similar approach as in the case of IoT, we estimated the direct contribution of this ecosystem to the Japanese economy. Starting with the local spending in AR/VR by category (hardware, software, and contents), and apportioning those figures by the respective shares of local production and margins, we were able to estimate the total producer surplus. By relying on a ratio built from 6 GHz AR/VR related products, we were able to subtract the specific contribution attributed to 6 GHz from the surplus corresponding to current bands. Accordingly, we expect by 2021 a direct contribution from the AR/VR ecosystem of $457 million, increasing to reach $2.1 billion by 2025 (Table J-39).

Table J-39. Japan: AR/VR ecosystem direct contribution (2021-2025)

Variable	2021	2022	2023	2024	2025
Spending in AR/VR - Hardware $Billion	$0.61	$1.09	$1.81	$2.90	$4.63
Spending in AR/VR - Software, Contents, Services ($Billion)	$1.43	$2.45	$3.79	$5.42	$9.26
Total Spending in AV/VR ($Billion)	$2.05	$3.54	$5.60	$8.31	$13.89
Share of local production - Hardware	35.78%	35.78%	35.78%	35.78%	35.78%
Share of local production - Software, Contents, Services	90.00%	90.00%	90.00%	90.00%	90.00%
Local production for local consumption - Hardware ($Billion)	$0.22	$0.39	$0.65	$1.04	$1.66
Local production for local consumption - Software, Contents, Services ($Billion)	$1.29	$2.21	$3.41	$4.87	$8.33
Local Producer Surplus - Hardware ($Billion)	$0.09	$0.15	$0.26	$0.41	$0.65
Local Producer Surplus - Software, Contents, Services ($Billion)	$1.00	$1.71	$2.64	$3.78	$6.45
Total Producer Surplus	$1.09	$1.86	$2.89	$4.18	$7.11
Share attributable to Wi-Fi (excluding 6 GHz)	42.02%	38.80%	32.18%	30.88%	29.32%
Producer Surplus attributed to Wi-Fi (not including 6 GHz) ($Million)	$456.55	$722.37	$931.27	$1,292.03	$2,084.03

Sources: PwC, ABI; Telecom Advisory Services analysis

Wider deployment of AR/VR solutions if 6 GHz allocated

By relying on a ratio built from 6 GHz AR/VR related products, we were able to isolate the specific economic contribution of the new spectrum allocation. Following an approach similar as that one described above, the direct contribution from AR/VR ecosystem in Japan attributed to 6 GHz in 2025 will yield $2.1 billion.

Table J-40. Japan: AR/VR direct contribution attributed to 6 GHz (2021-2025)

Variable	2021	2022	2023	2024	2025
Spending in AR/VR ($Billion)	$2.05	$3.54	$5.60	$8.31	$13.89
Share attributed to 6 GHz	24.58%	25.59%	26.64%	27.73%	28.87%
Spending in AR/VR attributed to 6 GHz ($Billion)	$0.50	$0.90	$1.49	$2.30	$4.01
Local production for local consumption 6 GHz ($Billion)	$0.37	$0.66	$1.08	$1.64	$2.88
Local Producer Surplus ($Billion)	$267.04	$476.36	$770.99	$1,160.32	$2,052.01

Sources: PwC, ABI, Telecom Advisory Services analysis

J.7. Wi-Fi contribution to employment

The estimation of employment generated by Wi-Fi's economic value is calculated by relying on the total GDP contribution resulting from the effects analyzed above and using that as an input to the communications sector of an input-output matrix of the Japanese economy. Table J-41 presents the GDP contribution, as sum of all GDP sources discussed above, enabled by Wi-Fi projected for the period 2021-2025.

Table J-41. Japan: Wi-Fi enabled GDP contribution (2021-2025)

Year	GDP contribution enabled by Wi-Fi ($Million)		
	Attributed to current bands	Attributed to 6 GHz	Total
2021	$58,504	$2,988	$61,492
2022	$44,544	$6,479	$51,023
2023	$33,954	$7,261	$41,215
2024	$37,383	$9,507	$46,890
2025	$41,897	$12,644	$54,541

Sources: Telecom Advisory Services analysis

These inputs generate the following annual employment effects based on the input/output matrix for the Japanese economy (Table J-42).

Table J-42. Japan: Wi-Fi generated Annual Employment

Variable	2021			2025		
	Current bands	6 GHz	Total	Current bands	6 GHz	Total
Direct jobs	182,782	9,334	192,116	130,896	39,504	170,400
Indirect jobs	65,159	3,327	68,486	46,662	14,083	60,745
Induced jobs	23,372	1,194	24,566	16,738	5,051	21,789
Total	271,313	13,855	285,168	194,296	58,639	252,935

Sources: GTAP; Telecom Advisory Services analysis

According to the contribution to GDP, Wi-Fi will generate approximately 285,000 jobs in 2021 and is expected to create almost 253,000 in 2025. The main reason that explains the reduction in jobs is related to the fact that the GDP impact of IoT declines considerably due to a decreasing growth rate of M2M installed base. Job estimates include direct jobs (those jobs created by the specific Wi-Fi contribution), indirect jobs (those jobs created by suppliers to the Wi-Fi sector) and induced jobs (those jobs created by spending of direct and indirect workers).

The sector breakdown of 2021 employment (including the additional jobs created by 6 GHz) is as follows (Table J-43).

Table J-43. Japan: Sector Breakdown of Wi-Fi generated annual employment (2021)

Sector	Direct	Indirect	Induced	Total
Agriculture	0	0	340	340
Extractive industries	0	0	3	3
Manufacturing	0	14,951	168	15,119
Construction	0	4,128	0	4,128
Trade	0	7,474	7,590	15,064
Transportation	0	10,542	0	10,542
Communications	192,116	0	0	192,116
Financial Services	0	8,925	0	8,925
Business services	0	22,466	0	22,466
Other services	0	0	16,464	16,464
Total	192,116	68,486	24,566	285,168

Sources: GTAP; Telecom Advisory Services analysis

K. ECONOMIC VALUE OF WI-FI IN SOUTH KOREA

Wi-Fi has become a pervasive feature in South Korea telecommunications landscape. According to the Cisco Annual Internet Report Highlights Tool 2018-2023, there were 400,000 paid Wi-Fi access points operating in the South Korea territory in 2018, while Wiman estimates that there are currently 1,027,000 open hotspots in the country (598,000 in Seoul, 273,000 in Incheon, and 100,000 in Busan). Given the Wi-Fi access point density, hotspots have become a very important connectivity feature. According to Opensignal[222], South Korea wireless users spend 54.9% of their communications time connected to Wi-Fi networks rather than relying on their cellular data connection.

The increasing importance of Wi-Fi technology in the South Korean digital infrastructure ecosystem results in a significant social and economic contribution. As shown in the following section, South Korea's Ministry of Science and ICT's recent decision to approve the use of 1200 MHz of spectrum in the 6GHz band will provide an additional boost to Wi-Fi's economic value[223]. This section presents the results and calculations of the economic assessment.

K.1. Total Economic Value of Wi-Fi in South Korea (2021-2025)

In the prior study of Wi-Fi's economic contribution[224], its economic value for South Korea in 2021 was estimated at $103.52 billion. Before considering the additional effect of allocating the 6 GHz spectrum band for unlicensed use, the total economic value of Wi-Fi in South Korea in 2021 according to this update will amount to $87.2 billion. The decline in value between the 2018 study and the current update is mainly explained due to the fact that local cellular prices declined at a faster pace than expected. As a result, the economic benefits for consumers due to Wi-Fi use at home for devices that lack a wired port, as well as that of free Wi-Fi, have been reduced considerably with respect to our previous estimates. The decline in cellular prices also reduces the producer surplus derived from business Internet traffic transmitted through Wi-Fi. In addition, in the current study we are not assuming CAPEX and OPEX savings due to cellular off-loading, since by 2021 the country is expected to reach 97% of 5G coverage. Therefore, those savings will materialize before the time frame of the current study.

The total economic value in 2021 is broken down by $31.9 billion in consumer surplus, $31.0 billion in producer surplus, and $24.3 billion in a net contribution to GDP. Even before accounting for the acceleration effect resulting from the allocation of 1200 MHz in the 6 GHz band, the 2025 forecast of economic value will reach $126.1 billion, composed of $57.6 billion in consumer surplus, $43.6 billion in producer surplus, and $24.9 billion in GDP contribution (see Table K-1).

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[222] Khatri, H. and Fenwick, S. (2020). "Analyzing mobile experience during the coronavirus pandemic: Time on Wi-Fi". *Opensignal* (March 30).
[223] Cho Mu-Hyun (2020). "South Korea makes 6 GHz band available for Wi-Fi", *ZDNet* (October 16).
[224] Katz, R. and Callorda, F. (2018). *The Economic value of Wi-Fi: A Global View (2018 and 2023)*. New York: Telecom Advisory Services. October.

Table K-1. South Korea: Economic Value of Wi-Fi (Baseline Scenario)

Agent	Source	Economic Value ($Million)					
		2021	2022	2023	2024	2025	Category
1. Free Wi-Fi	1.1. Savings generated by free Wi-Fi traffic offered in public sites	$616	$572	$524	$469	$405	Consumer Surplus
	1.2. Deployment of free Wi-Fi in public sites	$67	$69	$71	$73	$76	GDP contribution
2. Residential Wi-Fi	2.1. Internet access for home usage of devices that lack a wired port	$19,209	$23,503	$28,727	$35,082	$42,814	Consumer Surplus
	2.2. Avoidance of investment in in-house wiring	$8,736	$9,367	$9,803	$9,872	$9,925	Consumer Surplus
	2.3. Benefit to consumers from speed increases	$995	$1,260	$1,568	$1,831	$2,109	Consumer Surplus
	2.4. Residential Wi-Fi devices and equipment deployed	$2,323	$2,380	$2,447	$2,410	$2,331	Consumer Surplus
	2.5. Bridging digital divide: use of Wi-Fi to increase coverage in rural and isolated areas	$0	$0	$0	$0	$0	GDP contribution
3. Enterprise Wi-Fi	3.1. Business Internet traffic transmitted through Wi-Fi	$8,899	$10,174	$11,632	$13,299	$15,205	Producer surplus
	3.2. Avoidance of enterprise inside wiring costs	$7,462	$7,673	$7,889	$8,112	$8,341	Producer surplus
	3.3. Return to speed: contribution to GDP derived from an increase in average mobile speed	$3,106	$3,906	$4,847	$5,946	$7,216	GDP contribution
	3.4. Wide deployment of IoT	$20,683	$17,640	$16,004	$16,471	$16,951	GDP contribution
	3.5. Deployment of AR/VR solutions	$261	$285	$306	$427	$431	GDP contribution
4. ISPs	4.1. CAPEX and OPEX savings due to cellular off-loading	$0	$0	$0	$0	$0	Producer surplus
	4.2. Revenues of service providers offering paid Wi-Fi access in public places	$214	$222	$228	$230	$227	GDP contribution
	4.3. Aggregated revenues of WISPs	$0	$0	$0	$0	$0	GDP contribution
5. Wi-Fi ecosystem	5.1. Locally manufactured residential Wi-Fi devices and equipment	$11,228	$12,296	$13,729	$13,449	$12,980	Producer surplus
	5.2. Locally manufactured Wi-Fi enterprise equipment	$0	$0	$0	$0	$0	Producer surplus
	5.3. Locally produced IoT products and services	$3,270	$3,906	$4,646	$5,526	$6,573	Producer surplus
	5.4. Locally produced of AR/VR solutions	$110	$175	$226	$316	$508	Producer surplus
Total		$87,179	$93,428	$102,647	$113,513	$126,092	

Source: Telecom Advisory Services analysis

In addition to the value generated from the unlicensed use of the 2.4 GHz and 5 GHz bands (referred to as the baseline scenario), the allocation of the 6 GHz spectrum band for unlicensed use and the deployment of Wi-Fi 6 and Wi-Fi 6E devices will trigger an additional boost in economic value, reaching $13.4 billion in 2025 (see Table K-2).

Table K-2. South Korea: Economic Value of Wi-Fi (only attributed to 6 GHz)

Agent	Source	Economic Value ($Million)					
		2021	2022	2023	2024	2025	Category
1. Free Wi-Fi	1.1. Savings generated by free Wi-Fi traffic offered in public sites	$0	$6	$20	$42	$71	Consumer Surplus
	1.2. Deployment of free Wi-Fi in public sites	$0	$7	$14	$21	$29	GDP contribution
	1.3. Benefit of faster free Wi-Fi with Wi-Fi 6E devices	$0	$1	$1	$2	$3	Consumer Surplus
2. Residential Wi-Fi	2.3. Benefit to consumers from speed increases	$0	$133	$296	$451	$588	Consumer Surplus
	2.4. Residential Wi-Fi devices and equipment deployed	$84	$204	$443	$680	$920	Consumer Surplus
	2.5. Bridging digital divide: use of Wi-Fi to increase coverage in rural and isolated areas	$0	$0	$0	$0	$0	GDP contribution
3. Enterprise Wi-Fi	3.1. Business Internet traffic transmitted through Wi-Fi	$0	$462	$617	$813	$1,058	Producer surplus
	3.3. Return to speed: contribution to GDP derived from an increase in average mobile speed	$0	$363	$798	$1,265	$1,710	GDP contribution
	3.4. Wide deployment of Internet of Things	$1,015	$2,296	$2,552	$2,627	$2,703	GDP contribution
	3.5. Deployment of AR/VR solutions	$153	$188	$254	$383	$425	GDP contribution
4. ISPs	4.1 CAPEX and OPEX savings due to cellular off-loading	$347	$347	$347	$347	$347	Producer surplus
	4.2. Revenues of service providers offering paid Wi-Fi access in public places	$0	$9	$18	$28	$36	GDP contribution
	4.3. Aggregated revenues of WISPs	$0	$0	$0	$0	$0	GDP contribution
5.Wi-Fi ecosystem	5.1. Locally manufactured residential Wi-Fi devices and equipment	$291	$801	$1,993	$3,056	$4,135	Producer surplus
	5.2. Locally manufactured Wi-Fi enterprise equipment	$0	$0	$0	$0	$0	Producer surplus
	5.3. Locally produced IoT products and services	$97	$201	$364	$584	$879	Producer surplus
	5.4. Locally produced of AR/VR solutions	$65	$115	$187	$284	$500	Producer surplus
Total		$2,052	$5,133	$7,904	$10,583	$13,404	

Source: Telecom Advisory Services analysis

Considering that by 2025 only 40% of Wi-Fi traffic will rely on the 6 GHz channels, the accelerated effect derived from the new spectrum allocation and latest Wi-Fi technologies will still be far from reaching its maximum potential at this time. By combining the baseline and the Wi-Fi 6 and 6 GHz scenarios, the overall economic value of Wi-Fi for South Korea will yield $139.5 billion in 2025 (see Table K-3).

Table K-3. South Korea: Total Economic Value of Wi-Fi (including Wi-Fi 6 and 6 GHz)

Agent	Source	Economic Value ($Million)					
		2021	2022	2023	2024	2025	Category
1. Free Wi-Fi	1.1. Savings to consumers of free Wi-Fi traffic offered in public sites	$616	$578	$544	$511	$476	Consumer Surplus
	1.2. Deployment of free Wi-Fi in public sites	$67	$76	$85	$94	$104	GDP contribution
	1.3. Benefit of faster free Wi-Fi with Wi-Fi 6E devices	$0	$1	$1	$2	$3	Consumer Surplus
2. Residential Wi-Fi	2.1. Internet access for home usage of devices that lack a wired port	$19,209	$23,503	$28,727	$35,082	$42,814	Consumer Surplus
	2.2. Avoidance of investment in in-house wiring	$8,736	$9,367	$9,803	$9,872	$9,925	Consumer Surplus
	2.3. Benefit to consumers from speed increases	$995	$1,393	$1,863	$2,282	$2,697	Consumer Surplus
	2.4. Residential Wi-Fi devices and equipment deployed	$2,408	$2,584	$2,890	$3,090	$3,251	Consumer Surplus
	2.5. Bridging digital divide: use of Wi-Fi to increase coverage in rural and isolated areas	$0	$0	$0	$0	$0	GDP contribution
3. Enterprise Wi-Fi	3.1. Business Internet traffic transmitted through Wi-Fi	$8,899	$10,636	$12,250	$14,112	$16,263	Producer surplus
	3.2. Avoidance of enterprise inside wiring costs	$7,462	$7,673	$7,889	$8,112	$8,341	Producer surplus
	3.3. Return to speed: contribution to GDP derived from an increase in average mobile speed	$3,106	$4,269	$5,645	$7,211	$8,926	GDP contribution
	3.4. Wide deployment of IoT	$21,698	$19,936	$18,557	$19,098	$19,655	GDP contribution
	3.5. Deployment of AR/VR solutions	$414	$474	$560	$810	$856	GDP contribution
4. ISPs	4.1 CAPEX and OPEX savings due to cellular off-loading	$347	$347	$347	$347	$347	Producer surplus
	4.2. Revenues of service providers offering paid Wi-Fi access in public places	$214	$231	$246	$257	$264	GDP contribution
	4.3. Aggregated revenues of WISPs	$0	$0	$0	$0	$0	GDP contribution
5. Wi-Fi ecosystem	5.1. Locally manufactured residential Wi-Fi devices and equipment	$11,519	$13,097	$15,721	$16,504	$17,115	Producer surplus
	5.2. Locally manufactured Wi-Fi enterprise equipment	$0	$0	$0	$0	$0	Producer surplus
	5.3. Locally produced IoT products and services	$3,367	$4,107	$5,009	$6,109	$7,451	Producer surplus
	5.4. Locally produced of AR/VR solutions	$175	$290	$414	$599	$1,007	Producer surplus
Total		$89,232	$98,562	$110,551	$124,092	$139,495	

Source: Telecom Advisory Services analysis

The following sections will present in detail the calculation of each source of value, disaggregating the economic contribution between the current spectrum allocation and the enhanced effect due to Wi-Fi 6 availability and the 6 GHz band.

K.2. Value from free Wi-Fi service

The economic value of free Wi-Fi service originates from three sources:

- Savings to consumers by accessing the Internet in free Wi-Fi sites rather than incurring cellular costs
- The use of Wi-Fi to expand broadband coverage to the unserved population
- The return to speed of Wi-Fi compared to the use of cellular service

K.2.1. Savings incurred by accessing free Wi-Fi in public sites

The economic value of free Wi-Fi is measured in terms of consumer surplus, calculated by estimating the benefit that flows to consumers as a result of savings incurred by not relying on cellular service. We begin by forecasting the traffic generated at free Wi-Fi access points. In order to isolate the effect from the increased capacity derived from the 6 GHz allocation, we calculate the portion of free Wi-Fi traffic attributed to current spectrum bands. For this, we relied on the assumption (verified in field studies) that current traffic levels are already producing congestion in most free Wi-Fi hotspots at times of peak demand. Thus, we assume that traffic per hotspot beyond 2021 will remain at 2020 levels (1,396 GB per year), although overall free traffic will continue growing as new hotspots will continue to be deployed: from 1,634.30 million GB in 2021 to 2,831.42 million GB in 2025. (see Table K-4).

Table K-4. South Korea: Total Free Wi-Fi Traffic projection (2021-2025)

Variable	2021	2022	2023	2024	2025
Free Wi-Fi traffic (Million GB Per year) - considering current trends	1,703.86	2,071.47	2,558.20	3,205.73	4,070.57
Free Wi-Fi hotspots (Million)	1.17	1.34	1.54	1.77	2.03
Traffic per hotspot - considering current trends	1,455.96	1,542.85	1,660.78	1,813.99	2,007.69
Traffic per hotspot - capped due to congestion	1,396.52	1,396.52	1,396.52	1,396.52	1,396.52
Total traffic (not attributed to 6 GHz) (Million GB)	1,634.30	1,874.99	2,151.14	2,467.95	2,831.42

Sources: Cisco; Wiman; Telecom Advisory Services analysis

We calculate consumer surplus by multiplying the total free traffic (not attributed to 6 GHz) by the difference between what the consumer would have to pay if she/he were to rely on a wireless carrier and the cost of offering free Wi-Fi (incurred by the retailer or public site). To do so, we estimate the average price per GB of wireless data transmitted by wideband networks, calculated by averaging the most economic "dollar per GB" plan of four major wireless carriers in South Korea[225] (see Table K-5).

[225] The average is calculated by prorating every price per GB by the carrier's market share.

Table K-5. South Korea: Average Price Per Gigabyte (2020)

Carrier	Plan	Price per GB ($)
KT	Super Plan	$1.43
SK Telecom	Special	$0.47
LG Uplus	Data Special D	$2.45

Note: The average price per GB is converted to U.S. dollars in order to calculate total economic value.
Sources: Operator websites; Telecom Advisory Services analysis

Historical data allowed for a projection of future prices per gigabyte. Based on these estimates, we expect the average price per GB in South Korea will reach an estimated $0.67 in 2025 from $1.02 in 2021. By relying on the total free Wi-Fi traffic not attributed to 6 GHz allocation shown in Table K-4 and the average price per cellular gigabyte minus the cost of provisioning Wi-Fi service, we calculated the consumer surplus of free Wi-Fi traffic (see Table K-6).

Table K-6. South Korea: Consumer Surplus of Free Wi-Fi Traffic (2021-2025)

Variable	2021	2022	2023	2024	2025
Total Free Traffic (not attributed to 6 GHz) (Million GB)	1,634.30	1,874.99	2,151.14	2,467.95	2,831.42
Price per cellular gigabyte ($)	$1.02	$0.92	$0.83	$0.75	$0.67
Cost per Wi-Fi provisioning ($)	$0.64	$0.61	$0.58	$0.56	$0.53
Consumer surplus per gigabyte ($)	$0.38	$0.31	$0.24	$0.19	$0.14
Total Consumer surplus ($Million)	$615.79	$572.05	$523.89	$468.68	$405.09

Sources: Websites of cellular operators; Telecom Advisory Services analysis

As indicated in Table K-6, consumer surplus of free Wi-Fi traffic would reach an estimated $616 million in 2021, decreasing to $405 million in 2025 due to lower prices and the congestion created if the 6 GHz spectrum had not been allocated.

Enhanced free Wi-Fi traffic due to 6 GHz allocation

The allocation of the 6 GHz spectrum band, coupled with the technological advances provided by the Wi-Fi 6 standard, will remove the above-mentioned bottlenecks causing congestion. As a result, the traffic per hotspot will be able to continue growing at its natural rate as determined by the extrapolation of recent past trends. That being said, we must take into account that not all Wi-Fi traffic will benefit immediately from opening the 6 GHz band, as most current devices are not prepared to support the new standards. Thus, we expect the traffic through the 6 GHz channel to gradually increase until reaching a 40% of total free traffic by 2025.

Once computed the additional traffic "above and beyond" the future previsions under current spectrum bands, we follow a similar approach to calculate the consumer surplus under this scenario by multiplying it by the difference between what the consumer would have to pay if he were to utilize a wireless carrier and the cost of offering free Wi-Fi (Table K-7). As a result, we project an additional consumer surplus of $71 million from free Wi-Fi traffic attributed to 6 GHz.

Table K-7. South Korea: Additional Consumer Surplus of Free Wi-Fi Traffic generated due to 6 GHz (2021-2025)

Variable	2021	2022	2023	2024	2025
Demand not satisfied due to congestion (Million GB)	69.56	196.48	407.06	737.78	1,239.15
Traffic through the 6 GHz Channel (%)	0%	10%	20%	30%	40%
Total traffic (attributed to 6 GHz) (Million GB)	0.00	19.65	81.41	221.33	495.66
Consumer Surplus (attributed to 6 GHz) ($Million)	$0.00	$5.99	$19.83	$42.03	$70.91

Source: Telecom Advisory Services analysis

The additional surplus generated by the allocation of the 6 GHz spectrum band will mitigate the declining trend of consumer surplus derived from free Wi-Fi under the current spectrum allocation.

K.2.2. Free Wi-Fi to provide broadband to the unserved population

As explained in sections A and B, free Wi-Fi in public sites can provide Internet access to the unserved population. Consumers that do not have broadband at home because they lack the economic means to acquire services can rely on free Wi-Fi to gain Internet access. The net result is that more people can be connected, which in turn enhances the economic contribution of broadband.

The estimation of this particular economic impact starts by calculating which portion of households that lack broadband service are already accessing Internet through free hotspots. Total households' evolution was estimated from data reported by the statistics office of South Korea, while Forbes reported in 2017 that 99.2% of those had some sort of connectivity. We capped the extrapolated trend of connected households, by assuming that 0.5% will remain unconnected until 2025. We follow a conservative approach and assume that only 5% of unconnected households rely on free hotspots for accessing Internet. After calculating the increase in broadband penetration due to households relying on free Wi-Fi, we rely on the broadband economic impact coefficient calculated by Katz and Callorda (2018b) in their econometric models developed for Asia-Pacific. As a result, the GDP contribution of this particular effect is expected to amount to $67.4 million in 2021, reaching $75.5 million in 2025 (see Table K-8).

Table K-8. South Korea: GDP contribution due to households relying on Free Wi-Fi (2021-2025)

Variable	2021	2022	2023	2024	2025
Households without Internet	100,369	101,009	101,653	102,301	102,953
Households that don't buy because access Internet free hotspots (%)	5%	5%	5%	5%	5%
Households served by Free Wi-Fi hot spots	5,018	5,050	5,083	5,115	5,148
Increase in national broadband penetration	0.03%	0.03%	0.03%	0.03%	0.03%
Impact of fixed broadband adoption in GDP	16.32%	16.32%	16.32%	16.32%	16.32%
Increase in the GDP due to the new broadband adoption (% GDP)	0.004%	0.004%	0.004%	0.004%	0.004%
GDP ($Billion)	$1,643.17	$1,690.72	$1,739.32	$1,790.03	$1,842.23
Total impact in GDP ($Million)	$67.38	$69.33	$71.32	$73.40	$75.54

Sources: Statistics office of Korea; Forbes; Telecom Advisory Services analysis

The contribution to GDP of additional broadband service to the unconnected materializes through multiple effects: creation of new businesses, increasing productivity of existing enterprises (especially small), and the growth of average income per household.

Enhanced GDP contribution due to 6 GHz allocation

As stated above, Wi-Fi 6 technology operating in the 6 GHz band supports a higher number of devices per access point than Wi-Fi sites relying on the 2.4 GHz and 5 GHz bands. Accordingly, the improved throughput of free Wi-Fi hotspots under the 6 GHz allocation will allow the possibility of serving additional unconnected households under similar quality performance. The potential universe of additional users that could be served under this effect is significant, as most unconnected households usually identify that costs are their main barrier for accessing to connectivity and thus, may potentially be served by free hotspots as long as they are in proximity to the access point. However, evidence suggests that not many people undergoing the affordability barrier rely exclusively on free Wi-Fi as their main source of Internet access[226], so we will follow again a conservative approach and assume that a further 5% of unconnected households will be served through free hotspots under the allocation of the 6 GHz band. On the other hand, we have also considered that the expansion of traffic through the new band will take place gradually, reaching 40% in 2025. All in all, we estimate that additional 1,956 households in South Korea will be served by free hotspots operating under 6 GHz spectrum in 2025, yielding an additional GDP contribution of approximately $28.7 million (Table K-9).

Table K-9. South Korea: GDP contribution due to households relying on Free Wi-Fi due to 6 GHz (2021-2025)

Variable	2021	2022	2023	2024	2025
Households without Internet (not served by free Wi-Fi and not new adopters of WISP)	95,351	95,958	96,570	97,185	97,805
Potential households that could be served through free Wi-Fi hotspots under increased capacity (% of those not connected)	5%	5%	5%	5%	5%
Traffic through the 6 GHz Channel (%)	0%	10%	20%	30%	40%
Additional households served by Free Wi-Fi hot spots with 6 GHz	0	480	966	1,458	1,956
Increase in national broadband penetration	0.000%	0.002%	0.005%	0.007%	0.010%
Increase in the GDP due to the new broadband adoption (% GDP)	0.000%	0.000%	0.001%	0.001%	0.002%
Total impact in GDP ($Million)	$0.00	$6.59	$13.55	$20.92	$28.71

Source: Telecom Advisory Services analysis

K.2.3. Benefit to consumers for enjoying higher speed from free Wi-Fi if 6 GHz band is allocated

When the 6 GHz band is adopted by free Wi-Fi access points it will deliver service at faster broadband speeds. Current speeds from free hotspots are quite modest[227].

[226] They tend to also use broadband service provided at work or at an educational institution.
[227] Given the lack of reliable data on free Wi-Fi speed in South Korea, we made an estimation based on U.S. data, and applying the percentual differential between both countries in terms of fixed broadband speed. Accordingly, we estimate free Wi-Fi speed in South Korea to reach 18.2 Mbps in 2020.

Thus, the expanded capabilities due to the allocation of 6 GHz spectrum band will enhance free Wi-Fi speed, and as a result, will increase consumer surplus. We assume that under the 6 GHz allocation, speed from free hotspots will be similar to the Wi-Fi speeds from mobile devices reported by Cisco. After calculating the average speed by considering the expected share of traffic through 6 GHz, we follow Nevo et al. (2016) estimates of willingness-to-pay for speed increase and calculate the additional consumer surplus per household relying on free Wi-Fi. We expect the consumer surplus resulting from faster speed in free Wi-Fi sites to reach $3 million in 2025 (Table K-10).

Table K-10. South Korea: Consumer surplus for enjoying higher speed from free Wi-Fi if 6 GHz band allocated (2021-2025)

Variable	2021	2022	2023	2024	2025
Free Wi-Fi mean speed with no 6 GHz (Mbps)	19.00	19.85	20.73	20.09	19.48
Wi-Fi Speeds from Mobile Device (Mbps)	101.75	127.59	160.00	200.64	251.60
Traffic through the 6 GHz Channel (%)	0.00%	10.00%	20.00%	30.00%	40.00%
Free Wi-Fi mean speed with 6 GHz (Mbps)	19.00	30.62	48.58	74.26	112.33
Demand for average download speed	78.07	78.87	79.66	78.97	78.27
New Demand for average download speed	78.07	87.55	96.70	105.09	113.26
Additional Monthly Consumer surplus	$0.00	$8.68	$17.04	$26.13	$34.99
Additional Yearly Consumer Surplus	$0.00	$104.22	$204.49	$313.51	$419.85
Households that rely on Free Wi-Fi	5,018	5,530	6,048	6,573	7,104
Consumer surplus ($Million)	$0	$1	$1	$2	$3

Sources: Rotten Wi-Fi; Nevo et al. (2016); Telecom Advisory Services analysis

K.3. Residential Wi-Fi

The economic value of Wi-Fi in South Korean consumer residences is the result of five factors:

- Provision of connectivity to the home network for devices that lack an Ethernet port;
- Cost avoidance of ethernet inside wiring;
- Consumer surplus resulting from faster broadband speeds relative to cellular networks;
- Consumer surplus derived from usage of home devices connected to the home network; and
- Provision of Internet access to consumers located in rural and isolated areas.

K.3.1. Home Internet access for devices that lack an Ethernet port

The underlying premise of this analysis is that in the absence of Wi-Fi, users of devices lacking an Ethernet port would have to depend on the cellular network to gain Internet access. For this reason, estimating value measures the traffic generated by these devices at home and then multiplies it by the average price charged by cellular carriers.

To estimate the traffic of smartphones and tablets, we relied on 2018 Cisco estimates for the period 2016-21 and extrapolated those growth rates to 2025. It must be said, however, that in 2019 Cisco adjusted its predictions upwards. However, we preferred to rely on the original estimates to avoid incurring in the risk of overestimation. Thus, it may be possible that the projections reported here are slightly downward biased. In addition, we considered that, according to Cisco IBSG (2012), 43.12% of use time of devices that lack an Ethernet port occurs at home. Therefore, the portion of said traffic generated at home in South Korea will reach 18,802 million gigabytes in 2021 (see Table K-11).

Table K-11. South Korea: Total Mobile Internet Traffic (2021-2025) (Million gigabytes)

Variable	2021	2022	2023	2024	2025
Total Annual traffic - Smartphones	38,310.1	52,524.7	71,883.9	98,228.7	134,060.1
Total Annual traffic - Tablets	5,294.3	6,734.3	8,565.8	10,895.4	13,858.7
Share of traffic at Home	43.12%	43.12%	43.12%	43.12%	43.12%
Total Traffic at Home - Smartphones	16,518.8	22,647.5	30,994.7	42,354.0	57,803.7
Total Traffic at Home - Tablets	2,282.8	2,903.7	3,693.4	4,697.9	5,975.6
Total Traffic at Home	18,801.6	25,551.1	34,688.1	47,051.9	63,779.2
Average Price per GB ($)	$1.02	$0.92	$0.83	$0.75	$0.67
Price per home traffic ($Million)	$19,209.12	$23,502.97	$28,727.14	$35,082.27	$42,814.35

Sources: Cisco; GSMA Intelligence; Websites of cellular operators; Telecom Advisory Services analysis

If this traffic had to be transported by cellular networks, at the average price per GB estimated above (Table K-5), it would result in costs of $19.2 billion in 2021 reaching $42.8 billion in 2025.

K.3.2. Avoidance of inside wiring investment

Residential Wi-Fi allows consumers to avoid paying for wiring to connect all home devices (printers, laptops, storage units, etc.). Considering that 90% of connected households will have Wi-Fi in 2021[228], and the wiring cost estimated for households[229], the avoidance costs of inside wiring for approximately 18 million households yields a total of $8.7 billion. By 2025, all connected households are expected to have adopted Wi-Fi. Therefore, the savings from inside wiring avoidance would have reached $9.9 billion (Table K-12).

Table K-12. South Korea: Consumer surplus from avoidance of investment in in-house wiring (2021-2025)

Variable	2021	2022	2023	2024	2025
Total Wiring Cost	$486.27	$485.81	$485.36	$484.90	$484.45
Households with Internet	19,973,467	20,100,800	20,228,945	20,357,906	20,487,690
Households with Wi-Fi (%)	90%	96%	100%	100%	100%
Households with Internet and Wi-Fi	17,965,984	19,280,000	20,198,147	20,357,906	20,487,690
Inside Wiring Costs ($Million)	$8,736	$9,367	$9,803	$9,872	$9,925

Sources: Statistics office of Korea; Watkins (2012); Telecom Advisory Services analysis

[228] Extrapolation based on data from Watkins (2012).
[229] We estimate for South Korea a similar value as in the U.S., adjusted by PPP differences.

K.3.3. Benefits derived from speed increase

As described in Chapter B, consumer surplus increases if users enjoy faster Internet speeds. Thus, the welfare of residential Wi-Fi customers is expected to benefit from faster services than those provided by cellular networks. After prorating broadband speeds with the percentage of traffic carried out through Wi-Fi at home, we calculated the average speed advantage of using Wi-Fi versus cellular networks. By applying the willingness-to-pay parameters calculated in Nevo et al. (2016), the expected consumer surplus derived from Wi-Fi speed in South Korea will amount to $995 million in 2021, reaching $2.1 billion in 2025 (see Table K-13).

Table K-13. South Korea: Consumer surplus from faster speed in households (2021-2025)

Variable	2021	2022	2023	2024	2025
Average Speed in households if Wi-Fi traffic were carried through mobile networks (Mbps)	97.75	112.04	128.70	148.18	171.03
Average Speed in household with Wi-Fi (Mbps)	123.06	147.50	177.83	215.60	262.80
Demand for average download speed	110.90	113.53	116.19	118.90	121.66
New Demand for average download speed	115.52	119.03	122.66	126.40	130.23
Additional Monthly Consumer surplus	$4.62	$5.51	$6.47	$7.50	$8.58
Additional Yearly Consumer Surplus	$55.39	$66.08	$77.63	$89.95	$102.94
Households with Internet and Wi-Fi	17,965,984	19,075,358	20,198,147	20,357,906	20,487,690
Impact ($Million)	$995	$1,260	$1,568	$1,831	$2,109

Sources: Telecom Advisory Services analysis based on data from Cisco and Nevo et al. (2016).

Additional benefit to consumers from speed increase due to 6 GHz

The well-being of residential Wi-Fi customers resulting from Wi-Fi speed is expected to receive further benefit from the 6 GHz allocation in South Korea due to faster Internet service under Wi-Fi 6E. In October 2020, South Korea's Ministry of Science and ICT announced that it had approved the use of 1200 MHz of spectrum in the 6GHz band for unlicensed use. In the ministry's own testing, it demonstrated that 6GHz Wi-Fi could reach speeds of 2.1 Gbps, which is five times faster than the currently available Wi-Fi speed of around 400 to 600 Mbps[230].

As described in Chapter B, households acquiring a 150 Mbps (or faster) fixed broadband line will receive the benefit of the recent spectrum allocation since they are already undergoing current router bottlenecks. To assess the percentage of households with connections above 150 Mbps, we interpolated from OECD data estimates for South Korea by speed tiers and assumed it will evolve until 2025 following a similar growth rate as Cisco projects growth in the 100 Mbps spied tier

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[230] Cho Mu-Hyun (2020). "South Korea makes 6 GHz band available for Wi-Fi", *ZDNet* (October 16).

for South Korea. After calculating the difference in average speed attributed to 6 GHz, the additional consumer surplus will yield $588 million in 2025 (see Table K-14).

Table K-14. South Korea: Consumer surplus from faster speed in households if 6 GHz allocated (2021-2025)

Variable	2021	2022	2023	2024	2025
Households that have connections over 150 Mbps (%)	21.76%	25.16%	29.08%	33.62%	38.87%
Percentage of household traffic that goes through Wi-Fi	65.96%	68.32%	70.59%	72.76%	74.82%
Traffic through the 6 GHz Channel (%)	0.00%	10.00%	20.00%	30.00%	40.00%
Share of traffic affected due to 6 GHz (%)	0.00%	1.72%	4.11%	7.34%	11.63%
Average speed with no 6 GHz (Mbps)	123.06	147.50	177.83	215.60	262.80
Average speed with 6 GHz (Mbps)	123.06	151.84	189.00	236.47	296.21
Demand for average download speed	115.52	119.03	122.66	126.40	130.23
New Demand for average download speed	115.52	119.61	123.88	128.25	132.62
Additional Yearly Consumer Surplus	$0.00	$6.97	$14.63	$22.16	$28.68
Households with Wi-Fi	17,965,984	19,075,358	20,198,147	20,357,906	20,487,690
Impact ($Million)	$0	$133	$296	$451	$588

Sources: OECD, Cisco; Nevo et al. (2016); Telecom Advisory Services analysis

K.3.4. Residential Wi-Fi devices and equipment

The consumer surplus derived from the adoption of residential Wi-Fi devices and equipment focuses on seven consumers products which are intrinsically linked to Wi-Fi: smart home devices and systems such as Wi-Fi speakers and home security systems, home networking systems, Wi-Fi tablets, access points, external adapters, routers, and gateways. Two different approaches are used in these cases: one assuming that consumer surplus is roughly equal to producer surplus in six of the seven products (excluding tablets), and an assessment of tablets' willingness-to-pay.

The estimation of economic value in the first approach begins by compiling local sales in the six product categories in South Korea[231]. After computing the sales in South Korea, we applied the prorated margin estimated by CSI markets (39.44%) which yields an estimated producer surplus for these particular products of $2.2 billion in 2021. As mentioned above, it is assumed that the consumer surplus is of the same magnitude. This methodology was also used to calculate the consumer surplus up to 2023. However, the gradual adoption of Wi-Fi 6 devices is forecast to reduce the sales and economic value from the devices relying on the 2.4 GHz and 5 GHz spectrum bands. Non 6 GHz consumer devices shipments are expected by IDC to decrease by 1.2% in 2024 and 3.1% in 2025. Based on this estimate, we extrapolated the consumer surplus from non 6 GHz reliant residential Wi-Fi devices and equipment between 2021 and 2025.

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[231] Calculated by prorating data for the United States based on GDP.

In addition, we calculated the consumer surplus attributed to tablets bought by local consumers. Starting with CTA/Statista worldwide tablet revenue estimates, we interpolated the revenue figures for South Korea (by prorating the country's share on global GDP), and extrapolated the evolution of local revenue up to 2025 by considering Cisco estimates of tablet evolution for the period. We reviewed the data on tablet prices for the market leader (taking as a reference the Apple iPad 10.2 Inch 128 GB, as Apple has 59% of the local market share in tablets[232]) and for the rest of the market (taking as a reference a Samsung Wi-Fi tablet 128 GB), and assumed consumer willingness-to-pay levels in a similar percentage above prices as in the U.S. average. Based on that information, we were able to estimate a consumer surplus attributed to tablets of $81 million in 2021, expected to decline $49 million in 2025.

To sum up, overall consumer surplus for Wi-Fi enabled residential products is expected to yield $2.3 billion in 2021, remaining stable till 2025 (Table K-15).

Table K-15. South Korea: Economic Value of Wi-Fi enabled consumer products (2021-2025)

Variable	2021	2022	2023	2024	2025
Consumer surplus (ex. Tablets) ($Million)	$2,243	$2,310	$2,385	$2,355	$2,282
Consumer surplus (Tablets) ($Million)	$81	$70	$62	$55	$49
Total consumer surplus ($Million)	$2,323	$2,380	$2,447	$2,410	$2,331

Sources: Consumer Technology Association; ABI Research; CS Markets; IDC; Telecom Advisory Services analysis

Consumer surplus derived from Wi-Fi enabled residential equipment for 6 GHz

As discussed above, sales of residential Wi-Fi devices and equipment operating in the 6 GHz band are expected to gradually replace those of former generations. According to IDC, global shipments of consumer devices operating in the 6 GHz (802.11ax standard) will represent 40% of sales from prior generations. As a result, we can expect that, at least, the consumer surplus derived from 6 GHz devices will represent 40% of that of former technology residential devices. Our estimates for consumer surplus attributed to 6 GHz residential devices in South Korea amount to $920 million in 2025 (see Table K-16).

Table K-16. South Korea: Economic Value of Wi-Fi enabled consumer products for 6 GHz (2021-2025)

Variable	2021	2022	2023	2024	2025
Consumer surplus (ex. Tablets) ($Million)	$2,243	$2,310	$2,385	$2,355	$2,282
Consumer 6 GHz / no 6 GHz device ratio	3.76%	8.83%	18.59%	28.86%	40.30%
Consumer surplus 6 GHz devices ($Million)	$84	$204	$443	$680	$920

Sources: IDC; Telecom Advisory Services analysis

[232] Source: Gs StatCounter

K.3.5. Bridging the digital divide: use of Wi-Fi to increase coverage in rural and isolated areas

Wi-Fi is an appropriate technology to offer Internet access in rural and isolated areas. However, since we were unable to find evidence of WISPs operating in South Korea, we will not quantify an economic effect attributable to the role of Wi-Fi to increase coverage in rural areas.

K.4. Enterprise Wi-Fi

Beyond the impact on consumers, Wi-Fi also contributes significant economic value to South Korean enterprises. This section provides estimates in five areas:

- Support of business Internet traffic;
- Avoidance of campus and enterprise facilities inside wiring;
- Contribution to GDP resulting from Wi-Fi speed faster than cellular connections;
- Deployment of IoT solutions; and
- Implementation of business focused AR/VR use cases.

K.4.1. Business Internet traffic transmitted through Wi-Fi

Wi-Fi enterprise telecommunications savings result from wireless traffic that is routed through Wi-Fi access points rather than cellular networks. Based on Cisco 2016-21 projections for South Korea, we estimate that total business Internet traffic will reach 16.8 billion GB in 2021, of which 8.7 billion GB will be transported through Wi-Fi access points. Considering the average price per GB transported by cellular (from Table K-5), savings from Wi-Fi will reach $8.9 billion, an addition to the producer surplus[233]. By 2025, this benefit will reach $15.2 billion (see Table K-17).

Table K-17. South Korea: Savings in business wireless traffic (2021-2025)

Variable	2021	2022	2023	2024	2025
Share of Business Internet Traffic by Wi Fi	52.00%	53.06%	54.15%	55.25%	56.38%
Total Business Internet Traffic (Million GB)	16,750.4	20,845.2	25,941.1	32,282.7	40,174.6
Total Wi-Fi enterprise traffic (Million GB)	8,710.2	11,060.9	14,046.0	17,836.8	22,650.6
Average Price per GB	$1.02	$0.92	$0.83	$0.75	$0.67
Economic Impact ($Million)	$8,899.01	$10,174.27	$11,632.29	$13,299.25	$15,205.09

Sources: Cisco; Telecom Advisory Services analysis

Enhanced business Internet traffic transmitted through Wi-Fi due to 6 GHz

The deployment of the latest enterprise applications will generate an exponential growth in data traffic that will be handled by devices operating in unlicensed spectrum, through the combination of the existing spectrum and the 6 GHz band. In

[233] We acknowledge that enterprises are likely to negotiate wireless rates lower than those offered in the consumer market; however, data in this area is not available.

2019, an updated Cisco traffic forecast that accounted for the explosive growth of IoT and AR/VR applications among other factors, increased total business Internet traffic projections from the prior 2016-21 estimates. We assume that part of the growth accounted in the new forecast was driven by "natural" growth, while the remainder was triggered by Wi-Fi traffic stimulated by shifting traffic to the 6 GHz band. The sum of the difference due to broader Wi-Fi traffic will reach $1.1 billion in 2025 (see Table K-18).

Table K-18. South Korea: Savings in business wireless traffic due to 6 GHz (2021-2025) ($Million)

Variable	2021	2022	2023	2024	2025
Total value of business Wi-Fi traffic 2016-21	$8,899.01	$10,174.27	$11,632.29	$13,299.25	$15,205.09
Total value of business Wi-Fi traffic 2017/22	$12,044.0	$14,459.5	$17,359.4	$20,840.9	$25,020.7
Difference between the 2 estimations	$3,145.0	$4,285.2	$5,727.1	$7,541.7	$9,815.6
Difference because natural growth	$2,946.4	$3,823.3	$5,109.7	$6,728.7	$8,757.4
Difference due to 6 GHz	$0.00	$461.96	$617.39	$813.01	$1,058.13

Sources: Cisco; analysis Telecom Advisory Services

K.4.2. Avoidance in enterprise building inside wiring

Similar to residential Wi-Fi savings due to capital investment avoidance in inside wiring, we assume that the total number of business establishments are equipped with Wi-Fi access points and multiply this value by a standard cost of deploying a CAT 6 network (although in this case, the cost is higher than for households) (see Table K-19).

Table K-19. South Korea: Savings in business wiring CAPEX (2021-2025)

Variable	2021	2022	2023	2024	2025
Total Wiring Cost	$1,620.90	$1,619.38	$1,617.86	$1,616.34	$1,614.83
Number of Establishments	4,603,839	4,738,202	4,876,486	5,018,806	5,165,279
Establishments with Wi-Fi (%)	100%	100%	100%	100%	100%
Establishments with Wi-Fi	4,603,839	4,738,202	4,876,486	5,018,806	5,165,279
Inside Wiring Costs ($Million)	$7,462	$7,673	$7,889	$8,112	$8,341

Sources: Korean Economic Census; Telecom Advisory Services analysis

K.4.3. Return to speed: contribution to GDP derived from an increase in average mobile speed

Since Wi-Fi accessibility allows, in general, faster access to the Internet than cellular networks do, higher speeds generate a positive contribution to the economy in terms of increased overall efficiency and innovation. This contribution is measured in terms of GDP growth. As described in section K.2.3 for the case of consumer surplus, we start with the quantification of the average broadband speed if cellular networks transported all Wi-Fi traffic, and compare it with the presence of Wi-Fi technology.

Having calculated the percentage of speed increase, we then apply this value to the coefficient derived from the model developed by Katz and Callorda (2019) to gauge the potential impact on GDP from Wi-Fi enhanced speed. Table K-20 indicates that the economic value of Wi-Fi in terms of increasing the speed of transporting wireless will account to $3.1 billion in 2021, before attaining $7.2 billion in 2025.

Table K-20. South Korea: Estimation of speed differential for total traffic (2021-2025)

Variable	2021	2022	2023	2024	2025
Average Download Speed if Wi-Fi traffic were carried through mobile networks (Mbps)	97.75	112.04	128.70	148.18	171.03
Average Speed with Wi-Fi (Mbps)	123.06	147.50	177.83	215.60	262.80
Speed increase (%)	26%	32%	38%	46%	54%
Impact of speed in GDP	0.73%	0.73%	0.73%	0.73%	0.73%
Increase in GDP	0.19%	0.23%	0.28%	0.33%	0.39%
GDP ($Billion)	$1,643.17	$1,690.72	$1,739.32	$1,790.03	$1,842.23
GDP increase ($Million)	$3,106	$3,906	$4,847	$5,946	$7,216

Sources: Cisco; Telecom Advisory Services analysis

Additional return to speed effect due to 6 GHz

As previously described, only those broadband connections above 150 Mbps will be affected due to current router bottlenecks, and hence, the speed experienced will not be equivalent to that delivered by the fixed network. Thus, the allocation of spectrum in the 6 GHz band will remove those barriers, increasing broadband speed. After calculating the difference in average speed attributed to 6 GHz in the enterprise market, the additional GDP contribution will yield $1.7 billion in 2025 (Table K-21).

Table K-21. South Korea: Estimation of speed differential due to 6 GHz (2021-2025)

Variable	2021	2022	2023	2024	2025
Mean speed with no 6 GHz (Mbps)	123.06	147.50	177.83	215.60	262.80
Mean speed with 6 GHz (Mbps)	123.06	151.84	189.00	236.47	296.21
Speed increase due to 6Ghz (%)	0%	3%	6%	10%	13%
Impact speed on GDP	0.73%	0.73%	0.73%	0.73%	0.73%
Increase in GDP (%)	0.00%	0.02%	0.05%	0.07%	0.09%
GDP increase ($Million)	$0	$363	$798	$1,265	$1,710

Sources: Cisco; Telecom Advisory Services analysis

K.4.4. IoT deployment

IoT adoption contributes to GDP growth through the multiplicity of use cases that improve efficiency in processes such as preventive maintenance, production monitoring and the like. To estimate this, we rely on a coefficient of GDP impact calculated through an aggregate simple production function which estimates that a 10% rise in M2M connections results in annual increases in GDP of between 0.3% and 0.9%[234]. Given the strength of the industrial and technological sector in South

[234] See Frontier Economics (2018).

Korea, we assume a 0.9% GDP increase after a 10% increase in the M2M installed base.

Starting with a 2021 installed base of 9.7 million M2M devices in the country, we estimate the growth that can be exclusively attributed to the allocation of additional spectrum to indoor Wi-Fi devices. By subtracting the growth in M2M attributed to 6 GHz, the IoT impact for 2021 according to the natural growth is forecast to reach $20.7 billion (see Table K-22).

Table K-22. South Korea: GDP Contribution of IoT Deployment Boost (2021-2025)

Variable	2021	2022	2023	2024	2025
Connections, Cellular M2M	9,654,842	10,919,767	12,214,236	13,662,156	15,281,718
Growth Rate (%)	15.36%	13.10%	11.85%	11.85%	11.85%
Natural Growth Rate (%)	13.99%	11.59%	10.22%	10.22%	10.22%
Impact of 1% M2M Growth on GDP	9.00%	9.00%	9.00%	9.00%	9.00%
Impact on GDP (%)	1.26%	1.04%	0.92%	0.92%	0.92%
GDP ($Billion)	$1,643	$1,691	$1,739	$1,790	$1,842
Impact ($Million)	$20,682.67	$17,639.54	$16,004.46	$16,471.15	$16,951.45

Sources: GSMA Intelligence; Frontier Economics; Telecom Advisory Services analysis

It should be noted that the GDP impact of IoT declines due to a decreasing growth rate of M2M installed base.

Accelerated effect of IoT due to 6 GHz

As described above, a share of the M2M growth can be attributed to IoT traffic shifting to the 6 GHz spectrum. According to the data in Table K-23, cumulative impact of enhanced IoT deployment driven by 6 GHz spectrum proposals will reach $2.7 billion by 2025.

Table K-23. South Korea: GDP Contribution of IoT Deployment Boost caused by 6 GHz (2021-2025)

Variable	2021	2022	2023	2024	2025
Growth due to 6 GHz (%)	1.37%	1.51%	1.63%	1.63%	1.63%
Level of development of new bands (%)	50%	100%	100%	100%	100%
Impact on GDP (%)	0.06%	0.14%	0.15%	0.15%	0.15%
Impact ($Million)	$1,015.00	$2,296.32	$2,552.18	$2,626.60	$2,703.19

Sources: GSMA Intelligence; Frontier Economics; Telecom Advisory Services analysis

K.4.5. Deployment of AR/VR solutions

The adoption of AR/VR solutions among South Korean businesses will have a spillover effect on productivity, thereby contributing to the growth of GDP. Estimating spillover effects of AR/VR is a not a trivial exercise considering the embryonic adoption of some of the use cases based on this technology. Since the objective is to estimate the spillover effect of AR/VR sales in the South Korean enterprise market, we consider the estimate by PwC of the total GDP contribution of

AR/VR for 2021 and 2022[235], and the sales of AR/VR components as estimated by ABI Research[236]. The extrapolation of these two parameters allows estimating the indirect (spillover) contribution of AR/VR to South Korea economy for the period under analysis.

Starting values are reduced by the proportion that can be attributed to other networking (i.e. Bluetooth) rather than Wi-Fi. After computing the resulting value, we subtracted the impact of the 6 GHz spectrum bands. To do so, we took as a reference a ratio of AR/VR product developments for each technology (built with data from ABI Research). Once the amounts to be attributed to GDP contribution and direct sales were estimated, the annual indirect to direct multiplier can be calculated. The lowest multiplier value is applied to sales of AR/VR in the South Korea market to calculate the total spillovers (see Table K-24). Accordingly, total spillover value of AR/VR in South Korea in 2021 will account for $261 million and is expected to increase to $431 million by 2025.

Table K-24. South Korea: GDP contribution resulting from AR/VR spillovers (2021-2025)

Variable	2021	2022	2023	2024	2025
AR/VR total contribution to GDP ($Billion)	$1.33	$1.96	$2.90	$4.27	$6.29
Share attributed to Wi-Fi (excluding 6 GHz)	42.02%	38.80%	32.18%	30.88%	29.32%
Portion of GDP contribution attributed to Wi-Fi (excluding 6 GHz) ($Billion)	$0.56	$0.76	$0.93	$1.32	$1.85
Direct impact (sales) attributed to Wi-Fi (excluding 6 GHz) ($Billion)	$0.30	$0.48	$0.63	$0.89	$1.41
Indirect impact ($Billion)	$0.26	$0.29	$0.31	$0.43	0.43
Indirect/Direct multiplier	0.87	0.60	0.49	0.48	0.31
Indirect impact ($Million)	$261.02	$285.46	$306.44	$426.89	$431.33

Sources: PwC, ABI; Telecom Advisory Services analysis

Wider deployment of AR/VR solutions (accelerated effect due to 6 GHz)

Higher throughput enabled by the allocation of 6 GHz spectrum is expected to spur the adoption and use of AR/VR among enterprises, hence increasing the associated spillover effects. By relying on the ratio built from 5 GHz and 6 GHz AR/VR related products from above, we were able to isolate the specific economic contribution of the new spectrum allocation. Following a similar procedure as the one described above, spillovers from AR/VR in the South Korea attributed to 6 GHz were calculated. They will account for $153 million in 2021 and are expected to reach $424 million by 2025 (Table K-25).

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[235] See PWC (2019). *Seeing is believing how virtual reality and augmented reality are transforming business and the economy.*

[236] See ABI Research, *Augmented and Mixed Reality Market Data: devices, use cases, verticals and value chain*. MD-ARMR-103, QTR 4 2019, and ABI Research, *Virtual Reality Market Data: devices, verticals, and value chain*. MD-VR-108, QTR 1 2020.

Table K-25. South Korea: GDP contribution resulting from AR/VR spillovers due to 6 GHz (2021-2025)

Variable	2021	2022	2023	2024	2025
AR/VR total contribution to GDP ($Billion)	$1.33	$1.96	$2.90	$4.27	$6.29
Share attributed to 6 GHz (%)	24.58%	25.59%	26.64%	27.73%	28.87%
Portion of GDP contribution attributed to 6 GHz ($Billion)	$0.33	$0.50	$0.77	$1.18	$1.82
Direct impact (sales) attributed to 6 GHz ($Billion)	$0.17	$0.31	$0.52	$0.80	$1.39
Indirect impact ($Billion)	$0.15	$0.19	$0.25	$0.38	$0.42
Indirect/Direct multiplier	0.87	0.60	0.49	0.48	0.31
Indirect impact ($Million)	$152.67	$188.24	$253.70	$383.37	$424.70

Sources: PwC, ABI; Telecom Advisory Services analysis

K.5. Internet Service Providers

In addition to the economic value generated by the sources analyzed above, Wi-Fi will also contribute to either producer surplus or GDP of Internet Service Providers. This section will assess the economic value in three sources:

- Producer surplus of cellular operators resulting from CAPEX savings incurred in network deployment
- Revenues of Wi-Fi carriers offering service in public spaces
- Revenues of Wireless ISPs (this effect differs from the GDP impact of WISPs as a result of their deployment in rural and isolated areas analyzed in section K.3.5.)

K.4.1. Cellular network savings by off-loading traffic to Wi-Fi

The estimation of CAPEX savings starts by considering the GSMA Intelligence aggregate investment estimates of 5G deployments. It is assumed that all the CAPEX invested during the period would be dedicated to 5G deployment. In this context, Wi-Fi becomes a key enabler of 5G services. The upcoming flexible, radio-neutral 5G environment will be intrinsically supported by the next wave of 802.11 Wi-Fi standards and short-range wireless technologies operating in unlicensed bands. However, as GSMA Intelligence forecast a 97% 5G coverage already for 2020, which will remain stable until 2025, we understand that most CAPEX savings generated by Wi-Fi will have already taken place before 2021. Consequently, we do not quantify a specific economic value for the period 2021-2025.

Enhanced capability for cellular off-loading if 6 GHz allocated

The complementarity between Wi-Fi and cellular networks for Wi-Fi 6E and 5G, adds further potential gains derived from the savings in capital and operating expenses required to accommodate exploding data traffic. The key objective is to estimate the savings in capital investment as a result of an increase in traffic offloading with Wi-Fi benefits from the additional spectrum allocated, particularly, due to the ability to leverage 160 MHz within single contiguous channels.

The estimation of CAPEX savings starts by considering the GSMA Intelligence aggregate investment estimates of 5G deployments. By relying on the geographic disaggregation of Oughton and Frias, we estimate that CAPEX can be split in urban, suburban, and rural geographies. To estimate the percentage of population living in areas over 1 million inhabitants, we considered those living in the metropolitan areas of Seoul, Busan, Incheon, Daejeon, Gwangju, Ulsan, and Daegu. The percentage of rural population was obtained from Statista, while the remaining share of the population was classified in the suburban group (see Table K-26).

Table K-26. South Korea: 5G CAPEX estimated by geographical breakdown

Geography	South Korea		
	Population Breakdown (%)	5G CAPEX ($Billion)	5G CAPEX (%)
Urban (cities>1 Million)	44.17%	$1.15	4.60%
Suburban	47.67%	$5.37	21.41%
Rural	8.16%	$18.58	74.00%
Total	100%	$25.11	100%

Sources: Oughton and Frias (2016); GSMA; Telecom Advisory Services analysis

We conservatively assume that Wi-Fi 6 will not be critical in sustaining investment in urban areas, but that it will play a significant role beyond those geographies. Based on the cost advantage of carrier grade Wi-Fi, we assume that it will become effective for a portion of the suburban (approximately 15%) and rural network (approximately 5%) deployment. Therefore, this will yield yearly CAPEX savings of $347 million.

K.5.2 Wi-Fi carrier revenues

The value of Wi-Fi carriers includes the sum of revenues generated by paid public Wi-Fi access. In order to estimate this amount, we start by calculating the number of commercial Wi-Fi hotspots in South Korea. According to Cisco, in 2021 there will be 12.23 million public Wi-Fi hotspots in the country, although that figure includes home spots (such as the guest account service provided by cable operators). By subtracting the home spots from the public Wi-Fi estimates of Cisco, we estimated a total of 470,000 commercial Wi-Fi hotspots for 2021, which will increase reaching 500,000 by 2025. On the other hand, based on revenue per hotspot generated by Boingo in the United States, and adjusting the metric by PPP we estimated the value for South Korea. Accordingly, the revenues of Wi-Fi carriers in the country amount to $214 million in 2021, gradually increasing to reach $227 million in 2025 (Table K-27).

Table K-27. South Korea: Revenues of Wi-Fi carriers (2021-2025)

Variable	2021	2022	2023	2024	2025
Public Wi-Fi hotspots (Million)	12.23	14.03	16.10	18.47	21.19
Home spots (Million)	11.76	13.55	15.60	17.97	20.69
Commercial Wi-Fi hotspots (Million)	0.47	0.49	0.50	0.51	0.50
Revenue per hotspot ($)	$455.88	$455.46	$455.03	$454.60	$454.18
Revenue ($Million)	$214.29	$222.10	$227.51	$229.64	$227.40

Sources: Cisco, Boingo, Telecom Advisory Services

Increased revenues of Wi-Fi carriers in public places due to 6 GHz

The allocation of the 6 GHz spectrum band offers an opportunity for commercial Wi-Fi carriers to enhance their business. As Wi-Fi 6E developments will allow up to 1,500 connected devices per access point, Wi-Fi carriers will have the possibility of adding more clients without quality limitations due to congestion. By considering a conservative potential increase of 40% in the number of connected devices in public venues and prorating that figure by the gradual expansion of the latest technology, we expect commercial Wi-Fi carriers to increase their user base by 16% in 2025. If the revenue per hotspot increases in the same amount, that will yield an increase in overall revenues for the sector of an additional $36 million by 2025 (Table K-28).

Table K-28. South Korea: Revenues of Wi-Fi carriers due to 6 GHz (2021-2025)

Variable	2021	2022	2023	2024	2025
Potential increase in connected devices in public venues	40%	40%	40%	40%	40%
Traffic through the 6 GHz Channel (%)	0%	10%	20%	30%	40%
Increase in connected devices due to 6 GHz	0%	4%	8%	12%	16%
Revenue per hotspot if 6 GHz allocated ($)	$455.88	$473.67	$491.43	$509.15	$526.84
Revenue if 6 GHz allocated ($Million)	$0.00	$8.88	$18.20	$27.56	$36.38

Sources: Boingo, Telecom Advisory Services

K.6. Wi-Fi ecosystem

The economic value of Wi-Fi for Wi-Fi ecosystem companies in South Korea is calculated based on the following three sources:

- The producer surplus (i.e. margins) of residential Wi-Fi devices and equipment manufactured in South Korea;
- The producer surplus of local firms providing products and services in the IoT ecosystem (hardware, software and systems integration) in South Korea; and
- The producer surplus of local firms providing products and services in the AR/VR ecosystem (hardware, software and content) in South Korea.

K.6.1 Locally manufactured residential Wi-Fi devices and equipment

In section K.2.4 we calculated the producer surplus attributed to residential Wi-Fi devices and equipment, relying on Milgrom et al. (2011) assumption that consumer surplus could be approximated by that of the producers. By adding to that value, the producer surplus estimated for the case of tablets (considering the production of local giant Samsung), we estimate a total economic value of $11.2 billion in 2021, which we expect to slightly increase to $13 billion in 2025 (Table K-29).

Table K-29. South Korea: Producer Surplus from locally manufactured residential Wi-Fi devices and equipment (2021-2025)

Variable	2021	2022	2023	2024	2025
Producer surplus (exc. Tablets)	$7.723,05	$9.073,24	$10.722,26	$10.589,23	$10.260,75
Tablet producer surplus (in $Million)	$3.504,90	$3.222,33	$3.006,36	$2.859,39	$2.719,61
Total producer surplus ($Million)	$11,227.95	$12,295.57	$13,728.62	$13,448.62	$12,980.35

Sources: Consumer Technology Association; ABI Research; IDC; HIS; Moffett; CS Markets; Telecom Advisory Services analysis

Locally manufactured Wi-Fi 6 devices and equipment for residential use

As mentioned above, devices for 6 GHz are expected to gradually replace those of prior generations. According to IDC, global shipments of consumer devices linked to 6 GHz spectrum (802.11ax) will represent 40% of the shipments of those from previous generations in 2025. Therefore, we expect the producer surplus attributed to 6 GHz devices to yield $4.1 billion in economic value by 2025 (see Table K-30).

Table K-30. South Korea: Producer Surplus from locally manufactured residential Wi-Fi 6 devices and equipment (2021-2025)

Variable	2021	2022	2023	2024	2025
Consumer 6 GHz / no 6 GHz	3.76%	8.83%	18.59%	28.86%	40.30%
Producer surplus 6 GHz devices ($Million)	$290.77	$801.49	$1,992.78	$3,055.68	$4,134.68

Sources: IDC; Telecom Advisory Services

K.6.2. Firms belonging to the IoT ecosystem

According to estimates from Statista and Bain & Co, we expect total industrial IoT revenue in South Korea to amount to $9.74 billion in 2021. By relying on the percentage of hardware connectivity spending in IoT in Asia-Pacific, we were able to split that figure into the two main industry segments: (i) hardware; and (ii) software, contents, and services. By prorating those amounts by the share of local production (37% for hardware, 60% for software and services) and the margins (39.44% and 77.46%, respectively), we can estimate the overall producer surplus. However, the share attributed to 6 GHz should be subtracted from the total economic value. To do so, we estimated a natural growth rate, by subtracting the corresponding share attributed to 6 GHz spectrum according to the growth rates indicated in Section K.3.4. Thus, we estimate a producer surplus not attributed to 6 GHz of $3.3 billion in 2021, expecting to reach $6.6 billion in 2025 (Table K-31).

Table K-31. South Korea: IoT ecosystem direct contribution (2021-2025)

Variable	2021	2022	2023	2024	2025
IoT revenue - Hardware ($billions)	$3.65	$4.45	$5.43	$6.63	$8.08
IoT revenue - Software, Contents, Services ($billions)	$6.09	$7.42	$9.05	$11.04	$13.47
Total Industrial IoT revenue in ($Billion)	$9.74	$11.88	$14.49	$17.67	$21.55
Local production (%) - Hardware	37%	37%	37%	37%	37%
Local production (%) - Software & Services	60%	60%	60%	60%	60%
Margins (%) - Hardware	39%	39%	39%	39%	39%
Margins (%) - Software & Services	77%	77%	77%	77%	77%
Margins - IoT Hardware revenue	$0.54	$0.66	$0.80	$0.98	$1.19
Margins - Software, contents and services IoT revenue	$2.83	$3.45	$4.21	$5.13	$6.26
Producer surplus ($Million)	$3,367.46	$4,107.11	$5,009.22	$6,109.48	$7,451.40
Growth rate (%)	10.64%	21.96%	21.96%	21.96%	21.96%
Growth rate not attributed to 6 GHz (%)	9.69%	19.43%	18.94%	18.94%	18.94%
Producer surplus not attributed to 6 GHz ($Million)	$3,270.22	$3,905.77	$4,645.67	$5,525.73	$6,572.51

Sources: Statista;, Bain & Co; CSI; Telecom Advisory Services analysis

Wider deployment of Internet of Things under 6 GHz

Following the previous analysis, we were able to estimate which portion of IoT producer surplus growth can be attributed to the 6 GHz spectrum. As Table K-32 indicates, we expect the additional IoT surplus generated by 6 GHz to reach $879 million in 2025.

Table K-32. South Korea: IoT direct contribution attributed to 6 GHz (2021-2025) ($Million)

Variable	2021	2022	2023	2024	2025
Producer surplus	$3,367.46	$4,107.11	$5,009.22	$6,109.48	$7,451.40
Producer surplus not attributed to 6 GHz	$3,270.22	$3,905.77	$4,645.67	$5,525.73	$6,572.51
Additional surplus due to 6 GHz	$97.24	$201.34	$363.55	$583.75	$878.89

Sources: Statista;, Bain & Co; CSI; Telecom Advisory Services analysis

K.6.3. Firms belonging to the AR/VR ecosystem

Following a similar approach as in the case of IoT, we estimated the direct contribution of the firms in the AR/VR ecosystem to the South Korean economy. Starting with the local spending in AR/VR by category (hardware, software, and contents), and apportioning those figures by the respective shares of local production and margins, we were able to estimate the total producer surplus. By relying on a ratio built from 6 GHz AR/VR related products, we were able to subtract the specific contribution attributed to 6 GHz from the surplus corresponding to current bands. Accordingly, we expect by 2021 a direct contribution from the AR/VR ecosystem of $110 million, increasing to reach $508 million by 2025 (Table K-33).

Table K-33. South Korea: AR/VR ecosystem direct contribution (2021-2025)

Variable	2021	2022	2023	2024	2025
Spending in AR/VR - Hardware $Billion	$0.21	$0.38	$0.63	$1.01	$1.61
Spending in AR/VR - Software, Contents, Services ($Billion)	$0.50	$0.85	$1.31	$1.88	$3.21
Total Spending in AV/VR ($Billion)	$0.71	$1.23	$1.94	$2.89	$4.82
Share of local production - Hardware	37.40%	37.40%	37.40%	37.40%	37.40%
Share of local production - Software, Contents, Services	60.00%	60.00%	60.00%	60.00%	60.00%
Local production for local consumption - Hardware ($Billion)	$0.08	$0.14	$0.24	$0.38	$0.60
Local production for local consumption - Software, Contents, Services ($Billion)	$0.30	$0.51	$0.79	$1.13	$1.93
Local Producer Surplus - Hardware ($Billion)	$0.03	$0.06	$0.09	$0.15	$0.24
Local Producer Surplus - Software, Contents, Services ($Billion)	$0.23	$0.40	$0.61	$0.87	$1.49
Total Producer Surplus	$0.26	$0.45	$0.70	$1.02	$1.73
Share attributable to Wi-Fi (excluding 6 GHz)	42.02%	38.80%	32.18%	30.88%	29.32%
Producer Surplus attributed to Wi-Fi (not including 6 GHz) ($Million)	$110.47	$175.05	$226.40	$315.70	$507.63

Sources: PwC, ABI; Telecom Advisory Services analysis

Wider deployment of AR/VR solutions if 6 GHz allocated

By relying on a ratio built from 6 GHz AR/VR related products, we were able to isolate the specific economic contribution of the new spectrum allocation. Following an approach similar as that one described above, the direct contribution from AR/VR ecosystem in South Korea attributed to 6 GHz in 2025 will yield almost $500 million (see Table K-34).

Table K-34. South Korea: AR/VR direct contribution attributed to 6 GHz (2021-2025)

Variable	2021	2022	2023	2024	2025
Spending in AR/VR ($Billion)	$0.71	$1.23	$1.94	$2.89	$4.82
Share attributed to 6 GHz	24.58%	25.59%	26.64%	27.73%	28.87%
Spending in AR/VR attributed to 6 GHz ($Billion)	$0.17	$0.31	$0.52	$0.80	$1.39
Local production for local consumption 6 GHz ($Billion)	$0.09	$0.17	$0.27	$0.42	$0.73
Local Producer Surplus ($Million)	$64.62	$115.44	$187.43	$283.52	$499.83

Sources: PwC, ABI, Telecom Advisory Services analysis

K.7. Wi-Fi contribution to employment

The estimation of employment generated by Wi-Fi's economic value is calculated by relying on the total GDP contribution resulting from the effects analyzed above and using that as an input to the communications sector of an input-output matrix of the South Korean economy. Table K-35 presents the GDP contribution, as sum of all GDP sources discussed above, enabled by Wi-Fi projected for the period 2021-2025.

Table K-35. South **Korea: Wi-Fi enabled GDP contribution (2021-2025)**

Year	GDP contribution enabled by Wi-Fi ($Million)		
	Attributed to current bands	Attributed to 6 GHz	Total
2021	$24,331	$1,168	$25,499
2022	$22,122	$2,863	$24,986
2023	$21,457	$3,636	$25,092
2024	$23,147	$4,323	$27,470
2025	$24,902	$4,903	$29,805

Sources: Telecom Advisory Services analysis

These inputs generate the following annual employment effects based on the input/output matrix for the South Korean economy (Table K-36).

Table K-36. South **Korea: Wi-Fi generated Annual Employment**

Variable	2021			2025		
	Current bands	6 GHz	Total	Current bands	6 GHz	Total
Direct jobs	106,919	5,131	112,050	109,426	21,544	130,970
Indirect jobs	45,623	2,190	47,813	46,693	9,193	55,886
Induced jobs	26,857	1,289	28,145	27,486	5,412	32,898
Total	179,399	8,609	188,008	183,606	36,148	219,754

Sources: GTAP; Telecom Advisory Services analysis

According to the contribution to GDP, Wi-Fi will generate approximately 188,000 jobs in 2021 and is expected to create over 219,700 in 2025. Job estimates include direct jobs (those jobs created by the specific Wi-Fi contribution), indirect jobs (those jobs created by suppliers to the Wi-Fi sector) and induced jobs (those jobs created by spending of direct and indirect workers).

The sector breakdown of 2021 employment (including the additional jobs created by 6 GHz) is as follows (Table K-37).

Table K-37. South **Korea: Sector Breakdown of Wi-Fi generated annual employment (2021)**

Sector	Direct	Indirect	Induced	Total
Agriculture	0	0	668	668
Extractive industries	0	0	23	23
Manufacturing	0	6,431	492	6,923
Construction	0	671	0	671
Trade	0	11,601	20,320	31,921
Transportation	0	3,466	0	3,466
Communications	112,050	0	0	112,050
Financial Services	0	5,776	0	5,776
Business services	0	19,868	0	19,868
Other services	0	0	6,642	6,642
Total	112,050	47,813	28,145	188,008

Sources: GTAP; Telecom Advisory Services analysis

L. ECONOMIC VALUE OF WI-FI IN SINGAPORE

Wi-Fi has become a critical component of Singapore telecommunications infrastructure. According to an interpolation from Cisco Annual Internet Report Highlights Tool 2018-2023 for the rest of Asia-Pacific, we estimate there were 60,000 public Wi-Fi access points operating in the Singapore territory in 2018, while Wiman estimates that there are currently 342,000 free Wi-Fi access points. Given the Wi-Fi access point density in the city-state, hotspots have become a very important connectivity feature. According to Opensignal[237], Singapore wireless users spent 55.5% of their communications time connected to Wi-Fi networks rather than relying on their cellular data connection in the third week of March 2020. The increasing importance of Wi-Fi technology in the digital infrastructure ecosystem of Singapore should result in a significant socio-economic contribution. This section presents the results and calculations of the economic assessment. The methodology reviewed in section B was used to calculate each source of economic value.

L.1. Total Economic Value of Wi-Fi in Singapore (2021-2025)

Before considering the additional effect of allocating the 6 GHz spectrum band for unlicensed use, the total economic value of Wi-Fi in Singapore in 2021 (baseline scenario) will amount to $10.4 billion. This economic value is broken down by $1.8 billion in consumer surplus, $4.6 billion in producer surplus, and $4.0 billion in a net contribution to GDP. Likewise, before accounting for the acceleration effect resulting from the allocation of the 6 GHz band, the 2025 forecast of economic value will remain at $10.4 billion, composed of $2.8 billion in consumer surplus, $3.3 billion in producer surplus, and $4.3 billion in GDP contribution (see Table L-1).

Table L-1. Singapore: Economic Value of Wi-Fi (Baseline Scenario)

Agent	Source	Economic Value ($Million)					
		2021	2022	2023	2024	2025	Category
1. Free Wi-Fi	1.1. Savings generated by free Wi-Fi traffic offered in public sites	$22	$21	$20	$19	$18	Consumer Surplus
	1.2. Deployment of free Wi-Fi in public sites	$15	$15	$15	$16	$16	GDP contribution
2. Residential Wi-Fi	2.1. Internet access for home usage of devices that lack a wired port	$608	$735	$889	$1,074	$1,298	Consumer Surplus
	2.2. Avoidance of investment in in-house wiring	$556	$605	$657	$679	$701	Consumer Surplus
	2.3. Benefit to consumers from speed increases	$83	$112	$148	$181	$217	Consumer Surplus
	2.4. Residential Wi-Fi devices and equipment deployed	$528	$542	$558	$550	$533	Consumer Surplus
	2.5. Bridging digital divide: use of Wi-Fi to increase coverage in rural and isolated areas	$0	$0	$0	$0	$0	GDP contribution

[237] Khatri, H. and Fenwick, S. (2020). "Analyzing mobile experience during the coronavirus pandemic: Time on Wi-Fi". *Opensignal* (March 30).

Agent	Source	Economic Value ($Million)					
		2021	2022	2023	2024	2025	Category
3. Enterprise Wi-Fi	3.1. Business Internet traffic transmitted through Wi-Fi	$740	$808	$882	$962	$1,050	Producer surplus
	3.2. Avoidance of enterprise inside wiring costs	$559	$598	$640	$685	$733	Producer surplus
	3.3. Return to speed: contribution to GDP derived from an increase in average mobile speed	$934	$1,224	$1,582	$2,016	$2,523	GDP contribution
	3.4. Wide deployment of IoT	$2,903	$1,288	$1,285	$1,317	$1,350	GDP contribution
	3.5. Deployment of AR/VR solutions	$62	$69	$75	$105	$111	GDP contribution
4. ISPs	4.1. CAPEX and OPEX savings due to cellular off-loading	$2,588	$195	$312	$363	$5	Producer surplus
	4.2. Revenues of service providers offering paid Wi-Fi access in public places	$69	$97	$136	$190	$262	GDP contribution
	4.3. Aggregated revenues of WISPs	$0	$0	$0	$0	$0	GDP contribution
5. Wi-Fi ecosystem	5.1. Locally manufactured residential Wi-Fi devices and equipment	$0	$0	$0	$0	$0	Producer surplus
	5.2. Locally manufactured Wi-Fi enterprise equipment	$0	$0	$0	$0	$0	Producer surplus
	5.3. Locally produced IoT products and services	$713	$852	$1,013	$1,205	$1,433	Producer surplus
	5.4. Locally produced of AR/VR solutions	$23	$37	$48	$66	$107	Producer surplus
Total		$10,403	$7,198	$8,260	$9,428	$10,357	

Source: Telecom Advisory Services analysis

In addition to the value generated from the unlicensed use of the 2.4 GHz and 5 GHz bands (the baseline scenario), the allocation of the 6 GHz spectrum band for unlicensed use and the deployment of Wi-Fi 6 and Wi-Fi 6E devices will trigger an additional boost in the technology's economic value, reaching $2 billion in 2025 (see Table L-2).

Table L-2. Singapore: Economic Value of Wi-Fi (only attributed to 6 GHz)

Agent	Source	Economic Value ($Million)					
		2021	2022	2023	2024	2025	Category
1. Free Wi-Fi	1.1. Savings generated by free Wi-Fi traffic offered in public sites	$0	$0	$0	$0	$0	Consumer Surplus
	1.2. Deployment of free Wi-Fi in public sites	$0	$1	$3	$5	$6	GDP contribution
	1.3. Benefit of faster free Wi-Fi with Wi-Fi 6E devices	$0	$0	$0	$0	$0	Consumer Surplus
2. Residential Wi-Fi	2.3. Benefit to consumers from speed increases	$0	$17	$42	$72	$105	Consumer Surplus
	2.4. Residential Wi-Fi devices and equipment deployed	$19	$46	$100	$154	$208	Consumer Surplus
	2.5. Bridging digital divide: use of Wi-Fi to increase	$0	$0	$0	$0	$0	GDP contribution

Agent	Source	Economic Value ($Million)					
		2021	2022	2023	2024	2025	Category
	coverage in rural and isolated areas						
3. Enterprise Wi-Fi	3.1. Business Internet traffic transmitted through Wi-Fi	$0	$0	$0	$1	$2	Producer surplus
	3.3. Return to speed: contribution to GDP derived from an increase in average mobile speed	$0	$155	$381	$675	$1,021	GDP contribution
	3.4. Wide deployment of Internet of Things	$142	$168	$205	$210	$215	GDP contribution
	3.5. Deployment of AR/VR solutions	$36	$46	$62	$95	$110	GDP contribution
4. ISPs	4.1 CAPEX and OPEX savings due to cellular off-loading	$0	$0	$0	$0	$0	Producer surplus
	4.2. Revenues of service providers offering paid Wi-Fi access in public places	$0	$4	$11	$23	$42	GDP contribution
	4.3. Aggregated revenues of WISPs	$0	$0	$0	$0	$0	GDP contribution
5. Wi-Fi ecosystem	5.1. Locally manufactured residential Wi-Fi devices and equipment	$0	$0	$0	$0	$0	Producer surplus
	5.2. Locally manufactured Wi-Fi enterprise equipment	$0	$0	$0	$0	$0	Producer surplus
	5.3. Locally produced IoT products and services	$21	$44	$79	$127	$192	Producer surplus
	5.4. Locally produced of AR/VR solutions	$14	$24	$39	$59	$105	Producer surplus
Total		$232	$505	$922	$1,421	$2,006	

Source: Telecom Advisory Services analysis

Considering that by 2025 only 40% of Wi-Fi traffic will rely on the 6 GHz channels, the acceleration effect derived from the new spectrum allocation and latest Wi-Fi devices will still be far from reaching its maximum potential at this time.

By combining the baseline and the Wi-Fi 6 and 6 GHz scenarios, the overall economic value of Wi-Fi for Singapore will yield $12.4 billion in 2025 (see Table L-3).

Table L-3. Singapore: Total Economic Value of Wi-Fi (including Wi-Fi 6 and 6 GHz)

Agent	Source	Economic Value ($Million)					
		2021	2022	2023	2024	2025	Category
1. Free Wi-Fi	1.1. Savings to consumers of free Wi-Fi traffic offered in public sites	$22	$21	$20	$19	$18	Consumer Surplus
	1.2. Deployment of free Wi-Fi in public sites	$15	$17	$18	$20	$22	GDP contribution
	1.3. Benefit of faster free Wi-Fi with Wi-Fi 6E devices	$0	$0	$0	$0	$0	Consumer Surplus
2. Residential Wi-	2.1. Internet access for home usage of devices that lack a wired port	$608	$735	$889	$1,074	$1,298	Consumer Surplus

Agent	Source	Economic Value ($Million)					
		2021	2022	2023	2024	2025	Category
	2.2. Avoidance of investment in in-house wiring	$556	$605	$657	$679	$701	Consumer Surplus
	2.3. Benefit to consumers from speed increases	$83	$129	$190	$253	$322	Consumer Surplus
	2.4. Residential Wi-Fi devices and equipment deployed	$547	$588	$658	$704	$741	Consumer Surplus
	2.5. Bridging digital divide: use of Wi-Fi to increase coverage in rural and isolated areas	$0	$0	$0	$0	$0	GDP contribution
3. Enterprise Wi-Fi	3.1. Business Internet traffic transmitted through Wi-Fi	$740	$808	$882	$963	$1,052	Producer surplus
	3.2. Avoidance of enterprise inside wiring costs	$559	$598	$640	$685	$733	Producer surplus
	3.3. Return to speed: contribution to GDP derived from an increase in average mobile speed	$934	$1,378	$1,963	$2,691	$3,543	GDP contribution
	3.4. Wide deployment of IoT	$3,046	$1,456	$1,490	$1,527	$1,565	GDP contribution
	3.5. Deployment of AR/VR solutions	$98	$115	$138	$200	$221	GDP contribution
4. ISPs	4.1 CAPEX and OPEX savings due to cellular off-loading	$2,588	$195	$312	$363	$5	Producer surplus
	4.2. Revenues of service providers offering paid Wi-Fi access in public places	$69	$101	$147	$212	$304	GDP contribution
	4.3. Aggregated revenues of WISPs	$0	$0	$0	$0	$0	GDP contribution
5. IT companies	5.1. Locally manufactured residential Wi-Fi devices and equipment	$0	$0	$0	$0	$0	Producer surplus
	5.2. Locally manufactured Wi-Fi enterprise equipment	$0	$0	$0	$0	$0	Producer surplus
	5.3. Locally produced IoT products and services	$734	$895	$1,092	$1,332	$1,625	Producer surplus
	5.4. Locally produced of AR/VR solutions	$37	$61	$87	$126	$212	Producer surplus
Total		$10,636	$7,702	$9,183	$10,848	$12,362	

Source: Telecom Advisory Services analysis

As indicated in Tables L-1 through L-3, if the 6 GHz spectrum is not allocated, Wi-Fi economic value will remain stable. The following sections will present in detail the calculations for each source of value, disaggregating the economic contribution between the current spectrum allocation and the enhanced effect due to Wi-Fi 6 availability and the 6 GHz band.

L.2. Value from free Wi-Fi service

The economic value of free Wi-Fi service originates from three contribution sources:

- Savings to consumers by accessing the Internet in free Wi-Fi sites rather than incurring cellular costs;
- The use of Wi-Fi to expand broadband coverage to the unserved population; and
- The return to speed of Wi-Fi compared to the use of cellular service.

L.2.1. Savings incurred by accessing free Wi-Fi in public sites

The economic value of free Wi-Fi is measured in terms of consumer surplus, calculated by estimating the benefit that flows to consumers as a result of savings incurred by not relying on cellular service. We begin by forecasting the traffic generated at free Wi-Fi access points. In Singapore, most free hotspots are part of the Wireless@SG program, regulated by the IMDA, and operated by Singtel and other carriers (see Table L-4).

Table L-4. Singapore: Total Free Wi-Fi Traffic projection (2021-2025)

Variable	2021	2022	2023	2024	2025
Free Wi-Fi traffic (Million GB Per year) - considering current trends	126.13	148.48	177.51	215.51	265.62
Free Wi-Fi hotspots (Million)	0.06	0.09	0.14	0.20	0.30
Traffic per hotspot - considering current trends	1,976.31	1,580.23	1,283.18	1,058.17	885.90
Traffic per hotspot - capped due to congestion	1,976.31	1,580.23	1,283.18	1,058.17	885.90
Total traffic (not attributed to 6 GHz) (Million GB)	126.13	148.48	177.51	215.51	265.62

Sources: Cisco; The Straits Times; Telecom Advisory Services analysis

We calculate consumer surplus by multiplying the total free traffic by the difference between what the consumer would have to pay if she/he were to rely on a wireless carrier and the cost of offering free Wi-Fi (incurred by the retailer or public site). To do so, we needed an estimate of the average price per GB of wireless data transmitted by wideband networks, which was calculated by averaging the most economic "dollar per GB" plan of four major wireless carriers in Singapore[238] (see Table L-5).

Table L-5. Singapore: Average Price Per Gigabyte (2020)

Carrier	Plan	Price per GB ($)
Singtel	Only Sim 55	$0.99
Grid Communications	40GB	$0.46
M1	$50 Plan	$0.25
StarHub	55GB	$0.40

Note: The average price per GB is converted to U.S. dollars in order to calculate total economic value.
Sources: Operator websites; Telecom Advisory Services analysis

Historical data allowed for a projection of future prices per gigabyte. Based on these prices, we expect the average price per GB will reach an estimated $0.31 in 2025 from $0.47 in 2021. By relying on the total free Wi-Fi traffic presented in Table L-4 and the average price per cellular gigabyte minus the cost of provisioning Wi-Fi service, the consumer surplus of free Wi-Fi traffic was calculated (see Table L-6).

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[238] The average is calculated by prorating every price per GB by the carrier's market share.

Table L-6. Singapore: Consumer Surplus of Free Wi-Fi Traffic (2021-2025)

Variable	2021	2022	2023	2024	2025
Total Free Traffic (not attributed to 6 GHz) (Million GB)	126.13	148.48	177.51	215.51	265.62
Price per cellular gigabyte ($)	$0.47	$0.42	$0.38	$0.34	$0.31
Cost per Wi-Fi provisioning ($)	$0.30	$0.28	$0.27	$0.26	$0.24
Consumer surplus per gigabyte ($)	$0.17	$0.14	$0.11	$0.09	$0.07
Total Consumer surplus ($Million)	$21.93	$20.90	$19.95	$18.89	$17.54

Sources: Websites of cellular operators; Telecom Advisory Services analysis

As indicated in Table L-6, consumer surplus of free Wi-Fi traffic would reach an estimated $21.9 million in 2021, decreasing to $17.5 million in 2025.

Given that forecasted traffic per hotspot is expected to gradually decrease through 2025, we will not attribute any enhanced effect in this segment to the 6 GHz allocation[239].

L.2.2. Free Wi-Fi to provide broadband to the unserved population

As explained in section B, free Wi-Fi in public sites can provide Internet access to the unserved population. Consumers that do not have broadband at home because they lack the economic means to acquire services can rely on free Wi-Fi to gain Internet access. The net result is that more people can be connected, which in turn enhances the economic contribution of broadband.

The estimation of this particular economic impact starts by estimating the number of households that lack broadband service at home but access Internet through free hotspots. Total households' evolution was estimated from Statista, while the percentage of household connectivity was based on information from the Singapore regulatory body IMDA. We capped the extrapolated trend of connected households, by assuming that 0.5% will remain unconnected till 2025. We follow a conservative approach and assume that only 5% of unconnected households rely on free hotspots for accessing Internet. After calculating the increase in broadband penetration due to households relying on free Wi-Fi, we rely on the broadband impact coefficient calculated by Katz and Callorda (2018b) in their econometric models developed for Asia-Pacific. As a result, the GDP contribution of this particular effect is expected to amount to $14.8 million in 2021, reaching $16.3 million in 2025 (see Table L-7).

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[239] A decline in average traffic per hotspot may help to reduce the congestion that the 6 GHz spectrum allocation is expected to address.

Table L-7. Singapore: GDP contribution due to households relying on Free Wi-Fi (2021-2025)

Variable	2021	2022	2023	2024	2025
Households without Internet	7,250	7,453	7,661	7,875	8,095
Households that don't buy because access Internet free hotspots (%)	5%	5%	5%	5%	5%
Households served by Free Wi-Fi hot spots	363	373	383	394	405
Increase in national broadband penetration	0.025%	0.025%	0.025%	0.025%	0.025%
Impact of fixed broadband adoption in GDP	16.32%	16.32%	16.32%	16.32%	16.32%
Increase in the GDP due to the new broadband adoption (% GDP)	0.004%	0.004%	0.004%	0.004%	0.004%
GDP ($Billion)	$360.60	$368.59	$377.26	$386.69	$396.36
Total impact in GDP ($Million)	$14.79	$15.11	$15.47	$15.86	$16.25

Sources: Statista; IMDA; Telecom Advisory Services analysis

Enhanced GDP contribution due to 6 GHz allocation

As stated above, Wi-Fi 6 technology operating in the 6 GHz band supports a higher number of devices per access point than Wi-Fi sites relying on the 2.4 GHz and 5 GHz bands. Accordingly, the improved throughput of free Wi-Fi hotspots under the 6 GHz allocation will allow the possibility of serving additional unconnected households. The evidence suggests that not many people undergoing the affordability barrier rely exclusively on free Wi-Fi as their main source of Internet access[240], so we will follow again a conservative approach and assume that a further 5% of unconnected households will be served through free hotspots under the allocation of the 6 GHz band. On the other hand, we have also considered that the expansion of traffic through the new band will take place gradually, reaching 40% in 2025. All in all, we estimate that additional 154 households in Singapore will be served by free hotspots operating under 6 GHz spectrum in 2025, yielding an additional GDP contribution of approximately $6 million (Table L-8).

Table L-8. Singapore: GDP contribution due to households relying on Free Wi-Fi due to 6 GHz (2021-2025)

Variable	2021	2022	2023	2024	2025
Households without Internet (not served by free Wi-Fi)	6,888	7,080	7,278	7,481	7,690
Potential households that could be served through free Wi-Fi hotspots under increased capacity (% of those not connected)	5%	5%	5%	5%	5%
Traffic through the 6 GHz Channel (%)	0%	10%	20%	30%	40%
Additional households served by Free Wi-Fi hot spots with 6 GHz	0	35	73	112	154
Increase in national broadband penetration	0.000%	0.002%	0.005%	0.007%	0.010%
Increase in the GDP due to the new broadband adoption (% GDP)	0.000%	0.000%	0.001%	0.001%	0.002%
Total impact in GDP ($Million)	$0	$1.44	$2.94	$4.52	$6.18

Source: Telecom Advisory Services analysis

L.2.3. Benefit to consumers for enjoying higher speed from free Wi-Fi if 6 GHz band is allocated

[240] They tend to use also broadband service provided at work or at an educational institution.

When the 6 GHz band is adopted by free Wi-Fi access points it will deliver service at faster broadband speeds. Current speeds from free hotspots in Singapore are fairly modest[241]. Thus, the expanded capabilities due to the allocation of 6 GHz spectrum band will enhance free Wi-Fi speed, and as a result, will increase consumer surplus. We assume that under the 6 GHz allocation, speed from free hotspots will be similar to the Wi-Fi speeds from mobile devices reported by Cisco. After calculating the average speed by considering the expected share of traffic through 6 GHz, we apply to willingness-to-pay estimates calculated by Nevo et al. (2016) and estimate the additional consumer surplus per household relying on free Wi-Fi. Given that Singapore has achieved universal service (only 500 households do not acquire service likely to benefit from free Wi-Fi) the impact of free service in this city-state is close to nil (Table L-9).

Table L-9. Singapore: Consumer surplus for enjoying higher speed from free Wi-Fi if 6 GHz band allocated (2021-2025)

Variable	2021	2022	2023	2024	2025
Free Wi-Fi mean speed with no 6 GHz (Mbps)	18.56	19.67	20.85	22.10	23.42
Wi-Fi Speeds from Mobile Device (Mbps)	50.03	62.47	78.00	97.39	121.61
Traffic through the 6 GHz Channel (%)	0.00%	10.00%	20.00%	30.00%	40.00%
Free Wi-Fi mean speed with 6 GHz (Mbps)	18.56	23.95	32.28	44.69	62.69
Demand for average download speed	68.32	69.63	70.94	72.26	73.60
New Demand for average download speed	68.32	73.11	78.72	84.84	91.26
Additional Monthly Consumer surplus	$0.00	$3.49	$7.78	$12.58	$17.66
Additional Yearly Consumer Surplus	$0.00	$41.85	$93.32	$150.95	$211.93
Households that rely on Free Wi-Fi	363	408	456	506	559
Consumer surplus ($Million)	$0.00	$0.02	$0.04	$0.08	$0.12

Sources: Cisco; Rotten Wi-Fi; Nevo et al. (2016); Telecom Advisory Services analysis

L.3. Residential Wi-Fi

The economic value of Wi-Fi in the consumer residential segment is the result of five factors:

- Provision of connectivity to the home network for devices that lack an Ethernet port;
- Cost avoidance of ethernet inside wiring;
- Consumer surplus resulting from faster broadband speeds relative to cellular networks;
- Consumer surplus derived from usage of home devices connected to the home network; and
- Provision of Internet access to consumers located in rural and isolated areas.

L.3.1. Home Internet access for devices that lack an Ethernet port

[241] From data reported in Rotten Wi-Fi, download speed at free sites in Singapore was extrapolated to reach 17.5 Mbps in 2020.

The underlying premise of this analysis is that in the absence of Wi-Fi, users of devices lacking an Ethernet port would have to depend on the cellular network to gain Internet access. For this reason, estimating value would first measure the traffic generated by these devices at home and then multiply it by the average price charged by cellular carriers.

To estimate the traffic of smartphones and tablets, we relied on 2018 Cisco estimates for the period 2016-21 and extrapolated those growth rates to 2025. As the Cisco Visual networking Index does not provide specific traffic data for Singapore, we relied on their estimates for the "rest of Asia-Pacific" and interpolated the value according to the country's GDP weight in that region. It must be said, however, that in 2019 Cisco adjusted its predictions upwards. However, we preferred to rely on the original estimates to avoid incurring in the risk of overestimation. Thus, it may be possible that our previsions reported here are slightly downward biased. In addition, according to Cisco IBSG (2012), 43.12% of use time of devices that lack an Ethernet port occurs at home. Therefore, the portion of said traffic generated at home in Singapore is expected to reach 1,290 million gigabytes in 2021. If this traffic had to be transported by cellular networks, at the average price per GB estimated above Table L-5), it would result in costs of $608 million in 2021 reaching $1.3 billion in 2025 (see Table L-10).

Table L-10. Singapore: Total Mobile Internet Traffic (2021-2025) (Million gigabytes)

Variable	2021	2022	2023	2024	2025
Total Annual traffic - Smartphones	1,433.6	1,965.7	2,690.1	3,677.3	5,025.8
Total Annual traffic - Tablets	1,558.2	2,052.2	2,702.9	3,559.9	4,688.5
Share of traffic at Home	43.12%	43.12%	43.12%	43.12%	43.12%
Total Traffic at Home - Smartphones	618.2	847.6	1,159.9	1,585.6	2,167.0
Total Traffic at Home - Tablets	671.9	884.9	1,165.4	1,534.9	2,021.6
Total Traffic at Home	1,290.0	1,732.5	2,325.3	3,120.5	4,188.6
Average Price per GB ($)	$0.47	$0.42	$0.38	$0.34	$0.31
Price per home traffic ($Million)	$608.21	$735.39	$888.67	$1,073.69	$1,297.55

Sources: Cisco; GSMA; Telecom Advisory Services analysis

L.3.2. Avoidance of inside wiring investment

Residential Wi-Fi allows consumers to avoid paying for wiring to connect all home devices (printers, laptops, storage units, etc.). Considering that 90% of connected households will have Wi-Fi in 2021[242], and the average wiring cost per household[243], the avoidance costs of inside wiring almost 1.3 million households yields a total of $556 million. By 2025, almost all connected households are expected to have adopted Wi-Fi. Therefore, the savings from inside wiring avoidance would have reached $701 million (Table L-11).

[242] Assuming a similar figure than in the United States

[243] We estimate for Singapore a similar value as in the U.S., adjusted by PPP differences.

Table L-11. Singapore: Consumer surplus from avoidance of investment in in-house wiring (2021-2025)

Variable	2021	2022	2023	2024	2025
Total Wiring Cost	$428.13	$429.85	$431.58	$433.32	$435.07
Households with Internet	1,442,839	1,483,115	1,524,516	1,567,072	1,610,816
Households with Wi-Fi (%)	90%	95%	100%	100%	100%
Households with Internet and Wi-Fi	1,297,823	1,407,454	1,522,195	1,567,072	1,610,816
Inside Wiring Costs ($Million)	$556	$605	$657	$679	$701

Sources: IMDA; Watkins (2012); Telecom Advisory Services analysis

L.3.3. Benefits derived from speed increase

As described in section B, consumer surplus increases if users enjoy faster Internet speeds. Thus, the welfare of residential Wi-Fi customers is expected to benefit from faster services than those provided by cellular networks. Given that the Cisco Annual Internet Report Highlights Tool 2018-2023 does not provide specific speed data for Singapore, fixed broadband speed data was obtained from Ookla, while the remaining speeds levels were assumed to be those reported from Cisco for the "rest of Asia-Pacific" group. After weighting the corresponding broadband speeds with the percentage of traffic carried out through Wi-Fi at home, the average speed advantage of using Wi-Fi in comparison to cellular networks was calculated. By applying the willingness-to-pay parameters defined in Nevo et al. (2016), the expected consumer surplus will amount to $83 million in 2021, increasing to $217 million in 2025.

Table L-12. Singapore: Consumer surplus from faster speed in households (2021-2025)

Variable	2021	2022	2023	2024	2025
Average Speed in households if Wi-Fi traffic were carried through mobile networks (Mbps)	69.46	71.03	73.32	76.58	81.09
Average Speed in household with Wi-Fi (Mbps)	94.11	103.33	115.44	131.26	151.80
Demand for average download speed	91.61	92.37	93.31	94.46	95.87
New Demand for average download speed	96.97	99.02	101.39	104.09	107.12
Additional Monthly Consumer surplus	$5.36	$6.64	$8.08	$9.63	$11.24
Additional Yearly Consumer Surplus	$64.32	$79.71	$96.91	$115.50	$134.92
Households with Internet and Wi-Fi	1,297,823	1,407,454	1,522,195	1,567,072	1,610,816
Impact ($Million)	$83	$112	$148	$181	$217

Sources: Cisco; Ookla; Nevo et al. (2016); Telecom Advisory Services analysis

Additional benefit to consumers from speed increase due to 6 GHz

The well-being of residential Wi-Fi customers is expected to increase from the 6 GHz allocation due to faster Internet service under Wi-Fi 6E. As previously described in Chapter III, only households acquiring a 150 Mbps (or faster) fixed broadband line will receive this benefit since they are the ones undergoing current router bottlenecks. As we were unable to find local data to assess the percentage of connections above 150 Mbps in the country, we assumed for Singapore a similar percentage as that of South Korea, given that both countries exhibit similar network performance across available indicators. After calculating the difference in average speed attributed to 6 GHz, the additional consumer surplus will reach $105 million in 2025 (see Table L-13).

Table L-13. Singapore: Consumer surplus from faster speed in households if 6 GHz allocated (2021-2025)

Variable	2021	2022	2023	2024	2025
Households that have connections over 150 Mbps (%)	21.76%	25.16%	29.08%	33.62%	38.87%
Percentage of household traffic that goes through Wi-Fi	76.68%	79.53%	82.11%	84.43%	86.50%
Traffic through the 6 GHz Channel (%)	0.00%	10.00%	20.00%	30.00%	40.00%
Share of traffic affected due to 6 GHz (%)	0.00%	2.00%	4.78%	8.52%	13.45%
Average speed with no 6 GHz (Mbps)	94.11	103.33	115.44	131.26	151.80
Average speed with 6 GHz (Mbps)	94.11	109.26	131.42	162.66	205.35
Demand for average download speed	96.97	99.02	101.39	104.09	107.12
New Demand for average download speed	96.97	100.01	103.69	107.92	112.54
Additional Yearly Consumer Surplus	$0.00	$11.88	$27.68	$45.98	$65.03
Households with Wi-Fi	1,297,823	1,407,454	1,522,195	1,567,072	1,610,816
Impact ($Million)	$0	$17	$42	$72	$105

Sources: OECD; Cisco; Ookla; Nevo et al. (2016); Telecom Advisory Services analysis

L.3.4. Residential Wi-Fi devices and equipment

The consumer surplus derived from the adoption of residential Wi-Fi devices and equipment focuses on seven consumers products which are intrinsically linked to Wi-Fi: smart home devices and systems such as Wi-Fi speakers and home security systems, home networking systems, Wi-Fi tablets, access points, external adapters, routers, and gateways. Two different approaches are used in this case: one assuming that consumer surplus is roughly equal to producer surplus in six of the seven products (excluding tablets), and an assessment of tablets' willingness-to-pay.

The estimation of economic value in the first approach begins by compiling local sales in the six product categories in Singapore[244]. After computing the sales in Singapore, we applied the prorated margin estimated by CSI markets (39.44%) which yields an estimated producer surplus for these particular products of $508 million in 2021. As mentioned above, it is assumed that the consumer surplus is of the same magnitude. This methodology was also used to calculate the consumer surplus up to 2023. However, the gradual adoption of Wi-Fi 6 devices is forecast to reduce the sales and economic value from the devices relying on the 2.4 GHz and 5 GHz spectrum bands. Non 6 GHz consumer devices shipments are expected by IDC to decrease by 1.2% in 2024 and 3.1% in 2025. Based on this estimate, we extrapolated the consumer surplus from non 6 GHz reliant residential Wi-Fi devices and equipment between 2021 and 2025.

We also calculated the consumer surplus attributed to tablets bought by local consumers. Starting with CTA/Statista worldwide tablet revenue estimates, we interpolated the revenue figures for Singapore (by weighting by the country's share on global GDP), and extrapolated the evolution of local revenue up to 2025 by

[244] Calculated by prorating data for the United States based on GDP.

considering Cisco's estimates of tablet evolution for the period. We reviewed the data on tablet prices for the market leader (taking as a reference the Apple iPad 10.2 Inch 128 GB, as Apple has 66% of the local market share in tablets[245]) and for the rest of the market (taking as a reference a Samsung Wi-Fi tablet 128 GB), and assumed consumer willingness-to-pay levels in a similar percentage above prices as in the U.S. average. Combining all that information, we were able to estimate a consumer surplus attributed to tablets of $20 million in 2021, expected to reach $16 million in 2025.

Table L-14. Singapore: Economic Value of Wi-Fi enabled consumer products (2021-2025)

Variable	2021	2022	2023	2024	2025
Consumer surplus (exc. tablets) ($Million)	$508	$523	$540	$534	$517
Tablet consumer surplus ($Million)	$20	$18	$17	$16	$16
Total consumer surplus ($Million)	$528	$542	$558	$550	$533

Sources: CTA; Telecom Advisory Services analysis

Consumer surplus derived from Wi-Fi enabled residential equipment for 6 GHz

As discussed above, sales of residential Wi-Fi devices and equipment operating in the 6 GHz band are expected to gradually replace those of former generations. According to IDC, global shipments of consumer devices operating in the 6 GHz (802.11ax standard) will represent 40% of sales from prior generations. As a result, if the shipments ratio reaches 40% in 2025, we can expect that, at least, the consumer surplus derived from 6 GHz devices will represent 40% of that of former technology residential devices. As a result, our estimates for consumer surplus attributed to 6 GHz residential devices amount to $208 million in 2025 (see Table L-15).

Table L-15. Singapore: Economic Value of Wi-Fi enabled consumer products attributable to 6 GHz (2021-2025)

Variable	2021	2022	2023	2024	2025
Ratio consumer 6 GHz / no 6 GHz	3.76%	8.83%	18.59%	28.86%	40.30%
Total consumer surplus ($Million) – 6 GHz	$19	$46	$100	$154	$208

Sources: IDC; Telecom Advisory Services analysis

L.3.5. Bridging the digital divide: use of Wi-Fi to increase coverage in rural and isolated areas

Given the nature of Singapore (mostly urban), and the lack of evidence regarding the local role of WISP, we do not attribute an economic value of Wi-Fi for this source.

L.4. Enterprise Wi-Fi

Beyond the impact on consumers, Wi-Fi also contributes significant economic value in the Singapore enterprise market. This section provides estimates in five areas:

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[245] Source: Gs StatCounter

- Support of business Internet traffic;
- Avoidance of campus and enterprise facilities inside wiring;
- Contribution to GDP resulting from Wi-Fi speed faster than cellular connections;
- Deployment of IoT solutions; and
- Implementation of business focused AR/VR use cases.

L.4.1. Business Internet traffic transmitted through Wi-Fi

Wi-Fi enterprise telecommunications savings result from wireless traffic that is routed through Wi-Fi access points rather than cellular networks. Based on Cisco 2016-21 projections for Asia-Pacific (interpolated for Singapore), we estimate that total business Internet traffic will reach 3.4 billion GB in 2021, of which 1.6 billion GB would have been transported through Wi-Fi access points. Considering the average price per GB transported by cellular (see Table L-5), savings from Wi-Fi will amount to $740 million in 2021, an addition to the producer surplus. By 2025, this benefit will reach $1 billion (see Table L-16).

Table L-16. Singapore: Savings in business wireless traffic (2021-2025)

Variable	2021	2022	2023	2024	2025
Share of Business Internet Traffic by Wi Fi	46.00%	45.42%	44.85%	44.29%	43.73%
Total Business Internet Traffic (Million GB)	3,414.2	4,190.4	5,143.1	6,312.3	7,747.3
Total Wi-Fi enterprise traffic (Million GB)	1,570.6	1,903.4	2,306.8	2,795.6	3,388.1
Average Price per GB	$0.47	$0.42	$0.38	$0.34	$0.31
Economic Impact ($Million)	$740.48	$807.95	$881.58	$961.91	$1,049.57

Sources: Cisco; Telecom Advisory Services analysis

Enhanced business Internet traffic transmitted through Wi-Fi due to 6 GHz

The deployment of the latest enterprise applications will generate an exponential growth in data traffic that will be handled by devices operating in unlicensed spectrum, through the combination of the existing unlicensed spectrum and the 6 GHz band. In 2019, an updated Cisco traffic forecast based on the explosion of IoT and AR/VR applications among other factors, increased total business Internet traffic projections from the prior 2016-21 estimates from 2018. We assume that part of the traffic increase was driven by "natural" growth, while the remainder was triggered by Wi-Fi traffic stimulated by shifting traffic to the 6 GHz band. The sum of the difference due to broader Wi-Fi traffic will reach $2 million in 2025 (see Table L-17).

Table L-17. Singapore: Savings in business wireless traffic due to 6 GHz (2021-2025) ($Million)

Variable	2021	2022	2023	2024	2025
Total value of business Wi-Fi traffic 2016-21	$740.5	$808.0	$881.6	$961.9	$1,049.6
Total value of business Wi-Fi traffic 2017/22	$729.5	$802.7	$883.3	$971.9	$1,069.5
Difference due to 6 GHz	$0.00	$0.00	$0.18	$1.08	$2.15

Sources: Cisco; analysis Telecom Advisory Services

L.4.2. Avoidance in enterprise building inside wiring

Similar to residential Wi-Fi savings due to capital investment avoidance in inside wiring, we assume that the total number of business establishments are equipped with Wi-Fi access points and multiply this value by a standard cost of deploying a CAT 6 network (see Table L-18). The number of establishments was estimated from local data reported by the Accounting and Corporate Regulatory Authority.

Table L-18. Singapore: Savings in business wiring CAPEX (2021-2025)

Variable	2021	2022	2023	2024	2025
Total Wiring Cost	$1,427.09	$1,432.84	$1,438.62	$1,444.41	$1,450.23
Number of Establishments	391,891	417,678	445,161	474,453	505,672
Establishments with Wi-Fi (%)	100%	100%	100%	100%	100%
Establishments with Wi-Fi	391,891	417,678	445,161	474,453	505,672
Inside Wiring Costs ($Million)	$559	$598	$640	$685	$733

Sources: ACRA; Telecom Advisory Services

L.4.3. Return to speed: contribution to GDP derived from an increase in average mobile speed

Since Wi-Fi accessibility allows, in general, faster access to the Internet than cellular networks do, higher speeds have a positive contribution on the economy in terms of increased overall efficiency and innovation. This contribution is measured in terms of GDP growth. As described in section L.2.3 for the case of consumer surplus, we start with the quantification of the average broadband speed if cellular networks transported all Wi-Fi traffic, and compare it with the speed of Wi-Fi technology. Having calculated the speed increase percentage, we then apply this percentage to the coefficient derived from the model developed by Katz and Callorda (2019) to gauge the potential impact on GDP from Wi-Fi enhanced speed. The economic value of Wi-Fi in terms of increasing the speed of transporting wireless will account to $934 million in 2021, increasing to $2.5 billion by 2025.

Table L-19. Singapore: Estimation of speed differential for total traffic (2021-2025)

Variable	2021	2022	2023	2024	2025
Average Download Speed if Wi-Fi traffic were carried through mobile networks (Mbps)	69.46	71.03	73.32	76.58	81.09
Average Speed with Wi-Fi (Mbps)	94.11	103.33	115.44	131.26	151.80
Speed increase (%)	35%	45%	57%	71%	87%
Impact of speed in GDP	0.73%	0.73%	0.73%	0.73%	0.73%
Increase in GDP	0.26%	0.33%	0.42%	0.52%	0.64%
GDP ($Billion)	$360.60	$368.59	$377.26	$386.69	$396.36
GDP increase ($Million)	$934	$1,224	$1,582	$2,016	$2,523

Sources: Cisco; Ookla; Telecom Advisory Services analysis

Additional return to speed effect due to 6 GHz

As previously described, only those broadband connections above 150 Mbps will be affected due to current router bottlenecks, and hence, the speed experienced will not be equivalent to that delivered by the fixed network. Thus, the allocation of spectrum in the 6 GHz band will remove those barriers, increasing broadband speed. After calculating the difference in average speed attributed to 6 GHz in the enterprise segment, the additional GDP contribution will yield $1 billion in 2025 (Table L-20).

Table L-20. Singapore: Estimation of speed differential due to 6 GHz (2021-2025)

Variable	2021	2022	2023	2024	2025
Mean speed with no 6 GHz (Mbps)	94.11	103.33	115.44	131.26	151.80
Mean speed with 6 GHz (Mbps)	94.11	109.26	131.42	162.66	205.35
Speed increase due to 6Ghz (%)	0%	6%	14%	24%	35%
Impact speed on GDP	0.73%	0.73%	0.73%	0.73%	0.73%
Increase in GDP (%)	0.00%	0.04%	0.10%	0.17%	0.26%
GDP increase ($Million)	$0	$155	$381	$675	$1,021

Sources: Cisco; Ookla; Telecom Advisory Services analysis

L.4.4. IoT deployment

IoT adoption has a contribution to GDP growth through the multiplicity of use cases that improve efficiency in business processes such as preventive maintenance, production monitoring and the like. To estimate this, we rely on a coefficient of GDP impact calculated through an aggregate simple production function which estimates that a 10% rise in M2M connections results in annual increases in GDP of between 0.3% and 0.9%[246]. Given the strength of the technological sector in Singapore, we assume a 0.9% GDP increase due to a 10% increase in the M2M installed base.

Starting with a 2021 installed base of 740,670 M2M devices in Singapore, we estimate the growth that can be exclusively attributed to the allocation of additional spectrum to indoor Wi-Fi devices. By subtracting the growth in M2M attributed to 6 GHz, the IoT impact for 2021 according to the natural grow is forecast to reach $2.9 billion (see Table L-21).

Table L-21. Singapore: GDP Contribution of IoT Deployment Boost (2021-2025)

Variable	2021	2022	2023	2024	2025
Connections, Cellular M2M	740,670	773,174	807,104	842,524	879,498
Growth Rate (%)	9.82%	4.39%	4.39%	4.39%	4.39%
Natural Growth Rate (%)	8.95%	3.88%	3.78%	3.78%	3.78%
Impact of 1% M2M Growth on GDP	9.00%	9.00%	9.00%	9.00%	9.00%
Impact on GDP (%)	0.81%	0.35%	0.34%	0.34%	0.34%
GDP ($Billion)	$361	$369	$377	$387	$396
Impact ($Million)	$2,903.07	$1,288.11	$1,285.10	$1,317.24	$1,350.18

Sources: GSMA Intelligence; Frontier Economics; Telecom Advisory Services analysis

It should be noted that the GDP impact of IoT declines due to a decreasing growth rate of M2M installed base.

Accelerated effect of IoT due to 6 GHz

As described above, a share of the M2M growth can be attributed to IoT traffic shifting to the 6 GHz spectrum. According to the data in Table L-22, cumulative impact of enhanced IoT deployment driven by 6 GHz spectrum proposals will reach $215 million by 2025.

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[246] See Frontier Economics (2018).

Table L-22. Singapore: GDP Contribution of IoT Deployment Boost caused by 6 GHz (2021-2025)

Variable	2021	2022	2023	2024	2025
Growth due to 6 GHz (%)	0.88%	0.51%	0.60%	0.60%	0.60%
Level of development of new bands (%)	50%	100%	100%	100%	100%
Impact on GDP (%)	0.04%	0.05%	0.05%	0.05%	0.05%
Impact ($Million)	$142.47	$167.69	$204.93	$210.06	$215.31

Sources: GSMA Intelligence; Frontier Economics; Telecom Advisory Services analysis

L.4.5. Deployment of AR/VR solutions

The adoption of AR/VR among Singapore business will have a spillover effect on productivity, thereby contributing to the growth of GDP. Estimating spillover effects of AR/VR is a not a trivial exercise considering the embryonic adoption of some of the use cases based on this technology. Since the objective is to estimate the spillover effect of AR/VR sales in the domestic Singapore market, we consider the estimate by PwC of the total GDP contribution of AR/VR for 2021 and 2022[247], and the sales of AR/VR components as estimated by ABI Research[248]. The extrapolation of these two parameters allow estimating the indirect (spillover) contribution of AR/VR to Singapore economy for the period under analysis.

Starting values are reduced by the proportion that can be attributed to other technologies rather than Wi-Fi (i.e. Bluetooth). After computing the resulting value, we subtracted the impact of the 6 GHz spectrum bands. To do so, we took as a reference a ratio of AR/VR product developments for each technology (built with data from ABI Research). Once the amounts to be attributed to GDP contribution and direct sales were estimated, the annual indirect to direct multiplier was calculated. The lowest multiplier value is applied to sales of AR/VR in the Singapore market to calculate the total spillovers. Accordingly, total spillover value of AR/VR in Singapore in 2021 will account for $62 million and is expected to increase by 2025 to $111 million (see Table L-23).

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[247] See PWC (2019). *Seeing is believing how virtual reality and augmented reality are transforming business and the economy.*

[248] See ABI Research, *Augmented and Mixed Reality Market Data: devices, use cases, verticals and value chain*. MD-ARMR-103, QTR 4 2019, and ABI Research, *Virtual Reality Market Data: devices, verticals, and value chain*. MD-VR-108, QTR 1 2020.

Table L-23. Singapore: GDP contribution resulting from AR/VR spillovers (2021-2025)

Variable	2021	2022	2023	2024	2025
AR/VR total contribution to GDP ($Billion)	$0.30	$0.44	$0.66	$0.97	$1.43
Share attributed to Wi-Fi (excluding 6 GHz)	42.02%	38.80%	32.18%	30.88%	29.32%
Portion of GDP contribution attributed to Wi-Fi (excluding 6 GHz) ($Billion)	$0.13	$0.17	$0.21	$0.30	$0.42
Direct impact (sales) attributed to Wi-Fi (excluding 6 GHz) ($Billion)	$0.06	$0.10	$0.14	$0.19	$0.31
Indirect impact ($Billion)	$0.06	$0.07	$0.08	$0.11	$0.11
Indirect/Direct multiplier	0.96	0.67	0.56	0.54	0.36
Indirect impact ($Million)	$62.01	$69.25	$75.44	$105.28	$111.32

Sources: PwC, ABI; Telecom Advisory Services analysis

Wider deployment of AR/VR solutions (accelerated effect due to 6 GHz)

Higher throughput enabled by the allocation of 6 GHz spectrum is expected to spur the adoption and use of AR/VR among enterprises, hence increasing the associated spillover effects. By relying on the ratio built from 5 GHz and 6 GHz AR/VR related products from above, we were able to isolate the specific economic contribution of the new spectrum allocation. Following a similar procedure as the one described above, spillovers from AR/VR in the Singapore attributed to 6 GHz were calculated. They will account for $36 million in 2021 and are expected to reach $110 million by 2025 (Table L-24).

Table L-24. Singapore: GDP contribution resulting from AR/VR spillovers due to 6 GHz (2021-2025)

Variable	2021	2022	2023	2024	2025
AR/VR total contribution to GDP ($Billion)	$0.30	$0.44	$0.66	$0.97	$1.43
Share attributed to 6 GHz (%)	24.58%	25.59%	26.64%	27.73%	28.87%
Portion of GDP contribution attributed to 6 GHz ($Billion)	$0.07	$0.11	$0.17	$0.27	$0.41
Direct impact (sales) attributed to 6 GHz ($Billion)	$0.04	$0.07	$0.11	$0.17	$0.30
Indirect impact ($Billion)	$0.04	$0.05	$0.06	$0.09	$0.11
Indirect/Direct multiplier	0.96	0.67	0.56	0.54	0.36
Indirect impact ($Million)	$36.27	$45.67	$62.45	$94.55	$109.61

Sources: PwC, ABI; Telecom Advisory Services analysis

L.5. Internet Service Providers

In addition to the economic value generated by the sources analyzed above, Wi-Fi will also contribute to either producer surplus or GDP of Internet Service Providers. This section will assess the economic value from two sources:

- Producer surplus of cellular operators resulting from CAPEX savings incurred in network deployment; and
- Revenues of Wi-Fi carriers offering service in public spaces,

L.5.1. Cellular network savings by off-loading traffic to Wi-Fi

The estimation of CAPEX savings starts by considering the GSMA Intelligence aggregate investment estimates of 5G deployment. It is assumed that all the CAPEX invested during the period would be dedicated to 5G deployment. In this context, Wi-Fi becomes a key enabler of 5G services. The upcoming flexible, radio-neutral 5G environment will be intrinsically supported by the next wave of 802.11 Wi-Fi standards and short-range wireless technologies operating in unlicensed bands. Considering that the total CAPEX required to deploy 5G in Singapore, and the growth in 5G coverage between 2021 and 2025 as reported in GSMA Intelligence, we are able to calculate the 5G CAPEX for each year of the period under consideration. Once this is estimated, the savings incurred by Wi-Fi is estimated by calculating the capital spending reduction ratio from Table L-36.

Based on the simulation model developed to estimate the impact of Wi-Fi off-loading in 5G deployment, we estimate that the savings of deploying carrier-grade Wi-Fi complementing the rollout of 5G to accommodate future traffic growth would amount to 32.9% of CAPEX, while the OPEX savings are $2.82 for each dollar saved in CAPEX. The estimation of CAPEX savings starts by considering the GSMA Intelligence aggregate investment estimates of 5G deployments in Singapore, which amount to $31.60 billion between 2019 and 2025. It is assumed that all the CAPEX invested during the period would be dedicated to 5G deployment. Considering the total CAPEX required to deploy 5G in Singapore, and the incremental 5G coverage between 2021 and 2025 we are able to interpolate the 5G CAPEX for each year of the period considered. Assuming that this amount already reflects the savings incurred by relying on Wi-Fi sites, this would result in a total producer surplus (adding CAPEX and OPEX savings) of $2.6 billion in 2021, declining to $5 million in 2025.

Table L-25. Singapore: Savings due to traffic off-loading (2021-2025) (in $Million)

Variable	2021	2022	2023	2024	2025
5G coverage (%)	87%	90%	93%	98%	98%
CAPEX without saving	$2,058.90	$155.49	$248.39	$288.58	$3.95
CAPEX reduction due to Wi-Fi off-loading	$677.4	$51.2	$81.7	$94.9	$1.3
OPEX reduction due to Wi-Fi off-loading	$1,910.2	$144.3	$230.4	$267.7	$3.7
Total Cost of Ownership	$2,588	$195	$312	$363	$5

Sources: GSMA; Telecom Advisory Services

The decline in savings over time is compensated by the increase in economic benefit under the 6 GHz spectrum allocation.

Enhanced capability for cellular off-loading if 6 GHz allocated

Given the nature of Singapore (100% urban), and the fact that savings attributed to 6 GHz are primarily focused in suburban and rural areas, we do not quantify any enhanced effect due to the new spectrum bands in this source.

L.5.2 Wi-Fi carrier revenues

The value of Wi-Fi carriers includes the sum of revenues generated by paid public Wi-Fi access. In order to estimate this value, we start by calculating the number of commercial Wi-Fi hotspots in Singapore. According to an extrapolation from Cisco, in 2021 there will be 390,000 million public Wi-Fi hotspots in the country, although that figure includes home spots (such as the guest account service provided by cable operators). By subtracting the home spots from the public Wi-Fi estimates of Cisco, we estimated a total of 170,000 commercial Wi-Fi hotspots for 2021, which will increase reaching 640,000 in 2025. On the other hand, based on revenue per hotspot generated by Boingo in the United States, and adjusting the metric by PPP we estimated the value for Singapore. Accordingly, this amounts to $69 million in 2021, gradually increasing to reach $262 million in 2025 (Table L-26).

Table L-26. Singapore: Revenues of Wi-Fi carriers (2021-2025)

Variable	2021	2022	2023	2024	2025
Public Wi-Fi hotspots (Million)	0.39	0.57	0.85	1.25	1.83
Home spots (Million)	0.22	0.33	0.51	0.78	1.19
Commercial Wi-Fi hotspots (Million)	0.17	0.24	0.34	0.47	0.64
Revenue per hotspot ($)	$401.37	$402.99	$404.62	$406.25	$407.88
Revenue ($Million)	$69.06	$97.16	$136.08	$189.58	$262.48

Sources: Cisco, Boingo, Telecom Advisory Services

Increased revenues of Wi-Fi carriers in public places due to 6 GHz

The allocation of the 6 GHz spectrum band offers an opportunity for commercial Wi-Fi carriers to enhance their business. As Wi-Fi 6E developments will allow up to 1,500 connected devices per access point, Wi-Fi carriers will have the possibility of adding more clients without quality limitations due to congestion. By considering a conservative potential increase of 40% in the number of connected devices in public venues and weighting that figure by the gradual expansion of the latest technology, we expect commercial Wi-Fi carriers to increase their user base by 16% in 2025. If the revenue per hotspot increases in the same amount, that will yield an increase in overall revenues for the sector of an additional $42 million by 2025 (Table L-27).

Table L-27. Singapore: Revenues of Wi-Fi carriers due to 6 GHz (2021-2025)

Variable	2021	2022	2023	2024	2025
Potential increase in connected devices in public venues	40%	40%	40%	40%	40%
Traffic through the 6 GHz Channel (%)	0%	10%	20%	30%	40%
Increase in connected devices due to 6 GHz	0%	4%	8%	12%	16%
Revenue per hotspot if 6 GHz allocated ($)	$401.37	$419.11	$436.98	$455.00	$473.15
Revenue if 6 GHz allocated ($Million)	$0.00	$3.89	$10.89	$22.75	$42.00

Sources: Boingo, Telecom Advisory Services

L.6. Wi-Fi ecosystem

The economic value generated by Wi-Fi within Wi-Fi ecosystem companies in Singapore is generated from the following two sources:

- The producer surplus of local firms providing products and services in the IoT ecosystem (hardware, software and systems integration) in Singapore; and
- The producer surplus of local firms providing products and services in the AR/VR ecosystem (hardware, software and content) in Singapore.

L.6.2. Firms belonging to the IoT ecosystem

According to estimates from Statista and Bain & Co, we expect total industrial IoT revenue in Singapore to amount $10 million in 2021. By relying on the percentage of hardware connectivity spending in IoT in Asia-Pacific, we split that value into the two main segments: (i) hardware; and (ii) software, contents, and services. By weighting those amounts by the share of local production (29% for hardware, 90% for software and services) and their margins (39.44% and 77.46%, respectively), we can estimate the overall producer surplus. However, the share attributed to 6 GHz should be subtracted from the total economic value in order to isolate the amount corresponding to the 2.4 GHz and 5 GHz spectrum. To do so, we estimated a natural growth rate, subtracting the corresponding share attributed to 6 GHz spectrum according to the growth rates indicated in Section I.3.4. Accordingly, we estimate a producer surplus not attributed to 6 GHz of $713 million in 2021, expecting to reach $1.4 billion in 2025 (Table L-28).

Table L-28. Singapore: IoT ecosystem direct contribution (2021-2025)

Variable	2021	2022	2023	2024	2025
IoT revenue - Hardware ($billions)	$0.83	$1.01	$1.23	$1.50	$1.83
IoT revenue - Software, Contents, Services ($billions)	$1.38	$1.68	$2.05	$2.50	$3.05
Total Industrial IoT revenue in ($Billion)	$2.21	$2.69	$3.28	$4.00	$4.88
Local production (%) - Hardware	29%	29%	29%	29%	29%
Local production (%) - Software & Services	60%	60%	60%	60%	60%
Margins (%) - Hardware	39%	39%	39%	39%	39%
Margins (%) - Software & Services	77%	77%	77%	77%	77%
Margins - IoT Hardware revenue	$0.09	$0.11	$0.14	$0.17	$0.21
Margins - Software, contents and services IoT revenue	$0.64	$0.78	$0.95	$1.16	$1.42
Producer surplus ($Million)	$734.18	$895.44	$1,092.12	$1,332.00	$1,624.56
Growth rate (%)	10.64%	21.96%	21.96%	21.96%	21.96%
Growth rate not attributed to 6 GHz (%)	9.69%	19.43%	18.94%	18.94%	18.94%
Producer surplus not attributed to 6 GHz ($Million)	$712.98	$851.54	$1,012.85	$1,204.73	$1,432.95

Sources: Statista, Bain & Co, CSI, Telecom Advisory Services analysis

Wider deployment of Internet of Things under 6 GHz

Following the previous analysis, we were able to estimate which portion of IoT producer surplus growth is attributed to the 6 GHz spectrum. As Table L-29 indicates, the additional IoT surplus generated by 6 GHz is estimated to reach for $191 million in 2025.

Table L-29. Singapore: IoT direct contribution attributed to 6 GHz (2021-2025)

Variable	2021	2022	2023	2024	2025
Producer surplus ($Million)	$734.18	$895.44	$1,092.12	$1,332.00	$1,624.56
Producer surplus not attributed to 6 GHz ($Million)	$712.98	$851.54	$1,012.85	$1,204.73	$1,432.95
Additional surplus due to 6 GHz ($Million)	$21.20	$43.90	$79.26	$127.27	$191.62

Sources: Statista, Bain & Co, CSI, Telecom Advisory Services analysis

L.6.3. Firms belonging to the AR/VR ecosystem

Following a similar approach as in the case of IoT, we estimated the direct contribution of this ecosystem to Singapore's economy. Starting with the local spending in AR/VR by category (hardware, software, and contents), and apportioning those figures by the respective shares of local production and margins, we estimate the total producer surplus. By relying on a ratio built from 6 GHz AR/VR related products, we subtracted the specific contribution attributed to 6 GHz from the surplus corresponding to current bands. Accordingly, we expect by 2021 a direct contribution from the AR/VR ecosystem of $23 million, increasing to reach $107 million by 2025 (Table L-30).

Table L-30. Singapore: AR/VR ecosystem direct contribution (2021-2025)

Variable	2021	2022	2023	2024	2025
Spending in AR/VR - Hardware $Billion	$0.05	$0.08	$0.14	$0.22	$0.35
Spending in AR/VR - Software, Contents, Services ($Billion)	$0.11	$0.18	$0.29	$0.41	$0.70
Total Spending in AV/VR ($Billion)	$0.15	$0.27	$0.42	$0.63	$1.05
Share of local production - Hardware	28.61%	28.61%	28.61%	28.61%	28.61%
Share of local production - Software, Contents, Services	60.00%	60.00%	60.00%	60.00%	60.00%
Local production for local consumption - Hardware ($Billion)	$0.01	$0.02	$0.04	$0.06	$0.10
Local production for local consumption - Software, Contents, Services ($Billion)	$0.06	$0.11	$0.17	$0.24	$0.42
Local Producer Surplus - Hardware ($Billion)	$0.01	$0.01	$0.02	$0.02	$0.04
Local Producer Surplus - Software, Contents, Services ($Billion)	$0.05	$0.09	$0.13	$0.19	$0.32
Total Producer Surplus	$0.06	$0.10	$0.15	$0.21	$0.36
Share attributable to Wi-Fi (excluding 6 GHz)	42.02%	38.80%	32.18%	30.88%	29.32%
Producer Surplus attributed to Wi-Fi (not including 6 GHz) ($Million)	$23.29	$36.87	$47.59	$66.14	$106.57

Sources: PwC, ABI; Telecom Advisory Services analysis

Wider deployment of AR/VR solutions if 6 GHz allocated

By relying on a ratio built from 6 GHz AR/VR related products, we isolate the specific economic contribution of the new spectrum allocation. Following an approach similar as that one described for IoT, the direct contribution from AR/VR ecosystem in Singapore attributed to 6 GHz in 2025 was estimated at $105 million.

Table L-31. Singapore: AR/VR direct contribution attributed to 6 GHz ($Billion) (2021-2025)

Variable	2021	2022	2023	2024	2025
Spending in AR/VR	$0.15	$0.27	$0.42	$0.63	$1.05
Share attributed to 6 GHz (%)	24.58%	25.59%	26.64%	27.73%	28.87%
Spending in AR/VR attributed to 6 GHz	$0.04	$0.07	$0.11	$0.17	$0.30
Local production for local consumption 6 GHz	$0.02	$0.03	$0.06	$0.09	$0.15
Local Producer Surplus	$13.62	$24.31	$39.40	$59.40	$104.93

Sources: PwC, ABI, Telecom Advisory Services analysis

L.7. Wi-Fi contribution to employment

The estimation of employment generated by Wi-Fi's economic value is calculated by relying on the total GDP contribution resulting from the effects analyzed above and using that as an input to the communications sector of an input-output matrix of Singapore's economy. Table L-32 presents the GDP contribution, as sum of all GDP sources discussed above, projected for the period 2021-2025.

Table L-32. Singapore: Wi-Fi enabled GDP contribution (2021-2025)

Year	GDP contribution enabled by Wi-Fi ($Million)		
	Attributed to current bands	Attributed to 6 GHz	Total
2021	$3,983	$179	$4,162
2022	$2,693	$373	$3,067
2023	$3,094	$662	$3,757
2024	$3,644	$1,007	$4,651
2025	$4,263	$1,394	$5,657

Sources: Telecom Advisory Services analysis

These inputs generate the following annual employment effects based on the input/output matrix for the Singapore economy (Table L-33).

Table L-33. Singapore: Wi-Fi generated Annual Employment

Variable	2021			2025		
	Current bands	6 GHz	Total	Current bands	6 GHz	Total
Direct jobs	8,990	0,404	9,394	9,622	3,147	12,769
Indirect jobs	2,435	0,109	2,545	2,607	0,852	3,459
Induced jobs	1,267	0,057	1,324	1,356	0,443	1,799
Total	12,692	0,570	13,263	13,585	4,442	18,027

Sources: GTAP; Telecom Advisory Services analysis

According to the contribution to GDP, Wi-Fi will generate approximately 13,200 jobs in 2021 and is expected to create over 18,000 in 2025. Job estimates include direct jobs (those jobs created by the specific Wi-Fi contribution), indirect jobs (those jobs created by suppliers to the Wi-Fi sector) and induced jobs (those jobs created by spending of direct and indirect workers).

The sector breakdown of 2021 employment (including the additional jobs created by 6 GHz) is as follows (Table L-34).

Table L-34. Singapore: Sector Breakdown of Wi-Fi generated annual employment (2021)

Sector	Direct	Indirect	Induced	Total
Agriculture	0	0	0	0
Extractive industries	0	0	0	0
Manufacturing	0	264	3	266
Construction	0	289	0	289
Trade	0	124	186	310
Transportation	0	132	0	132
Communications	9,394	0	0	9,394
Financial Services	0	449	0	449
Business services	0	1,286	0	1,286
Other services	0	0	1,135	1,135
Total	9,394	2,545	1,324	13,263

Sources: GTAP; Telecom Advisory Services analysis

M. ECONOMIC VALUE OF WI-FI IN AUSTRALIA

Wi-Fi technology has become a critical component in Australia's telecommunications infrastructure. According to the Cisco Annual Internet Report Highlights Tool 2018-2023, there were 100,000 public Wi-Fi access points operating in the Australian territory in 2018, while the Wiman site estimates that there are currently 664,000 free hotspots in the country (36,000 in Sydney, 50,000 in Melbourne, 17,000 in Adelaide, and 15,000 in Perth). Given the Wi-Fi access point density, hotspots have become a very important connectivity feature. According to Opensignal[249], Australian wireless users currently spend 52.4% of their communications time connected to Wi-Fi networks, rather than relying on their cellular data connection. The increasing importance of Wi-Fi technology in the digital infrastructure ecosystem should have a significant social and economic contribution. This section presents the results and calculations of the economic assessment. The methodology reviewed in section B was used to calculate each source of economic value.

M.1. Total Economic Value of Wi-Fi in Australia (2021-2025)

Before considering the additional effect of allocating the 6 GHz spectrum band for unlicensed use, the total economic value of Wi-Fi in Australia in 2021 (baseline scenario) will amount to $34.1 billion, broken down by $9.3 billion in consumer surplus, $18.1 billion in producer surplus, and $6.6 billion in a net contribution to GDP. Even before accounting for the acceleration effect resulting from the allocation of the 6 GHz band, the 2025 forecast of economic value will reach $36.3 billion, composed of $13.3 billion in consumer surplus, $14.4 billion in producer surplus, and $8.6 billion in GDP contribution (see Table M-1).

[249] Khatri, H. and Fenwick, S. (2020). "Analyzing mobile experience during the coronavirus pandemic: Time on Wi-Fi". *Opensignal* (March 30).

Table M-1. Australia: Economic Value of Wi-Fi (Baseline Scenario)

Agent	Source	Economic Value ($Million)					
		2021	2022	2023	2024	2025	Category
1. Free Wi-Fi	1.1. Savings generated by free Wi-Fi traffic offered in public sites	$65	$57	$50	$42	$34	Consumer Surplus
	1.2. Deployment of free Wi-Fi in public sites	$1,651	$1,665	$1,678	$1,690	$1,702	GDP contribution
2. Residential Wi-Fi	2.1. Internet access for home usage of devices that lack a wired port	$2,126	$2,643	$3,308	$4,163	$5,270	Consumer Surplus
	2.2. Avoidance of investment in in-house wiring	$5,163	$5,490	$5,821	$5,876	$5,922	Consumer Surplus
	2.3. Benefit to consumers from speed increases	$0	$0	$0	$0	$107	Consumer Surplus
	2.4. Residential Wi-Fi devices and equipment deployed	$1,970	$2,018	$2,074	$2,043	$1,976	Consumer Surplus
	2.5. Bridging digital divide: use of Wi-Fi to increase coverage in rural and isolated areas	$2,229	$2,155	$2,088	$2,021	$1,955	GDP contribution
3. Enterprise Wi-Fi	3.1. Business Internet traffic transmitted through Wi-Fi	$1,966	$2,160	$2,373	$2,608	$2,865	Producer surplus
	3.2. Avoidance of enterprise inside wiring costs	$5,585	$5,689	$5,795	$5,903	$6,013	Producer surplus
	3.3. Return to speed: contribution to GDP derived from an increase in average mobile speed	$0	$0	$0	$0	$413	GDP contribution
	3.4. Wide deployment of IoT	$2,305	$2,479	$3,699	$3,796	$3,897	GDP contribution
	3.5. Deployment of AR/VR solutions	$226	$249	$269	$375	$386	GDP contribution
4. ISPs	4.1. CAPEX and OPEX savings due to cellular off-loading	$7,951	$0	$0	$0	$0	Producer surplus
	4.2. Revenues of service providers offering paid Wi-Fi access in public places	$64	$63	$62	$60	$57	GDP contribution
	4.3. Aggregated revenues of WISPs	$130	$148	$156	$164	$175	GDP contribution
5. Wi-Fi ecosystem	5.1. Locally manufactured residential Wi-Fi devices and equipment	$0	$0	$0	$0	$0	Producer surplus
	5.2. Locally manufactured Wi-Fi enterprise equipment	$0	$0	$0	$0	$0	Producer surplus
	5.3. Locally produced IoT products and services	$2,542	$3,036	$3,611	$4,295	$5,108	Producer surplus
	5.4. Locally produced of AR/VR solutions	$86	$137	$176	$243	$393	Producer surplus
Total		$34.059	$27,989	$31,160	$33,279	$36,273	

Source: Telecom Advisory Services analysis

In addition to the value generated from the unlicensed use of the 2.4 GHz and 5 GHz bands (referred to as the baseline scenario), the allocation of the 6 GHz spectrum band for unlicensed use and the deployment of Wi-Fi 6 and Wi-Fi 6E devices will trigger an additional boost in economic value, reaching $5.4 billion in 2025 (see Table M-2).

Table M-2. Australia: Economic Value of Wi-Fi (only attributed to 6 GHz)

Agent	Source	Economic Value ($Million)					
		2021	2022	2023	2024	2025	Category
1. Free Wi-Fi	1.1. Savings generated by free Wi-Fi traffic offered in public sites	$0	$2	$6	$11	$17	Consumer Surplus
	1.2. Deployment of free Wi-Fi in public sites	$0	$158	$317	$478	$640	GDP contribution
	1.3. Benefit of faster free Wi-Fi with Wi-Fi 6E devices	$0	$12	$24	$37	$51	Consumer Surplus
2. Residential Wi-Fi	2.3. Benefit to consumers from speed increases	$0	$53	$122	$196	$276	Consumer Surplus
	2.4. Residential Wi-Fi devices and equipment deployed	$72	$173	$376	$576	$780	Consumer Surplus
	2.5. Bridging digital divide: use of Wi-Fi to increase coverage in rural and isolated areas	$0	$108	$166	$220	$271	GDP contribution
3. Enterprise Wi-Fi	3.1. Business Internet traffic transmitted through Wi-Fi	$0	$19	$25	$31	$39	Producer surplus
	3.3. Return to speed: contribution to GDP derived from an increase in average mobile speed	$0	$203	$454	$753	$1,095	GDP contribution
	3.4. Wide deployment of Internet of Things	$113	$323	$590	$605	$621	GDP contribution
	3.5. Deployment of AR/VR solutions	$132	$164	$223	$337	$380	GDP contribution
4. ISPs	4.1 CAPEX and OPEX savings due to cellular off-loading	$166	$166	$166	$166	$166	Producer surplus
	4.2. Revenues of service providers offering paid Wi-Fi access in public places	$0	$3	$5	$7	$9	GDP contribution
	4.3. Aggregated revenues of WISPs	$0	$4	$6	$9	$12	GDP contribution
5. Wi-Fi ecosystem	5.1. Locally manufactured residential Wi-Fi devices and equipment	$0	$0	$0	$0	$0	Producer surplus
	5.2. Locally manufactured Wi-Fi enterprise equipment	$0	$0	$0	$0	$0	Producer surplus
	5.3. Locally produced IoT products and services	$76	$156	$283	$454	$683	Producer surplus
	5.4. Locally produced of AR/VR solutions	$50	$90	$145	$218	$387	Producer surplus
Total		$609	$1,634	$2,908	$4,098	$5,427	

Source: Telecom Advisory Services analysis

Considering that by 2025 only 40% of Wi-Fi traffic will rely on the 6 GHz channels, the accelerated effect derived from the new spectrum allocation and latest Wi-Fi technologies will still be far from reaching its maximum potential at this time.

By combining the baseline and the Wi-Fi 6 and 6 GHz scenarios, the overall economic value of Wi-Fi for Australia will yield $41.7 billion in 2025 (see Table M-3).

Table M-3. Australia: Total Economic Value of Wi-Fi (including Wi-Fi 6 and 6 GHz)

Agent	Source	Economic Value ($Million)					
		2021	2022	2023	2024	2025	Category
1. Free Wi-Fi	1.1. Savings to consumers of free Wi-Fi traffic offered in public sites	$65	$59	$55	$53	$52	Consumer Surplus
	1.2. Deployment of free Wi-Fi in public sites	$1,651	$1,822	$1,995	$2,168	$2,342	GDP contribution
	1.3. Benefit of faster free Wi-Fi with Wi-Fi 6E devices	$0	$12	$24	$37	$51	Consumer Surplus
2. Residential Wi-Fi	2.1. Internet access for home usage of devices that lack a wired port	$2,126	$2,643	$3,308	$4,163	$5,270	Consumer Surplus
	2.2. Avoidance of investment in in-house wiring	$5,163	$5,490	$5,821	$5,876	$5,922	Consumer Surplus
	2.3. Benefit to consumers from speed increases	$0	$53	$122	$196	$383	Consumer Surplus
	2.4. Residential Wi-Fi devices and equipment deployed	$2,042	$2,191	$2,450	$2,620	$2,756	Consumer Surplus
	2.5. Bridging digital divide: use of Wi-Fi to increase coverage in rural and isolated areas	$2,229	$2,263	$2,254	$2,240	$2,226	GDP contribution
3. Enterprise Wi-Fi	3.1. Business Internet traffic transmitted through Wi-Fi	$1,966	$2,179	$2,398	$2,639	$2,905	Producer surplus
	3.2. Avoidance of enterprise inside wiring costs	$5,585	$5,689	$5,795	$5,903	$6,013	Producer surplus
	3.3. Return to speed: contribution to GDP derived from an increase in average mobile speed	$0	$203	$454	$753	$1,508	GDP contribution
	3.4. Wide deployment of IoT	$2,418	$2,802	$4,289	$4,402	$4,518	GDP contribution
	3.5. Deployment of AR/VR solutions	$358	$413	$492	$712	$767	GDP contribution
4. ISPs	4.1 CAPEX and OPEX savings due to cellular off-loading	$8,117	$166	$166	$166	$166	Producer surplus
	4.2. Revenues of service providers offering paid Wi-Fi access in public places	$64	$66	$67	$67	$66	GDP contribution
	4.3. Aggregated revenues of WISPs	$130	$152	$162	$173	$186	GDP contribution
5. IT companies	5.1. Locally manufactured residential Wi-Fi devices and equipment	$0	$0	$0	$0	$0	Producer surplus
	5.2. Locally manufactured Wi-Fi enterprise equipment	$0	$0	$0	$0	$0	Producer surplus
	5.3. Locally produced IoT products and services	$2,617	$3,192	$3,893	$4,749	$5,792	Producer surplus
	5.4. Locally produced of AR/VR solutions	$137	$227	$321	$462	$780	Producer surplus
Total		$34,668	$29,622	$34,066	$37,379	$41,703	

Source: Telecom Advisory Services analysis

The following sections will present in detail the calculation of each source of value, disaggregating the economic contribution between the current spectrum allocation and the enhanced effect due to Wi-Fi 6 availability and the 6 GHz band.

M.2. Value from free Wi-Fi service

The economic value of free Wi-Fi service originates from three contribution sources:

- Savings to consumers by accessing the Internet in free Wi-Fi sites rather than incurring cellular costs;
- The use of Wi-Fi to expand broadband coverage to the unserved population; and
- The return to speed of Wi-Fi compared to the use of cellular service.

M.2.1. Savings incurred by accessing free Wi-Fi in public sites

The economic value of free Wi-Fi is measured in terms of consumer surplus, calculated by estimating the benefit that flows to consumers as a result of savings incurred by not relying on cellular service. We begin by forecasting the traffic generated at free Wi-Fi access points. In order to isolate the effect from the increased capacity derived from the 6 GHz allocation, we calculate the portion of free Wi-Fi traffic attributed to current spectrum bands. For this, we relied on the assumption (verified in field studies) that current traffic levels are already producing congestion in most free Wi-Fi hotspots at times of peak demand. Thus, we assume that traffic per hotspot beyond 2021 will remain at 2020 levels (687.72 GB per year), although overall free traffic will continue growing as new hotspots will continue to be deployed (see Table M-4).

Table M-4. Australia: Total Free Wi-Fi Traffic projection (2021-2025)

Variable	2021	2022	2023	2024	2025
Free Wi-Fi traffic (Million GB Per year) - considering current trends	568.78	717.18	916.12	1,185.96	1,556.27
Free Wi-Fi hotspots (Million)	0.72	0.79	0.85	0.93	1.01
Traffic per hotspot - considering current trends	787.57	913.18	1,072.67	1,276.92	1,540.86
Traffic per hotspot - capped due to congestion	687.72	687.72	687.72	687.72	687.72
Total traffic (not attributed to 6 GHz) (Million GB)	496.67	540.11	587.36	638.73	694.60

Sources: Cisco; Wiman; Telecom Advisory Services

We calculate consumer surplus by multiplying the total free traffic (not attributed to 6 GHz) by the difference between what the consumer would have to pay if she/he were to rely on a wireless carrier and the cost of offering free Wi-Fi (incurred by the retailer or public site). To do so, we needed an estimate of the average price per GB of wireless data transmitted by wideband networks, which we calculated by averaging the most economic "dollar per GB" plan of four major wireless carriers in Australia[250] (see Table M-5).

[250] The average is calculated by prorating every price per GB by the carrier's market share.

Table M-5. Australia: Average Price Per Gigabyte (2020)

Carrier	Plan	Price per GB ($)
Optus (Singtel)	Optus One	$0.17
Vodafone (Vodafone Hutchison)	60 GB	$0.66
Telstra	Extra Large	$0.46

Note: The average price per GB is converted to U.S. dollars in order to calculate total economic value.

Sources: Websites of cellular operators; Telecom Advisory Services analysis

Historical data allowed for a projection of future prices per gigabyte. Based on these prices, we expect the average price per GB will reach an estimated $0.23 in 2025 from $0.35 in 2021. By relying on the total free Wi-Fi traffic not attributed to 6 GHz allocation shown in Table M-4 and the average price per cellular gigabyte minus the cost of provisioning Wi-Fi service, we calculated the consumer surplus of free Wi-Fi traffic (see Table M-6).

Table M-6. Australia: Consumer Surplus of Free Wi-Fi Traffic (2021-2025)

Variable	2021	2022	2023	2024	2025
Total Free Traffic (not attributed to 6 GHz) (Million GB)	496.67	540.11	587.36	638.73	694.60
Price per cellular gigabyte ($)	$0.35	$0.32	$0.29	$0.26	$0.23
Cost per Wi-Fi provisioning ($)	$0.22	$0.21	$0.20	$0.19	$0.18
Consumer surplus per gigabyte ($)	$0.13	$0.11	$0.08	$0.07	$0.05
Total Consumer surplus ($Million)	$64.83	$57.09	$49.56	$42.02	$34.43

Sources: Websites of cellular operators; Telecom Advisory Services analysis

As indicated in Table M-6, consumer surplus of free Wi-Fi traffic in 2021 would reach an estimated $65 million, decreasing to $34 million in 2025 due to lower prices and the congestion created if the 6 GHz spectrum is not allocated.

Enhanced free Wi-Fi traffic due to 6 GHz allocation

The allocation of the 6 GHz spectrum band coupled with the technological advances provided by the Wi-Fi 6 standard will remove the above-mentioned bottlenecks causing congestion. As a result, the traffic per hotspot will be able to continue growing at its natural rate as determined by the extrapolation of past recent trends. That being said, we must take into account that not all Wi-Fi traffic will benefit immediately from opening the 6 GHz band, as most current devices are not prepared to support the new standards. Thus, we expect the traffic through the 6 GHz channel to gradually increase until reaching a 40% of total free traffic by 2025.

Once computed the additional traffic "above and beyond" the future previsions under current spectrum bands, we follow a similar approach to calculate the consumer surplus, by multiplying it by the difference between what the consumer would have to pay if he were to utilize a wireless carrier and the cost of offering free Wi-Fi (Table M-7). As a result, we project an additional consumer surplus of $17 million from free Wi-Fi traffic attributed to 6 GHz.

Table M-7. Australia: Additional Consumer Surplus of Free Wi-Fi Traffic generated due to 6 GHz (2021-2025)

Variable	2021	2022	2023	2024	2025
Demand not satisfied due to congestion (Million GB)	72.11	177.06	328.77	547.23	861.67
Traffic through the 6 GHz Channel (%)	0%	10%	20%	30%	40%
Total traffic (attributed to 6 GHz) (Million GB)	0.00	17.71	65.75	164.17	344.67
Consumer Surplus (attributed to 6 GHz) ($Million)	$0.00	$1.87	$5.55	$10.80	$17.08

Source: Telecom Advisory Services analysis

The additional surplus generated by the allocation of the 6 GHz spectrum band will mitigate the decreasing trend of consumer surplus derived from free Wi-Fi under the current spectrum allocation.

M.2.2. Free Wi-Fi to provide broadband to the unserved population

As explained in section B, free Wi-Fi in public sites can provide Internet access to the unserved population. Consumers that do not have broadband at home because they lack the economic means to acquire services can rely on free Wi-Fi to gain Internet access. The net result is that more people can be connected, which in turn enhances the economic contribution of broadband.

The estimation of this particular economic impact starts by calculating the percentage of households that lack broadband service but are already accessing Internet through free hotspots. Total households' evolution, and the percentage unconnected were estimated based on data from the Australia Bureau of Statistics. We follow a conservative approach and assume that only 5% of unconnected households rely on free hotspots for accessing Internet. After calculating the increase in broadband penetration due to households relying on free Wi-Fi, we rely on the broadband impact coefficient calculated by Katz and Callorda (2018b) in their econometric models developed for Asia-Pacific. As a result, the GDP contribution of this particular effect is expected to amount to $1.7 billion in 2021, reaching a similar figure in 2025 (see Table M-8).

Table M-8. Australia: GDP contribution due to households relying on Free Wi-Fi (2021-2025)

Variable	2021	2022	2023	2024	2025
Households without Internet	1,270,696	1,267,921	1,264,782	1,261,267	1,257,367
Households that don't buy because access Internet free hotspots (%)	5%	5%	5%	5%	5%
Households served by Free Wi-Fi hot spots	63,535	63,396	63,239	63,063	62,868
Increase in national broadband penetration	0.7%	0.7%	0.7%	0.7%	0.7%
Impact of fixed broadband adoption in GDP	16.32%	16.32%	16.32%	16.32%	16.32%
Increase in the GDP due to the new broadband adoption (% GDP)	0.12%	0.12%	0.12%	0.11%	0.11%
GDP ($Billion)	$1,366.90	$1,403.79	$1,441.28	$1,479.33	$1,518.39
Total impact in GDP ($Million)	$1,650.92	$1,664.93	$1,678.11	$1,690.37	$1,702.19

Sources: Australia Bureau Statistics; Telecom Advisory Services analysis

Enhanced GDP contribution due to 6 GHz allocation

As stated above, Wi-Fi 6 technology operating in the 6 GHz band supports a higher number of devices per access point than Wi-Fi sites relying on the 2.4 GHz and 5 GHz bands. Accordingly, the improved throughput of free Wi-Fi hotspots under the 6 GHz allocation will allow the possibility of serving additional unconnected households. The potential universe of additional users that could be served with this additional spectrum is significant, as most unconnected households usually identify that costs are their main barrier for accessing to connectivity and thus, may potentially be served by free hotspots as long as they are in proximity to the access point. However, evidence suggests that not many people undergoing the affordability barrier rely exclusively on free Wi-Fi as their main source of Internet access[251]. Therefore, we follow again a conservative approach and assume that a further 5% of unconnected households will be served through free hotspots under the allocation of the 6 GHz band. On the other hand, we have also considered that the expansion of traffic through the new band will take place gradually, reaching 40% in 2025. All in all, we estimate that additional 23,625 households in Australia will be served by free hotspots operating under 6 GHz spectrum in 2025, yielding an additional GDP contribution of approximately $640 million (Table M-9).

Table M-9. Australia: GDP contribution due to households relying on Free Wi-Fi due to 6 GHz (2021-2025)

Variable	2021	2022	2023	2024	2025
Households without Internet (not served by free Wi-Fi and not new adopters of WISP)	1,207,161	1,199,664	1,193,866	1,187,762	1,181,236
Potential households that could be served through free Wi-Fi hotspots under increased capacity (% of those unconnected)	5%	5%	5%	5%	5%
Traffic through the 6 GHz Channel (%)	0%	10%	20%	30%	40%
Additional households served by Free Wi-Fi hot spots with 6 GHz	0	5,998	11,939	17,816	23,625
Increase in national broadband penetration	0	0.069%	0.13%	0.20%	0.26%
Increase in the GDP due to the new broadband adoption (% GDP)	0	0.01%	0.02%	0.03%	0.04%
Total impact in GDP ($Million)	0	$157.53	$316.80	$477.56	$639.65

Source: Telecom Advisory Services analysis

M.2.3. Benefit to consumers for enjoying higher speed from free Wi-Fi if 6 GHz band is allocated

When the 6 GHz band is adopted by free Wi-Fi access points it will deliver service at faster broadband speeds. Current download speed from free hotspots in Australia are quite modest[252]. Thus, the expanded capabilities due to the allocation of 6 GHz spectrum band will enhance free Wi-Fi speed, and as a result, will increase consumer surplus. We assume that under the 6 GHz allocation, speed from free hotspots will be similar to the Wi-Fi speeds from mobile devices reported by the Cisco Annual

[251] They tend to also use broadband service provided at work or at an educational institution.

[252] Given the lack of reliable data on free Wi-Fi speed in Australia, we made an estimation based on U.S. data, and applying the percentual differential between both countries in terms of fixed broadband speed. Then, we estimate free Wi-Fi speed in Australia to reach 4.5 Mbps in 2020.

Internet Report Highlights Tool 2018-2023. After calculating the average speed by considering the expected share of traffic through 6 GHz, we follow Nevo et al. (2016) and calculate the additional consumer surplus per household relying on free Wi-Fi. We expect the consumer surplus resulting from faster speed in free Wi-Fi sites to reach $51 million in 2025 (Table M-10).

Table M-10. Australia: Consumer surplus for enjoying higher speed from free Wi-Fi if 6 GHz band allocated (2021-2025)

Variable	2021	2022	2023	2024	2025
Free Wi-Fi mean speed with no 6 GHz (Mbps)	4.65	4.82	5.00	4.81	4.63
Wi-Fi Speeds from Mobile Device (Mbps)	32.43	38.62	46.00	54.78	65.24
Traffic through the 6 GHz Channel (%)	0.00%	10.00%	20.00%	30.00%	40.00%
Free Wi-Fi mean speed with 6 GHz (Mbps)	4.65	8.20	13.20	19.80	28.87
Demand for average download speed	68.57	68.99	69.40	67.79	66.20
New Demand for average download speed	68.57	83.51	95.72	105.85	115.04
Additional Monthly Consumer surplus	$0.00	$14.52	$26.32	$38.06	$48.85
Additional Yearly Consumer Surplus	$0.00	$174.22	$315.89	$456.74	$586.17
Households that rely on Free Wi-Fi	63,535	69,394	75,178	80,880	86,493
Consumer surplus ($Million)	$0	$12	$24	$37	$51

Sources: Rotten Wi-Fi; Cisco; Nevo et al. (2016); Telecom Advisory Services

M.3. Residential Wi-Fi

The economic value of Wi-Fi in the consumer residential segment is the result of five factors:

- Provision of connectivity to the home network for devices that lack an Ethernet port;
- Cost avoidance of ethernet inside wiring;
- Consumer surplus resulting from faster broadband speeds relative to cellular networks;
- Consumer surplus derived from usage of home devices connected to the home network; and
- Provision of Internet access to consumers located in rural and isolated areas.

M.3.1. Home Internet access for devices that lack an Ethernet port

The underlying premise of this analysis is that in the absence of Wi-Fi, users of devices lacking an Ethernet port would have to depend on the cellular network to gain Internet access. For this reason, estimating value would first measure the traffic generated by these devices at home and then multiply it by the average price charged by cellular carriers.

To estimate the traffic of smartphones and tablets, we relied on 2018 Cisco estimates for the period 2016-21 and extrapolated those growth rates to 2025. It must be said, however, that in 2019 Cisco adjusted its predictions upwards. However, we preferred to rely on the original estimates to avoid incurring in the risk of overestimation. Thus, it may be possible that our previsions reported here are slightly downward biased. In addition, we have to consider that according to Cisco IBSG (2012), 43.12% of use time of devices that lack an Ethernet port occurs at home. Therefore, the portion of said traffic generated at home in Australia will reach 6,005 million gigabytes in 2021 (see Table M-11).

Table M-11. Australia: Total Mobile Internet Traffic (2021-2025) (Million gigabytes)

Variable	2021	2022	2023	2024	2025
Total Annual traffic - Smartphones	10,462.7	15,141.5	21,895.9	31,654.5	45,785.0
Total Annual traffic - Tablets	3,465.3	4,096.6	4,842.9	5,725.2	6,768.2
Share of traffic at Home	43.12%	43.12%	43.12%	43.12%	43.12%
Total Traffic at Home - Smartphones	4,511.3	6,528.7	9,441.0	13,648.7	19,741.5
Total Traffic at Home - Tablets	1,494.2	1,766.4	2,088.2	2,468.6	2,918.3
Total Traffic at Home	6,005.4	8,295.0	11,529.2	16,117.2	22,659.7
Average Price per GB ($)	$0.35	$0.32	$0.29	$0.26	$0.23
Price per home traffic ($Million)	$2,125.63	$2,643.39	$3,307.81	$4,163.24	$5,269.80

Sources: Cisco; GSMA; Telecom Advisory Services analysis

If this traffic had to be transported by cellular networks, at the average price per GB estimated above Table M-5), it would result in costs of $2.1 billion in 2021 reaching $5.3 billion in 2025.

M.3.2. Avoidance of inside wiring investment

Residential Wi-Fi allows consumers to avoid paying for wiring to connect all home devices (printers, laptops, storage units, etc.). Considering that 90% of Australian connected households will have Wi-Fi in 2021[253], and the wiring cost estimated for households[254], the avoidance costs of inside wiring over 7.7 million households yields a total of $5.2 billion. By 2025, all connected households are expected to have adopted Wi-Fi. Therefore, the savings from inside wiring avoidance would have reached $5.9 billion (Table M-12).

Table M-12. Australia: Consumer surplus from avoidance of investment in in-house wiring (2021-2025)

Variable	2021	2022	2023	2024	2025
Total Wiring Cost	$668.61	$663.16	$657.75	$652.39	$647.07
Households with Internet	8,585,013	8,723,435	8,864,088	9,007,010	9,152,236
Households with Wi-Fi (%)	90%	95%	100%	100%	100%
Households with Internet and Wi-Fi	7,722,154	8,278,409	8,850,593	9,007,010	9,152,236
Inside Wiring Costs ($Million)	$5,163	$5,490	$5,821	$5,876	$5,922

Sources: Australia Bureau Statistics; Watkins (2012); Telecom Advisory Services

M.3.3. Benefits derived from speed increase

As described before, consumer surplus increases if users enjoy faster Internet speeds through Wi-Fi than from cellular networks. However, as estimated by the Cisco Annual Internet Report Highlights Tool 2018-2023, smartphone and mobile speeds in Australia are expected to be similar to that of Wi-Fi between 2021 and 2024. As only for 2025 Cisco forecasts a higher speed from Wi-Fi in comparison to

[253] Inside wiring costs in Australia assumed to be similar to that of the United States.
[254] We estimate for Australia a similar value as in the U.S., adjusted by PPP differences.

smartphones, we attribute an economic value specifically for that year. The expected consumer surplus will yield $107 million in 2025.

Additional benefit to consumers from speed increase due to 6 GHz

The well-being of residential Wi-Fi customers is expected to receive further benefit from the 6 GHz allocation due to faster Internet service under Wi-Fi 6E. As previously described in Chapter III, only households acquiring a 150 Mbps (or faster) fixed broadband line will receive the benefit since they are undergoing current router bottlenecks. To assess the percentage of households with connections above 150 Mbps, we interpolated from OECD estimates for Australia by speed tiers and assumed that it will grow until 2025 following a rate similar to what Cisco projects for the 50 Mbps segment in Australia. After calculating the difference in average speed attributed to 6 GHz, the additional consumer surplus will yield $276 million in 2025 (see Table M-13).

Table M-13. Australia: Consumer surplus from faster speed in households if 6 GHz allocated (2021-2025)

Variable	2021	2022	2023	2024	2025
Households that have connections over 150 Mbps (%)	2.81%	3.20%	3.66%	4.18%	4.78%
Percentage of household traffic that goes through Wi-Fi	69.92%	70.27%	70.62%	70.97%	71.31%
Traffic through the 6 GHz Channel (%)	0.00%	10.00%	20.00%	30.00%	40.00%
Share of traffic affected due to 6 GHz (%)	0.00%	0.23%	0.52%	0.89%	1.36%
Average speed with no 6 GHz (Mbps)	34.79	40.90	48.12	56.63	66.70
Average speed with 6 GHz (Mbps)	34.79	41.71	50.19	60.58	73.28
Demand for average download speed	124.01	127.42	130.79	134.11	137.38
New Demand for average download speed	124.01	127.96	131.94	135.92	139.89
Additional Yearly Consumer Surplus	$0.00	$6.42	$13.76	$21.75	$30.15
Households with Wi-Fi	7,722,154	8,278,409	8,850,593	9,007,010	9,152,236
Impact ($Million)	$0	$53	$122	$196	$276

Sources: OECD; Cisco; Nevo et al. (2016); Telecom Advisory Services analysis

M.3.4. Residential Wi-Fi devices and equipment

The consumer surplus derived from the adoption of residential Wi-Fi devices and equipment focuses on seven consumers products which are intrinsically linked to Wi-Fi: smart home devices and systems such as Wi-Fi speakers and home security systems, home networking systems, Wi-Fi tablets, access points, external adapters, routers, and gateways. Two different approaches are used in these cases: one assuming that consumer surplus is roughly equal to producer surplus in six of the seven products (excluding tablets), and an assessment of tablets' willingness-to-pay.

The estimation of economic value in the first approach begins by compiling local sales in the six product categories in Australia[255]. After computing the sales in Australia, we applied the prorated margin estimated by CSI markets (39.44%) which yields an estimated producer surplus for these particular products of $1.9

[255] Calculated by prorating data for the United States based on GDP.

billion in 2021. As mentioned above, it is assumed that the consumer surplus is of the same magnitude. This methodology was also used to calculate the consumer surplus up to 2023. However, the gradual adoption of Wi-Fi 6 devices is forecast to reduce the sales and economic value from the devices relying on the 2.4 GHz and 5 GHz spectrum bands. Non 6 GHz consumer devices shipments are expected by IDC to decrease by 1.2% in 2024 and 3.1% in 2025. Based on this estimate, we extrapolated the consumer surplus from non 6 GHz reliant residential Wi-Fi devices and equipment between 2021 and 2025.

In addition, we calculated the consumer surplus attributed to tablets bought by local consumers. Starting with CTA/Statista worldwide tablet revenue estimates, we interpolated the revenue figures for Australia (by weighting by the country's share on global GDP), and extrapolated the evolution of local revenue up to 2025 by considering Cisco estimates of tablet evolution for the period. We reviewed the data on tablet prices for the market leader (taking as a reference the Apple iPad 10.2 Inch 128 GB, as Apple has 84% of the local market share in tablets[256]) and for the rest of the market (taking as a reference a Samsung Wi-Fi tablet 128 GB), and assumed consumer willingness-to-pay levels in a similar percentage above prices as in the U.S. average. Combining all that information, we were able to estimate a consumer surplus attributable to tablets of $68 million in 2021, expected to reach $41 million in 2025.

Table M-14. Australia: Economic Value of Wi-Fi enabled consumer products (2021-2025)

Variable	2021	2022	2023	2024	2025
Consumer surplus (exc. tablets) ($Million)	$1,902	$1,959	$2,022	$1,997	$1,935
Tablet consumer surplus ($Million)	$68	$59	$52	$46	$41
Total consumer surplus ($Million)	$1,970	$2,018	$2,074	$2,043	$1,976

Sources: CTA; Telecom Advisory Services analysis

Consumer surplus derived from Wi-Fi enabled residential equipment for 6 GHz

As discussed above, sales of residential Wi-Fi devices and equipment operating in the 6 GHz band are expected to gradually replace those of former generations. According to IDC, global shipments of consumer devices operating in the 6 GHz (802.11ax standard) will represent 40% of sales from prior generations. As a result, if the shipments ratio reaches 40% in 2025, we can expect that, at least, the consumer surplus derived from 6 GHz devices will represent 40% of that of former technology residential devices. As a result, our estimates for consumer surplus attributed to 6 GHz residential devices amount to $780 million in 2025 (see Table M-15).

Table M-15. Australia: Economic Value of Wi-Fi enabled consumer products attributable to 6 GHz (2021-2025)

Variable	2021	2022	2023	2024	2025
Ratio consumer 6 GHz / no 6 GHz	3.76%	8.83%	18.59%	28.86%	40.30%
Total consumer surplus ($Million) – 6 GHz	$71.60	$173.06	$375.88	$576.36	$779.88

Sources: IDC; Telecom Advisory Services analysis

[256] Source: Gs StatCounter

M.3.5. Bridging the digital divide: use of Wi-Fi to increase coverage in rural and isolated areas

Wi-Fi is an appropriate technology to offer Internet access in rural and isolated areas. The incremental number of lines supported by WISPs represents an increase in penetration, which in turn contributes to the Australian GDP. According to the Australian association WISPAU, there are approximately 200,000 broadband subscriptions relying on this technology in the country. In order to estimate Wi-Fi's contribution, and considering the characteristics of the Australian geography, we assume that 50% of WISP potential connections may be theoretically served by other technologies (i.e. satellite) covering the same isolated footprint. Thus, we can conservatively expect 50% of broadband subscriptions in remote locations exclusively attributed to WISPs. With this value, we calculate the impact on GDP by relying on the coefficient estimated by Katz and Callorda (2018b) through regression models that links increase in broadband penetration to economic growth. However, the calculation of Wi-Fi contribution to GDP must subtract the direct impact of WISPs sales (estimated in Section M.5.3.) to avoid double counting. As a result, by reducing the digital divide and increasing broadband penetration, we estimate a GDP contribution of $2.2 billion in 2021, which will slightly decrease until 2025 (see Table M-16).

Table M-16. Australia: Estimation of GDP Contribution derived from reducing the digital divide (2021-2025)

Variable	2021	2022	2023	2024	2025
WISP subscribers	200,000	200,000	200,000	200,000	200,000
Additional broadband penetration due to WISP	2.06%	1.95%	1.84%	1.74%	1.65%
Impact of fixed broadband adoption in GDP	16.32%	16.32%	16.32%	16.32%	16.32%
GDP ($Billion)	$1,367	$1,404	$1,441	$1,479	$1,518
WISP TOTAL impact ($Million)	$4.59	$4.46	$4.33	$4.21	$4.08
WISP Revenues ($Million)	$0.13	$0.15	$0.16	$0.16	$0.17
Share that exist because WISP	50.00%	50.00%	50.00%	50.00%	50.00%
WISP spillovers on GDP ($Million)	$2,229.00	$2,155.00	$2,087.52	$2,020.79	$1,954.90

Sources: WISPAU; Telecom Advisory Services analysis

The contribution to GDP materializes through multiple effects: creation of new businesses, increasing productivity of existing enterprises, and growth of average income per household.

Economic impact of enhanced coverage and affordability due to 6 GHz

The allocation of the 6 GHz band to unlicensed use will allow WISPs to increase their subscriber base within their same coverage footprint. Therefore, a first effect derived from the allocation of the new spectrum band is related to additional households served due to additional coverage. We follow a cautious approach and consider that the expanded coverage will yield a gradual increase on WISP subscribers, from 2% in 2022 to 5% in 2025 over the figures projected above. In addition, an increase of the user base would allow service providers to lower their operating costs. Thus, by assuming stability in prices, affordability would increase as GDP per capita grows as economic growth resumes. All in all, we can expect an overall increase in approximately 13,262 WISP connections in 2025, contributing to an increase 0.13% in national broadband penetration. Considering the impact coefficient of broadband on the economy, which will yield $271 million of GDP contribution.

Table M-17. Australia: GDP Contribution derived from reducing the digital divide due to 6 GHz (2021-2025)

Variable	2021	2022	2023	2024	2025
New subscribers due to expanded coverage (%)	0%	2%	3%	4%	5%
New subscribers due to expanded coverage	0	4,000	6,000	8,000	10,000
New WISP adoption after price decrease (% households)	2.2%	2.1%	2.1%	2.0%	2.0%
Traffic through the 6 GHz Channel (%)	0.00%	10.00%	20.00%	30.00%	40.00%
Increase in WISP connections due to lower prices (households that buy the service)	0	861	1,677	2,442	3,262
Overall increase in WISP connections due to 6 GHz	0	4,861	7,677	10,442	13,262
Increase in national broadband penetration	0.00%	0.05%	0.08%	0.10%	0.13%
Impact of fixed broadband adoption in GDP	16.32%	16.32%	16.32%	16.32%	16.32%
Increase in the GDP due to the new broadband adoption (% GDP)	0.000%	0.008%	0.012%	0.015%	0.018%
Total impact in GDP ($Million)	$0.00	$108.37	$166.25	$219.59	$270.86

Source: Telecom Advisory Services analysis

M.4. Enterprise Wi-Fi

Beyond the impact on consumers, Wi-Fi also contributes significant economic value to the Australian enterprise segment. This section provides estimates in five areas:

- Support of business Internet traffic;
- Avoidance of campus and enterprise facilities inside wiring;
- Contribution to GDP resulting from Wi-Fi speed faster than cellular connections;
- Deployment of IoT solutions; and
- Implementation of business focused AR/VR use cases.

M.4.1. Business Internet traffic transmitted through Wi-Fi

Wi-Fi enterprise savings results from wireless traffic that is routed through Wi-Fi access points. Based on Cisco 2016-21 projections for Australia, we estimate that total business Internet traffic will reach 9.4 billion GB in 2021, of which 5.6 billion GB would have been transported through Wi-Fi access points. Considering the average price per GB transported by cellular (see Table M-5), savings from Wi-Fi will reach almost $2 billion, an addition to the producer surplus. By 2025, this benefit will reach $2.9 billion (see Table M-18).

Table M-18. Australia: Savings in business wireless traffic (2021-2025)

Variable	2021	2022	2023	2024	2025
Share of Business Internet Traffic by Wi Fi	59.00%	59.20%	59.40%	59.61%	59.81%
Total Business Internet Traffic (Million GB)	9,412.0	11,447.8	13,923.9	16,935.6	20,598.7
Total Wi-Fi enterprise traffic (Million GB)	5,553.1	6,777.3	8,271.5	10,095.0	12,320.6
Average Price per GB	$0.35	$0.32	$0.29	$0.26	$0.23
Economic Impact ($Million)	$1,965.52	$2,159.74	$2,373.14	$2,607.64	$2,865.30

Sources: Cisco; Telecom Advisory Services analysis

Enhanced business Internet traffic transmitted through Wi-Fi due to 6 GHz

The deployment of the latest enterprise applications will generate an exponential growth in business data traffic that will be handled by devices operating in unlicensed spectrum, through the combination of the existing bands and the 6 GHz band. In 2019, an updated Cisco Annual Internet Report Highlights Tool 2018-2023 traffic forecast based on the explosion of IoT and AR/VR applications, among other factors, increased total business Internet traffic projections from the prior 2016-21 estimates. We assume that part of the growth was driven by "natural" growth, while the remainder was triggered by Wi-Fi traffic stimulated by shifting traffic to the 6 GHz band. The sum of the difference due to broader Wi-Fi traffic will reach $39 million in 2025 (see Table M-19).

Table M-19. Australia: Savings in business wireless traffic due to 6 GHz (2021-2025) ($Million)

Variable	2021	2022	2023	2024	2025
Total value of business Wi-Fi traffic 2016-21	$1,965.5	$2,159.7	$2,373.1	$2,607.6	$2,865.3
Total value of business Wi-Fi traffic 2017/22	$2,097.7	$2,336.7	$2,603.0	$2,899.6	$3,230.1
Difference between the 2 estimations	$132.1	$177.0	$229.9	$292.0	$364.8
Difference because natural growth	$123.8	$157.9	$205.1	$260.5	$325.5
Difference due to 6 GHz	$0.00	$19.08	$24.78	$31.48	$39.32

Sources: Cisco; analysis Telecom Advisory Services

M.4.2. Avoidance in enterprise building inside wiring

Similar to residential Wi-Fi savings due to capital investment avoidance in inside wiring, we assume that the total number of business establishments are equipped with Wi-Fi access points and multiply this value by a standard cost of deploying a CAT 6 network for a business facility. The number of establishments was estimated from local data reported by the Australia Bureau Statistics (see Table M-20).

Table M-20. Australia: Savings in business wiring CAPEX (2021-2025)

Variable	2021	2022	2023	2024	2025
Total Wiring Cost	$2,228.69	$2,210.52	$2,192.51	$2,174.63	$2,156.91
Number of Establishments	2,505,782	2,573,442	2,642,928	2,714,291	2,787,580
Establishments with Wi-Fi (%)	100%	100%	100%	100%	100%
Establishments with Wi-Fi	2,505,782	2,573,442	2,642,928	2,714,291	2,787,580
Inside Wiring Costs ($Million)	$5,585	$5,689	$5,795	$5,903	$6,013

Sources: Australia Bureau Statistics; Telecom Advisory Services

M.4.3. Return to speed: contribution to GDP derived from an increase in average mobile speed

As reviewed before, the Cisco Annual Internet Report Highlights Tool 2018-2023 projects a Wi-Fi speed above that of cellular for Australia only in the year 2025. In consequence, we only compute an economic return for increased speed for that particular year. By applying the coefficient linking the impact of broadband speed on GDP, the expected contribution will yield $413 million in 2025.

Additional return to speed effect due to 6 GHz

As previously described, only those broadband connections above 150 Mbps will be affected due to current router bottlenecks, and hence, the speed experienced will not be equivalent to that delivered by the fixed network. Thus, the allocation of spectrum in the 6 GHz band will remove those barriers, increasing broadband speed. After calculating the difference in average speed attributed to 6 GHz, the additional GDP contribution will yield $1.1 billion in 2025 (Table M-21).

Table M-21. Australia: Estimation of speed differential due to 6 GHz (2021-2025)

Variable	2021	2022	2023	2024	2025
Mean speed with no 6 GHz (Mbps)	34.79	40.90	48.12	56.63	66.70
Mean speed with 6 GHz (Mbps)	34.79	41.71	50.19	60.58	73.28
Speed increase due to 6Ghz (%)	0%	2%	4%	7%	10%
Impact speed on GDP	0.26%	0.73%	0.73%	0.73%	0.73%
Increase in GDP (%)	0.00%	0.01%	0.03%	0.05%	0.07%
GDP increase ($Million)	$0	$203	$454	$753	$1,095

Sources: Cisco; Telecom Advisory Services analysis

M.4.4. IoT deployment

IoT adoption contributes to GDP growth through the multiplicity of use cases that improve efficiency in business operational processes such as preventive maintenance, production monitoring and the like. To estimate this, we rely on a coefficient of GDP impact calculated through an aggregate simple production function which estimates that a 10% rise in M2M connections results in annual increases in GDP of between 0.3% and 0.9%[257]. For Australia, we assume a conservative 0.3% GDP increase after a 10% increase in the M2M installed base.

Starting with a 2021 installed base of 6.7 million M2M devices in Australia, we estimate the growth that can be exclusively attributed to the allocation of additional spectrum to indoor Wi-Fi devices. By subtracting the growth in M2M attributed to 6 GHz, the IoT impact for 2021 according to the natural growth is forecast to reach $2.3 billion (see Table M-22).

[257] See Frontier Economics (2018).

Table M-22. Australia: GDP Contribution of IoT Deployment Boost (2021-2025)

Variable	2021	2022	2023	2024	2025
Connections, Cellular M2M	6,698,067	7,143,646	7,852,194	8,631,020	9,487,094
Growth Rate (%)	6.17%	6.65%	9.92%	9.92%	9.92%
Natural Growth Rate (%)	5.62%	5.89%	8.55%	8.55%	8.55%
Impact of 1% M2M Growth on GDP	3.00%	3.00%	3.00%	3.00%	3.00%
Impact on GDP (%)	0.17%	0.18%	0.26%	0.26%	0.26%
GDP ($Billion)	$1,367	$1,404	$1,441	$1,479	$1,518
Impact ($Million)	$2,304.69	$2,478.85	$3,698.81	$3,796.46	$3,896.68

Sources: GSMA Intelligence; Frontier Economics; Telecom Advisory Services analysis

Accelerated effect of IoT due to 6 GHz

As described above, a share of the M2M growth can be attributed to IoT traffic shifting to the 6 GHz spectrum. According to the data in Table M-23, the cumulative impact of enhanced IoT deployment driven by 6 GHz spectrum proposals will reach $621 million by 2025.

Table M-23. Australia: GDP Contribution of IoT Deployment Boost caused by 6 GHz (2021-2025)

Variable	2021	2022	2023	2024	2025
Growth due to 6 GHz (%)	0.55%	0.77%	1.36%	1.36%	1.36%
Level of development of new bands (%)	50%	100%	100%	100%	100%
Impact on GDP (%)	0.01%	0.02%	0.04%	0.04%	0.04%
Impact ($Million)	$113.10	$322.70	$589.84	$605.41	$621.39

Sources: GSMA Intelligence; Frontier Economics; Telecom Advisory Services analysis

M.4.5. Deployment of AR/VR solutions

The adoption of AR/VR among Australian enterprises will have a spillover effect on productivity, thereby contributing to the growth of GDP. Estimating spillover effects of AR/VR is a not a trivial exercise considering the embryonic adoption of some of the use cases based on this technology. Since the objective is to estimate the spillover effect of AR/VR sales in the domestic Australian business market, we consider the estimate by PwC of the total GDP contribution of AR/VR for 2021 and 2022[258], and the sales of AR/VR components as estimated by ABI Research[259]. The extrapolation of these two parameters allow estimating the indirect (spillover) contribution of AR/VR to Australian economy for the period under analysis.

Starting values are reduced by the proportion that can be attributed to other technologies rather than Wi-Fi (i.e. Bluetooth). After computing the resulting value, we subtracted the impact of the 6 GHz spectrum bands. To do so, we took as a reference a ratio of AR/VR product developments for each technology (built with data from ABI Research). Once the amounts to be attributed to GDP contribution and

[258] See PWC (2019). *Seeing is believing how virtual reality and augmented reality are transforming business and the economy.*
[259] See ABI Research, *Augmented and Mixed Reality Market Data: devices, use cases, verticals and value chain*. MD-ARMR-103, QTR 4 2019, and ABI Research, *Virtual Reality Market Data: devices, verticals, and value chain*. MD-VR-108, QTR 1 2020.

direct sales were estimated, the annual indirect to direct multiplier can be calculated. The lowest multiplier value is applied to sales of AR/VR in the Australia market to calculate the total spillovers. Accordingly, the total spillover value of AR/VR in Australia in 2021 will account for $226 million and is expected to increase by 2025 to $386 million (see Table M-24).

Table M-24. Australia: GDP contribution resulting from AR/VR spillovers (2021-2025)

Variable	2021	2022	2023	2024	2025
AR/VR total contribution to GDP ($Billion)	$1.13	$1.67	$2.46	$3.62	$5.34
Share attributed to Wi-Fi (excluding 6 GHz)	42.02%	38.80%	32.18%	30.88%	29.32%
Portion of GDP contribution attributed to Wi-Fi (excluding 6 GHz) ($Billion)	$0.47	$0.65	$0.79	$1.12	$1.56
Direct impact (sales) attributed to Wi-Fi (excluding 6 GHz) ($Billion)	$0.25	$0.40	$0.52	$0.74	$1.18
Indirect impact ($Billion)	$0.23	$0.25	$0.27	$0.37	$0.39
Indirect/Direct multiplier	0.91	0.63	0.52	0.50	0.33
Indirect impact ($Million)	$225.69	$249.00	$268.97	$374.98	$386.36

Sources: PwC, ABI; Telecom Advisory Services analysis

Wider deployment of AR/VR solutions (accelerated effect due to 6 GHz)

Higher throughput enabled by the allocation of 6 GHz spectrum is expected to spur the adoption and use of AR/VR among Australian enterprises, hence increasing the associated spillover effects. By relying on the ratio built from 5 GHz and 6 GHz AR/VR related products from above, we were able to isolate the specific economic contribution of the new spectrum allocation. Following a similar procedure as the one described above spillovers from AR/VR in Australia attributed to 6 GHz spectrum were calculated. They will account for $132 million in 2021 and are expected to reach $380 million by 2025 (Table M-25).

Table M-25. Australia: GDP contribution resulting from AR/VR spillovers due to 6 GHz (2021-2025)

Variable	2021	2022	2023	2024	2025
AR/VR total contribution to GDP ($Billion)	$1.13	$1.67	$2.46	$3.62	$5.34
Share attributed to 6 GHz (%)	24.58%	25.59%	26.64%	27.73%	28.87%
Portion of GDP contribution attributed to 6 GHz ($Billion)	$0.28	$0.43	$0.65	$1.00	$1.54
Direct impact (sales) attributed to 6 GHz ($Billion)	$0.15	$0.26	$0.43	$0.67	$1.16
Indirect impact ($Billion)	$0.13	$0.16	$0.22	$0.34	$0.38
Indirect/Direct multiplier	0.91	0.63	0.52	0.50	0.33
Indirect impact ($Million)	$132.01	$164.20	$222.67	$336.75	$380.42

Sources: PwC, ABI; Telecom Advisory Services analysis

M.5. Internet Service Providers

In addition to the economic value generated by the sources analyzed above, Wi-Fi will also contribute to either producer surplus or GDP from Internet Service Providers. This section will assess the economic value in three sources:

- Producer surplus of cellular operators resulting from CAPEX savings incurred in network deployment;
- Revenues of Wi-Fi carriers offering service in public spaces; and
- Revenues of Wireless ISPs (this effect differs from the GDP impact of WISPs as a result of their deployment in rural and isolated areas analyzed in section XIV.3.5.)

M.5.1. Cellular network savings by off-loading traffic to Wi-Fi

The estimation of CAPEX savings starts by considering the GSMA Intelligence aggregate investment estimates of 5G deployment. It is assumed that all the CAPEX invested during the period would be dedicated to 5G deployment. In this context, Wi-Fi becomes a key enabler of 5G services. The upcoming flexible, radio-neutral 5G environment will be intrinsically supported by the next wave of 802.11 Wi-Fi standards (802.11n/ac, 802.11ax, WiGig), and short-range wireless technologies operating in unlicensed bands. Considering that the total CAPEX required to deploy 5G in Australia, and the country's 5G coverage reported in GSMA Intelligence, we calculate the 5G CAPEX and consequently, the savings incurred of deploying carrier-grade Wi-Fi complementing the rollout of 5G to accommodate future traffic growth, expected to amount to 32.9% of CAPEX, while the OPEX savings are $2.82 for each dollar saved in CAPEX. Based on the simulation model developed to estimate the impact of Wi-Fi off-loading in 5G deployment, we estimate savings only for 2021, when 5G coverage will reach 91%.

Table M-26. Australia: Savings due to traffic off-loading (2021-2025)

Variable	2021	2022	2023	2024	2025
5G coverage	91%	91%	91%	91%	91%
CAPEX without saving ($Million)	$6,326.3	$0.0	$0.0	$0.0	$0.0
CAPEX reduction due to Wi-Fi off-loading ($Million)	$2,081.3	$0.0	$0.0	$0.0	$0.0
OPEX reduction due to Wi-Fi off-loading ($Million)	$5,869.4	$0.0	$0.0	$0.0	$0.0
Total Cost of Ownership ($Million)	$7,951	$0	$0	$0	$0

Sources: GSMA; Telecom Advisory Services analysis

Enhanced capability for cellular off-loading if 6 GHz allocated

The complementarity between Wi-Fi and cellular networks for Wi-Fi 6E and 5G, adds further economic gains derived from the savings in capital and operating expenses required to accommodate exploding data traffic. The key objective is to estimate the savings in capital investment as a result of an increase in traffic offloading with Wi-Fi benefits from the additional spectrum allocated, particularly, due to the ability to leverage 160 MHz within single contiguous channels.

The estimation of CAPEX savings starts by considering the GSMA Intelligence aggregate investment estimates of 5G deployments. By relying on the geographic disaggregation of Oughton and Frias, we estimate that CAPEX can be split in urban, suburban, and rural geographies. To estimate the percentage of population living in areas over 1 million inhabitants, we considered those living in the metropolitan areas of Sydney, Melbourne, Perth, Brisbane, and Adelaide. The percentage of rural population was obtained from the Australian Institute of Health and Welfare, while the remaining share of the population was classified in the suburban group (see Table M-27).

Table M-27. Australia: 5G CAPEX estimated by geographical breakdown

Geography	Australia		
	Population Breakdown (%)	5G CAPEX ($Billion)	5G CAPEX (%)
Urban (cities>1 Million)	64.3%	$0.41	2.45%
Suburban	6.7%	$0.18	1.11%
Rural	29.0%	$16.05	96.44%
Total	100%	$16.64	100%

Sources: Oughton and Frias (2016); Australian Institute of Health and Welfare; GSMA; Telecom Advisory Services analysis

We conservatively assume that Wi-Fi 6 will not be critical in sustaining investment in urban areas, but that it will play a significant role beyond those geographies. Based on the cost advantage of carrier grade Wi-Fi, we assume that it will become effective for a portion of the suburban (approximately 15%) and rural network (approximately 5%) deployment. Therefore, this will yield yearly CAPEX savings of $167 million.

M.5.2. Wi-Fi carrier revenues

The economic value generated by Wi-Fi carriers includes the sum of revenues generated by commercial public Wi-Fi access. In order to estimate this value, we start by calculating the number of commercial Wi-Fi hotspots in Australia. According to the Cisco Annual Internet Report Highlights Tool 2018-2023, in 2021 there will be 6.17 million public Wi-Fi hotspots in the country, although that figure includes home spots (such as the guest account service provided by cable operators). By subtracting the home spots from the public Wi-Fi estimates of Cisco, we calculate a total of 100,000 commercial Wi-Fi hotspots for 2021, which will decrease reaching 90,000 in 2025. On the other hand, based on revenue per hotspot generated by Boingo in the United States, and adjusting the metric by PPP we estimated the value for Australia. Accordingly, this amounts to $64 million in 2021, gradually decreasing to reach $57 million in 2025 (Table M-28).

Table M-28. Australia: Revenues of Wi-Fi carriers (2021-2025)

Variable	2021	2022	2023	2024	2025
Public Wi-Fi hotspots (Million)	6.17	6.71	7.30	7.94	8.63
Home spots (Million)	6.07	6.61	7.20	7.84	8.54
Commercial Wi-Fi hotspots (Million)	0.10	0.10	0.10	0.10	0.09
Revenue per hotspot ($)	$626.83	$621.72	$616.65	$611.62	$606.64
Revenue ($Million)	$64.07	$63.14	$61.66	$59.55	$56.72

Sources: Cisco, Boingo, Telecom Advisory Services

Increased revenues of Wi-Fi carriers in public places due to 6 GHz

The allocation of the 6 GHz spectrum band offers an opportunity for commercial Wi-Fi carriers to enhance their business. As Wi-Fi 6E developments will allow up to 1,500 connected devices per access point, Wi-Fi carriers will have the possibility of adding more clients without quality limitations due to congestion. By considering a conservative potential increase of 40% in the number of connected devices in public venues and weighting that figure by the gradual expansion of the latest technology, we expect commercial Wi-Fi carriers to increase their user base by 16% in 2025. If the revenue per hotspot increases in the same amount, that will yield an increase in overall revenues for the sector of an additional $9 million by 2025 (Table M-29).

Table M-29. Australia: Revenues of Wi-Fi carriers due to 6 GHz (2021-2025)

Variable	2021	2022	2023	2024	2025
Potential increase in connected devices in public venues	40%	40%	40%	40%	40%
Traffic through the 6 GHz Channel (%)	0%	10%	20%	30%	40%
Increase in connected devices due to 6 GHz	0%	4%	8%	12%	16%
Revenue per hotspot if 6 GHz allocated ($)	$626.83	$646.59	$665.98	$685.02	$703.70
Revenue if 6 GHz allocated ($Million)	$0.00	$2.53	$4.93	$7.15	$9.07

Sources: Boingo, Telecom Advisory Services

M.5.3. Wireless ISPs revenues

The 2021 GDP contribution related to the WISP industry was calculated as a function of the number of subscribers (conservatively assumed to undergo no growth from the current base of 200,000) and the ARPU (from the United States, adjusted by PPP), yielding a total of $130 million (Table M-30).

Table M-30. Australia: WISP revenues (2021-2025)

Variable	2021	2022	2023	2024	2025
Subscribers (Million)	0.20	0.20	0.20	0.20	0.20
Revenues ($Million)	$130.07	$148.26	$155.91	$164.41	$174.84

Sources: WISPAU, Telecom Advisory Services

Increased revenues of WISPs due to 6 GHz

As described in Section M.2.5, the allocation of 6 GHz spectrum will potentially increase the WISP user base by 13,000 subscribers in 2025, due to expanded coverage and better affordability. Thus, by assuming the same ARPU values as described above, the new subscriptions will amount to an additional $11.59 million in revenues in 2025 (Table M-31).

Table M-31. Australia: WISP revenues due to 6 GHz (2021-2025)

Variable	2021	2022	2023	2024	2025
WISP annual ARPU ($)	$650.35	$741.32	$779.57	$822.05	$874.22
New subscribers if 6 GHz allocated (Million)	0.000	0.005	0.008	0.010	0.013
New revenue ($Million)	$0.00	$3.60	$5.98	$8.58	$11.59

Source: Telecom Advisory Services

M.6. Wi-Fi ecosystem

The economic value generated by Wi-Fi within Wi-Fi ecosystem companies in Australia is generated from the following two sources:

- The producer surplus of local firms providing products and services in the IoT ecosystem (hardware, software and systems integration) in Australia; and
- The producer surplus of local firms providing products and services in the AR/VR ecosystem (hardware, software and content) in Australia.

M.6.1. Firms belonging to the IoT ecosystem

According to estimates from Statista and Bain & Co, we expect total industrial IoT revenue in Australia to amount $8.3 billion in 2021. By relying on the percentage of hardware connectivity spending in IoT in Asia-Pacific, we were able to split that figure into the two main segments: (i) hardware; and (ii) software, contents, and services. By weighting those amounts by the share of local production (18% for hardware, 60% for software and services) and the margins (39.44% and 77.46%, respectively), we can estimate the overall producer surplus. However, the share attributed to 6 GHz should be subtracted from the total economic value. To do so, we estimated a natural growth rate, by subtracting the corresponding share attributed to 6 GHz spectrum according to the growth rates indicated in Section M.3.4. Thus, we estimate a producer surplus not attributed to 6 GHz of $2.5 billion in 2021, expecting to reach $5.1 billion in 2025 (Table M-32).

Table M-32. Australia: IoT ecosystem direct contribution (2021-2025)

Variable	2021	2022	2023	2024	2025
IoT revenue - Hardware ($billions)	$3.10	$3.78	$4.61	$5.62	$6.85
IoT revenue - Software, Contents, Services ($billions)	$5.16	$6.29	$7.68	$9.36	$11.42
Total Industrial IoT revenue in ($Billion)	$8.26	$10.07	$12.28	$14.98	$18.27
Local production (%) - Hardware	18%	18%	18%	18%	18%
Local production (%) - Software & Services	60%	60%	60%	60%	60%
Margins (%) - Hardware	39%	39%	39%	39%	39%
Margins (%) - Software & Services	77%	77%	77%	77%	77%
Margins - IoT Hardware revenue	$0.22	$0.27	$0.33	$0.40	$0.48
Margins - Software, contents and services IoT revenue	$2.40	$2.93	$3.57	$4.35	$5.31
Producer surplus ($Million)	$2,617.32	$3,192.21	$3,893.36	$4,748.52	$5,791.52
Growth rate (%)	10.64%	21.96%	21.96%	21.96%	21.96%
Growth rate not attributed to 6 GHz (%)	9.69%	19.43%	18.94%	18.94%	18.94%
Producer surplus not attributed to 6 GHz ($Million)	$2,541.74	$3,035.72	$3,610.79	$4,294.81	$5,108.41

Sources: Statist; Bain & Co; CSI; Telecom Advisory Services analysis

Wider deployment of Internet of Things under 6 GHz

Following the previous analysis, we were able to estimate which portion of IoT producer surplus growth can be attributed to the 6 GHz spectrum. As Table M-33 indicates, we expect the additional IoT surplus generated by 6 GHz to account for $683 million in 2025.

Table M-33. Australia: IoT direct contribution attributed to 6 GHz (2021-2025)

Variable	2021	2022	2023	2024	2025
Producer surplus ($Million)	$2,617.32	$3,192.21	$3,893.36	$4,748.52	$5,791.52
Producer surplus not attributed to 6 GHz ($Million)	$2,541.74	$3,035.72	$3,610.79	$4,294.81	$5,108.41
Additional surplus due to 6 GHz ($Million)	$75.58	$156.49	$282.57	$453.71	$683.11

Sources: Statista; Bain & Co; CSI; Telecom Advisory Services analysis

M.6.2. Firms belonging to the AR/VR ecosystem

Following a similar approach as in the case of IoT, we estimated the direct contribution of this ecosystem to the Australian economy. Starting with the local spending in AR/VR by category (hardware, software, and contents), and apportioning those figures by the respective shares of local production and margins, we were able to estimate the total producer surplus. By relying on a ratio built from 6 GHz AR/VR related products, we were able to subtract the specific contribution attributed to 6 GHz from the surplus corresponding to current spectrum bands. Accordingly, we expect by 2021 a direct contribution from the AR/VR ecosystem of $86 million, increasing to reach $393 million by 2025 (Table M-34).

Table M-34. Australia: AR/VR ecosystem direct contribution (2021-2025)

Variable	2021	2022	2023	2024	2025
Spending in AR/VR - Hardware $Billion	$0.18	$0.31	$0.52	$0.84	$1.34
Spending in AR/VR - Software, Contents, Services ($Billion)	$0.42	$0.71	$1.10	$1.57	$2.68
Total Spending in AV/VR ($Billion)	$0.59	$1.02	$1.62	$2.41	$4.02
Share of local production - Hardware	17.90%	17.90%	17.90%	17.90%	17.90%
Share of local production - Software, Contents, Services	60.00%	60.00%	60.00%	60.00%	60.00%
Local production for local consumption - Hardware ($Billion)	$0.03	$0.06	$0.09	$0.15	$0.24
Local production for local consumption - Software, Contents, Services ($Billion)	$0.25	$0.43	$0.66	$0.94	$1.61
Local Producer Surplus - Hardware ($Billion)	$0.01	$0.02	$0.04	$0.06	$0.09
Local Producer Surplus - Software, Contents, Services ($Billion)	$0.19	$0.33	$0.51	$0.73	$1.25
Total Producer Surplus	$0.21	$0.35	$0.55	$0.79	$1.34
Share attributable to Wi-Fi (excluding 6 GHz)	42.02%	38.80%	32.18%	30.88%	29.32%
Producer Surplus attributed to Wi-Fi (not including 6 GHz) ($Million)	$86.33	$136.50	$175.71	$243.20	$392.85

Sources: PwC, ABI; Telecom Advisory Services analysis

Wider deployment of AR/VR solutions if 6 GHz allocated

By relying on a ratio developed to estimate 6 GHz AR/VR related products, we isolated the specific economic contribution of the new spectrum allocation. Following an approach similar as that one described above, the direct contribution from AR/VR ecosystem in Australia attributed to 6 GHz will yield $387 million in 2025 (see Table M-35).

Table M-35. Australia: AR/VR direct contribution attributed to 6 GHz (2021-2025)

Variable	2021	2022	2023	2024	2025
Spending in AR/VR ($Billion)	$0.59	$1.02	$1.62	$2.41	$4.02
Share attributed to 6 GHz (%)	24.58%	25.59%	26.64%	27.73%	28.87%
Spending in AR/VR attributed to 6 GHz ($Billion)	$0.15	$0.26	$0.43	$0.67	$1.16
Local production for local consumption 6 GHz ($Billion)	$0.07	$0.12	$0.20	$0.30	$0.53
Local Producer Surplus ($Million)	$50.50	$90.02	$145.47	$218.41	$386.82

Sources: PwC; ABI; Telecom Advisory Services analysis

M.7. Wi-Fi contribution to employment

The estimation of employment generated by Wi-Fi's economic value is calculated by relying on the sum of total GDP contribution resulting from the effects analyzed above and using that as an input to the communications sector of an input-output matrix of the Australian economy. Table M-36 presents the GDP contribution, as sum of all GDP sources discussed above, enabled by Wi-Fi projected for the period 2021-2025.

Table M-36. Australia: Wi-Fi enabled GDP contribution (2021-2025)

Year	GDP contribution enabled by Wi-Fi ($Million)		
	Attributed to current bands	Attributed to 6 GHz	Total
2021	$6,604	$245	$6,850
2022	$6,759	$962	$7,721
2023	$7,951	$1,761	$9,712
2024	$8,107	$2,408	$10,514
2025	$8,585	$3,028	$11,613

Source: Telecom Advisory Services analysis

These inputs generate the following annual employment effects based on the Input/output matrix for the Australian economy (Table M-37).

Table M-37. Australia: Wi-Fi generated Annual Employment

Variable	2021			2025		
	Current bands	6 GHz	Total	Current bands	6 GHz	Total
Direct jobs	7,796	0,289	8,085	10,134	3,574	13,708
Indirect jobs	10,630	0,395	11,024	13,817	4,873	18,691
Induced jobs	3,079	0,114	3,193	4,003	1,412	5,414
Total	21,505	0,798	22,303	27,954	9,859	37,813

Sources: GTAP; Telecom Advisory Services analysis

Based on the contribution to GDP, Wi-Fi will generate approximately 22,300 jobs in 2021 and is expected to create over 37,800 in 2025. Job estimates include direct jobs (those jobs created by the specific Wi-Fi contribution), indirect jobs (those jobs created by suppliers to the Wi-Fi sector), and induced jobs (those jobs created by spending of direct and indirect workers).

The sector breakdown of 2021 employment (including the additional jobs created by 6 GHz) is as follows (Table M-38).

Table M-38. Australia: Sector Breakdown of Wi-Fi generated annual employment (2021)

Sector	Direct	Indirect	Induced	Total
Agriculture	0	0	96	96
Extractive industries	0	0	24	24
Manufacturing	0	599	52	650
Construction	0	508	0	508
Trade	0	1,019	1,407	2,426
Transportation	0	1,297	0	1,297
Communications	8,085	0	0	8,085
Financial Services	0	1,030	0	1,030
Business services	0	6,572	0	6,572
Other services	0	0	1,615	1,615
Total	8,085	11,024	3,193	22,303

Sources: GTAP; Telecom Advisory Services analysis

N. ECONOMIC VALUE OF WI-FI IN NEW ZEALAND

Wi-Fi has become a pervasive feature in New Zealand telecommunications landscape. According to the Wiman site estimates that there are currently 151,400 open hotspots in the country (of which, 37,000 in Auckland, 22,000 in Wellington, and 26,000 in North Shore). The increasing importance of Wi-Fi technology in the digital infrastructure ecosystem of New Zealand should result in a significant social and economic contribution. This section presents the results and calculations of the economic assessment. The methodology reviewed in section B was used to calculate each source of economic value.

N.1. Total Economic Value of Wi-Fi in New Zealand (2021-2025)

Before considering the additional effect of allocating the 6 GHz spectrum band for unlicensed use, the total economic value of Wi-Fi in New Zealand in 2021 will amount to $6.6 billion, broken down by $2.4 billion in consumer surplus, $2.8 billion in producer surplus, and $1.4 billion in a net contribution to GDP. Even before accounting for the acceleration effect resulting from the allocation of the 6 GHz band, the 2025 forecast of economic value will reach $8.8 billion, composed of $4.4 billion in consumer surplus, $3.1 billion in producer surplus, and $1.4 billion in GDP contribution (see Table N-1).

Table N-1. New Zealand: Economic Value of Wi-Fi (Baseline Scenario)

Agent	Source	Economic Value ($Million)					
		2021	2022	2023	2024	2025	Category
1. Free Wi-Fi	1.1. Savings generated by free Wi-Fi traffic offered in public sites	$35	$33	$31	$28	$25	Consumer Surplus
	1.2. Deployment of free Wi-Fi in public sites	$262	$245	$226	$207	$187	GDP contribution
2. Residential Wi-Fi	2.1. Internet access for home usage of devices that lack a wired port	$1,119	$1,423	$1,807	$2,294	$2,913	Consumer Surplus
	2.2. Avoidance of investment in in-house wiring	$904	$964	$1,026	$1,035	$1,043	Consumer Surplus
	2.3. Benefit to consumers from speed increases	$25	$39	$55	$70	$86	Consumer Surplus
	2.4. Residential Wi-Fi devices and equipment deployed	$293	$300	$309	$304	$294	Consumer Surplus
	2.5. Bridging digital divide: use of Wi-Fi to increase coverage in rural and isolated areas	$362	$370	$378	$387	$395	GDP contribution
3. Enterprise Wi-Fi	3.1. Business Internet traffic transmitted through Wi-Fi	$712	$802	$904	$1,018	$1,147	Producer surplus
	3.2. Avoidance of enterprise inside wiring costs	$1,119	$1,111	$1,102	$1,094	$1,086	Producer surplus
	3.3. Return to speed: contribution to GDP derived from an increase in average mobile speed	$84	$128	$178	$233	$295	GDP contribution
	3.4. Wide deployment of IoT	$540	$240	$240	$246	$252	GDP contribution
	3.5. Deployment of AR/VR solutions	$34	$38	$42	$58	$62	GDP contribution

Agent	Source	Economic Value ($Million)					
		2021	2022	2023	2024	2025	Category
4. ISPs	4.1. CAPEX and OPEX savings due to cellular off-loading	$618	$408	$293	$161	$45	Producer surplus
	4.2. Revenues of service providers offering paid Wi-Fi access in public places	$21	$22	$22	$23	$23	GDP contribution
	4.3. Aggregated revenues of WISPs	$125	$147	$159	$173	$189	GDP contribution
5. Wi-Fi ecosystem	5.1. Locally manufactured residential Wi-Fi devices and equipment	$0	$0	$0	$0	$0	Producer surplus
	5.2. Locally manufactured Wi-Fi enterprise equipment	$0	$0	$0	$0	$0	Producer surplus
	5.3. Locally produced IoT products and services	$373	$446	$530	$631	$750	Producer surplus
	5.4. Locally produced of AR/VR solutions	$12	$20	$25	$35	$56	Producer surplus
Total		$6,638	$6,736	$7,327	$7,997	$8,848	

Sources: Telecom Advisory Services analysis

In addition to the value generated from the unlicensed use of the 2.4 GHz and 5 GHz bands (referred to as the baseline scenario), the allocation of the 6 GHz spectrum band for unlicensed use and the deployment of Wi-Fi 6 and Wi-Fi 6E devices will trigger an additional boost in economic value, reaching $956 million in 2025 (see Table N-2).

Table N-2. New Zealand: Economic Value of Wi-Fi (only attributed to 6 GHz)

Agent	Source	Economic Value ($millions)					
		2021	2022	2023	2024	2025	Category
1. Free Wi-Fi	1.1. Savings generated by free Wi-Fi traffic offered in public sites	$0	$1	$2	$4	$7	Consumer Surplus
	1.2. Deployment of free Wi-Fi in public sites	$0	$23	$41	$56	$65	GDP contribution
	1.3. Benefit of faster free Wi-Fi with Wi-Fi 6E devices	$0	$2	$3	$4	$5	Consumer Surplus
2. Residential Wi-Fi	2.3. Benefit to consumers from speed increases	$0	$6	$16	$28	$43	Consumer Surplus
	2.4. Residential Wi-Fi devices and equipment deployed	$11	$26	$56	$86	$116	Consumer Surplus
	2.5. Bridging digital divide: use of Wi-Fi to increase coverage in rural and isolated areas	$0	$90	$146	$201	$249	GDP contribution
3. Enterprise Wi-Fi	3.1. Business Internet traffic transmitted through Wi-Fi	$0	$16	$22	$30	$38	Producer surplus
	3.3. Return to speed: contribution to GDP derived from an increase in average mobile speed	$0	$20	$49	$89	$140	GDP contribution
	3.4. Wide deployment of Internet of Things	$26	$31	$38	$39	$40	GDP contribution
	3.5. Deployment of AR/VR solutions	$20	$25	$35	$52	$61	GDP contribution

Agent	Source	Economic Value ($millions)					
		2021	2022	2023	2024	2025	Category
4. ISPs	4.1 CAPEX and OPEX savings due to cellular off-loading	$21	$21	$21	$21	$21	Producer surplus
	4.2. Revenues of service providers offering paid Wi-Fi access in public places	$0	$1	$2	$3	$4	GDP contribution
	4.3. Aggregated revenues of WISPs	$0	$3	$6	$9	$11	GDP contribution
5. Wi-Fi ecosystem	5.1. Locally manufactured residential Wi-Fi devices and equipment	$0	$0	$0	$0	$0	Producer surplus
	5.2. Locally manufactured Wi-Fi enterprise equipment	$0	$0	$0	$0	$0	Producer surplus
	5.3. Locally produced IoT products and services	$11	$23	$42	$67	$100	Producer surplus
	5.4. Locally produced of AR/VR solutions	$7	$13	$21	$31	$56	Producer surplus
Total		$96	$301	$500	$720	$956	

Source: Telecom Advisory Services analysis

Considering that by 2025 only 40% of Wi-Fi traffic will rely on the 6 GHz channels, the accelerated effect derived from the new spectrum allocation and latest Wi-Fi technologies will still be far from reaching its maximum potential at this time.

By combining the baseline and the Wi-Fi 6 and 6 GHz scenarios, the overall economic value of Wi-Fi for New Zealand will yield $9.8 billion in 2025 (see Table N-3).

Table N-3. New Zealand: Total Economic Value of Wi-Fi (including Wi-Fi 6 and 6 GHz)

Agent	Source	Economic Value ($Million)					
		2021	2022	2023	2024	2025	Category
1. Free Wi-Fi	1.1. Savings to consumers of free Wi-Fi traffic offered in public sites	$35	$33	$33	$32	$31	Consumer Surplus
	1.2. Deployment of free Wi-Fi in public sites	$262	$268	$268	$263	$252	GDP contribution
	1.3. Benefit of faster free Wi-Fi with Wi-Fi 6E devices	$0	$2	$3	$4	$5	Consumer Surplus
2. Residential Wi-Fi	2.1. Internet access for home usage of devices that lack a wired port	$1,119	$1,423	$1,807	$2,294	$2,913	Consumer Surplus
	2.2. Avoidance of investment in in-house wiring	$904	$964	$1,026	$1,035	$1,043	Consumer Surplus
	2.3. Benefit to consumers from speed increases	$25	$45	$71	$98	$129	Consumer Surplus
	2.4. Residential Wi-Fi devices and equipment deployed	$303	$326	$364	$390	$410	Consumer Surplus
	2.5. Bridging digital divide: use of Wi-Fi to increase coverage in rural and isolated areas	$362	$460	$524	$587	$644	GDP contribution
3. Enterpris	3.1. Business Internet traffic transmitted through Wi-Fi	$712	$819	$926	$1,048	$1,186	Producer surplus

Agent	Source	Economic Value ($Million)					
		2021	2022	2023	2024	2025	Category
	3.2. Avoidance of enterprise inside wiring costs	$1,119	$1,111	$1,102	$1,094	$1,086	Producer surplus
	3.3. Return to speed: contribution to GDP derived from an increase in average mobile speed	$84	$148	$227	$322	$435	GDP contribution
	3.4. Wide deployment of IoT	$566	$272	$278	$285	$292	GDP contribution
	3.5. Deployment of AR/VR solutions	$55	$64	$76	$111	$122	GDP contribution
4. ISPs	4.1 CAPEX and OPEX savings due to cellular off-loading	$639	$428	$314	$182	$66	Producer surplus
	4.2. Revenues of service providers offering paid Wi-Fi access in public places	$21	$22	$24	$25	$26	GDP contribution
	4.3. Aggregated revenues of WISPs	$125	$150	$165	$181	$201	GDP contribution
5. Wi-Fi ecosystem	5.1. Locally manufactured residential Wi-Fi devices and equipment	$0	$0	$0	$0	$0	Producer surplus
	5.2. Locally manufactured Wi-Fi enterprise equipment	$0	$0	$0	$0	$0	Producer surplus
	5.3. Locally produced IoT products and services	$384	$469	$572	$698	$851	Producer surplus
	5.4. Locally produced of AR/VR solutions	$20	$33	$46	$66	$112	Producer surplus
Total		$6,735	$7,037	$7,826	$8,715	$9,804	

Source: Telecom Advisory Services analysis

The following sections will present in detail the calculation of each source of value, disaggregating the economic contribution between the current spectrum allocation and the enhanced effect due to Wi-Fi 6 availability and the 6 GHz band.

N.2. Value from free Wi-Fi service

The economic value of free Wi-Fi service originates from three contribution sources:

- Savings to consumers by accessing the Internet in free Wi-Fi sites rather than incurring cellular costs;
- The use of Wi-Fi to expand broadband coverage to the unserved population; and
- The return to speed of Wi-Fi compared to the use of cellular service.

N.2.1. Savings incurred by accessing free Wi-Fi in public sites

The economic value of free Wi-Fi is measured in terms of consumer surplus, calculated by estimating the benefit that flows to consumers as a result of savings incurred by not relying on cellular service. We begin by forecasting the traffic generated at free Wi-Fi access points. In order to isolate the effect from the increased capacity derived from the 6 GHz allocation, we calculate the portion of free Wi-Fi traffic attributed to current spectrum bands. For this, we relied on the assumption (verified in field studies) that current traffic levels are already producing congestion in most free Wi-Fi hotspots at times of peak demand. Thus, we assume that traffic per hotspot beyond 2021 will remain at 2020 levels (515.33 GB), although overall free traffic will continue growing as new hotspots will be deployed (see Table N-4).

Table N-4. New Zealand: Total Free Wi-Fi Traffic projection (2021-2025)

Variable	2021	2022	2023	2024	2025
Free Wi-Fi traffic (million GB Per year) - considering current trends	98.56	126.24	163.98	215.89	287.83
Free Wi-Fi hotspots (Million)	0.18	0.21	0.24	0.28	0.33
Traffic per hotspot - considering current trends	556.26	608.92	676.00	760.67	866.74
Traffic per hotspot - capped due to congestion	515.33	515.33	515.33	515.33	515.33
Total traffic (not attributed to 6 GHz) (Million GB)	91.31	106.84	125.00	146.26	171.13

Sources: Cisco; Wiman; Telecom Advisory Services analysis

We calculate consumer surplus by multiplying the total free traffic (not attributed to 6 GHz) by the difference between what the consumer would have to pay if she/he were to rely on a wireless carrier and the cost of offering free Wi-Fi (incurred by the retailer or public site). To do so, we needed an estimate of the average price per GB of wireless data transmitted by cellular networks, which we calculated by averaging the most economic "dollar per GB" plan of four major wireless carriers in New Zealand[260] (see Table N-5).

Table N-5. New Zealand: Average Price Per Gigabyte (2020)

Carrier	Plan	Price per GB ($)
Spark	Unlimited speed	$1.34
2degrees (Trilogy)	40 GB	$1.42
Vodafone	Extra Large	$0.67

Note: The average price per GB is converted to U.S. dollars in order to calculate total economic value.

Sources: Operator websites; Telecom Advisory Services analysis

Historical data allowed for a projection of future prices per gigabyte. Based on these prices, we expect the average price per GB will reach an estimated $0.68 in 2025 from $1.03 in 2021. By relying on the total free Wi-Fi traffic not attributed to 6 GHz allocation shown in Table N-4 and the average price per cellular gigabyte minus the cost of provisioning Wi-Fi service, we calculated the consumer surplus of free Wi-Fi traffic (see Table N-6).

Table N-6. New Zealand: Consumer Surplus of Free Wi-Fi Traffic (2021-2025)

Variable	2021	2022	2023	2024	2025
Total Free Traffic (not attributed to 6 GHz) (Million GB)	91.31	106.84	125.00	146.26	171.13
Price per cellular gigabyte ($)	$1.03	$0.93	$0.84	$0.75	$0.68
Cost per Wi-Fi provisioning ($)	$0.65	$0.62	$0.59	$0.56	$0.53
Consumer surplus per gigabyte ($)	$0.38	$0.31	$0.25	$0.19	$0.14
Total Consumer surplus ($Million)	$34.70	$32.87	$30.70	$28.01	$24.69

Source: Telecom Advisory Services analysis

[260] The average is calculated by prorating every price per GB by the carrier's market share.

As indicated in Table N-6, consumer surplus of free Wi-Fi traffic in 2021 would reach an estimated $34.7 million, decreasing to $24.7 million in 2025 due to lower prices and the congestion created if the 6 GHz spectrum is not allocated.

Enhanced free Wi-Fi traffic due to 6 GHz allocation

The allocation of the 6 GHz spectrum band coupled with the technological advances provided by the Wi-Fi 6 standard will remove the above-mentioned bottlenecks causing congestion. As a result, the traffic per hotspot will be able to continue growing at its natural rate as determined by the extrapolation of past recent trends. That being said, we must take into account that not all Wi-Fi traffic will benefit immediately from opening the 6 GHz band, as most current wireless devices are not prepared to support the new standards. Thus, we expect the traffic through the 6 GHz channel to gradually increase until reaching a 40% of total free traffic by 2025.

Once computed the additional traffic "above and beyond" the future previsions under current spectrum bands, we follow a similar approach to calculate the consumer surplus, multiplying it by the difference between what the consumer would have to pay if he were to utilize a wireless carrier and the cost of offering free Wi-Fi (Table N-7). As a result, we project an additional consumer surplus of $6.7 million from free Wi-Fi traffic attributed to 6 GHz in 2025.

Table N-7. New Zealand: Additional Consumer Surplus of Free Wi-Fi Traffic generated due to 6 GHz (2021-2025)

Variable	2021	2022	2023	2024	2025
Demand not satisfied due to congestion (Million GB)	7.25	19.40	38.97	69.63	116.70
Traffic through the 6 GHz Channel (%)	0%	10%	20%	30%	40%
Total traffic (attributed to 6 GHz) (Million GB)	0.00	1.94	7.79	20.89	46.68
Consumer Surplus (attributed to 6 GHz) ($Million)	$0.00	$0.60	$1.91	$4.00	$6.74

Source: Telecom Advisory Services analysis

The additional surplus generated by the allocation of the 6 GHz spectrum band will mitigate the decreasing trend of consumer surplus derived from free Wi-Fi under the current spectrum allocation.

N.2.2. Free Wi-Fi to provide broadband to the unserved population

As explained in section B, free Wi-Fi in public sites can provide Internet access to the unserved population. Consumers that do not have broadband at home because they lack the economic means to acquire services can rely on free Wi-Fi to gain Internet access. The net result is that more people can be connected, which in turn enhances the economic contribution of broadband.

The estimation of this particular economic impact starts by calculating which portion of households that lack broadband service at home are already accessing Internet through free hotspots. Total households' evolution was estimated from Stats NZ data, while the percentage unconnected was estimated based on data from the local ISP survey[261]. We follow a conservative approach and assume that only 5% of unconnected households rely on free hotspots for accessing Internet. After calculating the increase in broadband penetration due to households relying on free Wi-Fi, we rely on the broadband impact coefficient calculated by Katz and Callorda (2018b) in their econometric models developed for Asia-Pacific. As a result, the GDP contribution of this particular effect is expected to amount to $262 million in 2021, decreasing to $187 million in 2025 due to the expected decline in unconnected households, which will reduce the quantity of families relying on free hotspots for accessing Internet (see Table N-8).

Table N-8. New Zealand: GDP contribution due to households relying on Free Wi-Fi (2021-2025)

Variable	2021	2022	2023	2024	2025
Households without Internet	262,026	244,792	226,755	207,178	186,880
Households that don't buy because access Internet free hotspots (%)	5%	5%	5%	5%	5%
Households served by Free Wi-Fi hot spots	13,101	12,240	11,338	10,359	9,344
Increase in national broadband penetration	0.8%	0.7%	0.7%	0.6%	0.5%
Impact of fixed broadband adoption in GDP	16.32%	16.32%	16.32%	16.32%	16.32%
Increase in the GDP due to the new broadband adoption (% GDP)	0.13%	0.12%	0.11%	0.10%	0.08%
GDP ($Billion)	$201.19	$206.41	$211.50	$216.77	$222.16
Total impact in GDP ($Million)	$262.29	$244.83	$226.31	$207.09	$187.09

Sources: Stats NZ; Telecom Advisory Services analysis

Enhanced GDP contribution due to 6 GHz allocation

As stated above, Wi-Fi 6 technology operating in the 6 GHz band supports a higher number of devices per access point than Wi-Fi sites relying on the 2.4 GHz and 5 GHz bands. Accordingly, the improved throughput of free Wi-Fi hotspots under the 6 GHz allocation will allow to serve additional unconnected households. The potential universe of additional users that could be served under this effect is significant, as most unconnected households usually identify that costs are their main barrier for accessing to connectivity and thus, may potentially be served by free hotspots as long as they are in proximity to the access point. However, evidence suggests that not many people undergoing the affordability barrier rely exclusively on free Wi-Fi as their main source of Internet access[262], so we will follow again a conservative approach and assume that a further 5% of unconnected households will be served through free hotspots under the allocation of the 6 GHz band. On the other hand, we have also considered that the expansion of traffic through the new band will take place gradually, reaching 40% in 2025. All in all, we estimate that additional 3,259 households in New Zealand will be served by free hotspots operating under 6 GHz spectrum in 2025, yielding an additional GDP contribution of approximately $65 million (Table N-9).

[261] The ISP Survey is an annual survey from Stats NZ that is sent to all operators in New Zealand. The reviewed information was obtained from Billd (2018): "Digital Divide worse than appears in latest report", 20/20 Trust (June 22nd)

[262] They tend to use also broadband service provided at work or at an educational institution.

Table N-9. New Zealand: GDP contribution due to households relying on Free Wi-Fi due to 6 GHz (2021-2025)

Variable	2021	2022	2023	2024	2025
Households without Internet (not served by free Wi-Fi and not new adopters of WISP)	248,924	227,430	207,030	185,160	162,935
Potential households that could be served through free Wi-Fi hotspots under increased capacity (% of those not connected)	5%	5%	5%	5%	5%
Traffic through the 6 GHz Channel (%)	0%	10%	20%	30%	40%
Additional households served by Free Wi-Fi hot spots with 6 GHz	0	1,137	2,070	2,777	3,259
Increase in national broadband penetration	0	0.068%	0.12%	0.16%	0.18%
Increase in the GDP due to the new broadband adoption (% GDP)	0	0.01%	0.02%	0.03%	0.03%
Total impact in GDP ($Million)	$0.00	$22.75	$41.32	$55.52	$65.25

Sources: Stats NZ; Telecom Advisory Services analysis

N.2.3. Benefit to consumers for enjoying higher speed from free Wi-Fi if 6 GHz band is allocated

When the 6 GHz band is adopted by free Wi-Fi access points it will deliver service at faster broadband speeds. Current speeds from free hotspots are quite modest[263]. Thus, the expanded capabilities due to the allocation of 6 GHz spectrum band will enhance free Wi-Fi speed, and as a result, will increase consumer surplus. We assume that under the 6 GHz allocation, speed from free hotspots will be similar to the Wi-Fi speeds from mobile devices reported by Cisco. After calculating the average speed by considering the expected share of traffic through 6 GHz, we follow Nevo et al. (2016) in the estimate of willingness-to-pay for speed and calculate the additional consumer surplus per household relying on free Wi-Fi. We expect the consumer surplus resulting from faster speed in free Wi-Fi sites to reach $5 million in 2025 (Table N-10).

Table N-10. New Zealand: Consumer surplus for enjoying higher speed from free Wi-Fi if 6 GHz band allocated (2021-2025)

Variable	2021	2022	2023	2024	2025
Free Wi-Fi mean speed with no 6 GHz (Mbps)	10.46	11.61	12.89	13.28	13.68
Wi-Fi Speeds from Mobile Device (Mbps)	59.82	72.14	87.00	104.92	126.54
Traffic through the 6 GHz Channel (%)	0.00%	10.00%	20.00%	30.00%	40.00%
Free Wi-Fi mean speed with 6 GHz (Mbps)	10.46	17.67	27.71	40.77	58.83
Demand for average download speed	83.30	84.62	85.88	85.28	84.68
New Demand for average download speed	83.30	95.05	104.62	112.33	119.32
Additional Monthly Consumer surplus	$0.00	$10.43	$18.74	$27.05	$34.63
Additional Yearly Consumer Surplus	$0.00	$125.18	$224.90	$324.58	$415.58
Households that rely on Free Wi-Fi	13,101	13,377	13,408	13,136	12,603
Consumer surplus ($Million)	$0	$2	$3	$4	$5

Sources: Rotten Wi-Fi; Cisco; Nevo et al. (2016); Telecom Advisory Services analysis

[263] Given the lack of reliable data on free Wi-Fi speed in New Zealand, we made an estimation based on U.S. data, applying the percentage difference between both countries in terms of fixed broadband speed. Accordingly, we estimate free Wi-Fi speed in New Zealand to reach 9.4 Mbps in 2020.

N.3. Residential Wi-Fi

The economic value of Wi-Fi in consumer residences is the result of five factors:

- Provision of connectivity to the home network for devices that lack an Ethernet port;
- Cost avoidance of ethernet inside wiring;
- Consumer surplus resulting from faster broadband speeds relative to cellular networks;
- Consumer surplus derived from usage of home devices connected to the home network; and
- Provision of Internet access to consumers located in rural and isolated areas.

N.3.1. Home Internet access for devices that lack an Ethernet port

The underlying premise of this analysis is that in the absence of Wi-Fi, users of devices lacking an Ethernet port would have to depend on the cellular network to gain Internet access. For this reason, estimating value would first measure the traffic generated by these devices at home and then multiply it by the average price charged by cellular carriers.

To estimate the traffic of smartphones and tablets, we relied on the 2019 Cisco Visual Networking Index estimates for the period 2017/22 and extrapolated those growth rates to 2025. In addition, considering that according to Cisco IBSG (2012), 43.12% of use time of devices that lack an Ethernet port occurs at home, the portion of said traffic generated at home in New Zealand will reach 1,085 million gigabytes in 2021. If this traffic had to be transported by cellular networks, at the average price per GB estimated above (Table N-5), it would result in costs of $1.1 billion in 2021 reaching $2.9 billion in 2025 (see Table N-11).

Table N-11. New Zealand: Total Mobile Internet Traffic (2021-2025) (million gigabytes)

Variable	2021	2022	2023	2024	2025
Total Annual traffic - Smartphones	1,887.0	2,734.0	3,940.7	5,666.1	8,138.7
Total Annual traffic - Tablets	630.4	824.0	1,077.1	1,407.8	1,840.1
Share of traffic at Home	43.12%	43.12%	43.12%	43.12%	43.12%
Total Traffic at Home - Smartphones	813.6	1,178.8	1,699.1	2,443.1	3,509.2
Total Traffic at Home - Tablets	271.8	355.3	464.4	607.0	793.4
Total Traffic at Home	1,085.5	1,534.1	2,163.6	3,050.1	4,302.6
Average Price per GB ($)	$1.03	$0.93	$0.84	$0.75	$0.68
Price per home traffic ($Million)	$1,118.52	$1,423.28	$1,807.14	$2,293.72	$2,913.11

Sources: Cisco; GSMA; Telecom Advisory Services analysis

N.3.2. Avoidance of inside wiring investment

Residential Wi-Fi allows consumers to avoid paying for wiring to connect all home devices (printers, laptops, storage units, etc.). Considering that 90% of connected households in New Zealand will have Wi-Fi in 2021[264], and the estimated wiring cost per household[265], the avoidance costs of inside wiring over 1.4 million households yields a total of $904 million. By 2025, all connected households are expected to have adopted Wi-Fi. Therefore, the savings from inside wiring avoidance would have reached $1 billion (Table N-12).

Table N-12. New Zealand: Consumer surplus from avoidance of investment in in-house wiring (2021-2025)

Variable	2021	2022	2023	2024	2025
Total Wiring Cost	$612.74	$603.35	$594.11	$585.01	$576.05
Households with Internet	1,640,065	1,684,065	1,729,245	1,769,577	1,810,850
Households with Wi-Fi (%)	90%	95%	100%	100%	100%
Households with Internet and Wi-Fi	1,475,226	1,598,152	1,726,613	1,769,577	1,810,850
Inside Wiring Costs ($Million)	$904	$964	$1,026	$1,035	$1,043

Sources: Stats NZ; Watkins (2012); Telecom Advisory Services analysis

N.3.3. Benefits derived from speed increase

As described before, consumer surplus increases if users enjoy faster Internet speeds. Thus, the welfare of residential Wi-Fi customers is expected to benefit from faster services than those provided by cellular networks. After weighting the corresponding broadband speeds with the percentage of traffic carried out through Wi-Fi at home, we calculated the average speed advantage of using Wi-Fi in comparison to cellular networks. By applying the willingness-to-pay coefficient for broadband speed determined in Nevo et al. (2016), the expected consumer surplus will amount to $25 million in 2021, increasing to $86 million in 2025.

Table N-13. New Zealand: Consumer surplus from faster speed in households (2021-2025)

Variable	2021	2022	2023	2024	2025
Average Speed in households if Wi-Fi traffic were carried through mobile networks (Mbps)	62.98	73.62	85.93	100.14	116.58
Average Speed in household with Wi-Fi (Mbps)	66.60	79.90	95.82	114.90	137.76
Demand for average download speed	128.64	130.55	132.34	134.00	135.56
New Demand for average download speed	130.05	132.59	135.00	137.32	139.52
Additional Monthly Consumer surplus	$1.41	$2.03	$2.67	$3.31	$3.97
Additional Yearly Consumer Surplus	$16.94	$24.40	$32.02	$39.76	$47.58
Households with Internet and Wi-Fi	1,475,226	1,598,152	1,726,613	1,769,577	1,810,850
Impact ($Million)	$25	$39	$55	$70	$86

Sources: Cisco; Nevo et al. (2016); Telecom Advisory Services analysis

Additional benefit to consumers from speed increase due to 6 GHz

The well-being of residential Wi-Fi customers is expected to receive an additional benefit from the 6 GHz allocation due to faster Internet service under Wi-Fi 6E. As

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[264] Assuming a similar figure than in United States
[265] We estimate for New Zealand a similar value as in the U.S., adjusted by PPP differences.

previously described in Chapter III, only households acquiring a 150 Mbps (or faster) fixed broadband line will receive the benefit since they are undergoing current router bottlenecks. To assess the percentage of households with connections above 150 Mbps, we interpolated from OECD estimates for New Zealand by speed tiers and assumed that it will evolve up to 2025 following a similar growth rate as Cisco locally projects the increase for the 100 Mbps segment. After calculating the difference in average speed attributed to 6 GHz, the additional consumer surplus will yield $43 million in 2025 (see Table N-14).

Table N-14. New Zealand: Consumer surplus from faster speed in households if 6 GHz allocated (2021-2025)

Variable	2021	2022	2023	2024	2025
Households that have connections over 150 Mbps (%)	3.27%	4.13%	5.22%	6.61%	8.36%
Percentage of household traffic that goes through Wi-Fi	77.88%	80.26%	82.43%	84.42%	86.21%
Traffic through the 6 GHz Channel (%)	0.00%	10.00%	20.00%	30.00%	40.00%
Share of traffic affected due to 6 GHz (%)	0.00%	0.33%	0.86%	1.67%	2.88%
Average speed with no 6 GHz (Mbps)	66.60	79.90	95.82	114.90	137.76
Average speed with 6 GHz (Mbps)	66.60	80.96	98.87	121.34	149.64
Demand for average download speed	130.05	132.59	135.00	137.32	139.52
New Demand for average download speed	130.05	132.91	135.77	138.63	141.49
Additional Yearly Consumer Surplus	$0.00	$3.94	$9.21	$15.79	$23.57
Households with Wi-Fi	1,475,226	1,598,152	1,726,613	1,769,577	1,810,850
Impact ($Million)	$0	$6	$16	$28	$43

Sources: OECD; Cisco; Nevo et al. (2016); Telecom Advisory Services analysis

N.3.4. Residential Wi-Fi devices and equipment

The consumer surplus derived from the adoption of residential Wi-Fi devices and equipment focuses on seven consumers products which are intrinsically linked to Wi-Fi: smart home devices and systems such as Wi-Fi speakers and home security systems, home networking systems, Wi-Fi tablets, access points, external adapters, routers, and gateways. Two different approaches are used in these cases: one assuming that consumer surplus is roughly equal to producer surplus in six of the seven products (excluding tablets), and an assessment of tablets' willingness-to-pay.

The estimation of economic value in the first approach begins by compiling local sales in the six product categories in New Zealand[266]. After computing the sales in New Zealand, we applied the prorated margin estimated by CSI markets (39.44%) which yields an estimated producer surplus for these particular products of $283 million in 2021. As mentioned above, it is assumed that the consumer surplus is of the same magnitude. This methodology was also used to calculate the consumer surplus up to 2023. However, the gradual adoption of Wi-Fi 6 devices is forecast to reduce the sales and economic value from the devices relying on the 2.4 GHz and 5 GHz spectrum bands. Non 6 GHz consumer devices shipments are expected by IDC to decrease by 1.2% in 2024 and-3.1% in 2025. Based on this estimate, we

[266] Calculated by prorating data for the United States based on GDP.

extrapolated the consumer surplus from non 6 GHz reliant residential Wi-Fi devices and equipment between 2021 and 2025.

Additionally, we also calculated the consumer surplus attributed to tablets bought by local consumers. Starting with CTA/Statista worldwide tablet revenue estimates, we interpolated the revenue figures for New Zealand (prorating by the country's share of global GDP), and extrapolating the evolution of local revenue up to 2025 by considering Cisco estimates of tablet evolution for the period. We reviewed the data on tablet prices for the market leader (taking as a reference the Apple iPad 10.2 Inch 128 GB, as Apple has 75% of the local market share in tablets[267]) and for the rest of the market (taking as a reference a Samsung Wi-Fi tablet 128 GB), and assumed consumer willingness-to-pay levels in a similar percentage above prices as in the United States average. Based on that information, we estimated a consumer surplus attributed to tablets of $10 million in 2021, expected to reach $7 million in 2025 (Table N-15).

Table N-15. New Zealand: Economic Value of Wi-Fi enabled consumer products (2021-2025)

Variable	2021	2022	2023	2024	2025
Consumer surplus (exc. tablets) ($Million)	$283	$291	$300	$297	$288
Tablet consumer surplus ($Million)	$10	$9	$8	$7	$7
Total consumer surplus ($Million)	$293	$300	$309	$304	$294

Sources: CTA; Telecom Advisory Services analysis

Consumer surplus derived from Wi-Fi enabled residential equipment for 6 GHz

As discussed above, sales of residential Wi-Fi devices and equipment operating in the 6 GHz band are expected to gradually replace those of former generations. According to IDC, global shipments of consumer devices operating in the 6 GHz (802.11ax standard) will represent 40% of sales from prior generations. As a result, if the shipments ratio reaches 40% in 2025, we can expect that, at least, the consumer surplus derived from 6 GHz devices will represent 40% of that of former technology residential devices. As a result, our estimates for consumer surplus attributed to 6 GHz residential devices amount to $116 million in 2025 (see Table N-16).

Table N-16. New Zealand: Economic Value of Wi-Fi enabled consumer products attributable to 6 GHz (2021-2025)

Variable	2021	2022	2023	2024	2025
Ratio consumer 6 GHz / no 6 GHz	3.76%	8.83%	18.59%	28.86%	40.30%
Total consumer surplus ($Million) – 6 GHz	$10.64	$25.71	$55.85	$85.64	$115.88

Sources: IDC; Telecom Advisory Services analysis

[267] Source: Gs StatCounter

N.3.5. Bridging the digital divide: use of Wi-Fi to increase coverage in rural and isolated areas

Wi-Fi is an appropriate technology to offer Internet access in rural and isolated areas. The incremental number of lines supported by Wireless ISPs (WISPs) represents an increase in penetration, which in turn contributes to New Zealand's GDP.

According to reports provided by the New Zealand Commerce Commission, we estimate a deployment of approximately 200,000 WISP connections in the country. In order to estimate the Wi-Fi's contribution, we assume that 90% of WISP potential connections may be theoretically served by other technologies (i.e. satellite) covering the same isolated footprint. Thus, we can conservatively expect 10% of broadband subscriptions in remote locations exclusively attributed to Wi-Fi technology. With this value, we calculate the impact on the GDP by relying on the coefficient estimated by Katz and Callorda (2018b) through regression models that link increase in broadband penetration to economic growth. However, the calculation of Wi-Fi contribution to GDP must subtract the direct impact of WISPs sales (estimated in Section N.5.3.) to avoid double counting. As a result, by reducing the digital divide and increasing broadband penetration, we estimate a GDP contribution of $362 million in 2021, which will increase to $395 million in 2025 (see Table N-17).

Table N-17. New Zealand: Estimation of GDP Contribution derived from reducing the digital divide (2021-2025)

Variable	2021	2022	2023	2024	2025
WISP subscribers	209,869	217,710	225,844	234,282	243,035
Additional broadband penetration due to WISP	11.41%	11.41%	11.41%	11.41%	11.41%
Impact of fixed broadband adoption in GDP	16.32%	16.32%	16.32%	16.32%	16.32%
GDP ($Billion)	$201	$206	$211	$217	$222
WISP TOTAL impact ($Million)	$3.75	$3.85	$3.94	$4.04	$4.14
WISP Revenues ($Million)	$0.13	$0.15	$0.16	$0.17	$0.19
Share that exist because WISP	10.00%	10.00%	10.00%	10.00%	10.00%
WISP spillovers on GDP ($Million)	$362.29	$369.84	$378.10	$386.54	$394.95

Sources: New Zealand Commerce Commission; Telecom Advisory Services analysis

The contribution to GDP materializes through multiple effects: creation of new businesses, increasing productivity of existing enterprises, and growth of average income per household.

Economic impact of enhanced coverage and affordability due to 6 GHz

The allocation of the 6 GHz band to unlicensed use would allow WISPs to potentially increase their subscriber base within their same coverage footprint. Therefore, a first effect derived from the allocation of the new spectrum band is related to additional households served due to additional coverage. We follow a conservative approach and consider that the expanded coverage will yield a gradual increase in WISP subscribers, from 2% in 2022 to 5% in 2025 over the figures projected above. In addition, an increase of the user base would allow service providers to lower their operating costs. Thus, by assuming stability in prices, affordability would increase as GDP per capita grows. Based on these assumptions, we expect an overall increase of approximately 14,600 WISP connections in 2025, contributing to an increase 0.73% in national broadband penetration. Considering the impact coefficient of broadband on the economy, that value will yield $249 million of GDP contribution.

Table N-18. New Zealand: GDP Contribution derived from reducing the digital divide due to 6 GHz (2021-2025)

Variable	2021	2022	2023	2024	2025
New subscribers due to expanded coverage (%)	0%	2%	3%	4%	5%
New subscribers due to expanded coverage	0.00	4,354	6,775	9,371	12,152
New WISP adoption after price decrease (% households)	13%	12%	12%	12%	12%
Traffic through the 6 GHz Channel (%)	0%	10%	20%	30%	40%
Increase in WISP connections due to lower prices (households that buy the service)	0	768	1,612	2,288	2,449
Overall increase in WISP connections due to 6 GHz	0	5,122	8,387	11,659	14,601
Increase in national broadband penetration	0.00%	0.27%	0.43%	0.59%	0.73%
Impact of fixed broadband adoption in GDP	16.32%	16.32%	16.32%	16.32%	16.32%
Increase in the GDP due to the new broadband adoption (% GDP)	0.000%	0.044%	0.069%	0.093%	0.112%
Total impact in GDP ($Million)	$0.00	$90.47	$146.32	$200.95	$248.64

Source: Telecom Advisory Services analysis

N.4. Enterprise Wi-Fi

Beyond the impact on consumers, Wi-Fi also contributes significant economic value to the New Zealand enterprise segment. This section provides estimates in five areas:

- Support of business Internet traffic;
- Avoidance of campus and enterprise facilities inside wiring;
- Contribution to GDP resulting from Wi-Fi speed faster than cellular connections;
- Deployment of IoT solutions; and
- Implementation of business focused AR/VR use cases.

N.4.1. Business Internet traffic transmitted through Wi-Fi

Wi-Fi enterprise telecommunications savings result from wireless traffic that is routed through Wi-Fi access points. Based on an interpolation from Cisco 2016-21 "rest of Asia-Pacific" projections[268], we estimate that total business Internet traffic will reach 975 million GB in 2021, of which 691 million GB would have been transported through Wi-Fi access points. Considering the average price per GB transported by cellular (see Table N-5), savings from Wi-Fi will reach $711 million, an addition to the producer surplus. By 2025, this benefit will reach $1.1 billion (see Table N-19).

[268] Cisco did not include New Zealand in their 2016/21 projections

Table N-19. New Zealand: Savings in business wireless traffic (2021-2025)

Variable	2021	2022	2023	2024	2025
Share of Business Internet Traffic by Wi Fi	70.88%	73.00%	75.18%	77.43%	79.75%
Total Business Internet Traffic (Million GB)	974.8	1,184.5	1,439.2	1,748.7	2,124.8
Total Wi-Fi enterprise traffic (Million GB)	690.9	864.7	1,082.0	1,354.1	1,694.5
Average Price per GB	$1.03	$0.93	$0.84	$0.75	$0.68
Economic Impact ($Million)	$711.98	$802.17	$903.78	$1,018.27	$1,147.25

Sources: Cisco; Telecom Advisory Services analysis

Enhanced business Internet traffic transmitted through Wi-Fi due to 6 GHz

The deployment of the latest enterprise applications will generate an exponential growth in data traffic that will be handled by devices operating in unlicensed spectrum, through the combination of the existing spectrum and the 6 GHz band. In 2019, an updated Cisco traffic forecast based on the explosion of IoT and AR/VR applications among other factors, increased total business Internet traffic projections from the prior 2016-21 estimates. As in the case of the United States, we assume that part of the growth was driven by "natural" growth, while the remainder was triggered by Wi-Fi traffic stimulated by relying on the 6 GHz band. The sum of the difference due to broader Wi-Fi traffic will reach $38 million in 2025 (see Table N-20).

Table N-20. New Zealand: Savings in business wireless traffic due to 6 GHz (2021-2025) ($Million)

Variable	2021	2022	2023	2024	2025
Total value of business Wi-Fi traffic 2016-21	$712.0	$802.2	$903.8	$1,018.3	$1,147.3
Total value of business Wi-Fi traffic 2017/22	$820.3	$954.4	$1,110.5	$1,292.1	$1,503.4
Difference between the 2 estimations	$108.3	$152.3	$206.7	$273.9	$356.2
Difference because natural growth	$101.5	$135.6	$184.4	$244.3	$317.8
Difference due to 6 GHz	$0.00	$16.41	$22.29	$29.52	$38.40

Sources: Cisco; analysis Telecom Advisory Services

N.4.2. Avoidance in enterprise building inside wiring

Similarly to residential Wi-Fi savings due to capital investment avoidance in inside wiring, we assume that the total number of business establishments are equipped with Wi-Fi access points and multiply this value by a standard cost of deploying a CAT 6 network (see Table N-21). The number of establishments was estimated from local data reported by Stats NZ.

Table N-21. New Zealand: Savings in business wiring CAPEX (2021-2025)

Variable	2021	2022	2023	2024	2025
Total Wiring Cost	$2,042.45	$2,011.17	$1,980.36	$1,950.03	$1,920.16
Number of Establishments	547,871	552,254	556,672	561,126	565,615
Establishments with Wi-Fi (%)	100%	100%	100%	100%	100%
Establishments with Wi-Fi	547,871	552,254	556,672	561,126	565,615
Inside Wiring Costs ($Million)	$1,119	$1,111	$1,102	$1,094	$1,086

Sources: Stats NZ; Telecom Advisory Services

N.4.3. Return to speed: contribution to GDP derived from an increase in average mobile speed

Since Wi-Fi accessibility allows, in general, faster access to the Internet than cellular networks do, higher speeds have a positive economic contribution in terms of increased overall efficiency and innovation, translating into economic growth. As described in Section N.2.3 for the case of consumer surplus, we start with the quantification of the average broadband speed if cellular networks transported all Wi-Fi traffic. Having calculated the speed increase percentage, we then apply this percentage to the coefficient derived from the model developed by Katz and Callorda (2019) to gauge the potential impact on GDP from Wi-Fi enhanced speed. The economic value of Wi-Fi in terms of increasing the speed of transporting wireless will account to $84 million in 2021, increasing to $295 million in 2025 (see Table N-22).

Table N-22. New Zealand: Estimation of speed differential for total traffic (2021-2025)

Variable	2021	2022	2023	2024	2025
Average Download Speed if Wi-Fi traffic were carried through mobile networks (Mbps)	62.98	73.62	85.93	100.14	116.58
Average Speed with Wi-Fi (Mbps)	66.60	79.90	95.82	114.90	137.76
Speed increase (%)	6%	9%	12%	15%	18%
Impact of speed in GDP	0.73%	0.73%	0.73%	0.73%	0.73%
Increase in GDP	0.04%	0.06%	0.08%	0.11%	0.13%
GDP ($Billion)	$201.19	$206.41	$211.50	$216.77	$222.16
GDP increase ($Million)	$84	$128	$178	$233	$295

Sources: Cisco; Telecom Advisory Services analysis

Additional return to speed effect due to 6 GHz

As previously described, only those broadband connections above 150 Mbps will be affected by congestion due to current router bottlenecks. The allocation of spectrum in the 6 GHz band will remove those barriers, increasing broadband speed. After calculating the difference in average speed attributed to 6 GHz, the additional GDP contribution will reach $140 million in 2025 (Table N-22).

Table N-23. New Zealand: Estimation of speed differential due to 6 GHz (2021-2025)

Variable	2021	2022	2023	2024	2025
Mean speed with no 6 GHz (Mbps)	66.60	79.90	95.82	114.90	137.76
Mean speed with 6 GHz (Mbps)	66.60	80.96	98.87	121.34	149.64
Speed increase due to 6Ghz (%)	0%	1%	3%	6%	9%
Impact speed on GDP	0.73%	0.73%	0.73%	0.73%	0.73%
Increase in GDP (%)	0.00%	0.01%	0.02%	0.04%	0.06%
GDP increase ($Million)	$0	$20	$49	$89	$140

Sources: Cisco; Telecom Advisory Services analysis

N.4.4. IoT deployment

IoT adoption has a contribution to GDP growth through the multiplicity of use cases that improve efficiency in operational processes such as preventive maintenance, production monitoring and the like. To estimate this, we rely on a coefficient of GDP impact calculated through an aggregate simple production function which estimates that a 10% rise in M2M connections results in annual increases in GDP of between 0.3% and 0.9%[269]. For New Zealand, we assume a conservative 0.3% GDP increase after a 10% increase in the M2M installed base.

Starting with a 2021 installed base of 4.1 million M2M devices in New Zealand, we estimate the growth that can be exclusively attributed to the allocation of additional spectrum to indoor Wi-Fi devices. By subtracting the growth in M2M attributed to 6 GHz, the IoT impact for 2021 according to the natural growth is forecast to reach $540 million (see Table N-24).

Table N-24. New Zealand: GDP Contribution of IoT Deployment Boost (2021-2025)

Variable	2021	2022	2023	2024	2025
Connections, Cellular M2M	4,114,524	4,295,087	4,483,574	4,680,332	4,885,725
Growth Rate (%)	9.82%	4.39%	4.39%	4.39%	4.39%
Natural Growth Rate (%)	8.95%	3.88%	3.78%	3.78%	3.78%
Impact of 1% M2M Growth on GDP	3.00%	3.00%	3.00%	3.00%	3.00%
Impact on GDP (%)	0.27%	0.12%	0.11%	0.11%	0.11%
GDP ($Billion)	$201	$206	$211	$217	$222
Impact ($Million)	$539.91	$240.45	$240.15	$246.13	$252.26

Sources: GSMA Intelligence; Frontier Economics; Telecom Advisory Services analysis

It should be noted that the GDP impact of IoT declines due to a decreasing growth rate of M2M installed base. The same effect will be apparent in the case of traffic shifting to the 6 GHz band.

Accelerated effect of IoT due to 6 GHz

As described above, a share of the M2M growth can be attributed to IoT traffic shifting to the 6 GHz spectrum. According to the data in Table N-25, cumulative impact of enhanced IoT deployment driven by 6 GHz spectrum proposals will reach $40 million by 2025.

Table N-25. New Zealand: GDP Contribution of IoT Deployment Boost caused by 6 GHz (2021-2025)

Variable	2021	2022	2023	2024	2025
Growth due to 6 GHz (%)	0.88%	0.51%	0.60%	0.60%	0.60%
Level of development of new bands (%)	50%	100%	100%	100%	100%
Impact on GDP (%)	0.01%	0.02%	0.02%	0.02%	0.02%
Impact ($Million)	$26.50	$31.30	$38.30	$39.25	$40.23

Sources: GSMA Intelligence; Frontier Economics; Telecom Advisory Services analysis

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[269] See Frontier Economics (2018).

N.4.5. Deployment of AR/VR solutions

The adoption of AR/VR among New Zealand business will have a spillover effect on productivity, thereby contributing to the growth of GDP. Estimating spillover effects of AR/VR is a not a trivial exercise considering the embryonic adoption of some of the use cases based on this technology. Since the objective is to estimate the spillover effect of AR/VR sales in the domestic New Zealand market, we consider the estimate by PwC of the total GDP contribution of AR/VR for 2021 and 2022[270], and the sales of AR/VR components as estimated by ABI Research[271]. The extrapolation of these two parameters allow estimating the indirect (spillover) contribution of AR/VR to the New Zealand economy for the period under analysis.

Starting values are reduced by the proportion that can be attributed to other technologies rather than Wi-Fi (i.e. Bluetooth). After computing the resulting value, we subtracted the impact of the 6 GHz spectrum bands. To do so, we took as a reference a ratio of AR/VR product developments for each technology (built with data from ABI Research). Once the amounts to be attributed to GDP contribution and direct sales were estimated, the annual indirect to direct multiplier was calculated. The lowest multiplier value is applied to sales of AR/VR in the New Zealand market to calculate the total spillovers. Accordingly, total spillover value of AR/VR in New Zealand in 2021 will account for $34 million and is expected to increase by 2025 to $62 million (see Table N-26).

Table N-26. New Zealand: GDP contribution resulting from AR/VR spillovers (2021-2025)

Variable	2021	2022	2023	2024	2025
AR/VR total contribution to GDP ($Billion)	$0.17	$0.25	$0.36	$0.54	$0.79
Share attributed to Wi-Fi (excluding 6 GHz)	42.02%	38.80%	32.18%	30.88%	29.32%
Portion of GDP contribution attributed to Wi-Fi (excluding 6 GHz) ($Billion)	$0.07	$0.10	$0.12	$0.17	$0.23
Direct impact (sales) attributed to Wi-Fi (excluding 6 GHz) ($Billion)	$0.04	$0.06	$0.08	$0.11	$0.17
Indirect impact ($Billion)	$0.03	$0.04	$0.04	$0.06	$0.06
Indirect/Direct multiplier	0.95	0.67	0.55	0.54	0.36
Indirect impact ($Million)	$34.42	$38.42	$41.83	$58.37	$61.62

Sources: PwC, ABI; Telecom Advisory Services analysis

Wider deployment of AR/VR solutions (accelerated effect due to 6 GHz)

Higher throughput enabled by the allocation of 6 GHz spectrum is expected to spur the adoption and use of AR/VR among enterprises, hence increasing the associated spillover effects. By relying on the ratio built from 5 GHz and 6 GHz AR/VR related products from above, we isolated the specific economic contribution of the new spectrum allocation. Following a similar procedure as the one described above

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[270] See PWC (2019). *Seeing is believing: how virtual reality and augmented reality are transforming business and the economy.*

[271] See ABI Research, *Augmented and Mixed Reality Market Data: devices, use cases, verticals and value chain*. MD-ARMR-103, QTR 4 2019, and ABI Research, *Virtual Reality Market Data: devices, verticals, and value chain*. MD-VR-108, QTR 1 2020.

spillovers from AR/VR in the New Zealand attributed to 6 GHz were calculated. They will account for $20.1 million in 2021 and are expected to reach $60.7 million by 2025 (Table N-27).

Table N-27. New Zealand: GDP contribution resulting from AR/VR spillovers due to 6 GHz (2021-2025)

Variable	2021	2022	2023	2024	2025
AR/VR total contribution to GDP ($Billion)	$0.17	$0.25	$0.36	$0.54	$0.79
Share attributed to 6 GHz (%)	24.58%	25.59%	26.64%	27.73%	28.87%
Portion of GDP contribution attributed to 6 GHz ($Billion)	$0.04	$0.06	$0.10	$0.15	$0.23
Direct impact (sales) attributed to 6 GHz ($Billion)	$0.02	$0.04	$0.06	$0.10	$0.17
Indirect impact ($Billion)	$0.02	$0.03	$0.03	$0.05	$0.06
Indirect/Direct multiplier	0.95	0.67	0.55	0.54	0.36
Indirect impact ($Million)	$20.14	$25.34	$34.63	$52.42	$60.68

Sources: PwC, ABI; Telecom Advisory Services analysis

N.5. Internet Service Providers

In addition to the economic value generated by the sources analyzed above, Wi-Fi will also contribute to either producer surplus or weight on GDP of Internet Service Providers. This section will assess the economic value derived from three sources:

- Producer surplus of cellular operators resulting from CAPEX savings incurred in network deployment;
- Revenues of Wi-Fi carriers offering service in public spaces; and
- Revenues of Wireless ISPs (this effect differs from the GDP impact of WISPs as a result of their deployment in rural and isolated areas analyzed in section N.3.5.).

N.5.1. Cellular network savings by off-loading traffic to Wi-Fi

The estimation of CAPEX savings of cellular operators engaged in deploying 5 G starts by considering the GSMA Intelligence aggregate investment between 2021 and 2025. In this context, Wi-Fi is assumed to become a key enabler of 5G services. The upcoming flexible, radio-neutral 5G environment will be intrinsically supported by the next wave of 802.11 Wi-Fi standards as well as short-range wireless technologies operating in unlicensed bands. Considering that the total CAPEX required to deploy 5G in New Zealand, and the growth in 5G coverage between 2021 and 2025 as reported in GSMA Intelligence, we calculated the 5G CAPEX for each year of the period under consideration. Once this is estimated, the savings incurred by Wi-Fi is estimated by calculating the capital spending reduction ratio from table IV-36. Based on the simulation model developed to estimate the impact of Wi-Fi off-loading in 5 G deployment, we estimate that the savings of deploying carrier-grade Wi-Fi complementing the rollout of 5G to accommodate future traffic growth would amount to 32.9% of CAPEX, while the OPEX savings are $2.82 for each dollar saved in CAPEX.

The estimation of CAPEX savings starts by considering the GSMA Intelligence aggregate investment estimates of 5G deployments in New Zealand, which amount to $31.60 billion between 2019 and 2025. Assuming that this amount already reflects the savings incurred by relying on Wi-Fi sites, the application of a CAPEX savings simulation ratio would result in a total producer surplus (adding CAPEX and OPEX savings) of $618 million in 2021, being reduced to $45 million in 2025 (see Table N-28).

Table N-28. New Zealand: Savings due to traffic off-loading (2021-2025)

Variable	2021	2022	2023	2024	2025
5G coverage	60%	73%	82%	87%	88%
CAPEX without saving ($Million)	$492.1	$324.3	$233.4	$128.5	$35.9
CAPEX reduction due to Wi-Fi off-loading ($Million)	$161.9	$106.7	$76.8	$42.3	$11.8
OPEX reduction due to Wi-Fi off-loading ($Million)	$456.6	$300.9	$216.5	$119.2	$33.3
Total Cost of Ownership ($Million)	$618	$408	$293	$161	$45

Sources: GSMA; Telecom Advisory Services analysis

The decline in savings over time is compensated by the increase in economic benefit under the 6 GHz spectrum allocation.

Enhanced capability for cellular off-loading if 6 GHz allocated

The complementarity between Wi-Fi and cellular networks for Wi-Fi 6E and 5G, adds further potential gains derived from the savings in capital and operating expenses required to accommodate exploding data traffic. The key objective is to estimate the savings in capital investment as a result of an increase in traffic offloading with Wi-Fi benefits from the additional spectrum allocated, particularly due to the ability to leverage 160 MHz within single contiguous channels.

The estimation of CAPEX savings starts by considering the GSMA Intelligence aggregate investment estimates of 5G deployments. By relying on the geographic disaggregation of Oughton and Frias, we estimate that CAPEX can be split in urban, suburban and rural geographies. To estimate the percentage of population living in areas over 1 million inhabitants, we considered those living in the metropolitan area of Auckland. The percentage of rural population was obtained from Trading Economics, while the remaining share of the population was classified in the suburban group (see Table N-29).

Table N-29. New Zealand: 5G CAPEX estimated by geographical breakdown

Geography	New Zealand		
	Population Breakdown (%)	5G CAPEX ($Billion)	5G CAPEX (%)
Urban (cities>1 million)	28.60%	$0.03	1.98%
Suburban	58.02%	$0.27	17.33%
Rural	13.38%	$1.25	80.69%
Total	100%	$1.55	100%

Sources: Oughton and Frias (2016); GSMA; Trading Economics; Telecom Advisory Services analysis

We conservatively assume that Wi-Fi 6 will not be critical in sustaining investment in urban areas, but that it will play a significant role beyond those geographies. Based on the cost advantage of carrier grade Wi-Fi, we assume that it will become effective for a portion of the suburban (approximately 15%) and rural network (approximately 5%) deployment. Therefore, this will yield yearly CAPEX savings of $21 million through 2025.

N.5.2. Wi-Fi carrier revenues

The value of Wi-Fi carriers includes the sum of revenues generated by commercial public Wi-Fi access. In order to estimate this value, we start by calculating the number of commercial Wi-Fi hotspots in New Zealand. According to Cisco, in 2021 there will be 690,000 public Wi-Fi hotspots in the country, although that figure includes home spots (such as the guest account service provided by cable operators). By subtracting the home spots from the public Wi-Fi estimates of Cisco, we estimated a total of 40,000 commercial Wi-Fi hotspots for 2021, which will remain stable until 2025. On the other hand, based on revenue per hotspot generated by Boingo in the United States and adjusting the metric by PPP, we estimated the revenues for New Zealand Wi-Fi carriers. Accordingly, this amounts to $21 million in 2021, gradually increasing to reach $23 million in 2025 (Table N-30).

Table N-30. New Zealand: Revenues of Wi-Fi carriers (2021-2025)

Variable	2021	2022	2023	2024	2025
Public Wi-Fi hotspots (Million)	0.69	0.80	0.94	1.10	1.29
Home spots (Million)	0.65	0.77	0.90	1.06	1.24
Commercial Wi-Fi hotspots (Million)	0.04	0.04	0.04	0.04	0.04
Revenue per hotspot ($)	$574.45	$565.65	$556.98	$548.45	$540.05
Revenue ($Million)	$20.60	$21.52	$22.22	$22.63	$22.63

Sources: Cisco, Boingo, Telecom Advisory Services

Increased revenues of Wi-Fi carriers in public places due to 6 GHz

The allocation of the 6 GHz spectrum band offers an opportunity for commercial Wi-Fi carriers to enhance their business. As Wi-Fi 6E developments will allow up to 1,500 connected devices per access point, Wi-Fi carriers will have the possibility of adding more clients without quality limitations due to congestion. By considering a conservative potential increase of 40% in the number of connected devices in public venues and weighting that figure by the gradual expansion of the latest technology, we expect commercial Wi-Fi carriers in New Zealand to increase their user base by 16% in 2025. If the revenue per hotspot increases in the same amount, that will yield an increase in overall revenues for the sector of an additional $3.6 million by 2025 (Table N-31).

Table N-31. New Zealand: Revenues of Wi-Fi carriers due to 6 GHz (2021-2025)

Variable	2021	2022	2023	2024	2025
Potential increase in connected devices in public venues	40%	40%	40%	40%	40%
Traffic through the 6 GHz Channel (%)	0%	10%	20%	30%	40%
Increase in connected devices due to 6 GHz	0%	4%	8%	12%	16%
Revenue per hotspot if 6 GHz allocated ($)	$574.45	$588.27	$601.54	$614.27	$626.46
Revenue if 6 GHz allocated ($Million)	$0.00	$0.86	$1.78	$2.72	$3.62

Sources: Boingo, Telecom Advisory Services

N.5.3. Wireless ISPs revenues

The 2021 GDP contribution related to the WISP industry was calculated as a function of the number of subscribers and the ARPU (from U.S., adjusted by PPP), yielding a total of $125 million (Table N-32).

Table N-32. New Zealand: WISP revenues (2021-2025)

Variable	2021	2022	2023	2024	2025
Subscribers (Million)	0.21	0.22	0.23	0.23	0.24
Revenues ($Million)	$125.08	$146.84	$159.03	$172.70	$189.14

Sources: New Zealand Commerce Commission; Telecom Advisory Services

Increased revenues of WISPs due to 6 GHz

As described in section N.5.2, the allocation of 6 GHz spectrum will potentially increase the WISP user base by almost 15,000 subscribers in 2025 due to expanded coverage and better affordability. Thus, by assuming the same ARPU values as described above, the new subscriptions will amount to an additional $11 million in revenues in 2025 (Table N-33).

Table N-33. New Zealand: WISP revenues due to 6 GHz (2021-2025)

Variable	2021	2022	2023	2024	2025
WISP annual ARPU ($)	$596.00	$674.46	$704.14	$737.15	$778.26
New subscribers if 6 GHz allocated (Million)	0.000	0.005	0.008	0.012	0.015
New revenue ($Million)	$0.00	$3.45	$5.91	$8.59	$11.36

Source: Telecom Advisory Services

N.6. Wi-Fi ecosystem

The economic value generated by Wi-Fi within Wi-Fi ecosystem companies in New Zealand is generated from the following two sources:

- The producer surplus of local firms providing products and services in the IoT ecosystem (hardware, software and systems integration) in New Zealand; and
- The producer surplus of local firms providing products and services in the AR/VR ecosystem (hardware, software and content) in New Zealand.

N.6.1. Firms belonging to the IoT ecosystem

According to estimates from Statista and Bain & Co, we expect total industrial IoT revenue in New Zealand to amount to $1.2 billion in 2021. By relying on the percentage of hardware connectivity spending in IoT in Asia-Pacific, we were able to split that figure into the two main segments: (i) hardware; and (ii) software, contents, and services. By weighting those amounts by the share of local production (15% for hardware, 60% for software and services) and the margins (39.44% and 77.46%, respectively), we can estimate the overall producer surplus. However, the share attributed to 6 GHz should be subtracted from the total economic value. To do so, we estimated a natural growth rate by subtracting the corresponding share attributed to 6 GHz spectrum according to the growth rates indicated in Section N.3.4. Thus, we estimate a producer surplus not attributed to 6 GHz of $373 million in 2021, expecting to reach $750 million in 2025 (Table N-34).

Table N-34. New Zealand: IoT ecosystem direct contribution (2021-2025)

Variable	2021	2022	2023	2024	2025
IoT revenue - Hardware ($billions)	$0.46	$0.56	$0.68	$0.83	$1.02
IoT revenue - Software, Contents, Services ($billions)	$0.77	$0.94	$1.14	$1.39	$1.70
Total Industrial IoT revenue in ($Billion)	$1.23	$1.50	$1.83	$2.23	$2.72
Local production (%) - Hardware	15%	15%	15%	15%	15%
Local production (%) - Software & Services	60%	60%	60%	60%	60%
Margins (%) - Hardware	39%	39%	39%	39%	39%
Margins (%) - Software & Services	77%	77%	77%	77%	77%
Margins - IoT Hardware revenue	$0.03	$0.03	$0.04	$0.05	$0.06
Margins - Software, contents and services IoT revenue	$0.36	$0.43	$0.53	$0.65	$0.79
Producer surplus ($Million)	$384.50	$468.95	$571.96	$697.58	$850.80
Growth rate (%)	10.64%	21.96%	21.96%	21.96%	21.96%
Growth rate not attributed to 6 GHz (%)	9.69%	19.43%	18.94%	18.94%	18.94%
Producer surplus not attributed to 6 GHz ($Million)	$373.39	$445.96	$530.44	$630.93	$750.45

Sources: Statista; Bain & Co; CSI; Telecom Advisory Services analysis

Wider deployment of Internet of Things under 6 GHz

Following the previous analysis, we were able to estimate which portion of IoT producer surplus growth can be attributed to the 6 GHz spectrum. As Table N-35 indicates, we expect the additional IoT surplus generated by 6 GHz to account for $100 million in 2025.

Table N-35. New Zealand: IoT direct contribution attributed to 6 GHz (2021-2025)

Variable	2021	2022	2023	2024	2025
Producer surplus ($Million)	$384.50	$468.95	$571.96	$697.58	$850.80
Producer surplus not attributed to 6 GHz ($Million)	$373.39	$445.96	$530.44	$630.93	$750.45
Additional surplus due to 6 GHz ($Million)	$11.10	$22.99	$41.51	$66.65	$100.35

Sources: Statista; Bain & Co; CSI; Telecom Advisory Services analysis

N.6.2. Firms belonging to the AR/VR ecosystem

Following a similar approach as in the case of IoT, we estimated the direct contribution of this ecosystem to the New Zealand economy. Starting with the local spending in AR/VR by category (hardware, software, and contents), and apportioning those values by the respective shares of local production and margins, we were able to estimate the total producer surplus. By relying on a ratio built from 6 GHz AR/VR related products, we were able to subtract the specific contribution attributed to 6 GHz from the surplus corresponding to current bands. Accordingly, we expect by 2021 a direct contribution from the AR/VR ecosystem of $12.4 million, increasing to reach $56.4 million by 2025 (Table N-36).

Table N-36. New Zealand: AR/VR ecosystem direct contribution (2021-2025)

Variable	2021	2022	2023	2024	2025
Spending in AR/VR - Hardware $Billion	$0.03	$0.05	$0.08	$0.12	$0.19
Spending in AR/VR - Software, Contents, Services ($Billion)	$0.06	$0.10	$0.16	$0.23	$0.39
Total Spending in AV/VR ($Billion)	$0.09	$0.15	$0.23	$0.35	$0.58
Share of local production - Hardware	15.48%	15.48%	15.48%	15.48%	15.48%
Share of local production - Software, Contents, Services	60.00%	60.00%	60.00%	60.00%	60.00%
Local production for local consumption - Hardware ($Billion)	$0.00	$0.01	$0.01	$0.02	$0.03
Local production for local consumption - Software, Contents, Services ($Billion)	$0.04	$0.06	$0.10	$0.14	$0.23
Local Producer Surplus - Hardware ($Billion)	$0.00	$0.00	$0.00	$0.01	$0.01
Local Producer Surplus - Software, Contents, Services ($Billion)	$0.03	$0.05	$0.07	$0.11	$0.18
Total Producer Surplus	$0.03	$0.05	$0.08	$0.11	$0.19
Share attributable to Wi-Fi (excluding 6 GHz)	42.02%	38.80%	32.18%	30.88%	29.32%
Producer Surplus attributed to Wi-Fi (not including 6 GHz) ($Million)	$12.42	$19.62	$25.25	$34.91	$56.42

Sources: PwC, ABI; Telecom Advisory Services analysis

Wider deployment of AR/VR solutions if 6 GHz allocated

By relying on a ratio built from 6 GHz AR/VR related products, we isolated the specific economic contribution of the new spectrum allocation. Following an approach similar to that one described above, the direct contribution from AR/VR ecosystem in New Zealand attributed to 6 GHz in 2025 will reach $55.6 million.

Table N-37. New Zealand: AR/VR direct contribution attributed to 6 GHz (2021-2025)

Variable	2021	2022	2023	2024	2025
Spending in AR/VR ($Billion)	$0.03	$0.05	$0.08	$0.12	$0.19
Share attributed to 6 GHz	24.58%	25.59%	26.64%	27.73%	28.87%
Spending in AR/VR attributed to 6 GHz ($Billion)	$0.02	$0.04	$0.06	$0.10	$0.17
Local production for local consumption 6 GHz ($Billion)	$0.01	$0.02	$0.03	$0.04	$0.08
Local Producer Surplus ($Million)	$7.26	$12.94	$20.90	$31.35	$55.55

Sources: PwC, ABI, Telecom Advisory Services analysis

N.7. Wi-Fi contribution to employment

The estimation of employment generated by Wi-Fi's economic value is calculated by relying on the total GDP contribution resulting from the effects analyzed above and using that as an input to the communications sector of an input-output matrix of the New Zealand economy. Table N-38 presents the GDP contribution, as sum of all GDP sources discussed above, enabled by Wi-Fi projected for the period 2021-2025.

Table N-38. New Zealand: Wi-Fi enabled GDP contribution (2021-2025)

Year	GDP contribution enabled by Wi-Fi ($Million)		
	Attributed to current bands	Attributed to 6 GHz	Total
2021	$1,429	$47	$1,476
2022	$1,190	$194	$1,384
2023	$1,245	$317	$1,563
2024	$1,327	$448	$1,775
2025	$1,402	$570	$1,972

Source: Telecom Advisory Services analysis

These inputs generate the following annual employment effects based on the input/output matrix for the New Zealand economy (Table N-39).

Table N-39. New Zealand: Wi-Fi generated Annual Employment

Variable	2021			2025		
	Current bands	6 GHz	Total	Current bands	6 GHz	Total
Direct jobs	1,235	0,040	1,275	1,212	0,492	1,704
Indirect jobs	1,708	0,056	1,764	1,677	0,681	2,357
Induced jobs	0,462	0,015	0,477	0,453	0,184	0,637
Total	3,405	0,111	3,516	3,342	1,357	4,699

Sources: GTAP; Telecom Advisory Services analysis

According to the contribution to GDP, Wi-Fi will generate approximately 3,500 jobs in 2021 and is expected to create 4,700 in 2025. Job estimates include direct jobs (those jobs created by the specific Wi-Fi contribution), indirect jobs (those jobs created by suppliers to the Wi-Fi sector) and induced jobs (those jobs created by spending of direct and indirect workers).

The sector breakdown of 2021 employment (including the additional jobs created by 6 GHz) is as follows (Table N-40).

Table N-40. New Zealand: Sector Breakdown of Wi-Fi generated annual employment (2021)

Sector	Direct	Indirect	Induced	Total
Agriculture	0	0	31	31
Extractive industries	0	0	3	3
Manufacturing	0	139	7	145
Construction	0	134	0	134
Trade	0	121	155	276
Transportation	0	137	0	137
Communications	1,275	0	0	1,275
Financial Services	0	231	0	231
Business services	0	1,002	0	1,002
Other services	0	0	280	280
Total	1,275	1,764	477	3,516

Sources: GTAP; Telecom Advisory Services analysis

O. ECONOMIC VALUE OF WI-FI IN BRAZIL

Wi-Fi has become a critical component of Brazil's telecommunications infrastructure. According to the Cisco Annual Internet Report Highlights Tool 2018-2023, there are approximately 8,800,000 public Wi-Fi access points operating in the country. The Wiman site estimates that there are currently 364,960 free Wi-Fi sites (of which, 17,600 are in Sao Paulo, 7,243 in Rio de Janeiro, and 5,152 in Brasilia). In addition to Municipal Wi-Fi, public Wi-Fi sites represent a cost-advantaged approach for consumers "on the go" to access the Internet. Given the Wi-Fi access point density, hotspots have become a very important connectivity feature. According to Opensignal[272], Brazilian wireless users currently spend 70.1% of their communications time connected to Wi-Fi networks rather than relying on their cellular data connection. The increasing importance of Wi-Fi technology in the digital infrastructure ecosystem results in a significant social and economic impact. This chapter presents first the total economic value and then reviews each of the specific effects. This section presents the results and calculations of the economic assessment. The methodology reviewed in section B was used to calculate each source of economic value.

O.1. Total Economic Value of Wi-Fi in Brazil (2021-2025)

The total economic value of Wi-Fi in Brazil in 2021 before accounting for the acceleration effect resulting from the allocation of 1,200 MHz in the 6 GHz band is estimated at $102.5 billion. This value is broken down by $40.6 billion in consumer surplus, $38.7 billion in producer surplus, and $23.3 billion in a net contribution to GDP. Under the current spectrum allocation, the 2025 forecast of economic value will reach $109.6 billion, comprised of $69.3 billion in consumer surplus, $18.9 billion in producer surplus, and $21.4 billion in GDP contribution (see Table O-1).

Table O-1. Brazil: Economic Value of Wi-Fi (Baseline Scenario)

Agent	Source	Economic Value ($Million)					
		2021	2022	2023	2024	2025	Category
1. Free Wi-Fi	1.1. Savings generated by free Wi-Fi traffic offered in public sites	$1,095	$1,179	$1,306	$1,482	$1,715	Consumer Surplus
	1.2. Deployment of free Wi-Fi in public sites	$1,105	$1,045	$977	$898	$804	GDP contribution
2. Residenti al Wi-Fi	2.1. Internet access for home usage of devices that lack a wired port	$16,476	$20,110	$24,519	$29,889	$36,487	Consumer Surplus

[272] Khatri, H. and Fenwick, S. (2020). "Analyzing mobile experience during the coronavirus pandemic: Time on Wi-Fi". *Opensignal* (March, 30).

Agent	Source	Economic Value ($Million)					
		2021	2022	2023	2024	2025	Category
	2.2. Avoidance of investment in in-house wiring	$12,157	$12,982	$13,928	$14,987	$16,396	Consumer Surplus
	2.3. Benefit to consumers from speed increases	$8,227	$8,597	$9,729	$10,639	$12,078	Consumer Surplus
	2.4. Residential Wi-Fi devices and equipment deployed	$2,625	$2,691	$2,768	$2,729	$2,641	Consumer Surplus
	2.5. Bridging digital divide: use of Wi-Fi to increase coverage in rural and isolated areas	$1,620	$1,522	$1,425	$1,325	$1,213	GDP contribution
3. Enterprise Wi-Fi	3.1. Business Internet traffic transmitted through Wi-Fi	$7,167	$7,061	$6,957	$6,854	$6,753	Producer surplus
	3.2. Avoidance of enterprise inside wiring costs	$6,332	$6,371	$6,408	$6,444	$6,479	Producer surplus
	3.3. Return to speed: contribution to GDP derived from an increase in average mobile speed	$9,719	$10,674	$13,045	$14,942	$17,640	GDP contribution
	3.4. Wide deployment of IoT	$10,434	$7,457	$3,582	$2,135	$781	GDP contribution
	3.5. Deployment of AR/VR solutions	$268	$413	$553	$728	$864	GDP contribution
4. ISPs	4.1. CAPEX and OPEX savings due to cellular off-loading	$20,647	$15,468	$27,041	$5,897	$0	Producer surplus
	4.2. Revenues of service providers offering paid Wi-Fi access in public places	$109	$114	$106	$106	$106	GDP contribution
	4.3. Aggregated revenues of WISPs	$27	$25	$24	$22	$21	GDP contribution
5. Wi-Fi ecosystem	5.1. Locally manufactured residential Wi-Fi devices and equipment	$3,500	$3,622	$3,749	$3,703	$3,588	Producer surplus
	5.2. Locally manufactured Wi-Fi enterprise equipment	$0	$0	$0	$0	$0	Producer surplus
	5.3. Locally produced IoT products and services	$951	$1,221	$1,434	$1,558	$1,705	Producer surplus
	5.4. Locally produced of AR/VR solutions	$79	$137	$202	$290	$368	Producer surplus
Total		$102,538	$100,689	$117,753	$104,628	$109,639	

Source: Telecom Advisory Services analysis

In addition to the value generated from the unlicensed use of the 2.4 GHz and 5 GHz bands (referred to as the baseline scenario), the allocation of 1,200 MHz in the 6 GHz spectrum band for unlicensed use and the deployment of Wi-Fi 6 and Wi-Fi 6E devices will trigger an additional boost in economic value, reaching $14.7 billion in 2025 (see Table O-2).

Table O-2. Brazil: Economic Value of Wi-Fi (only attributed to 6 GHz)

Agent	Source	Economic Value ($Million)					
		2021	2022	2023	2024	2025	Category
1. Free Wi-Fi	1.1. Savings generated by free Wi-Fi traffic offered in public sites	$0	$0	$0	$0	$0	Consumer Surplus
	1.2. Deployment of free Wi-Fi in public sites	$90	$184	$284	$385	$482	GDP contribution
	1.3. Benefit of faster free Wi-Fi with Wi-Fi 6E devices	$9	$36	$79	$137	$212	Consumer Surplus
2. Residential Wi-Fi	2.3. Benefit to consumers from speed increases	$23	$108	$312	$549	$871	Consumer Surplus
	2.4. Residential Wi-Fi devices and equipment deployed	$95	$229	$497	$761	$1,030	Consumer Surplus
	2.5. Bridging digital divide: use of Wi-Fi to increase coverage in rural and isolated areas	$286	$648	$1,066	$1,516	$1,955	GDP contribution
3. Enterprise Wi-Fi	3.1. Business Internet traffic transmitted through Wi-Fi	$0	$27	$119	$265	$468	Producer surplus
	3.3. Return to speed: contribution to GDP derived from an increase in average mobile speed	$26	$125	$378	$665	$1,040	GDP contribution
	3.4. Wide deployment of Internet of Things	$119	$741	$2,734	$2,774	$2,828	GDP contribution
	3.5. Deployment of AR/VR solutions	$149	$334	$541	$899	$1,386	GDP contribution
4. ISPs	4.1 CAPEX and OPEX savings due to cellular off-loading	$1,730	$1,730	$1,730	$1,730	$1,730	Producer surplus
	4.2. Revenues of service providers offering paid Wi-Fi access in public places	$3	$7	$10	$13	$16	GDP contribution
	4.3. Aggregated revenues of WISPs	$0	$1	$2	$3	$3	GDP contribution
5. Wi-Fi ecosystem	5.1. Locally manufactured residential Wi-Fi devices and equipment	$132	$320	$697	$1,068	$1,446	Producer surplus
	5.2. Locally manufactured Wi-Fi enterprise equipment	$0	$0	$0	$0	$0	Producer surplus
	5.3. Locally produced IoT products and services	$16	$82	$282	$610	$927	Producer surplus
	5.4. Locally produced of AR/VR solutions	$9	$30	$72	$169	$350	Producer surplus
Total		$2,687	$4,602	$8,803	$11,544	$14,744	

Source: Telecom Advisory Services analysis

As indicated in table O-2, the constant increase in Wi-Fi value driven by the 6 GHz is important in terms of cancelling out the temporary decline in value taking place between 2023 and 2025 in the baseline case. Furthermore, considering that by 2025 only 37.5% of Wi-Fi traffic will rely on the 6 GHz channels, the accelerated effect derived from the new spectrum allocation and latest Wi-Fi technologies will still be far from reaching its maximum potential at this time.

By combining the baseline and the Wi-Fi 6 and 6 GHz scenarios, the overall economic value of Wi-Fi for Brazil will yield $124.4 billion in 2025 (see Table O-3).

Table O-3. Brazil: Total Economic Value of Wi-Fi (including Wi-Fi 6 and 6 GHz)

Agent	Source	Economic Value ($Million)					
		2021	2022	2023	2024	2025	Category
1. Free Wi-Fi	1.1. Savings to consumers of free Wi-Fi traffic offered in public sites	$1,095	$1,179	$1,306	$1,482	$1,715	Consumer Surplus
	1.2. Deployment of free Wi-Fi in public sites	$1,195	$1,230	$1,260	$1,283	$1,286	GDP contribution
	1.3. Benefit of faster free Wi-Fi with Wi-Fi 6E devices	$9	$36	$79	$137	$212	Consumer Surplus
2. Residential Wi-Fi	2.1. Internet access for home usage of devices that lack a wired port	$16,476	$20,110	$24,519	$29,889	$36,487	Consumer Surplus
	2.2. Avoidance of investment in in-house wiring	$12,157	$12,982	$13,928	$14,987	$16,396	Consumer Surplus
	2.3. Benefit to consumers from speed increases	$8,250	$8,705	$10,041	$11,188	$12,949	Consumer Surplus
	2.4. Residential Wi-Fi devices and equipment deployed	$2,720	$2,920	$3,264	$3,490	$3,672	Consumer Surplus
	2.5. Bridging digital divide: use of Wi-Fi to increase coverage in rural and isolated areas	$1,906	$2,170	$2,491	$2,841	$3,168	GDP contribution
3. Enterprise Wi-Fi	3.1. Business Internet traffic transmitted through Wi-Fi	$7,167	$7,088	$7,076	$7,120	$7,222	Producer surplus
	3.2. Avoidance of enterprise inside wiring costs	$6,332	$6,371	$6,408	$6,444	$6,479	Producer surplus
	3.3. Return to speed: contribution to GDP derived from an increase in average mobile speed	$9,745	$10,799	$13,423	$15,607	$18,680	GDP contribution
	3.4. Wide deployment of IoT	$10,552	$8,198	$6,316	$4,909	$3,609	GDP contribution
	3.5. Deployment of AR/VR solutions	$417	$747	$1,094	$1,627	$2,250	GDP contribution
4. ISPs	4.1 CAPEX and OPEX savings due to cellular off-loading	$22,377	$17,198	$28,771	$7,627	$1,730	Producer surplus
	4.2. Revenues of service providers offering paid Wi-Fi access in public places	$113	$121	$116	$119	$122	GDP contribution
	4.3. Aggregated revenues of WISPs	$27	$26	$25	$25	$24	GDP contribution
5. Wi-Fi ecosystem	5.1. Locally manufactured residential Wi-Fi devices and equipment	$3,632	$3,942	$4,446	$4,771	$5,034	Producer surplus

Agent	Source	Economic Value ($Million)					
		2021	2022	2023	2024	2025	Category
	5.2. Locally manufactured Wi-Fi enterprise equipment	$0	$0	$0	$0	$0	Producer surplus
	5.3. Locally produced IoT products and services	$968	$1,303	$1,716	$2,168	$2,632	Producer surplus
	5.4. Locally produced of AR/VR solutions	$88	$167	$274	$459	$718	Producer surplus
Total		$105,226	$105,292	$126,553	$116,173	$124,385	

Source: Telecom Advisory Services analysis

The following sections will present in detail the calculation of each source of value, disaggregating the economic contribution between the current spectrum allocation and the enhanced effect due to Wi-Fi 6 availability and the 6 GHz band.

O.2. Value from free Wi-Fi service

The economic value of free Wi-Fi service originates from three contribution sources:

- Savings to consumers by accessing the Internet in free Wi-Fi sites rather than incurring cellular costs;
- The use of Wi-Fi to expand broadband coverage to the unserved population; and
- The return to speed of Wi-Fi compared to the use of cellular service.

O.2.1. Savings incurred by accessing free Wi-Fi in public sites

As reviewed in Chapter III, the economic value of free Wi-Fi is measured in terms of consumer surplus, calculated by estimating the benefit that flows to consumers as a result of savings incurred by not relying on cellular service. We begin by forecasting the traffic generated from free Wi-Fi access points. In order to isolate the effect from the increased capacity derived from the 6 GHz allocation, we calculate the portion of free Wi-Fi traffic attributed to current spectrum bands. As the traffic per hotspot, based on Cisco and Wiman (2020) data, is not expected to increase in the coming years, it is conservatively assumed that the 6 GHz band allocation will not have a significant impact in this area (see Table O-4).

Table O-4. Brazil: Total Free Wi-Fi Traffic projection (2021-2025)

Variable	2021	2022	2023	2024	2025
Free Wi-Fi traffic (million GB Per year) - considering current trends	893	1,073	1,328	1,684	2,179
Free Wi-Fi hotspots (Million)	1.36	1.90	2.63	3.66	5.08
Traffic per hotspot - considering current trends	654	566	505	460	429
Traffic per hotspot - capped due to congestion	654	566	505	460	429
Total traffic (not attributed to 6 GHz) (Million GB)	893	1,073	1,328	1,684	2,179

Sources: Cisco; Wiman; Telecom Advisory Services analysis

We calculate consumer surplus by multiplying the total free traffic (not attributed to 6 GHz) by the difference between what the consumer would have to pay if he/she were to rely on a wireless carrier and the cost of offering free Wi-Fi (incurred by the retailer or public site). To do so, according to the Alliance for Affordable Internet, in 2019 the price for a 2 GB plan was $9.83, while a 5 GB plan was priced at $13.47, and a 10 GB plan was $16.38. The conversion to price per GB for the highest capacity plan, it resulted in $1.64. By relying on the annual price decline coefficient of 0.8994 for the United States, we forecast pricing through 2025 (see Table O-5).

Table O-5. Brazil: Average Price Per Gigabyte (2019-2025)

Year	Price per GB ($)
2019	$1.64
2020	$1.47
2021	$1.33
2022	$1.19
2023	$1.07
2024	$0.96
2025	$0.87

Sources: Alliance for Affordable Internet; Telecom Advisory Services analysis

By relying on the total free Wi-Fi traffic not attributed to 6 GHz allocation shown in Table O-4 and the average price per cellular gigabyte minus the cost of provisioning Wi-Fi service, we calculated the consumer surplus of free Wi-Fi traffic (see Table O-6).

Table O-6. Brazil: Consumer Surplus of Free Wi-Fi Traffic (2021-2025)

Variable	2021	2022	2023	2024	2025
Total Free Traffic (not attributed to 6 GHz) (Million GB)	893	1,073	1,328	1,684	2,179
Price per cellular gigabyte ($)	$1.33	$1.19	$1.07	$0.96	$0.87
Cost per Wi-Fi provisioning ($)	$0.10	$0.09	$0.09	$0.08	$0.08
Consumer surplus per gigabyte ($)	$1.23	$1.10	$0.98	$0.88	$0.79
Total Consumer surplus ($Million)	$1,095	$1,179	$1,306	$1,482	$1,715

Sources: Alliance for Affordable Internet; Telecom Advisory Services analysis

As indicated in Table O-6, consumer surplus of free Wi-Fi traffic in 2021 would reach an estimated $1,095 million, increasing to $1,715 million by 2025.

O.2.2. Free Wi-Fi to provide broadband to the unserved population

As explained in section B, free Wi-Fi in public sites can provide Internet access to the unserved population. Consumers that do not have broadband at home because they lack the economic means to acquire services can rely on free Wi-Fi to gain Internet access. The net result is that more people can be connected, which in turn enhances the economic contribution of broadband.

The estimation of this particular economic effect begins by calculating which portion of households that lack broadband service are already accessing Internet through free hotspots or through Municipal Wi-Fi points. We follow a conservative approach and assume that only 5% of unconnected households rely on free hotspots for accessing Internet and 10% rely on Municipal Wi-Fi. After calculating the increase in broadband penetration due to households relying on free Wi-Fi, we multiple it by the broadband impact coefficient calculated by Katz and Callorda (2018). As a result, the GDP contribution of this particular effect is expected to amount to $1,105 million in 2021, reaching $804 million in 2025 (see Table O-7).

Table O-7. Brazil: GDP contribution due to households relying on Free Wi-Fi (2021-2025)

Variable	2021	2022	2023	2024	2025
Households that don't buy because affordability in urban areas	4,017,410	4,017,410	4,017,410	4,017,410	4,017,410
Households that don't buy because lack of coverage at their homes in urban areas	392,645	392,645	392,645	392,645	392,645
Households that are now served by WISP	32,348	73,115	120,280	172,100	227,077
Potential Wi-Fi Municipal market (households)	4,377,707	4,336,940	4,289,775	4,237,955	4,182,978
Municipal Wi Fi deployment (% Total Municipalities)	40.99%	43.83%	46.88%	50.13%	53.61%
Share of the population that have access to a Wi Fi Municipal point	43.84%	44.48%	45.14%	45.80%	46.48%
Traffic NOT through 6 GHz Band	93%	85%	78%	70%	63%
New households that now can have broadband	727,617	718,817	703,484	681,199	651,460
Share of population that effectively goes to a Municipal Wi-Fi Point	10%	10%	10%	10%	10%
Households with Fixed Broadband	35,431,290	37,023,107	38,884,067	41,041,771	44,042,434
Increase in national broadband penetration	0.21%	0.19%	0.18%	0.17%	0.15%
Impact of fixed broadband adoption in GDP	0.15745	0.15745	0.15745	0.15745	0.15745
Increase in the GDP due to the new broadband adoption (% GDP)	0.03%	0.03%	0.03%	0.03%	0.02%
Total Impact Municipal	0.643	0.637	0.624	0.600	0.561
Municipalities that do not offer Free Wi-Fi	59.01%	56.17%	53.12%	49.87%	46.39%
New households that now can have broadband	1,047,568	921,030	797,180	677,576	563,621
Share of population that effectively goes to a Free Wi Fi Point	5.00%	5.00%	5.00%	5.00%	5.00%
Increase in national broadband penetration	0.15%	0.12%	0.10%	0.08%	0.06%
Total impact in GDP Hotspots ($Billion)	0.46	0.41	0.35	0.30	0.24
Total impact in GDP ($Million)	1,105	1,045	977	898	804

Note: The number of households not purchasing broadband service due to affordability barriers is driven by several variables difficult to quantify (i.e. growth in the economy, income distribution, technology adoption, digital literacy); in this case, the variable was conservatively assumed to remain constant.
Sources: Cetic.Br; ANATEL; IBGE; IMF; UIT; Telecom Advisory Services analysis

The decline is driven by the increase in household fixed connections and a gradual substitution by 6 GHz effect, analyzed below.

Enhanced GDP contribution due to 6 GHz allocation

As stated in section B, Wi-Fi technology operating in the 6 GHz band supports a higher number of devices per access point than Wi-Fi sites relying on the 2.4 GHz and 5 GHz bands. Accordingly, the improved throughput of free Wi-Fi hotspots under the 6 GHz allocation will allow free Wi-Fi sites to serve additional unconnected households. The potential universe of additional users that could be served under this effect in Brazil is significant, as most unconnected households in the country usually identify that broadband service cost is the main barrier adoption[273] and thus, could potentially be served by free hotspots as long as they are in proximity to the access point. However, evidence suggests that not many people undergoing the affordability barrier rely exclusively on free Wi-Fi as their main source of Internet access[274]. Therefore, we will follow again a conservative approach and assume that a further 5% of unconnected households will be served through free hotspots under the allocation of the 6 GHz band, and 10% for Municipal Wi-Fi. As a result, the GDP contribution of this particular effect is expected to amount to $90 million in 2021, reaching $482 million in 2025 (Table O-8).

Table O-8. Brazil: GDP contribution due to households relying on Free Wi-Fi or Municipal Wi-Fi due to 6 GHz (2021-2025)

Variable	2021	2022	2023	2024	2025
Households that don't buy because affordability in urban areas	4,017,410	4,017,410	4,017,410	4,017,410	4,017,410
Households that don't buy because lack of coverage at their homes in urban areas	392,645	392,645	392,645	392,645	392,645
Households that are now served by WISP	32,348	73,115	120,280	172,100	227,077
Potential Wi-Fi Municipal market (households)	4,377,707	4,336,940	4,289,775	4,237,955	4,182,978
Municipal Wi Fi deployment (% Total Municipalities)	40.99%	43.83%	46.88%	50.13%	53.61%
Share of the population that have access to a Wi Fi Municipal point	43.84%	44.48%	45.14%	45.80%	46.48%
Traffic through 6 GHz Band	7.50%	15.00%	22.50%	30.00%	37.50%
New households that now can have broadband	58,996	126,850	204,237	291,943	390,876
Share of population that effectively goes to a Municipal Wi-Fi Point	10%	10%	10%	10%	10%
Households with Fixed Broadband	35,431,290	37,023,107	38,884,067	41,041,771	44,042,434
Increase in national broadband penetration	0.02%	0.03%	0.05%	0.07%	0.09%
Impact of fixed broadband adoption in GDP	0.15745	0.15745	0.15745	0.15745	0.15745
Increase in the GDP due to the new broadband adoption (% GDP)	0.00%	0.01%	0.01%	0.01%	0.01%
Total Impact Municipal	0.052	0.112	0.181	0.257	0.337
Municipals that don't have Municipal Wi-Fi	59.01%	56.17%	53.12%	49.87%	46.39%
New households that now can have broadband	84,938	162,535	231,439	290,390	338,173
Share of population that effectively goes to a Free Wi Fi Point	5.00%	5.00%	5.00%	5.00%	5.00%
Increase in national broadband penetration	0.01%	0.02%	0.03%	0.04%	0.04%

[273] CGI.br/NIC.br, Centro Regional de Estudos para o Desenvolvimento da Sociedade da Informação (Cetic.br), Pesquisa sobre o uso das tecnologias de informação e comunicação nos domicílios brasileiros - TIC Domicílios 2019.
[274] They tend to use also broadband service provided at work or at an educational institution.

Variable	2021	2022	2023	2024	2025
Total impact in GDP Hotspots ($Billion)	0.04	0.07	0.10	0.13	0.15
Total impact in GDP ($Million)	90	184	284	385	482

Sources: Cetic.Br; ANATEL; IBGE; IMF; UIT; Telecom Advisory Services analysis

O.2.3. Benefit to consumers for enjoying higher speed from free Wi-Fi if 6 GHz band is allocated

When the 6 GHz band is adopted by free Wi-Fi access points, it will deliver service at faster broadband speed. Current speeds from free hotspots in Brazil are quite modest. Thus, the expanded capabilities due to the allocation of 6 GHz spectrum band will enhance free Wi-Fi speed, and as a result, will increase consumer surplus. To estimate this, we assume that current traffic per line stays at the current levels, while under Wi-Fi 6 it will grow as projected by the Cisco Annual Internet Report Highlights Tool 2018-2023. The difference is multiplied by the price per GB in Brazil as reported by the Alliance for Affordable Internet. We expect the consumer surplus resulting from faster speed in free Wi-Fi sites to reach $190 million in 2025 (Table O-9).

Table O-9. Brazil: Consumer surplus for enjoying higher speed from free Wi-Fi if 6 GHz band allocated (2021-2025)

Variable	2021	2022	2023	2024	2025
Free hotspots ('000)	2,326	2,326	2,326	2,326	2,326
Traffic through 6 GHz Band	8%	15%	23%	30%	38%
Hotspots using the 6 GHz Band ('000)	174	349	523	698	872
Traffic after speed increase (GB)	23.32	27.10	31.49	36.58	42.50
Traffic with speed without 6 GHz (GB)	20.08	20.08	20.08	20.08	20.08
Yearly Increase in traffic (Billion GB)	0.006	0.027	0.067	0.129	0.219
Price per GB	1.33	1.19	1.07	0.96	0.87
Total impact in consumer surplus ($Billion)	0.008	0.033	0.072	0.124	0.190

Sources: Wiman; Cisco VNI 2017-2022; Alliance for Affordable Internet; Nevo et al. (2016); Telecom Advisory Services analysis

A similar analysis was conducted for Municipal Wi-Fi. The objective in this case is to estimate the difference in the download speed of municipal Wi-Fi service before and after the allocation of 6 GHz spectrum for those households that do not purchase broadband service and are compelled to rely on this service to gain Internet access. We start by relying on Cetic.br survey data indicating those households that access the Internet from sites away from home (i.e. work, place of study, free sites, and municipal Wi-Fi): 1,077,742. Of this universe, not all households have the capability to access municipal Wi-Fi because not all local governments in Brazil have deployed networks (only 38.33% have done so, which based on their geographic coverage, amounts to 43.20% of the population served by those municipalities). Because the objective is to estimate the incremental impact of 6 GHz, we factor the population coverage by Wi-Fi 6 adoption in municipal Wi-Fi networks, which is assumed to grow from 8% in 2021 to 37.5% in 2025. Accordingly, we expect the consumer surplus resulting from faster speed in Municipal Wi-Fi sites to reach $22 million in 2025 (Table O-10).

Table O-10. Brazil: Consumer surplus for enjoying higher speed from Municipal Wi-Fi if 6 GHz band allocated (2021-2025)

Variable	2021	2022	2023	2024	2025
Households that do not buy broadband service because have access in another place in urban areas ('000)	1,078	1,078	1,078	1,078	1,078
Municipal Wi Fi deployment (% Total Municipalities)	40.99%	43.83%	46.88%	50.13%	53.61%
Share of the population that have access to a Wi Fi Municipal point	43.84%	44.48%	45.14%	45.80%	46.48%
Municipal networks adopting Wi-Fi 6	8%	15%	23%	30%	38%
Households covered by Wi-Fi Municipal with 6 GHz band	14,524	31,523	51,312	74,243	100,709
Traffic after speed increase (GB)	23.32	27.10	31.49	36.58	42.50
Traffic with speed without 6 GHz (GB)	20.08	20.08	20.08	20.08	20.08
Yearly Increase in traffic (Billion GB)	0.001	0.002	0.007	0.014	0.025
Price per GB	$1.33	$1.19	$1.07	$0.96	$0.87
Total impact in consumer surplus ($Billion)	$0.001	$0.003	$0.007	$0.013	$0.022

Sources: Cetic.Br; IBGE; Cisco VNI 2017-2022; Alliance for Affordable Internet; Nevo et al. (2016); Telecom Advisory Services analysis

O.3. Residential Wi-Fi

The economic value of Wi-Fi in consumer residences is the result of five factors:

- Provision of connectivity to the home network for devices that lack an Ethernet port;
- Cost avoidance of ethernet inside wiring;
- Consumer surplus resulting from faster broadband speeds relative to cellular networks;
- Consumer surplus derived from usage of home devices connected to the home network; and
- Provision of Internet access to consumers located in rural and isolated areas.

O.3.1. Home Internet access for devices that lack an Ethernet port

The underlying premise of this analysis is that in the absence of Wi-Fi, users of devices lacking an Ethernet port would have to depend on the cellular network to gain Internet access. For this reason, estimating value would first measure the traffic generated by these devices at home and then multiply it by the average price charged by cellular carriers.

To estimate the traffic of smartphones and tablets, we relied on 2018 Cisco estimates for the period 2016-21 and extrapolated those growth rates to 2025. It should be mentioned, however, that in 2019 Cisco adjusted its predictions upwards. However, we preferred to rely on the original estimates to avoid incurring in the risk of overestimation. In addition, we have to consider that according to Cisco IBSG (2012), 43.12% of use time of devices that lack an Ethernet port occurs at home. Therefore, the portion of said traffic generated at home in Brazil will reach 12,433 million gigabytes in 2021 (see Table O-11).

Table O-11. Brazil: Total Mobile Internet Traffic (2021-2025) (million gigabytes, unless indicated)

Variable	2021	2022	2023	2024	2025
Total Annual traffic - Smartphones	24,635	33,930	46,601	63,913	87,692
Total Annual traffic - Tablets	4,201	5,201	6,440	7,974	9,873
Share of traffic at Home	43.12%	43.12%	43.12%	43.12%	43.12%
Total Traffic at Home - Smartphones	10,622	14,630	20,093	27,558	37,811
Total Traffic at Home - Tablets	1,811	2,243	2,777	3,438	4,257
Total Traffic at Home	12,433	16,872	22,870	30,996	42,068
Average Price per GB ($)	$1.33	$1.19	$1.07	$0.96	$0.87
Price per home traffic ($Million)	$16,476	$20,110	$24,519	$29,889	$36,487

Sources: Cisco; GSMA; IBSG; Alliance for Affordable Internet; Telecom Advisory Services analysis

If this traffic had to be transported by cellular networks, at the average price per GB estimated above (Table O-5), it would result in costs of $16.5 billion in 2021 reaching $36.5 billion in 2025.

O.3.2. Avoidance of inside wiring investment

Residential Wi-Fi allows consumers to avoid paying for inside wiring to connect all home devices (printers, laptops, storage units, etc.). Considering that 91% of connected households will have Wi-Fi in 2021[275], and the wiring cost estimated for households approximates $377[276], the avoidance costs of inside wiring over 35.4 million households yields a total of $12.2 billion. By 2025, almost all connected households are expected to have adopted Wi-Fi. Therefore, the savings from inside wiring avoidance would have reached $16.4 billion (Table O-12).

Table O-12. Brazil: Consumer surplus from avoidance of investment in in-house wiring (2021-2025)

Variable	2021	2022	2023	2024	2025
Total Wiring Cost	$377.04	$377.04	$377.04	$377.04	$377.04
Households with Internet	35,431,290	37,023,107	38,884,067	41,041,771	44,042,434
Households with Wi-Fi (%)	91%	93%	95%	97%	99%
Households with Internet and Wi-Fi	32,242,474	34,431,489	36,939,864	39,749,130	43,486,132
Inside Wiring Costs ($Million)	$12,157	$12,982	$13,928	$14,987	$16,396

Sources: Watkins (2012); ANATEL; Telecom Advisory Services

O.3.3. Benefits derived from speed increase

As described before, consumer surplus increases if users enjoy faster Internet speeds through Wi-Fi than from cellular networks. By weighting the percentage of affected users by the benefits of relying on Wi-Fi rather than on cellular service and applying the willingness-to-pay parameters defined in Nevo et al. (2016), the expected consumer surplus will amount to $8,227 million in 2021, increasing to $12,078 million in 2025 (Table O-13).

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[275] Extrapolation based on data from Watkins (2012).
[276] The USA average for wiring a residence in USA is $660. For Brazil, we adjusted that number by the PPP conversion rate (0.57128), resulting in a cost for wiring a house of $377.

Table O-13. Brazil: Consumer surplus from faster Residential Wi-Fi speed (2021-2025)

Variable	2021	2022	2023	2024	2025
Demand for average download speed	$84.36	$87.44	$90.53	$93.63	$96.73
New Demand for average download speed	$105.62	$108.25	$112.48	$115.93	$119.87
Additional Monthly Consumer surplus	$21.26	$20.81	$21.95	$22.30	$23.15
Additional Yearly Consumer Surplus	$255.16	$249.69	$263.36	$267.65	$277.74
Affected Households (Million)	32.242	34.431	36.939	39.749	43.486
Impact ($Million)	$8,227	$8,597	$9,729	$10,639	$12,078

Sources: Cisco; ANATEL; Nevo et al. (2016); Telecom Advisory Services analysis

Additional benefit to residential consumers from speed increase due to 6 GHz

The well-being of residential Wi-Fi customers is expected to receive further benefit from the 6 GHz spectrum allocation due to faster Internet service under Wi-Fi 6E. As previously described in Chapter III, we limit this benefit to households acquiring a 150 Mbps (or faster) fixed broadband line since they are undergoing current router bottlenecks. After calculating the difference in average speed attributed to 6 GHz, the additional consumer surplus will yield $777 million in 2025 (see Table O-14).

Table O-14. Brazil: Consumer surplus from faster speed in households if 6 GHz allocated (2021-2025)

Variable	2021	2022	2023	2024	2025
Average Download Speed	48.27	54.43	66.04	77.32	92.58
New Average Download Speed	48.36	54.94	67.83	80.88	99.01
Demand for average download speed	105.62	108.25	112.48	115.94	119.88
New Demand for average download speed	105.67	108.46	113.07	116.92	121.35
Additional Monthly Consumer surplus	$0.04	$0.20	$0.59	$0.98	$1.47
Additional Yearly Consumer Surplus	$0.52	$2.43	$7.04	$11.82	$17.65
Fixed Broadband Connections (Million)	35.431	37.023	38.884	41.042	44.042
Impact ($Million)	$18	$90	$274	$485	$777

Sources: ANATEL; Nevo et al. (2016); Telecom Advisory Services analysis

In addition, Wireless ISP subscribers would benefit from faster broadband speed with the implied consumer surplus. The starting point of this estimate is to calculate the difference in broadband speed yielded by the 6 GHz spectrum. The multiplication of the speed increase by the willingness-to-pay coefficient for incremental broadband speed yields an enhancement of consumer surplus by line. Finally, the WTP per line is multiplied by the number of WISP lines (see Table O-15).

Table O-15. Brazil: Consumer surplus due to WISP user speed increase (2021-2025)

Variable	2021	2022	2023	2024	2025
Average Download Speed	9.54	9.54	9.54	9.54	9.54
New Average Download Speed	10.83	12.29	13.95	15.83	17.97
Demand for average download speed	70.16	70.16	70.16	70.16	70.16
New Demand for average download speed	72.93	75.69	78.46	81.23	84.00
Additional Monthly Consumer surplus	$2.77	$5.54	$8.31	$11.08	$13.85
Additional Yearly Consumer Surplus	$33.23	$66.47	$99.70	$132.93	$166.17
WISP Connections (Million)	1.962	1.837	1.720	1.610	1.507
Traffic through 6 GHz Band	7.50%	15.00%	22.50%	30.00%	37.50%
Impact ($Million)	$5	$18	$39	$64	$94

Sources: ANATEL; Nevo et al. (2016); Telecom Advisory Services analysis

O.3.4. Residential Wi-Fi devices and equipment

The consumer surplus derived from the adoption of residential Wi-Fi devices and equipment focuses on seven consumer products which are intrinsically linked to Wi-Fi: smart home devices and systems such as Wi-Fi speakers and home security systems, home networking systems, Wi-Fi tablets, access points, external adapters, routers, and gateways. Two different approaches are used in this case to measure consumer surplus: the first one addressing six of the seven products (excluding tablets) assumes that consumer surplus is roughly equal to producer surplus, while the second one provides a measure of tablets' willingness-to-pay.

The estimation of economic value in the first approach begins by calculating sales in the six product categories in Brazil[277]. After computing the sales in the country, we applied the prorated margin estimated by CSI markets (39.44%) which yields an estimated producer surplus for these specific products of $2.512 billion in 2021. As mentioned above, it is assumed that the consumer surplus is of the same magnitude. This methodology was also used to calculate the consumer surplus up to 2023. However, the gradual adoption of Wi-Fi 6 devices is forecast to reduce the sales and economic value from devices relying on the 2.4 GHz and 5 GHz spectrum bands. Non 6 GHz consumer devices shipments are expected by IDC to decrease by 1.2% in 2024 and 3.1% in 2025. Based on this estimate, we extrapolated the consumer surplus from non 6 GHz reliant residential Wi-Fi devices and equipment between 2021 and 2025.

Additionally, we also calculated the consumer surplus attributed to tablets bought by Brazilian consumers. Starting with CTA/Statista worldwide tablet revenue estimates, we interpolated the revenue figures for Brazil (prorating by the country's share of global GDP), and extrapolating the evolution of local revenue up to 2025 by considering Cisco estimates of tablet evolution for the period. We reviewed the data on tablet prices for the market leader (taking as a reference the Apple iPad 10.2 Inch 128 GB, as Apple has 75% of the local market share in tablets[278]) and for the rest of the market (taking as a reference a Samsung Wi-Fi tablet 128 GB), and assumed consumer willingness-to-pay levels in a similar percentage above prices as in the United States average. Based on that information, we estimated a consumer surplus attributed to tablets of $113 million in 2021, expected to reach $85 million in 2025. The aggregated consumer surplus of all residential Wi-Fi enabled products in Brazil is expected to reach 2,641 million in 2025 (Table O-16).

Table O-16. Brazil: Economic Value of Wi-Fi enabled consumer products (2021-2025)

Variable	2021	2022	2023	2024	2025
Consumer surplus (ex. Tablets) ($Million)	$2,512	$2,588	$2,672	$2,639	$2,557
Total tablets consumer surplus ($Million)	$113	$103	$96	$90	$85
Total consumer surplus ($Million)	$2,625	$2,691	$2,768	$2,729	$2,641

Sources: Consumer Technology Association; ABI Research; CS Markets; IDC; Telecom Advisory Services analysis

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[277] Calculated by prorating data for the United States based on GDP.
[278] Source: Gs StatCounter

Consumer surplus derived from Wi-Fi enabled residential equipment for 6 GHz

As discussed above, sales of residential Wi-Fi devices and equipment operating in the 6 GHz band are expected to gradually replace those of former generations. According to IDC, global shipments of consumer devices operating in the 6 GHz (802.11ax standard) will represent 40% of sales from prior generations. As a result, if the shipments ratio will reach 40% in 2025, we can expect that, at least, the consumer surplus derived from 6 GHz devices will represent 40% of that of former technology residential devices. As a result, our estimates for consumer surplus attributed to 6 GHz residential devices will amount to $1.0 billion in 2025 (see Table O-17).

Table O-17. Brazil: Economic Value of Wi-Fi enabled consumer products for 6 GHz (2021-2025)

Variable	2021	2022	2023	2024	2025
Consumer surplus (ex. Tablets) ($Million)	$2,512	$2,588	$2,672	$2,639	$2,557
Consumer 6 GHz / no 6 GHz device ratio	3.76%	8.83%	18.59%	28.86%	40.30%
Consumer surplus 6 GHz devices ($Million)	$95	$229	$497	$761	$1,030

Sources: IDC; Telecom Advisory Services analysis

O.3.5. Bridging the digital divide: use of Wi-Fi to increase coverage in rural and isolated areas

Wi-Fi is an appropriate technology to offer Internet access in rural and isolated areas. The incremental number of lines supported by WISPs represents an increase in penetration, which in turn contributes to the Brazilian GDP.

The Brazilian WISPs cover approximately 12 million households (33%). There are 3,450 Brazilian WISPs[279] registered in ANATEL with sizes ranging between 50 and 76,000 lines. In total, the Brazilian WISPs operate 1,962,163 wireless connections in 2020. Of these, 1,810,272 are Wi-Fi based and 151,891 rely either on WiMAX or other wireless technologies[280]. Most lines supplied by WISPs are in the lower speeds range: 24.9% are under 2 Mbps, and 57% are between 2 Mbps and 12 Mbps. In order to estimate Wi-Fi's contribution, we assume that 90% of WISP potential connections may be theoretically served by other technologies (i.e. satellite) covering the same isolated footprint. Thus, we can conservatively expect 10% of broadband subscriptions in remote locations exclusively attributed to WISPs. With this value, we calculate the impact on GDP by relying on the coefficient estimated by Katz and Callorda (2018b) through regression models that links increase in broadband penetration to economic growth. The contribution to GDP materializes through multiple effects: creation of new businesses, increasing productivity of existing enterprises, and growth of average income per household. However, the calculation

[279] The difference between this number extracted from the ANATEL files and the often-quoted 10,000 WISPs is due to some very small non-registered players (WISPs are not required to have a license in Brazil) and the fact that the above estimate does not double count WISPs serving more than one municipality.
[280] Analysis of ANATEL. Op. cit.

of Wi-Fi contribution to GDP must subtract the direct impact of WISPs sales (estimated in Section 0.5.3.) to avoid double counting. As a result, by reducing the digital divide and increasing broadband penetration, we estimate a GDP contribution of $1,213 million in 2025 (see Table 0-18).

Table 0-18. Brazil: Estimation of GDP Contribution derived from reducing the digital divide (2021-2025)

Variable	2021	2022	2023	2024	2025
WISP subscribers (Million)	1.837	1.720	1.610	1.507	1.411
Additional broadband penetration due to WISP	5.18%	4.64%	4.14%	3.67%	3.20%
Impact of fixed broadband adoption in GDP	15.75%	15.75%	15.75%	15.75%	15.75%
WISP TOTAL impact ($Million)	$16,227	$15,244	$14,270	$13,276	$12,149
WISP Revenues ($Million)	$27	$25	$24	$22	$21
Share that exist because WISP	10.00%	10.00%	10.00%	10.00%	10.00%
WISP spillovers on GDP ($Million)	$1,620	$1,522	$1,425	$1,325	$1,213

Sources: WISPA; ITU; ANATEL; IMF; Telecom Advisory Services analysis

Economic impact of enhanced coverage and affordability due to 6 GHz

The starting point for estimating the additional impact of the 6 GHz spectrum band on the expansion of coverage and increase of affordability is the number of households served by Brazilian WISPs. By assuming price stability of broadband services and accounting for the GDP growth forecast from the IMF, affordability increases at 3.60% per year. It should be acknowledged however that not all WISPs will migrate to Wi-Fi 6 immediately: we assume that 7.5% of lines will be impacted in 2021, reaching 37.50% in 2025. This yields the first effect of incremental lines due to enhanced affordability. The second effect is the increase in line sharing of existing lines because, with no congestion, sharing (a common feature in Brazil) becomes more feasible (see Table 0-19).

Table 0-19. Brazil: New WISP lines resulting from increased affordability (2021-2025)

Variable	2021	2022	2023	2024	2025
New WISP adoption after price decrease (% households)	2.89	2.69	2.51	2.34	2.18
Traffic through 6 GHz Band	7.50%	15.00%	22.50%	30.00%	37.50%
Increase in WISP connections due to lower prices (households that buy the service)	18,283	34,391	48,502	60,782	71,392
Sharing %	45.16%	49.38%	53.59%	57.80%	62.00%
Increase in WISP connections due to lower prices (considering households that share the connection)	26,540	51,372	74,492	95,913	115,659
New users due to higher sharing rate	5,808	21,743	45,788	76,187	111,418

Sources: WISPA; ANATEL; IMF; Telecom Advisory Services analysis

The compounding of both effects drives an increase in broadband penetration due to the 6 GHz allocation: up to 0.31% in 2025. Based on the impact coefficient of fixed broadband on GDP, the total economic contribution is estimated (see Table 0-20).

Table O-20. Brazil: GDP contribution of New WISP lines resulting from increased affordability (2021-2025)

Variable	2021	2022	2023	2024	2025
Increase in national broadband penetration	0.04%	0.10%	0.17%	0.24%	0.31%
Impact of fixed broadband adoption in GDP	0.15745	0.15745	0.15745	0.15745	0.15745
Increase in the GDP due to the new broadband adaptation (% GDP)	0.01%	0.03%	0.05%	0.07%	0.08%
Total impact in GDP ($Billion)	$0.286	$0.648	$1.066	$1.516	$1.955

Source: Telecom Advisory Services analysis

O.4. Enterprise Wi-Fi

Beyond the impact on consumers, Wi-Fi also contributes significant economic value in the Brazilian enterprise segment. This section provides estimates in five areas:

- Support of business Internet traffic;
- Avoidance of campus and enterprise facilities inside wiring;
- Contribution to GDP resulting from Wi-Fi speed faster than cellular connections;
- Deployment of IoT solutions; and
- Implementation of business focused AR/VR use cases.

O.4.1. Business Internet traffic transmitted through Wi-Fi

Wi-Fi enterprise telecommunications savings result from wireless traffic that is routed through Wi-Fi access points rather than cellular networks. Based on Cisco 2016-21 projections for Brazil, we estimate that total business Internet traffic will reach 10.2 billion GB in 2021, of which 5.4 billion GB would have been transported through Wi-Fi access points. Considering the average price per GB transported by cellular, savings from Wi-Fi will reach $7.2 billion, an addition to the producer surplus. By 2025, this benefit will reach $6.8 billion (see Table O-21).

Table O-21. Brazil: Savings in business wireless traffic (2021-2025)

Variable	2021	2022	2023	2024	2025
Share of Business Internet Traffic by Wi Fi	53.00%	52.23%	51.48%	50.74%	50.00%
Total Business Internet Traffic (Million GB)	10,205	11,342	12,606	14,010	15,572
Total Wi-Fi enterprise traffic (Million GB)	5,409	5,924	6,489	7,108	7,786
Average Price per GB	$1.33	$1.19	$1.07	$0.96	$0.87
Economic Impact ($Million)	$7,167	$7,061	$6,957	$6,854	$6,753

Sources: Cisco; Telecom Advisory Services analysis

Enhanced business Internet traffic transmitted through Wi-Fi due to 6 GHz

The deployment of the latest enterprise applications will generate an exponential growth in data traffic that will be handled by devices operating in unlicensed spectrum, through the combination of the existing bands and the 6 GHz band. In 2019, an updated Cisco traffic forecast based on the explosion of IoT and AR/VR applications, among other factors, increased total business Internet traffic projections from the prior 2016-21 estimates from 2018. As in the case of the United States, we assume that part of the growth was driven by "natural" growth, while the remainder was triggered by Wi-Fi traffic stimulated by shifting traffic to the 6 GHz band. The sum of the difference due to broader Wi-Fi traffic will reach $468 million in 2025 (see Table O-22).

Table O-22. Brazil: Savings in business wireless traffic due to 6 GHz (2021-2025) ($Million)

Variable	2021	2022	2023	2024	2025
Total Business Internet Traffic (Million GB)	10,085	11,493	13,098	14,927	17,012
Total Business Internet Traffic (Million GB) Old projection	10,205	11,342	12,606	14,010	15,572
Difference between the 2 estimations (Million GB)	0	151	493	917	1,440
Average Price per GB	$1.33	$1.19	$1.07	$0.96	$0.87
Economic Impact ($Billion)	$0.000	$0.180	$0.528	$0.884	$1.249
Traffic through 6 GHz Band	7.50%	15.00%	22.50%	30.00%	37.50%
Economic Impact ($Million)	$0	$27	$119	$265	$468

Sources: Cisco; analysis Telecom Advisory Services

O.4.2. Avoidance in enterprise building inside wiring

Similar to residential Wi-Fi savings due to capital investment avoidance in inside wiring, we assume that the total number of business establishments are equipped with Wi-Fi access points and multiply this value by a standard cost of deploying a CAT 6 network (although in this case, the cost is $1,257[281] per building) (see Table O-23).

Table O-23. Brazil: Savings in business wiring CAPEX (2021-2025)

Variable	2021	2022	2023	2024	2025
Total Wiring Cost	$1,257	$1,257	$1,257	$1,257	$1,257
Number of Establishments	5,038,278	5,069,114	5,098,647	5,126,854	5,155,217
Establishments with Wi-Fi (%)	100%	100%	100%	100%	100%
Establishments with Wi-Fi	5,038,278	5,069,114	5,098,647	5,126,854	5,155,217
Inside Wiring Costs ($Million)	$6,332	$6,371	$6,408	$6,444	$6,479

Sources: IBGE, Diretoria de Pesquisas, Coordenação de Cadastros e Classificações, Cadastro Central de Empresas 2018; Telecom Advisory Services analysis

O.4.3. Return to speed: contribution to GDP derived from an increase in average mobile speed

In Brazil, there is a significant gap between the speeds obtained through mobile traffic and traffic through fixed networks (48.27 Mbps vs 15.56 Mbps by 2021[282]). By weighting the percentage of impacted connections by the benefit of relying on Wi-Fi rather than cellular networks, and applying the coefficient linking the impact of speed in GDP, the expected contribution will yield $9,719 million in 2021, increasing to $17,640 million in 2025 (see Table O-24).

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[281] The cost for USA is $2,200, adjusted for Brazilian PPP conversion rate (0.57128), results in a cost for Brazil of $1,257

[282] Cisco estimation for mobile speed, and for fixed broadband speed Telecom Advisory Services estimation using CETIC.br and ANATEL historical data.

Table O-24. Brazil: Estimation of speed differential for total traffic (2021-2025)

Variable	2021	2022	2023	2024	2025
Speed increase for affected premises (%)	210%	172%	157%	134%	118%
Impact of speed in GDP	0.26%	0.34%	0.44%	0.56%	0.73%
Increase in GDP	0.55%	0.58%	0.68%	0.76%	0.86%
GDP ($Billion)	$1,778	$1,842	$1,909	$1,977	$2,049
GDP increase ($Million)	$9,719	$10,674	$13,045	$14,942	$17,640

Sources: Cisco; ANATEL; CETIC.br; IMF; Telecom Advisory Services analysis

Additional return to speed effect due to 6 GHz

As previously described, only those broadband connections above 150 Mbps will be affected due to current router bottlenecks, and hence, the speed experienced will not be equivalent to that delivered by the fixed network. Thus, the allocation of spectrum in the 6 GHz band will remove those barriers, increasing broadband speeds. After calculating the difference in average speed attributed to 6 GHz, the additional GDP contribution will yield $1.0 billion in 2025 (Table O-25).

Table O-25. Brazil: Estimation of speed differential due to 6 GHz (2021-2025)

Variable	2021	2022	2023	2024	2025
Mean speed with no 6 GHz (Mbps)	48.27	54.43	66.04	77.32	92.58
Mean speed with 6 GHz (Mbps)	48.36	54.94	67.83	80.88	99.01
Speed increase due to 6Ghz (%)	0%	1%	3%	5%	7%
Impact speed on GDP	0.73%	0.73%	0.73%	0.73%	0.73%
Increase in GDP (%)	0.00%	0.01%	0.02%	0.03%	0.05%
GDP increase ($Million)	$26	$125	$378	$665	$1,040

Sources: Cisco; ANATEL; Telecom Advisory Services analysis

O.4.4. IoT deployment

IoT adoption contributes to GDP growth through the multiplicity of use cases that improve efficiency in operational processes such as preventive maintenance, production monitoring and the like. To estimate this effect, we rely on a coefficient of GDP impact calculated through an aggregate simple production function which estimates that a 10% rise in M2M connections results in annual increases in GDP of between 0.3% and 0.9%[283]. Given the strength of the industrial and technological sector in Brazil, we assume a 0.7% GDP increase after a 10% increase in the M2M installed base.

Starting with a 2021 installed base of 26.7 million M2M devices in Brazil, we estimate the growth between 2020 and 2021 that can be exclusively attributed to the allocation of additional spectrum to indoor Wi-Fi devices. By subtracting the growth in M2M attributed to 6 GHz, the IoT impact for 2021 according to the natural grow is forecast to reach $10.4 billion (see Table O-26).

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[283] See Frontier Economics (2018).

Table O-26. Brazil: GDP Contribution of IoT Deployment Boost (2021-2025)

Variable	2021	2022	2023	2024	2025
Connections, Cellular M2M	26,654,443	27,749,688	26,640,956	25,576,523	24,554,619
Growth Rate (%)	9.21%	4.11%	-4.00%	-4.00%	-4.00%
Natural Growth Rate (%)	11.08%	9.21%	7.67%	6.38%	5.31%
Impact of 1% M2M Growth on GDP	7.00%	7.00%	7.00%	7.00%	7.00%
Impact on GDP (%)	0.78%	0.65%	0.54%	0.45%	0.37%
GDP ($Billion)	$1,778	$1,842	$1,909	$1,977	$2,049
Impact ($Million)	$10,433.82	$7,457.31	$3,581.66	$2,135.04	$781.38

Sources: GSMA Intelligence; Frontier Economics; IMF; Telecom Advisory Services analysis

It should be noted that the GDP impact of IoT declines due to a decreasing growth rate of M2M installed base.

Accelerated effect of IoT due to 6 GHz

As described above, a share of the M2M growth can be attributed to IoT traffic shifting to the 6 GHz spectrum. According to the data in Table O-27, the cumulative impact of enhanced IoT deployment driven by 6 GHz spectrum proposals will reach $2,828 million by 2025 (see Table O-27).

Table O-27. Brazil: GDP Contribution of IoT Deployment Boost caused by 6 GHz (2021-2025)

Variable	2021	2022	2023	2024	2025
Growth due to 6 GHz (%)	1.31%	1.08%	0.48%	0.48%	0.48%
Impact on GDP (%)	0.03%	0.05%	0.02%	0.02%	0.02%
Direct Impact ($Million)	$580.37	$971.92	$437.84	$444.54	$451.34
Sales due to 6Ghz Band (%)	1.68%	6.27%	16.42%	28.13%	35.21%
Impact ($Million)	$119	$741	$2,734	$2,774	$2,828

Sources: GSMA Intelligence; Frontier Economics; Telecom Advisory Services analysis

O.4.5. Deployment of AR/VR solutions

The adoption of AR/VR among Brazilian businesses will have a spillover effect on productivity, thereby contributing to the growth of GDP. Estimating spillover effects of AR/VR is a not a trivial exercise considering the embryonic adoption of some of the use cases based on this technology. Since the objective is to estimate the spillover effect of AR/VR sales in the domestic Brazilian market, we consider the estimate by PwC of the total GDP contribution of AR/VR between 2021 and 2025[284], and the sales of AR/VR components as estimated by ABI Research[285]. The extrapolation of these two parameters allows estimating the indirect (spillover) contribution of AR/VR to Brazil economy for the period under analysis. Accordingly, total spillover value of AR/VR in Brazil in 2021 will account for $268 million and is expected to increase to $864 by 2025 (see Table O-28).

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[284] See PWC (2019). *Seeing is believing: how virtual reality and augmented reality are transforming business and the economy.*

[285] See ABI Research, *Augmented and Mixed Reality Market Data: devices, use cases, verticals and value chain*. MD-ARMR-103, QTR 4 2019, and ABI Research, *Virtual Reality Market Data: devices, verticals, and value chain*. MD-VR-108, QTR 1 2020.

Table O-28. Brazil: GDP contribution resulting from AR/VR spillovers (2021-2025)

Variable	2021	2022	2023	2024	2025
AR/VR Boost to GDP (% GDP)	0.15%	0.20%	0.25%	0.31%	0.38%
Brazil GDP ($Million)	1,778,319	1,842,338	1,908,662	1,977,374	2,048,560
AR/VR Boost to GDP ($Million)	$2,667	$3,685	$4,772	$6,130	$7,785
AR/VR Boost to GDP without 6.0 GHz Band ($Million)	$2,489	$3,261	$4,034	$4,806	$5,578
Direct impact ($Million)	$268	$413	$553	$728	$864
Max multiplier Indirect/Direct	1	1	1	1	1
Indirect impact ($Million)	$268	$413	$553	$728	$864

Sources: PwC, ABI; Telecom Advisory Services analysis

Wider deployment of AR/VR solutions (accelerated effect due to 6 GHz)

Higher throughput enabled by the allocation of 6 GHz spectrum is expected to spur the adoption and use of AR/VR among enterprises, hence increasing the associated spillover effects. By relying on the ratio built from 5 GHz and 6 GHz AR/VR related products from above, we were able to isolate the specific economic contribution of the new spectrum allocation. Following a similar procedure as the one described above, spillovers from AR/VR in Brazil attributed to 6 GHz were calculated. They will account for $149 million in 2021 and are expected to reach $1.4 billion by 2025 (Table O-29).

Table O-29. Brazil: GDP contribution resulting from AR/VR spillovers due to 6 GHz (2021-2025)

Variable	2021	2022	2023	2024	2025
AR/VR Boost to GDP (% GDP)	0.15%	0.20%	0.25%	0.31%	0.38%
Brazil GDP ($Million)	1,778,319	1,842,338	1,908,662	1,977,374	2,048,560
AR/VR Boost to GDP ($Million)	$2,667	$3,685	$4,772	$6,130	$7,785
Total Impact on GDP 6 historic ($Billion)	$2,489	$3,261	$4,034	$4,806	$5,578
AR/VR Boost to GDP due to 6.0 GHz Band ($Million)	$179	$423	$738	$1,324	$2,206
Direct impact ($Billion)	$0.030	$0.090	$0.197	$0.425	$0.820
Indirect impact ($Million)	$149	$334	$541	$899	$1,386

Sources: PwC, ABI; Telecom Advisory Services analysis

O.5. Internet Service Providers

In addition to the economic value generated by the sources analyzed above, Wi-Fi will also contribute to either producer surplus or GDP of Internet Service Providers. This section will assess the economic value of three sources:

- Producer surplus of cellular operators resulting from CAPEX savings incurred in network deployment;
- Revenues of Wi-Fi carriers offering service in public spaces; and
- Revenues of Wireless ISPs (this effect differs from the GDP impact of WISPs as a result of their deployment in rural and isolated areas analyzed in section O.3.5.)

O.5.1. Cellular network savings by off-loading traffic to Wi-Fi

The estimation of CAPEX savings starts by considering the GSMA Intelligence aggregate investment estimates of 5G deployment. It is assumed that all the CAPEX invested during the period under consideration would be dedicated to 5G deployment. In this context, Wi-Fi becomes a key enabler of 5G services. The upcoming flexible, radio-neutral 5G environment will be intrinsically supported by the next wave of 802.11 Wi-Fi standards (802.11n/ac, 802.11ax, WiGig), and short-range wireless technologies operating in unlicensed bands.

Based on the simulation model developed to estimate the impact of Wi-Fi off-loading in 5 G deployment, we estimate that the savings of deploying carrier-grade Wi-Fi complementing the rollout to accommodate future traffic growth would amount to 32.9% of CAPEX, while the OPEX savings are $2.82 for each dollar saved in CAPEX. The estimation of CAPEX savings starts by considering the GSMA Intelligence aggregate investment estimates of 5G deployments in Brazil, which amount to $36.9 billion between 2019 and 2025. Considering the total CAPEX required to deploy 5G in Brazil, and the incremental 5G coverage between 2021 and 2025 we are able to interpolate the 5G CAPEX for each year of the period considered. Assuming that this amount already reflects the savings incurred by relying on Wi-Fi sites, this would result in a total producer surplus (adding CAPEX and OPEX savings) of $20.6 billion in 2021, and $5.9 billion in 2024, when the value of Wi-Fi will shift to the 6 GHz band (see Table O-30).

Table O-30. Brazil: Savings due to traffic off-loading (2021-2025)

Variable	2021	2022	2023	2024	2025
5G coverage	15%	26%	46%	50%	50%
CAPEX without saving ($Million)	$16,428	$12,308	$21,516	$4,692	$0
CAPEX reduction due to Wi-Fi off-loading ($Million)	$5,405	$4,049	$7,079	$1,544	$0
OPEX reduction due to Wi-Fi off-loading ($Million)	$15,242	$11,419	$19,962	$4,353	$0
Total Cost of Ownership ($Million)	$20,647	$15,468	$27,041	$5,897	$0

Sources: GSMA; Telecom Advisory Services

Enhanced capability for cellular off-loading if 6 GHz is allocated

The complementarity between Wi-Fi and cellular networks for Wi-Fi 6E and 5G, adds further potential gains derived from the savings in capital and operating expenses required to accommodate exploding data traffic. The key objective in this case is to estimate the savings in capital investment as a result of an increase in traffic offloading with Wi-Fi benefits from the additional spectrum allocated, particularly, due to the ability to leverage 160 MHz within single contiguous channels.

The analysis starts with an estimate of 5G deployment costs, absent the Wi-Fi offloading benefit. One approach is to sum wireless CAPEX estimated by GSMA Intelligence for the Brazil between 2019 and 2025: $36.867 billion. As an alternative approach, we rely on the only known rigorous cost estimation of 5G deployment to date: the one developed by Oughton and Frias (2016) for Ofcom in the United

Kingdom. The authors' baseline case estimates a CAPEX of $53.34 million, of which urban coverage investment amounts only to $890 million, while suburban deployment demands $7.13 billion, and rural coverage $45.32 billion. Using capital investment per population as a starting point (which does not include spectrum acquisition costs), deployment costs for networks aimed at providing 5G services in Brazil are calculated (Table O-31).

Table O-31. Brazil: CAPEX required for deployment of 5G

Geography	Brazil		
	Population Breakdown (%)	5G CAPEX ($Billion)	5G CAPEX (%)
Urban (cities>1 million)	41%	$3.87	2.78%
Suburban	46%	$18.78	13.48%
Rural	14%	$116.66	83.74%
Total	100%	$139.31	100%

Sources: Oughton and Frias (2016); Trading Economics; World Bank; U.S. Census Bureau; Trulia; Telecom Advisory Services analysis

Considering the cost decomposition of Oughton and Frias (2016), as well as that of the other estimates, the 5G investment under an exclusive licensed spectrum framework will remain significant for suburban ($18.78 billion) and rural ($116.66 billion) areas. In this context, unlicensed spectrum becomes a key enabler of 5G services. The upcoming flexible, radio-neutral 5G environment will be intrinsically supported by the next wave of 802.11 Wi-Fi standards, and short-range wireless technologies operating in unlicensed bands. A comparative analysis of CAPEX for 5G base station of pico cell vs. carrier grade Wi-Fi hotspot indicates a cost advantage of the latter amounting to 81%[286].It should be noted that the Wi-Fi advantage in hybrid networks becomes even more relevant with the 6 GHz spectrum given the hotspot capacity to handle large volumes of traffic.

We conservatively assume that Wi-Fi will not be critical in sustaining investment in urban areas, but that it will play a significant role in suburban and rural geographies. Based on the cost advantage of carrier grade Wi-Fi, we assume that it will become effective for a portion of the suburban (approximately 15%) and rural network (approximately 5%) deployment. Therefore, using the estimation of $18.78 billion for suburban coverage and $116.66 billion for rural coverage, the implementation of Wi-Fi hotspots leveraging 6 GHz will yield cumulative CAPEX savings of $8.64 billion spread evenly between 2021 and 2025[287].

O.5.2. Wi-Fi carrier revenues

The value of Wi-Fi carriers includes the sum of revenues generated by commercial public Wi-Fi access. In order to estimate this value, we start by calculating the number of paid Wi-Fi hotspots in Brazil. According to Cisco, in 2021 there will be

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[286] Nikolikj, V. and Janevski, T. (2014). "A Cost Modeling of High-Capacity LTE-Advanced and IEEE 802.11ac based Heterogeneous Networks, Deployed in the 700 MHz, 2.6 GHz and 5 GHz Bands," *Procedia Computer Science* 40 (2014) 49-56.

[287] An additional contribution could include Wi-Fi-like service operating within AFC channels.

12.33 million public Wi-Fi hotspots in the country, although that figure includes home spots (such as the guest account service provided by cable operators). By subtracting the home spots from the public Wi-Fi estimates of Cisco, we estimated a total of 310,000 paid Wi-Fi hotspots for 2021, which will decrease reaching 300,000 in 2025. On the other hand, based on revenue per hotspot generated by Boingo in the United States, and adjusting the metric by PPP we estimated the value for Brazil. Accordingly, this amounts to $109 million in 2021, gradually decreasing to reach $106 million in 2025 (Table O-32).

Table O-32. Brazil: Revenues of Wi-Fi carriers (2021-2025)

Variable	2021	2022	2023	2024	2025
Public Wi-Fi hotspots (Million)	12.33	17.13	23.80	33.06	45.93
Home spots (Million)	12.02	16.81	23.50	32.76	45.63
Paid Wi-Fi hotspots (Million)	0.31	0.32	0.30	0.30	0.30
Revenue per hotspot ($)	$353	$353	$353	$353	$353
Revenue ($Million)	$109	$114	$106	$106	$106

Note: With no forecast data available regarding the revenue per hotspot, this value was conservatively assumed to remain constant.

Sources: Cisco; Boingo; Telecom Advisory Services

Increased revenues of Wi-Fi carriers in public places due to 6 GHz

The allocation of the 6 GHz spectrum band offers an opportunity for commercial Wi-Fi carriers to enhance their business. As Wi-Fi 6E developments will allow up to 1,500 connected devices per access point, Wi-Fi carriers will have the possibility of adding more clients without quality limitations due to congestion. By considering a conservative potential increase of 40% in the number of connected devices in public venues and weighting that figure by the gradual expansion of the latest technology, we expect pay Wi-Fi carriers to increase their user base by 15% in 2025. If the revenue per hotspot increases in the same amount, that will yield an increase in overall revenues for the sector of an additional $16 million by 2025 (Table O-33).

Table O-33. Brazil: Revenues of Wi-Fi carriers due to 6 GHz (2021-2025)

Variable	2021	2022	2023	2024	2025
Potential increase in connected devices in public venues	40.00%	40.00%	40.00%	40.00%	40.00%
Traffic through the 6 GHz Channel (%)	8%	15%	23%	30%	38%
Increase in connected devices due to 6 GHz	3%	6%	9%	12%	15%
Revenue per hotspot if 6 GHz allocated ($)	$364	$375	$385	$396	$407
Revenue if 6 GHz allocated ($Million)	$3	$7	$10	$13	$16

Sources: Boingo, Telecom Advisory Services

O.5.3. Wireless ISPs revenues

The 2021 GDP contribution related to the WISP industry was calculated as a function of the number of subscribers (ANATEL data) and the ARPU (ABRINT data), yielding a total of $27 million in 2021(Table O-34).

Table O-34. Brazil: WISP revenues (2021-2025)

Variable	2021	2022	2023	2024	2025
Subscribers (Million)	1.84	1.72	1.61	1.51	1.41
Revenues ($Million)	$27	$25	$24	$22	$21

Sources: ANATEL; ABRINT, Telecom Advisory Services

Increased revenues of WISPs due to 6 GHz

As described in section O.2.5, the allocation of 6 GHz spectrum will potentially increase the WISP user base by 23,000 subscribers in 2025, due to expanded coverage and better affordability. Thus, by assuming the same ARPU values as described above, the new subscriptions will amount to an additional $3.33 million in revenues in 2025 (Table O-35).

Table O-35. Brazil: WISP revenues due to 6 GHz (2021-2025)

Variable	2021	2022	2023	2024	2025
WISP annual ARPU ($)	$14.66	$14.66	$14.66	$14.66	$14.66
New subscribers if 6 GHz allocated (Million)	0.03	0.07	0.12	0.17	0.23
New revenue ($Million)	$0.47	$1.07	$1.76	$2.52	$3.33

Sources: ABRINT; Telecom Advisory Services

O.6. Wi-Fi ecosystem

The economic value of Wi-Fi for Wi-Fi ecosystem companies is calculated based on the following three sources:

- The producer surplus (i.e. margins) of residential Wi-Fi devices and equipment manufactured in Brazil;
- The producer surplus of local firms providing products and services in the IoT ecosystem (hardware, software and systems integration) in Brazil; and
- The producer surplus of local firms providing products and services in the AR/VR ecosystem (hardware, software and content) in Brazil.

O.6.1 Locally manufactured residential Wi-Fi devices and equipment

In section O.2.4 we calculated the producer surplus attributed to residential Wi-Fi devices and equipment, relying on Milgrom et al. (2011) assumption that consumer surplus could be approximated by that of the producers. By adding to that value, the producer surplus estimated for the case of tablets (a product that is enabled mostly by Wi-Fi access[288]), we estimate a total economic value of $3.5 billion in 2021, which we expect to slightly increase to $3.6 billion in 2025 (Table O-36).

Table O-36. Brazil: Producer Surplus from locally manufactured residential Wi-Fi devices and equipment (2021-2025)

Variable	2021	2022	2023	2024	2025
Total producer surplus ($Million)	$3,500	$3,622	$3,749	$3,703	$3,588

Sources: Consumer Technology Association; ABI Research; CS Markets; Telecom Advisory Services analysis

Locally manufactured Wi-Fi 6 devices and equipment for residential use

As mentioned above, devices for 6 GHz are expected to gradually replace those of prior generations. According to IDC, global shipments of consumer devices linked to

[288] A similar approach was used in prior studies (Katz et al, 2014; 2017; 2018) and Milgrom et al. (2011).

6 GHz spectrum (802.11ax) will represent 40% of the shipments of those from previous generations in 2025. Therefore, we expect the producer surplus attributed to 6 GHz devices to yield $1.4 billion in economic value by 2025 (see Table O-37).

Table O-37. Brazil: Producer Surplus from locally manufactured residential Wi-Fi 6 devices and equipment (2021-2025)

Variable	2021	2022	2023	2024	2025
Consumer 6 GHz / no 6 GHz	3.76%	8.83%	18.59%	28.86%	40.30%
Producer surplus 6 GHz devices ($Million)	$131.78	$319.96	$696.80	$1,068.46	$1,445.74

Sources: IDC; Telecom Advisory Services analysis

O.6.2. Firms belonging to the IoT ecosystem

According to estimates from Frost and Sullivan, we expect total industrial IoT revenue in Brazil to amount $3.29 billion in 2021. We were able to split that figure into the two main segments: (i) hardware; and (ii) software, contents, and services. By weighting those amounts by the share of local production (5%-25% for hardware, 45%-65% for software and services) and the margins (39.44% and 77.46%, respectively), we can estimate the overall producer surplus. However, the share attributed to 6 GHz should be subtracted from the total economic value. To do so, we estimated a natural growth rate, by subtracting the corresponding share attributed to 6 GHz spectrum according to the growth rates indicated in Section O.3.4. Thus, we estimate a producer surplus not attributed to 6 GHz of $951 million in 2021, expecting to reach $1.7 billion in 2025 (Table O-38).

Table O-38. Brazil: IoT ecosystem direct contribution (2021-2025)

Variable	2021	2022	2023	2024	2025
IoT revenue - Hardware ($Billion)	$0.54	$0.63	$0.78	$0.95	$1.18
IoT revenue - Software, Contents, Services ($Billion)	$2.75	$3.30	$3.92	$4.50	$5.00
Total Industrial IoT revenue in ($Billion)	$3.29	$3.93	$4.70	$5.45	$6.17
Local production (%) - Hardware	5%	10%	15%	20%	25%
Local production (%) - Software & Services	45%	50%	55%	60%	65%
Margins (%) - Hardware	39%	39%	39%	39%	39%
Margins (%) - Software & Services	77%	77%	77%	77%	77%
Margins - IoT Hardware revenue	$0.01	$0.02	$0.05	$0.07	$0.12
Margins - Software, contents and services IoT revenue	$0.96	$1.28	$1.67	$2.09	$2.52
Producer surplus ($Million)	$968	$1,303	$1,716	$2,168	$2,632
Growth rate (%)	20%	20%	20%	16%	13%
Growth rate not attributed to 6 GHz (%)	98%	94%	84%	72%	65%
Producer surplus not attributed to 6 GHz ($Million)	$951	$1,221	$1,434	$1,558	$1,705

Sources: Frost and Sullivan, CSI, Telecom Advisory Services analysis

Wider deployment of Internet of Things under 6 GHz

Following the previous analysis, we were able to estimate which portion of IoT producer surplus growth can be attributed to the 6 GHz spectrum. As Table O-39 indicates, we expect the additional IoT surplus generated by 6 GHz to account for $927 million in 2025.

Table O -39. Brazil: IoT direct contribution attributed to 6 GHz (2021-2025)

Variable	2021	2022	2023	2024	2025
Producer surplus ($Million)	$968	$1,303	$1,716	$2,168	$2,632
Producer surplus not attributed to 6 GHz ($Million)	$951	$1,221	$1,434	$1,558	$1,705
Additional surplus due to 6 GHz ($Million)	$16	$82	$282	$610	$927

Sources: Frost and Sullivan, CSI, Telecom Advisory Services analysis

O.6.3. Firms belonging to the AR/VR ecosystem

Following a similar approach as in the case of IoT, we estimated the direct contribution of this ecosystem to the Brazilian economy. Starting with the local spending in AR/VR by category (hardware, software and contents), and apportioning those figures by the respective shares of local production and margins, we were able to estimate the total producer surplus. By relying on a ratio built from 6 GHz AR/VR related products, we were able to subtract the specific contribution attributed to 6 GHz from the surplus corresponding to current bands. Accordingly, we expect by 2021 a direct contribution from the AR/VR ecosystem of $79 million, increasing to reach $368 million by 2025 (Table O-40).

Table O-40. Brazil: AR/VR ecosystem direct contribution (2021-2025)

Variable	2021	2022	2023	2024	2025
Spending in AR/VR - Hardware $Billion	$0.07	$0.13	$0.21	$0.34	$0.55
Spending in AR/VR - Software, Contents, Services ($Billion)	$0.37	$0.66	$1.06	$1.63	$2.34
Total Spending in AV/VR ($Billion)	$0.45	$0.78	$1.28	$1.97	$2.89
Share of local production - Hardware	5.00%	10.00%	15.00%	20.00%	25.00%
Share of local production - Software, Contents, Services	45.00%	50.00%	55.00%	60.00%	65.00%
Local production for local consumption - Hardware ($Billion)	$0.00	$0.01	$0.03	$0.07	$0.14
Local production for local consumption - Software, Contents, Services ($Billion)	$0.17	$0.33	$0.59	$0.98	$1.52
Local Producer Surplus - Hardware ($Billion)	$0.00	$0.00	$0.01	$0.03	$0.05
Local Producer Surplus - Software, Contents, Services ($Billion)	$0.13	$0.25	$0.45	$0.76	$1.18
Total Producer Surplus	$0.13	$0.26	$0.47	$0.78	$1.23
Share attributable to Wi-Fi (excluding 6 GHz)	59.90%	52.90%	43.35%	37.01%	29.85%
Producer Surplus attributed to Wi-Fi (not including 6 GHz) ($Billion)	$78.78	$136.96	$202.03	$289.57	$368.34

Sources: PwC, ABI; Telecom Advisory Services analysis

Wider deployment of AR/VR solutions if 6 GHz allocated

By relying on a ratio built from 6 GHz AR/VR related products, we were able to isolate the specific economic contribution of the new spectrum allocation. Following an approach similar to the one described above, the direct contribution from AR/VR ecosystem in Brazil attributed to 6 GHz in 2025 will yield $350 million (Table O-41).

Table O-41. Brazil: AR/VR direct contribution attributed to 6 GHz (2021-2025)

Variable	2021	2022	2023	2024	2025
Spending in AR/VR ($Billion)	$0.45	$0.78	$1.28	$1.97	$2.89
Share attributed to 6 GHz	6.70%	11.49%	15.47%	21.60%	28.34%
Spending in AR/VR attributed to 6 GHz ($Billion)	$0.03	$0.09	$0.20	$0.42	$0.82
Local production for local consumption 6 GHz ($Billion)	$0.01	$0.04	$0.10	$0.23	$0.47
Local Producer Surplus ($Billion)	$8.81	$29.76	$72.10	$168.97	$349.71

Sources: PwC, ABI, Telecom Advisory Services analysis

O.7. Wi-Fi contribution to employment

The estimation of employment generated by Wi-Fi's economic value is calculated by relying on the total GDP contribution resulting from the effects analyzed above and using that as an input in the communications sector of an input/output matrix of the Brazilian economy. Table O-42 presents the GDP contribution, as sum of all GDP sources discussed above, enabled by Wi-Fi projected for the period 2021-2025.

Table O-42. Brazil: Wi-Fi enabled GDP contribution (2021-2025)

Year	GDP contribution enabled by Wi-Fi ($Million)		
	Attributed to current bands	Attributed to 6 GHz	Total
2021	$23,282	$672	$23,954
2022	$21,251	$2,040	$23,291
2023	$19,711	$5,014	$24,725
2024	$20,158	$6,254	$26,411
2025	$21,429	$7,710	$29,139

Source: Telecom Advisory Services analysis

These inputs generate the following annual employment effects based on the input/output matrix for the Brazilian economy (Table O-43).

Table O-43. Brazil: Wi-Fi generated Annual Employment

Variable	2021			2025		
	Current bands	6 GHz	Total	Current bands	6 GHz	Total
Direct jobs	216,947	6,263	223,210	199,675	71,845	271,520
Indirect jobs	84,910	2,451	87,361	78,150	28,119	106,269
Induced jobs	34,986	1,010	35,996	32,200	11,586	43,786
Total	336,843	9,724	346,567	310,025	111,551	421,576

Sources: GTAP; Telecom Advisory Services analysis

According to the contribution to GDP, Wi-Fi will generate approximately 346,500 jobs in 2021 and is expected to create over 421,500 in 2025. Job estimates include direct jobs (those jobs created by the specific Wi-Fi contribution), indirect jobs (those jobs created by suppliers to the Wi-Fi sector) and induced jobs (those jobs created by spending of direct and indirect workers).

The sector breakdown of 2021 employment (including the additional jobs created by 6 GHz) is as follows (Table O-44).

Table O-44. Brazil: Sector Breakdown of Wi-Fi generated annual employment (2021)

Sector	Direct	Indirect	Induced	Total
Agriculture	0	0	6,158	6,158
Extractive industries	0	0	348	348
Manufacturing	0	17,825	974	18,799
Construction	0	3,342	0	3,342
Trade	0	21,058	25,354	46,412
Transportation	0	6,987	0	6,987
Communications	223,210	0	0	223,210
Financial Services	0	11,655	0	11,655
Business services	0	26,494	0	26,494
Other services	0	0	3,160	3,160
Total	223,210	87,361	35,996	346,567

Sources: GTAP; Telecom Advisory

P. ECONOMIC VALUE OF WI-FI IN COLOMBIA

Wi-Fi has become a critical component of Colombia's telecommunications infrastructure. According to the Cisco Annual Internet Report Highlights Tool 2018-2023, there are approximately 520,000 public Wi-Fi access points operating in the country. The Wiman site estimates that there are currently 412,000 free Wi-Fi sites (of which, 217,000 are in Bogota, 70,000 in Medellin, and 34,000 in Cali). In addition to Municipal Wi-Fi, public Wi-Fi sites represent a cost-advantaged approach for consumers "on the go" to access the Internet. Additionally, 85% of broadband homes are equipped with a Wi-Fi router to support device connectivity. Given the Wi-Fi access point density, hotspots have become a very important connectivity feature.

The increasing importance of Wi-Fi technology in the digital infrastructure ecosystem results in a significant social and economic impact. This section presents the results and calculations of the economic assessment. The methodology reviewed in section B was used to calculate each source of economic value.

P.1. Total economic value of Wi-Fi in Colombia (2021-2025)

Before considering the additional effect of allocating the 6 GHz spectrum band for unlicensed use, the total economic value of Wi-Fi in Colombia in 2021 will amount to $18.7 billion. The total economic value in 2021 is comprised of $8.4 billion in consumer surplus, $4.9 billion in producer surplus, and $5.4 billion in contribution to GDP. The 2025 forecast of economic value will reach $36 billion without considering the acceleration effect from Wi-Fi 6 and the allocation of the 6 GHz band. The 2025 forecast of the baseline scenario will be composed of $16.2 billion in consumer surplus, $13.2 billion in producer surplus, and $6.6 billion in GDP contribution (see Table P-1).

Table P-1. Colombia: Economic Value of Wi-Fi (Baseline Scenario)

Agent	Source	Economic Value ($Million)					
		2021	2022	2023	2024	2025	Category
1. Free Wi-Fi	1.1. Savings generated by free Wi-Fi traffic offered in public sites	$203	$220	$242	$267	$297	Consumer Surplus
	1.2. Deployment of free Wi-Fi in public sites	$2,406	$2,401	$2,405	$2,402	$2,393	GDP contribution
2. Residential Wi-Fi	2.1. Internet access for home usage of devices that lack a wired port	$5,480	$6,768	$8,302	$10,137	$12,396	Consumer Surplus
	2.2. Avoidance of investment in in-house wiring	$1,838	$2,005	$2,182	$2,343	$2,346	Consumer Surplus
	2.3. Benefit to consumers from speed increases	$438	$488	$555	$610	$675	Consumer Surplus
	2.4. Residential Wi-Fi devices and equipment deployed	$478	$489	$503	$496	$481	Consumer Surplus
	2.5. Bridging digital divide: use of Wi-Fi to increase coverage in rural and isolated areas	$315	$359	$407	$456	$506	GDP contribution
3. Ent	3.1. Business Internet traffic transmitted through Wi-Fi	$3,182	$3,219	$3,218	$3,184	$3,126	Producer surplus

Agent	Source	Economic Value ($Million)					
		2021	2022	2023	2024	2025	Category
	3.2. Avoidance of enterprise inside wiring costs	$1,521	$1,531	$1,542	$1,554	$1,568	Producer surplus
	3.3. Return to speed: contribution to GDP derived from an increase in average mobile speed	$1,613	$1,743	$1,950	$2,220	$2,555	GDP contribution
	3.4. Wide deployment of IoT	$955	$848	$875	$924	$976	GDP contribution
	3.5. Deployment of AR/VR solutions	$33	$54	$73	$108	$158	GDP contribution
4. ISPs	4.1. CAPEX and OPEX savings due to cellular off-loading	$0	$0	$0	$5,772	$8,089	Producer surplus
	4.2. Revenues of service providers offering paid Wi-Fi access in public places	$9	$11	$12	$12	$8	GDP contribution
	4.3. Aggregated revenues of WISPs	$30	$33	$37	$41	$44	GDP contribution
5. Wi-Fi ecosystem	5.1. Locally manufactured residential Wi-Fi devices and equipment	$43	$44	$46	$45	$44	Producer surplus
	5.2. Locally manufactured Wi-Fi enterprise equipment	$0	$0	$0	$0	$0	Producer surplus
	5.3. Locally produced IoT products and services	$129	$155	$186	$223	$268	Producer surplus
	5.4. Locally produced of AR/VR solutions	$13	$22	$29	$43	$62	Producer surplus
Total		$18,686	$20,390	$22,564	$30,837	$35,992	

Source: Telecom Advisory Services analysis

In addition to the baseline scenario, the allocation of the 6 GHz spectrum band for unlicensed use and the deployment of Wi-Fi 6 and Wi-Fi 6E devices will trigger a growth of economic value, reaching $5.4 billion in 2025 (see Table P-2).

Table P-2. Colombia: Economic Value of Wi-Fi (only attributed to 6 GHz)

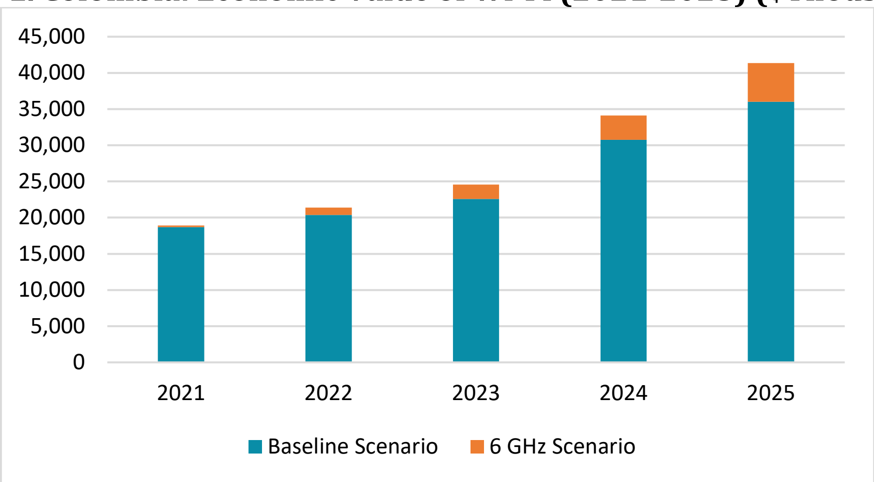
Agent	Source	Economic Value ($Million)					
		2021	2022	2023	2024	2025	Category
1. Free Wi-Fi	1.1. Savings generated by free Wi-Fi traffic offered in public sites	$0	$0	$0	$0	$0	Consumer Surplus
	1.2. Deployment of free Wi-Fi in public sites	$0	$227	$453	$676	$892	GDP contribution
	1.3. Benefit of faster free Wi-Fi with Wi-Fi 6E devices	$0	$15	$30	$48	$68	Consumer Surplus
2. Residential Wi-Fi	2.3. Benefit to consumers from speed increases	$0	$30	$100	$234	$464	Consumer Surplus
	2.4. Residential Wi-Fi devices and equipment deployed	$17	$40	$87	$134	$181	Consumer Surplus
	2.5. Bridging digital divide: use of Wi-Fi to increase coverage in rural and isolated areas	$0	$164	$364	$587	$862	GDP contribution

Agent	Source	Economic Value ($Million)					
		2021	2022	2023	2024	2025	Category
3. Enterprise Wi-Fi	3.1. Business Internet traffic transmitted through Wi-Fi	$65	$185	$351	$557	$797	Producer surplus
	3.3. Return to speed: contribution to GDP derived from an increase in average mobile speed	$0	$83	$282	$713	$1,594	GDP contribution
	3.4. Wide deployment of Internet of Things	$47	$110	$139	$147	$156	GDP contribution
	3.5. Deployment of AR/VR solutions	$20	$35	$60	$97	$156	GDP contribution
4. ISPs	4.1 CAPEX and OPEX savings due to cellular off-loading	$87	$87	$87	$87	$87	Producer surplus
	4.2. Revenues of service providers offering paid Wi-Fi access in public places	$0	$0	$1	$1	$1	GDP contribution
	4.3. Aggregated revenues of WISPs	$0	$2	$3	$5	$7	GDP contribution
5. Wi-Fi ecosystem	5.1. Locally manufactured residential Wi-Fi devices and equipment	$2	$4	$9	$13	$18	Producer surplus
	5.2. Locally manufactured Wi-Fi enterprise equipment	$0	$0	$0	$0	$0	Producer surplus
	5.3. Locally produced IoT products and services	$4	$8	$15	$25	$38	Producer surplus
	5.4. Locally produced of AR/VR solutions	$8	$14	$24	$38	$61	Producer surplus
Total		$250	$1,004	$2,005	$3,362	$5,382	

Source: Telecom Advisory Services analysis

Considering that we forecast that by 2025 only 40% of Wi-Fi traffic will rely on 6 GHz channels, the accelerated effect derived from the new spectrum allocation and latest Wi-Fi technologies will still be far from reaching its maximum potential at this time. However, a visual depiction of the trend provides a perspective of the growing importance of Wi-Fi 6 in the overall economic value (see Graphic P-1)

Graphic P-1. Colombia: Economic Value of Wi-Fi (2021-2025) ($Thousand)



Source: Telecom Advisory Services analysis

By combining the baseline and the Wi-Fi 6 and 6 GHz scenarios, the overall economic value of Wi-Fi for Colombia will yield $41.4 billion in 2025 (see Table P-3).

Table P-3. Colombia: Total Economic Value of Wi-Fi (including Wi-Fi 6 and 6 GHz)

Agent	Source	Economic Value ($Million)					
		2021	2022	2023	2024	2025	Category
1. Free Wi-Fi	1.1. Savings to consumers of free Wi-Fi traffic offered in public sites	$203	$220	$242	$267	$297	Consumer Surplus
	1.2. Deployment of free Wi-Fi in public sites	$2,406	$2,629	$2,859	$3,078	$3,285	GDP contribution
	1.3. Benefit of faster free Wi-Fi with Wi-Fi 6E devices	$0	$15	$30	$48	$68	Consumer Surplus
2. Residential Wi-Fi	2.1. Internet access for home usage of devices that lack a wired port	$5,480	$6,768	$8,302	$10,137	$12,396	Consumer Surplus
	2.2. Avoidance of investment in in-house wiring	$1,838	$2,005	$2,182	$2,343	$2,346	Consumer Surplus
	2.3. Benefit to consumers from speed increases	$438	$518	$655	$844	$1,139	Consumer Surplus
	2.4. Residential Wi-Fi devices and equipment deployed	$494	$529	$590	$630	$662	Consumer Surplus
	2.5. Bridging digital divide: use of Wi-Fi to increase coverage in rural and isolated areas	$315	$523	$771	$1,043	$1,368	GDP contribution
3. Enterprise Wi-Fi	3.1. Business Internet traffic transmitted through Wi-Fi	$3,247	$3,404	$3,569	$3,741	$3,922	Producer surplus
	3.2. Avoidance of enterprise inside wiring costs	$1,521	$1,531	$1,542	$1,554	$1,568	Producer surplus
	3.3. Return to speed: contribution to GDP derived from an increase in average mobile speed	$1,613	$1,827	$2,232	$2,933	$4,149	GDP contribution
	3.4. Wide deployment of IoT	$1,002	$958	$1,014	$1,071	$1,131	GDP contribution
	3.5. Deployment of AR/VR solutions	$53	$89	$133	$205	$314	GDP contribution
4. ISPs	4.1 CAPEX and OPEX savings due to cellular off-loading	$87	$87	$87	$5,859	$8,177	Producer surplus
	4.2. Revenues of service providers offering paid Wi-Fi access in public places	$9	$11	$13	$13	$9	GDP contribution
	4.3. Aggregated revenues of WISPs	$30	$35	$40	$46	$52	GDP contribution
5. Wi-i ecosystem	5.1. Locally manufactured residential Wi-Fi devices and equipment	$45	$48	$55	$59	$62	Producer surplus
	5.2. Locally manufactured Wi-Fi enterprise equipment	$0	$0	$0	$0	$0	Producer surplus
	5.3. Locally produced IoT products and services	$133	$163	$202	$248	$306	Producer surplus
	5.4. Locally produced of AR/VR solutions	$21	$36	$53	$81	$123	Producer surplus
Total		$18,935	$21,396	$24,571	$34,200	$41,374	

Source: Telecom Advisory Services analysis

The following sections will present in detail the calculation of each source of value, disaggregating the economic contribution under current the spectrum ecosystem and the enhanced effect due to Wi-Fi 6 availability and the 6 GHz band.

P.2. Value from free Wi-Fi service

The economic value of free Wi-Fi service originates from three contribution sources:

- Savings to consumers by accessing the Internet in free Wi-Fi sites rather than incurring cellular costs
- The use of Wi-Fi to expand broadband coverage to the unserved population
- The return to speed of Wi-Fi compared to the use of cellular service

P.2.1. Savings incurred by accessing free Wi-Fi in public sites

Free Wi-Fi offered in retail shops, libraries, schools, coffee shops, city halls, and corporate guest accounts allows consumers to save money that would otherwise be spent purchasing cellular service. In addition, free hotspots provide access to the Internet for consumers that cannot afford to purchase broadband service. This last effect has been particularly important in the ongoing pandemic, allowing households to access the Internet for telecommuting and continuing education.

The economic value of free Wi-Fi is measured in terms of consumer surplus, which is by estimating the benefit that flows to consumers as a result of the savings in wireless broadband service acquisition. We start by quantifying the mobile Internet traffic. In order to isolate the effect from the increased capacity derived from the 6 GHz allocation, we calculate the portion of free Wi-Fi traffic attributed to current spectrum bands. Using Cisco and Wiman data, is projected that the traffic per hotspot will decline from 274 GB in 2021 to 143 GB in 2025 (see Table P-4).

Table P-4. Colombia: Total Free Wi-Fi Traffic projection (2021-2025)

Variable	2021	2022	2023	2024	2025
Free Wi-Fi traffic (million GB Per year) - considering current trends	171	215	274	354	463
Free Wi-Fi hotspots (Million)	0.62	0.94	1.42	2.14	3.23
Traffic per hotspot - considering current trends	274	229	193	165	143
Traffic per hotspot - capped due to congestion	274	229	193	165	143
Total traffic (not attributed to 6 GHz) (Million GB)	171	215	274	354	463

Sources: Cisco; Wiman; Telecom Advisory Services analysis

We calculate consumer surplus by multiplying the total free traffic (not attributed to 6 GHz) by the difference between what the consumer would have to pay if they were to rely on a wireless carrier and the cost of offering free Wi-Fi (incurred by the retailer or public site). To do so, we needed an estimate of the average price per GB of wireless data transmitted by wideband networks, which we calculated by averaging the most economic "dollar per GB" plan of three major wireless carriers (see Table P-5).

Table P-5. Colombia: Average Price Per Gigabyte (2020)

Carrier	Plan	Price per GB ($)
Movistar	8 GB	$2.0147
Claro	Internet Movil M Pro	$2.2718
Tigo	2 GB	$2.6000

Sources: Colombia telecom´s operator´s webpages; Telecom Advisory Services analysis

Historical data allowed for a projection of future prices per gigabyte. Based on these prices, we expect the average price per GB will reach an estimated $1.36 in 2025. By relying on the total free Wi-Fi traffic not attributed to 6 GHz allocation shown in Table P-4 and the average price per cellular gigabyte minus the cost of provisioning Wi-Fi service, we calculated the consumer surplus of free Wi-Fi traffic (see Table P-6).

Table P-6. Colombia: Consumer Surplus of Free Wi-Fi Traffic (2021-2025)

Variable	2021	2022	2023	2024	2025
Total Free Traffic (not attributed to 6 GHz) (Million GB)	170.64	214.68	273.97	353.77	463.12
Price per cellular gigabyte ($)	$2.07	$1.87	$1.68	$1.51	$1.36
Cost per Wi-Fi provisioning ($)	$0.89	$0.84	$0.80	$0.76	$0.72
Consumer surplus per gigabyte ($)	$1.19	$1.03	$0.88	$0.75	$0.64
Total Consumer surplus ($Million)	$203	$220	$242	$267	$297

Sources: Cisco; Colombia telecom´s operator´s webpages; Telecom Advisory Services analysis

As indicated in Table P-6, consumer surplus of free Wi-Fi traffic in 2021 would reach an estimated $203 million, increasing to $297 million in 2025.

As shown in Table P-4 the expected traffic per hotspot in Colombia is expected to decrease between 2021 and 2025, so we do not consider the 6 GHz spectrum band's impact.

P.2.2. Free Wi-Fi to provide broadband to the unserved population

As explained in section B, deployment of free Wi-Fi provides Internet access to the unserved population. Consumers that do not have broadband at home because they lack the economic means to acquire services can rely on free Wi-Fi to gain Internet access. As a result, more people can be connected, which in turn enhances the economic contribution of broadband.

The calculation of this economic impact starts by calculating which portion of households that lack broadband service are already accessing Internet through free hotspots. We follow a conservative approach and assume that only 5% of unconnected households rely on free hotspots for accessing Internet. After calculating the increase in broadband penetration due to households relying on free Wi-Fi, we rely on the broadband impact coefficient from Katz and Callorda (2018b), for Europe. As a result, the GDP contribution of this particular effect is expected to amount to $2,406 million in 2021, reaching $2,393 million in 2025 (see Table P-7).

Table P-7. Colombia: GDP contribution due to households relying on Free Wi-Fi (2021-2025)

Variable	2021	2022	2023	2024	2025
Households without Internet	6,409,032	6,298,400	6,179,781	6,052,840	5,917,227
Households that don't buy because access Internet free hotspots (%)	5%	5%	5%	5%	5%
Households served by Free Wi-Fi hot spots	320,452	314,920	308,989	302,642	295,861
Increase in national broadband penetration	4.28%	4.06%	3.84%	3.63%	3.43%
Impact of fixed broadband adoption in GDP	15.75%	15.75%	15.75%	15.75%	15.75%
Increase in the GDP due to the new broadband adoption (% GDP)	0.67%	0.64%	0.61%	0.57%	0.54%
GDP ($Billion)	356.90	375.57	397.35	419.78	443.28
Total impact in GDP ($Million)	$2,406	$2,401	$2,405	$2,402	$2,393

Sources: MinTIC; UIT; IMF; Telecom Advisory Services analysis

Enhanced GDP contribution due to 6 GHz allocation

As stated above, Wi-Fi 6 technology enables supporting a high number of devices on a single access point. Accordingly, the improved throughput of free Wi-Fi hotspots under the 6 GHz allocation will allow the possibility of serving additional unconnected households.

The potential universe of additional households that could be served under this effect is enormous, as most unconnected households usually identify that costs are their main barrier for accessing to connectivity and thus, may potentially be served by free hotspots as long as they are in proximity to the access point. However, evidence suggests that not many people rely exclusively on free Wi-Fi as their main source of Internet access, so we will follow again a conservative approach and assume that a further 5% of unconnected households will be served through free hotspots under the allocation of the 6 GHz band. On the other hand, we have also considered that the expansion of traffic through the new band will take place gradually, reaching 40% in 2025. All in all, we estimate that additional 110,296 households will be served in 2025 due to free hotspots operating under 6 GHz spectrum, yielding an additional GDP contribution of approximately $892 million (Table P-8).

Table P-8. Colombia: GDP contribution due to households relying on Free Wi-Fi due to 6 GHz (2021-2025)

Variable	2021	2022	2023	2024	2025
Households without Internet (not served by free Wi-Fi and not new adopters of WISP)	6,088,581	5,961,973	5,823,985	5,676,206	5,514,793
Potential households that could be served through free Wi-Fi hotspots under increased capacity (% of those not connected)	5%	5%	5%	5%	5%
Traffic through the 6 GHz Channel (%)	0%	10%	20%	30%	40%
Additional households served by Free Wi-Fi hot spots with 6 GHz	0	29,810	58,240	85,143	110,296
Increase in national broadband penetration	0.00%	0.38%	0.72%	1.02%	1.28%
Increase in the GDP due to the new broadband adoption (% GDP)	0.00%	0.06%	0.11%	0.16%	0.20%
Total impact in GDP ($Million)	$0	$227	$453	$676	$892

Sources: MinTIC; UIT; IMF; Telecom Advisory Services analysis

P.2.3. Benefit to consumers for enjoying higher speed from free Wi-Fi if 6 GHz band is allocated

When the 6 GHz band is adopted by free Wi-Fi access points, it will deliver service at faster broadband speeds. Current speeds from free hotspots are quite modest[289]. Thus, the expanded capabilities due to the allocation of 6 GHz spectrum band will enhance free Wi-Fi speed, and as a result, will increase consumer surplus. We assume that under the 6 GHz allocation, speed from free hotspots will be similar to the Wi-Fi speeds from mobile devices reported by Cisco. After calculating the average speed by considering the expected share of traffic through 6 GHz, we follow Nevo et al. (2016) and calculate the additional consumer surplus per household relying on free Wi-Fi. We expect the consumer surplus resulting from faster speed in free Wi-Fi sites to reach $68 million in 2025 (Table P-9).

Table P-9. Colombia: Consumer surplus for enjoying higher speed from free Wi-Fi if 6 GHz band allocated (2021-2025)

Variable	2021	2022	2023	2024	2025
Free Wi-Fi mean speed with no 6 GHz (Mbps)	7.56	8.82	9.75	9.67	9.35
Wi-Fi Speeds from Mobile Device (Mbps)	37.11	43.00	49.82	57.72	66.87
Traffic through the 6 GHz Channel (%)	0.00%	10.00%	20.00%	30.00%	40.00%
Free Wi-Fi mean speed with 6 GHz (Mbps)	7.56	12.23	17.77	24.08	32.36
Demand for average download speed	33.46	35.11	36.18	36.04	35.67
New Demand for average download speed	33.46	38.79	42.90	46.25	49.56
Additional Monthly Consumer surplus	0.00	3.68	6.72	10.22	13.89
Additional Yearly Consumer Surplus	0.00	44.15	80.67	122.59	166.73
Households that rely on Free Wi-Fi	320,452	344,730	367,229	387,785	406,157
Consumer surplus ($Million)	$0.00	$15.22	$29.63	$47.54	$67.72

Sources: Cisco; Rotten Wi-Fi; Nevo et al. (2016); Telecom Advisory Services analysis

P.3. Residential Wi-Fi

The economic value of Wi-Fi in consumer residences is the result of five factors:

- Provision of connectivity to the home network for devices that lack an Ethernet port;
- Cost avoidance of ethernet inside wiring;
- Consumer surplus resulting from faster broadband speeds relative to cellular networks;
- Consumer surplus derived from usage of home devices connected to the home network; and
- Provision of Internet access to consumers located in rural and isolated areas.

P.3.1. Home Internet access for devices that lack an Ethernet port

[289] Given the lack of reliable data on free Wi-Fi speed in Colombia, we made an estimation based on U.S. data, and applying the percentual differential between both countries in terms of fixed broadband speed. Then, we estimate free Wi-Fi speed in Colombia to reach 9.35 Mbps in 2020.

The underlying premise of this analysis is that in the absence of Wi-Fi, users of devices lacking an Ethernet port would have to depend on the cellular network to gain Internet access. For this reason, estimating value would first measure the traffic generated by these devices at home and then multiply it by the average price charged by cellular carriers.

To estimate the traffic of smartphones and tablets, we relied on 2018 Cisco estimates for the period 2016-21 and extrapolated those growth rates to 2025. It must be said, however, that in 2019 Cisco adjusted its predictions upwards. However, we preferred to rely on the original figures to avoid incurring in the risk of overestimation. Thus, it may be possible that our previsions reported here are slightly downward biased. In addition, we have to consider that according to Cisco IBSG (2012), 43.12% of use time of devices that lack an Ethernet port occurs at home. Therefore, the portion of said traffic generated at home will reach 2,642 million gigabytes in 2021 (see Table P-10).

Table P-10. Colombia: Total Mobile Internet Traffic (2021-2025) (Million gigabytes)

Variable	2021	2022	2023	2024	2025
Total Annual traffic – Smartphones	5,271	7,279	9,970	13,581	18,528
Total Annual traffic - Tablets	856	1,126	1,482	1,950	2,566
Share of traffic at Home	43.12%	43.12%	43.12%	43.12%	43.12%
Total Traffic at Home - Smartphones	2,273	3,139	4,299	5,856	7,989
Total Traffic at Home - Tablets	369	486	639	841	1,106
Total Traffic at Home	2,642	3,624	4,938	6,697	9,095
Average Price per GB ($)	$2.07	$1.87	$1.68	$1.51	$1.36
Price per home traffic ($Million)	$5,480	$6,768	$8,302	$10,137	$12,396

Sources: Cisco; GSMA; Colombia telecom´s operator´s webpages; Telecom Advisory Services analysis

If this traffic had to be transported by cellular networks, at the average price per GB estimated, it would result in costs of $5.5 billion in 2021, before reaching $12.4 billion in 2025.

P.3.2. Avoidance of inside wiring investment

Residential Wi-Fi allows consumers to avoid paying for wiring to connect all home devices (printers, laptops, storage units, etc.). Considering that 90% of connected households will have Wi-Fi in 2021[290], and the wiring cost estimated for households[291], the avoidance costs of inside wiring over 6.7 million households yields a total of $1.8 billion. By 2025, almost all connected households are expected to have adopted Wi-Fi, so the savings would have reached $2.3 billion (Table P-11).

[290] Assumed equal to United States

[291] We took as a reference the value from United States and adjusted it for Colombia considering the differences in PPP between both countries.

Table P-11. Colombia: Consumer surplus from avoidance of investment in in-house wiring (2021-2025)

Variable	2021	2022	2023	2024	2025
Total Wiring Cost	$273.00	$272.39	$271.93	$271.58	$271.58
Households with Internet	7,483,632	7,755,127	8,036,472	8,630,000	8,638,000
Households with Wi-Fi (%)	90%	95%	100%	100%	100%
Households with Internet and Wi-Fi	6,731,470	7,359,499	8,024,236	8,630,000	8,638,000
Inside Wiring Costs ($Million)	$1,838	$2,005	$2,182	$2,343	$2,346

Sources: MinTIC; Telecom Advisory Services analysis

P.3.3. Benefits derived from speed increase

As described before, consumer surplus increases if users enjoy faster Internet speeds. Thus, the welfare of residential Wi-Fi customers is expected to benefit from faster services than those provided by cellular networks. After weighting the corresponding broadband speeds with the percentage of traffic carried out through Wi-Fi at home, we calculated the average speed advantage of using Wi-Fi in comparison to cellular networks. By applying the parameters determined in Nevo et al. (2016), the expected consumer surplus will yield $438 million in 2021, being increased to $675 million in 2025 (Table P-12).

Table P-12. Colombia: Consumer surplus from faster speed in households (2021-2025)

Variable	2021	2022	2023	2024	2025
Average Speed in households if Wi-Fi traffic were carried through mobile networks (Mbps)	27.00	31.76	36.19	40.38	44.42
Average Speed in household with Wi-Fi (Mbps)	43.71	51.96	60.53	69.64	79.50
Demand for average download speed	47.78	49.50	50.88	52.04	53.11
New Demand for average download speed	53.20	55.03	56.65	58.14	59.62
Additional Monthly Consumer surplus	$5.42	$5.53	$5.76	$6.10	$6.52
Additional Yearly Consumer Surplus	$65.09	$66.32	$69.18	$73.20	$78.19
Households with Internet and Wi-Fi	6,731,470	7,359,499	8,024,236	8,328,023	8,630,152
Impact ($Million)	$438	$488	$555	$610	$675

Sources: Cisco; Ookla; Nevo et al. (2016); MinTIC; Telecom Advisory Services analysis

Additional benefit to consumers from speed increase due to 6 GHz

The welfare of residential Wi-Fi customers is expected to receive further benefit from the 6 GHz allocation due to faster Internet service under Wi-Fi 6E. As previously described in Chapter III, only households acquiring a 150 Mbps (or faster) fixed broadband line will be affected due to current router bottlenecks, and hence, the speed experienced will not be equivalent to that delivered by the fixed network. After calculating the difference in average speed attributed to 6 GHz, the additional consumer surplus will yield $464 million in 2025 (Table P-13).

Table P-13. Colombia: Consumer surplus from faster speed in households if 6 GHz allocated (2021-2025)

Variable	2021	2022	2023	2024	2025
Households that have connections over 150 Mbps (%)	3.55%	5.78%	9.42%	15.35%	25.00%
Percentage of household traffic that goes through Wi-Fi	76.66%	78.46%	80.15%	81.74%	83.23%
Traffic through the 6 GHz Channel (%)	0.00%	10.00%	20.00%	30.00%	40.00%
Share of traffic affected due to 6 GHz (%)	0.00%	0.45%	1.51%	3.76%	8.32%
Average speed with no 6 GHz (Mbps)	43.71	51.96	60.53	69.64	79.50
Average speed with 6 GHz (Mbps)	43.71	53.54	66.41	85.83	118.66
Demand for average download speed	$53	$55	$57	$58	$60
New Demand for average download speed	$53	$55	$58	$60	$64
Additional Yearly Consumer Surplus	$0	$4	$12	$28	$54
Households with Wi-Fi	6,731,470	7,359,499	8,024,236	8,328,023	8,630,152
Impact ($Million)	$0	$30	$100	$234	$464

Sources: Cisco; Ookla; Nevo et al. (2016); MinTIC; Telecom Advisory Services analysis

P.3.4. Residential Wi-Fi devices and equipment

In the case of residential Wi-Fi enabled products, first we estimated the consumer surplus of wireless speakers, security systems, home networking systems, access points, external adapters, routers and Gateways assuming that the consumer surplus is equivalent to the producer surplus of that products if they were produced in Colombia. Secondly, we calculated the consumer surplus attributable to tablets bought by local consumers. Starting with CTA/Statista worldwide tablet revenue estimates, we interpolated the revenue figures for Colombia (by weighting by the country's share on global GDP), and extrapolated the evolution of local revenue to 2025 by considering Cisco estimates of tablet evolution for the period. We reviewed the data on tablet prices for the market leader (taking as a reference the Samsung Wi-Fi tablet 128 GB, as Samsung has 34% of the Colombia market share in tablets[292]) and for the rest of the market (taking as a reference the Apple iPad 10.2 Inch 128 GB), and assumed consumer willingness-to-pay levels in a similar percentage above prices as in the U.S. average. Combining all that information, we were able to estimate a consumer surplus of $478 million in 2021, expected to reach $481 million in 2025 (Table P-14).

Table P-14. Colombia: Economic Value of Wi-Fi enabled consumer products (2021-2025)

Variable	2021	2022	2023	2024	2025
Wireless speakers, security systems, home networking systems, access points, external adapters, routers and gateways consumer surplus ($Million)	$442	$455	$470	$464	$450
Tablet consumer surplus ($Million)	$36	$34	$33	$32	$31
Total consumer surplus ($Million)	$478	$489	$503	$496	$481

Sources: CSI Market Inc.; GS Stat Counter; Apple; Samsung; ABI Research; IDC; Telecom Advisory Services analysis

[292] Source: Gs StatCounter

Additional benefit to consumers from Wi-Fi enabled consumer products due to 6 GHz

We are able to estimate the impact in consumer surplus due to 6 GHz using the relationship between shipments of products 6 GHz/shipments of rest of products. We estimate a consumer surplus due to 6 GHz of $17 million in 2021, expected to reach $181 million in 2025 (Table P-15).

Table P-15. Colombia: Economic Value of Wi-Fi enabled consumer products due to 6 GHz (2021-2025)

Variable	2021	2022	2023	2024	2025
Global - Consumer total shipments (Million)	1,287	1,456	1,611	1,728	1,823
Global - Consumer only Wi-Fi 6 and 6 GHz shipments (Million)	47	118	252	387	524
Global - Total no 6 GHz shipments (Million)	1,240	1,338	1,358	1,341	1,300
Consumer 6 GHz / no 6 GHz	3.76%	8.83%	18.59%	28.86%	40.30%
Consumer surplus 6 GHz devices	$17	$40	$87	$134	$181

Sources: CSI Market Inc.; GS Stat Counter; Apple; Samsung; ABI Research; IDC; Telecom Advisory Services analysis

P.3.5. Bridging the digital divide: use of Wi-Fi to increase coverage in rural and isolated areas

Wi-Fi is an appropriate technology to offer Internet access in rural and isolated areas. Based on the data provided by MinTIC in subscriptions by technology, we can estimate 423,570 WISP subscriptions in 2021. The calculation of the Wi-Fi contribution to the reduction of the digital divide must subtract the direct impact of WISPs (Section P.5.3.) to avoid double counting. On the other hand, we assume that 90% of WISP potential connections may be theoretically served by other technologies (i.e. satellite) covering the same isolated footprint. Thus, we can conservatively expect 10% of broadband subscriptions in remote locations exclusively attributed to WISPs. Once this is done, we calculate the impact on GDP by relying on the coefficient estimated by Katz and Callorda (2018b) through regression models that links increase in broadband penetration to economic growth. The contribution to GDP materializes through multiple effects: creation of new businesses, increasing productivity of existing enterprises, and growth of average income per household. We expect a GDP contribution of $315 million in 2021, which will increase to $506 million in 2025 (see Table P-16).

Table P-16. Colombia: Estimation of GDP Contribution derived from reducing the digital divide (2021-2025)

Variable	2021	2022	2023	2024	2025
WISP subscribers	423,570	475,610	527,650	579,690	631,730
Additional broadband penetration due to WISP	5.66%	6.13%	6.57%	6.96%	7.32%
Impact of fixed broadband adoption in GDP	15.75%	15.75%	15.75%	15.75%	15.75%
GDP ($Billion)	$356.90	$375.57	$397.35	$419.78	$443.28
WISP TOTAL impact ($Billion)	$3.18	$3.63	$4.11	$4.60	$5.11
WISP Revenues ($Billion)	$0.03	$0.03	$0.04	$0.04	$0.04
Share that exist because WISP	10.00%	10.00%	10.00%	10.00%	10.00%
WISP spillovers on GDP ($Million)	$315.09	$359.33	$407.07	$456.01	$506.48

Sources: MinTIC; UIT; IMF; Telecom Advisory Services analysis

Economic impact of enhanced coverage and affordability due to 6 GHz

The allocation of the 6 GHz band to unlicensed use would allow WISPs to potentially increase their subscriber base within their same coverage footprint. Therefore, a first effect derived from the allocation of the new spectrum band is related to additional households served due to additional coverage. We will follow a cautious approach and consider that the expanded coverage will yield a gradual increase on WISP subscribers, from 2% in 2022 to 5% in 2025 over the figures projected without assuming the additional spectrum allocation. In addition, an increase of the user base would allow service providers to lower their operating costs. Thus, by assuming stability in prices, affordability would increase as GDP per capita grows as economic growth resumes. Also, an additional increase in connections would result as an increase in the sharing rates. All in all, we can expect an overall increase in almost 106,600 WISP connections in 2025, contributing to an increase 0.73% in national broadband penetration. Considering the impact coefficient of broadband on the economy that will yield a GDP contribution equivalent to $862 million (see Table P-17).

Table P-17. Colombia: GDP Contribution derived from reducing the digital divide due to 6 GHz (2021-2025)

Variable	2021	2022	2023	2024	2025
New subscribers due to expanded coverage (%)	0%	2%	3%	4%	5%
New subscribers due to expanded coverage	0	9,512	15,830	23,188	31,587
New WISP adoption after price decrease (% households)	5%	4%	4%	5%	5%
Traffic through the 6 GHz Channel (%)	0.00%	10.00%	20.00%	30.00%	40.00%
Increase in WISP connections due to lower prices (households that buy the service)	0	8,030	20,169	32,196	46,287
Sharing %	45%	49%	54%	58%	62%
Increase in WISP connections due to lower prices (considering households that share the connection)	0	11,995	30,977	50,804	74,986
Increase in WISP connections due to lower prices, sharing and extended coverage	0	21,507	46,807	73,992	106,573
Increase in national broadband penetration	0.00%	0.15%	0.33%	0.51%	0.73%
Impact of fixed broadband adoption in GDP	15.75%	15.75%	15.75%	15.75%	15.75%
Increase in the GDP due to the new broadband adaptation (% GDP)	0.00%	0.04%	0.09%	0.14%	0.19%
Total impact in GDP ($Million)	$0	$164	$364	$587	$862

Sources: MinTIC; UIT; IMF; Telecom Advisory Services analysis

P.4. Enterprise Wi-Fi

Beyond the impact on consumers, Wi-Fi also contributes significant economic value in the Colombian enterprise segment. This section provides estimates in five areas:

- Support of business Internet traffic;
- Avoidance of campus and enterprise facilities inside wiring;
- Contribution to GDP resulting from Wi-Fi speed faster than cellular connections;
- Deployment of IoT solutions; and
- Implementation of business focused AR/VR use cases.

P.4.1. Business Internet traffic transmitted through Wi-Fi

Wi-Fi enterprise savings results from wireless traffic that is routed through Wi-Fi access points. Considering Cisco 2016-21 projections, we estimate that total business Internet traffic will reach 3.0 billion GB in 2021, of which 1.5 billion GB would have been transported through Wi-Fi access points. Considering the average price per GB transported by cellular, savings from Wi-Fi will reach $3.2 billion, an addition to the producer surplus. By 2025, this benefit will reach $3.1 billion (see Table P-18).

Table P-18. Colombia: Savings in business wireless traffic (2021-2025)

Variable	2021	2022	2023	2024	2025
Share of Business Internet Traffic by Wi Fi	53.00%	51.53%	50.10%	48.71%	47.36%
Total Business Internet Traffic (Million GB)	2,953	3,537	4,236	5,074	6,077
Total Wi-Fi enterprise traffic (Million GB)	1,534	1,724	1,914	2,104	2,293
Average Price per GB	$2.07	$1.87	$1.68	$1.51	$1.36
Economic Impact ($Million)	$3,182	$3,219	$3,218	$3,184	$3,126

Sources: Cisco; Telecom Advisory Services analysis

Enhanced business Internet traffic transmitted through Wi-Fi due to 6 GHz

The deployment of the latest enterprise applications will generate an exponential growth in data traffic that will be handled by devices operating in unlicensed spectrum, through the combination of the existing bands and the 6 GHz band. As in the case of the U.S., we assume that part of the growth was driven by "natural" growth, and another portion was triggered by Wi-Fi traffic stimulated by changes in 6 GHz. The sum of the difference due to broader Wi-Fi traffic will reach $797 million in 2025 (see Table P-19).

Table P-19. Colombia: Savings in business wireless traffic due to 6 GHz (2021-2025)

Variable	2021	2022	2023	2024	2025
Economic Impact Natural Growth ($Million)	$3,182	$3,219	$3,218	$3,184	$3,126
Economic Impact with 6 GHz ($Million)	$3,247	$3,404	$3,569	$3,741	$3,922
Difference due to 6 GHz ($Million)	$65	$185	$351	$557	$797

Sources: Cisco; Telecom Advisory Services analysis

P.4.2. Avoidance in enterprise building inside wiring

Similar to residential Wi-Fi savings due to capital investment avoidance in inside wiring, we assume that the total number of business establishments are equipped with Wi-Fi access points and multiply this value by a standard cost of deploying a CAT 6 network (from U.S., adjusted by PPP) (see Table P-20).

Table P-20. Colombia: Savings in business wiring CAPEX (2021-2025)

Variable	2021	2022	2023	2024	2025
Total Wiring Cost	$910.00	$907.98	$906.44	$905.25	$905.25
Number of Establishments	1,671,098	1,686,152	1,701,304	1,716,618	1,732,071
Establishments with Wi-Fi (%)	100%	100%	100%	100%	100%
Establishments with Wi-Fi	1,671,098	1,686,152	1,701,304	1,716,618	1,732,071
Inside Wiring Costs ($Million)	$1,521	$1,531	$1,542	$1,554	$1,568

Sources: Cámara de Comercio y Confecamaras; Telecom Advisory Services analysis

P.4.3. Return to speed: contribution to GDP derived from an increase in average mobile speed

Since Wi-Fi accessibility allows, in general, faster access to the Internet than cellular networks do, higher speeds have a positive contribution on the economy in terms of increased overall efficiency and innovation. This contribution is measured in terms of economic growth. As described in section P.3.3 for the case of consumer surplus, we start with the quantification of the average broadband speed if cellular networks transported all Wi-Fi traffic, and compare it with the presence of Wi-Fi technology (see Table P-21).

Table P-21. Colombia: Estimation of speed differential for total traffic (2021-2025)

Variable	2021	2022	2023	2024	2025
Average Download Speed if Wi-Fi traffic were carried through mobile networks (Mbps)	27.00	31.76	36.19	40.38	44.42
Average Speed with Wi-Fi (Mbps)	43.71	51.96	60.53	69.64	79.50
Speed increase (%)	62%	64%	67%	72%	79%
Impact of speed in GDP	0.73%	0.73%	0.73%	0.73%	0.73%
Increase in GDP	0.45%	0.46%	0.49%	0.53%	0.58%
GDP ($Billion)	$357	$376	$397	$420	$443
GDP increase ($Million)	$1,613	$1,743	$1,950	$2,220	$2,555

Sources: Cisco; Ookla; IMF; Telecom Advisory Services analysis

Having calculated the speed increase percentage, we then apply this percentage to the coefficient derived from the model developed by Katz and Callorda (2019) to gauge the potential impact on GDP from Wi-Fi enhanced speed. Table P-21 indicates that the economic value of Wi-Fi in terms of increasing the speed of transporting wireless will account to $1.6 billion in 2021, before being increased to $2.6 billion in 2025.

Return to Speed additional effect due to 6 GHz

As previously described, only those broadband connections above 150 Mbps will be affected due to current router bottlenecks, and hence, the speed experienced will not be equivalent to that delivered by the fixed network. Thus, the allocation of the 6 GHz band will remove those barriers, increasing broadband speed. After calculating the difference in average speed attributed to 6 GHz, the additional GDP contribution will yield $1.6 billion in 2025 (Table P-22).

Table P-22. Colombia: Estimation of speed differential due to 6 GHz (2021-2025)

Variable	2021	2022	2023	2024	2025
Mean speed with no 6 GHz (Mbps)	43.71	51.96	60.53	69.64	79.50
Mean speed with 6 GHz (Mbps)	43.71	53.54	66.41	85.83	118.66
Speed increase due to 6Ghz (%)	0%	3%	10%	23%	49%
Impact speed on GDP	0.73%	0.73%	0.73%	0.73%	0.73%
Increase in GDP (%)	0.00%	0.02%	0.07%	0.17%	0.36%
GDP increase ($Million)	$0	$83	$282	$713	$1,594

Sources: Cisco; Ookla; IMF; Telecom Advisory Services analysis

P.4.4. IoT deployment

IoT adoption contributes to GDP growth through the multiplicity of use cases that improve efficiency in processes such as preventive maintenance, production monitoring and the like. To estimate this, we rely on a coefficient of GDP impact calculated through an aggregate simple production function which estimates that a 10% rise in M2M connections results in annual increases in GDP of between 0.3%

and 0.9%[293]. Following a conservative approach, for Colombia we assume a 0.3% GDP increase after a 10% raise in M2M.

Starting with a 2021 installed base of 3.1 million M2M devices, we estimate the growth that can be exclusively attributed to the allocation of additional spectrum to indoor Wi-Fi devices. Thus, by subtracting the growth in M2M attributed to 6 GHz, it is estimated that the IoT impact for 2021 according to the natural growth would reach $955 million (see Table P-23).

Table P-23. Colombia: GDP Contribution of IoT Deployment Boost (2021-2025)

Variable	2021	2022	2023	2024	2025
Connections, Cellular M2M	3,065,530	3,326,295	3,609,242	3,916,257	4,249,388
Growth Rate (%)	9.79%	8.51%	8.51%	8.51%	8.51%
Natural Growth Rate (%)	8.92%	7.53%	7.34%	7.34%	7.34%
Impact of 1% M2M Growth on GDP	3.00%	3.00%	3.00%	3.00%	3.00%
Impact on GDP (%)	0.27%	0.23%	0.22%	0.22%	0.22%
GDP ($Billion)	$357	$376	$397	$420	$443
Impact ($Million)	$955	$848	$875	$924	$976

Sources: GSMA Intelligence; Frontier Economics; IMF; Telecom Advisory Services analysis

Accelerated effect of IoT due to 6 GHz

As described above, a share of the M2M growth can be attributed to 6 GHz developments. According to the data in Table P-24, cumulative impact of enhanced IoT deployment driven by 6 GHz spectrum proposals will reach $156 million by 2025.

Table P-24. Colombia: GDP Contribution of IoT Deployment Boost caused by 6 GHz (2021-2025)

Variable	2021	2022	2023	2024	2025
Growth due to 6 GHz (%)	0.88%	0.98%	1.17%	1.17%	1.17%
Level of development of new bands (%)	50%	100%	100%	100%	100%
Impact on GDP (%)	0.01%	0.03%	0.04%	0.04%	0.04%
Impact ($Million)	$47	$110	$139	$147	$156

Sources: GSMA Intelligence; Frontier Economics; IMF; Telecom Advisory Services analysis

P.4.5. Deployment of AR/VR solutions

The adoption of AR/VR among Colombia business will in turn have a spillover effect on productivity, thereby contributing to the growth of GDP. Estimating spillover effects of AR/VR is a not a trivial exercise considering the embryonic adoption of some of these use cases. Since the objective is to estimate the spillover effect of AR/VR sales by local firms in the domestic market, we will take as points of departure the estimate by PwC of the total GDP contribution of AR/VR for 2021 and 2022, and the sales of AR/VR components as estimated by IDC. The extrapolation of these two parameters allow estimating the indirect (spillover) contribution of AR/VR to the local economy for the period under analysis.

[293] See Frontier Economics (2018)

Starting values are reduced by the proportion that can be attributed to the impact of the 6 GHz spectrum bands. To do so, we took as a reference a ratio of AR/VR product developments according to each technology. Once the amount to be attributed in both GDP contribution and direct sales is estimated, the annual indirect to direct multiplier can be calculated. The lowest multiplier value is applied to sales of AR/VR in the local market to calculate the total spillovers (see Table P-25). Total spillover value of AR/VR in Colombia in 2021 will account for $33 million and is expected to increase by 2025 to $158 million.

Table P-25. Colombia: GDP contribution resulting from AR/VR spillovers (2021-2025)

Variable	2021	2022	2023	2024	2025
AR/VR total contribution to GDP ($Billion)	$0.08	$0.14	$0.23	$0.35	$0.54
Share attributed to Wi-Fi (excluding 6 GHz)	42.02%	38.80%	32.18%	30.88%	29.32%
Portion of GDP contribution attributed to Wi-Fi (excluding 6 GHz) ($Billion)	$0.03	$0.05	$0.07	$0.11	$0.16
Direct impact (sales) attributed to Wi-Fi (excluding 6 GHz) ($Billion)	$0.03	$0.05	$0.07	$0.11	$0.16
Indirect impact ($Billion)	$0.19	$0.24	$0.25	$0.29	$0.34
Indirect/Direct multiplier	1.00	1.00	1.00	1.00	1.00
Indirect impact ($Million)	$33	$54	$73	$108	$158

Sources: PwC, ABI; Telecom Advisory Services analysis

Wider deployment of AR/VR solutions (accelerated effect due to 6 GHz)

Higher throughput enabled by the allocation of the 6 GHz band is expected to spur the adoption and use of AR/VR among enterprises, hence increasing the associated spillover effects. By relying on the ratio built from 5 GHz and 6 GHz AR/VR related products, we were able to isolate the specific economic contribution of the new spectrum allocation. Following a similar procedure as that described above, spillovers from AR/VR in Colombia attributed to 6 GHz in 2021 will account for $20 million and are expected to increase by 2025 to $156 million (Table P-26).

Table P-26. Colombia: GDP contribution resulting from AR/VR spillovers due to 6 GHz (2021-2025)

Variable	2021	2022	2023	2024	2025
AR/VR total contribution to GDP ($Billion)	$0.08	$0.14	$0.23	$0.35	$0.54
Share attributed to 6 GHz (%)	24.58%	25.59%	26.64%	27.73%	28.87%
Portion of GDP contribution attributed to 6 GHz ($Billion)	$0.13	$0.19	$0.26	$0.36	$0.49
Direct impact (sales) attributed to 6 GHz ($Billion)	$0.02	$0.04	$0.06	$0.10	$0.16
Indirect impact ($Billion)	$0.11	$0.16	$0.20	$0.26	$0.33
Indirect/Direct multiplier	1.00	1.00	1.00	1.00	1.00
Indirect impact ($Million)	$20	$35	$60	$97	$156

Sources: PwC, ABI; Telecom Advisory Services analysis

P.5. Internet Service Providers

In addition to the economic value generated by the sources analyzed above, Wi-Fi will also contribute to either producer surplus or GDP of Internet Service Providers. This section will assess the economic value in three sources:

- Producer surplus of cellular operators resulting from CAPEX savings incurred in network deployment
- Revenues of Wi-Fi carriers offering service in public spaces
- Revenues of Wireless ISPs (this effect differs from the GDP impact of WISPs as a result of their deployment in rural and isolated areas analyzed in section P.3.5.)

P.5.1. Cellular network savings by off-loading traffic to Wi-Fi

The estimation of CAPEX savings starts by considering the GSMA Intelligence aggregate projected investment by wireless carriers in Colombia, which amounts to $7.4 billion between 2019 and 2025. Considering the total CAPEX required to deploy 5G in Colombia, and the incremental 5G coverage between 2021 and 2025 we are able to interpolate the 5G CAPEX for each year of the period considered. It is assumed that all the CAPEX invested during the period would be dedicated to 5G deployment.

Based on the simulation model developed to forecast the impact of Wi-Fi off-loading in 5G deployment, would result in a total producer surplus (adding CAPEX and OPEX savings) of $5.8 billion in 2024, increasing to 8.1 billion in 2025, when 5G coverage will reach 30% (see Table P-27).

Table P-27. Colombia: Savings due to traffic off-loading (2021-2025)

Variable	2021	2022	2023	2024	2025
5G coverage	0%	0%	0%	13%	30%
CAPEX without saving ($Million)	$0	$0	$0	$4,593	$6,437
CAPEX reduction due to Wi-Fi off-loading ($Million)	$0	$0	$0	$1,511	$2,118
OPEX reduction due to Wi-Fi off-loading ($Million)	$0	$0	$0	$4,261	$5,972
Total Cost of Ownership ($Million)	$0	$0	$0	$5,772	$8,089

Sources: GSMA; Telecom Advisory Services analysis

Enhanced capability for cellular off-loading if 6 GHz allocated

The complementarity between Wi-Fi and cellular networks for Wi-Fi 6E and 5G, adds further potential gains derived from the savings in capital and operating expenses required to accommodate exploding data traffic. The key objective is to estimate the savings in capital investment as a result of an increase in traffic offloading with Wi-Fi benefits from the additional spectrum allocated, particularly, due to the ability to leverage 160 MHz within single contiguous channels.

The estimation of CAPEX savings starts by considering the GSMA Intelligence aggregate investment estimates of 5G deployments. By relying again on the geographic disaggregation of Oughton and Frias, we estimate that CAPEX can be split in urban, suburban and rural geographies. We conservatively assume that Wi-Fi 6 will not be critical in sustaining investment in urban areas, but that it will play a significant role beyond those geographies. Based on the cost advantage of carrier grade Wi-Fi, we assume that it will become effective for a portion of the suburban (approximately 15%) and rural network (approximately 5%) deployment. Therefore, this will yield yearly CAPEX savings of $436 million.

P.5.2. Wi-Fi carrier revenues

The value of Wi-Fi carriers includes the sum of revenues through paid public Wi-Fi access. In order to estimate those aggregated revenues, we start by calculating the number of paid Wi-Fi hotspots in Colombia. According to Cisco, in 2021 there will be 790,000 public Wi-Fi hotspots in the country, although that figure includes home spots (such as the guest account service provided by cable operators). By subtracting the home spots from the public Wi-Fi estimates of Cisco, we calculated a total of 40,000 paid Wi-Fi hotspots for 2021, which will decrease till reaching 30,000 in 2025. On the other hand, based on revenue figures per hotspot from Boingo for the U.S., by adjusting by PPP we were able to estimate a figure for the case of Colombia. Then, we estimate total revenues generated by this sector in Colombia: $9 million in 2021, reducing to reach $8 million in 2025 (Table P-28).

Table P-28. Colombia: Revenues of Wi-Fi carriers (2021-2025)

Variable	2021	2022	2023	2024	2025
Public Wi-Fi hotspots (Million)	0.79	1.19	1.80	2.72	4.11
Home spots (Million)	0.76	1.15	1.76	2.68	4.08
Paid Wi-Fi hotspots (Million)	0.04	0.04	0.05	0.05	0.03
Revenue per hotspot ($)	$256	$255	$255	$255	$255
Revenue ($Million)	$9	$11	$12	$12	$8

Sources: Cisco, Boingo, Telecom Advisory Services

Increased revenues of Wi-Fi carriers in public places due to 6 GHz

The allocation of the 6 GHz spectrum band offers an opportunity for pay Wi-Fi carriers to enhance their business. As Wi-Fi 6E developments will allow up to 1,500 connected devices per access point, Wi-Fi carriers will have the possibility of adding more clients without quality limitations due to congestion. By considering a conservative potential increase of 40% in the number of connected devices in public venues and weighting that figure by the gradual expansion of the latest technology, we expect pay Wi-Fi carriers to increase their user base by 16% in 2025. If the revenue per hotspot increases in the same amount, that will yield an increase in overall revenues for the sector of an additional $1.3 million by 2025 (Table P-29).

Table P-29. Colombia: Revenues of Wi-Fi carriers due to 6 GHz (2021-2025)

Variable	2021	2022	2023	2024	2025
Potential increase in connected devices in public venues	40.00%	40.00%	40.00%	40.00%	40.00%
Traffic through the 6 GHz Channel (%)	0%	10%	20%	30%	40%
Increase in connected devices due to 6 GHz	0%	4%	8%	12%	16%
Revenue per hotspot if 6 GHz allocated ($)	$255.94	$265.59	$275.34	$285.16	$295.34
Revenue if 6 GHz allocated ($Million)	$0.00	$0.43	$0.97	$1.41	$1.26

Sources: Boingo; Telecom Advisory Services

P.5.3. Wireless ISPs revenues

The 2021 GDP contribution related to the WISP industry was calculated as a function of the number of subscribers (420,000) and the ARPU (data from MinTIC), yielding a total of $30 million (Table P-30).

Table P-30. Colombia: WISP revenues (2021-2025)

Variable	2021	2022	2023	2024	2025
Subscribers (Million)	0.42	0.48	0.53	0.58	0.63
Revenues ($Million)	$29.65	$33.29	$36.94	$40.58	$44.22

Sources: MinTIC, Telecom Advisory Services

Increased revenues of WISPs due to 6 GHz

As described in section P.2.5, the allocation of 6 GHz spectrum band will potentially increase the WISP user base in 11,000 subscribers by 2025, due to expanded coverage and better affordability. Thus, by assuming the same ARPU values as described above, the new subscriptions will amount to an additional $7.5 million in revenues in 2025 (Table P-31).

Table P-31. Colombia: WISP revenues due to 6 GHz (2021-2025)

Variable	2021	2022	2023	2024	2025
WISP annual ARPU ($)	$70.00	$70.00	$70.00	$70.00	$70.00
New subscribers if 6 GHz allocated (Million)	0.00	0.02	0.05	0.07	0.11
New revenue ($Million)	$0.00	$1.51	$3.28	$5.18	$7.46

Sources: MinTIC, Telecom Advisory Services

P.6. Wi-Fi ecosystem

The economic value of Wi-Fi ecosystem companies is calculated based on the following three sources:

- The producer surplus (i.e. margins) of residential Wi-Fi devices and equipment manufactured in Colombia;
- The producer surplus of local firms providing products and services in the IoT ecosystem (hardware, software and systems integration) in Colombia; and
- The producer surplus of local firms providing products and services in the AR/VR ecosystem (hardware, software and content) in Colombia.

P.6.1 Locally manufactured residential Wi-Fi devices and equipment

The difference between market prices and locally manufactured costs of Wi-Fi enabled products represents the manufacturer's margin and, consequently, producer surplus. As detailed before in Chapter III, we identified seven producer products which are intrinsically linked to Wi-Fi: smart home devices and systems such as Wi-Fi speakers and home security systems, home networking systems, Wi-Fi tablets, access points, external adapters, routers, and gateways. By adding to that value, the producer surplus estimated for the case of tablets (a product that is enabled mostly by Wi-Fi access[294]), we estimate a total economic value of $43 million in 2021, which we expect to slightly increase to $44 billion in 2025 (Table P-32).

Table P-32. Colombia: Producer Surplus from locally manufactured residential Wi-Fi devices and equipment (2021-2025)

Variable	2021	2022	2023	2024	2025
Total producer surplus ($Million)	$43.00	$44.50	$46.06	$45.49	$44.07

Sources: Consumer Technology Association; ABI Research; CS Markets; Telecom Advisory Services analysis

Locally manufactured Wi-Fi 6 devices and equipment for residential use

As mentioned above, devices for 6 GHz are expected to gradually replace those of prior generations. According to IDC, global shipments of consumer devices linked to 6 GHz spectrum (802.11ax) will represent 40% of the shipments of those from previous generations in 2025. Therefore, we expect the producer surplus attributed to 6 GHz devices to yield $18 million in economic value by 2025 (see Table P-33).

Table P-33. Colombia: Producer Surplus from locally manufactured residential Wi-Fi 6 devices and equipment (2021-2025)

Variable	2021	2022	2023	2024	2025
Consumer 6 GHz / no 6 GHz	3.76%	8.83%	18.59%	28.86%	40.30%
Producer surplus 6 GHz devices ($Million)	$1.62	$3.93	$8.56	$13.13	$17.76

Sources: IDC; Telecom Advisory Services analysis

P.6.2. Firms belonging to the IoT ecosystem

According to an interpolation from Frost & Sullivan data, we expect total industrial IoT revenue in Colombia to amount $424 million in 2021. By relying on the percentage of hardware connectivity spending in IoT, we were able to split that figure into two main segments: hardware; and software, contents, and services. By weighting those amounts by the share of local production (15% for hardware, 60% for software and services) and the assumed margins (39.44% and 77.46%, respectively), we can estimate the overall producer surplus. However, from that economic value we should extract the share attributed to 6 GHz developments. To do so, we estimated a natural growth rate, by subtracting the corresponding share attributed to 6 GHz according to the growth rates indicated in Table P-33. Thus, we estimate a producer surplus not attributed to 6 GHz of $129 million in 2021, expected to reach $268 million in 2025 (Table P-34).

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[294] A similar approach was used in prior studies (Katz at al, 2014; 2017; 2018) and Milgrom et al. (2011).

Table P-34. Colombia: IoT ecosystem direct contribution (2021-2025)

Variable	2021	2022	2023	2024	2025
IoT revenue - Hardware ($billions)	$0.16	$0.20	$0.24	$0.30	$0.37
IoT revenue - Software, Contents, Services ($billions)	$0.27	$0.33	$0.40	$0.50	$0.61
Total Industrial IoT revenue in ($Billion)	$0.42	$0.52	$0.64	$0.79	$0.98
Local production (%) - Hardware	15%	15%	15%	15%	15%
Local production (%) - Software & Services	60%	60%	60%	60%	60%
Margins (%) - Hardware	39%	39%	39%	39%	39%
Margins (%) - Software & Services	77%	77%	77%	77%	77%
Margins - IoT Hardware revenue	$0.01	$0.01	$0.01	$0.02	$0.02
Margins - Software, contents and services IoT revenue	$0.12	$0.15	$0.19	$0.23	$0.28
Producer surplus ($Million)	$132.64	$163.49	$201.51	$248.37	$306.13
Growth rate (%)	23.26%	23.26%	23.26%	23.26%	23.26%
Growth rate not attributed to 6 GHz (%)	21.18%	20.58%	20.06%	20.06%	20.06%
Producer surplus not attributed to 6 GHz ($Million)	$128.56	$155.01	$186.10	$223.43	$268.24

Sources: Frost & Sullivan; GTAP, CSI, Telecom Advisory Services analysis

Wider deployment of Internet of Things under 6 GHz

Following the previous analysis, we were able to estimate which portion of IoT producer surplus growth can be attributed to 6 GHz. As Table P-35 indicates, we expect the additional IoT surplus generated by 6 GHz to account for $38 million in 2025.

Table P-35. Colombia: IoT direct contribution attributed to 6 GHz (2021-2025) ($Million)

Variable	2021	2022	2023	2024	2025
Producer surplus	$132.64	$163.49	$201.51	$248.37	$306.13
Producer surplus not attributable to 6 GHz	$128.56	$155.01	$186.10	$223.43	$268.24
Additional surplus due to 6 GHz	$4.08	$8.48	$15.41	$24.94	$37.89

Sources: Frost & Sullivan; GTAP, CSI, Telecom Advisory Services analysis

P.6.3. Firms belonging to the AR/VR ecosystem

Following a similar procedure as with the case of IoT, we can estimate the direct contribution of this ecosystem to the local economy. Starting with the local spending in AR/VR by category (hardware, software, and contents), and weighting those figures by the respective shares of local production and margins, we were able to estimate the total producer surplus. By relying on a ratio built from 5 GHz and 6 GHz AR/VR related products, we were able to subtract the specific contribution attributed to 6 GHz from the surplus corresponding to current bands. Then, we expect by 2021 a direct contribution from the AR/VR ecosystem of $13 million, which will increase until reaching $62 million by 2025 (Table P-36).

Table P-36. Colombia: AR/VR ecosystem direct contribution (2021-2025)

Variable	2021	2022	2023	2024	2025
Spending in AR/VR - Hardware $Billion	$0.01	$0.02	$0.04	$0.06	$0.10
Spending in AR/VR - Software, Contents, Services ($Billion)	$0.07	$0.12	$0.19	$0.29	$0.44
Total Spending in AV/VR ($Billion)	$0.08	$0.14	$0.23	$0.35	$0.54
Share of local production - Hardware	15.12%	15.12%	15.12%	15.12%	15.12%
Share of local production - Software, Contents, Services	60.00%	60.00%	60.00%	60.00%	60.00%
Local production for local consumption - Hardware ($Billion)	$0.00	$0.00	$0.01	$0.01	$0.01
Local production for local consumption - Software, Contents, Services ($Billion)	$0.04	$0.07	$0.11	$0.17	$0.26
Local Producer Surplus - Hardware ($Billion)	$0.00	$0.00	$0.00	$0.00	$0.01
Local Producer Surplus - Software, Contents, Services ($Billion)	$0.03	$0.05	$0.09	$0.13	$0.20
Total Producer Surplus	$0.03	$0.06	$0.09	$0.14	$0.21
Share attributable to Wi-Fi (excluding 6 GHz)	42.02%	38.80%	32.18%	30.88%	29.32%
Producer Surplus attributed to Wi-Fi (not including 6 GHz) ($Million)	$13.26	$21.51	$28.98	$42.53	$61.74

Sources: PwC, ABI; Telecom Advisory Services analysis

Wider deployment of AR/VR solutions if 6 GHz allocated

By relying on a ratio built from 5 GHz and 6 GHz AR/VR related products, we were able to isolate the specific economic contribution of the new spectrum allocation. Following a similar procedure as that described above, the direct contribution from AR/VR ecosystem in Colombia attributed to 6 GHz in 2025 will yield $61 million (see Table P-37).

Table P-37. Colombia: AR/VR direct contribution attributed to 6 GHz (2021-2025)

Variable	2021	2022	2023	2024	2025
Spending in AR/VR ($Billion)	$0.08	$0.14	$0.23	$0.35	$0.54
Share attributed to 6 GHz	24.58%	25.59%	26.64%	27.73%	28.87%
Spending in AR/VR attributed to 6 GHz ($Billion)	$0.02	$0.04	$0.06	$0.10	$0.16
Local production for local consumption 6 GHz ($Billion)	$0.01	$0.02	$0.03	$0.05	$0.08
Local Producer Surplus ($Million)	$7.76	$14.18	$24.00	$38.19	$60.79

Sources: PwC, ABI; Telecom Advisory Services analysis

P.7. Wi-Fi contribution to employment

The estimation of employment generated is calculated by relying on the total GDP contribution resulting from the effects analyzed above and using that as an input in the communications sector of an input-output matrix of Colombia economy. Table P-38 presents the GDP contribution enabled by Wi-Fi projected for the period 2021-2025.

Table P-38. Colombia: Wi-Fi enabled GDP contribution (2021-2025)

Year	GDP contribution enabled by Wi-Fi ($Million)		
	Attributed to current bands	Attributed to 6 GHz	Total
2021	$5,362	$66	$5,428
2022	$5,450	$622	$6,072
2023	$5,759	$1,304	$7,063
2024	$6,162	$2,227	$8,388
2025	$6,640	$3,668	$10,308

Source: Telecom Advisory Services analysis

These inputs generate the following annual employment effects based on the input/output matrix for the Colombia economy (Table P-39).

Table P-39. Colombia: Wi-Fi generated Annual Employment

Variable	2021			2025		
	Current bands	6 GHz	Total	Current bands	6 GHz	Total
Direct jobs	46,495	575	47,070	57,584	31,805	89,389
Indirect jobs	32,096	397	32,493	39,751	21,956	61,707
Induced jobs	18,842	233	19,075	23,336	12,889	36,225
Total	97,433	1,206	98,639	120,671	66,650	187,321

Sources: GTAP; Telecom Advisory Services analysis

According to the contribution to GDP, Wi-Fi will generate approximately 98,600 jobs in 2021 and is expected to generate over 187,300 in 2025. Job estimates include direct jobs (those jobs created by the specific Wi-Fi contribution), indirect jobs (those jobs created by suppliers to the Wi-Fi sector) and induced jobs (those jobs created by spending of direct and indirect workers).

The sector breakdown of 2021 employment (including the additional jobs created by 6 GHz) is as follows (Table P-40).

Table P-40. Colombia: Sector Breakdown of Wi-Fi generated annual employment (2021)

Sector	Direct	Indirect	Induced	Total
Agriculture	0	0	940	940
Extractive industries	0	0	116	116
Manufacturing	0	2,688	797	3,485
Construction	0	572	0	572
Trade	0	4,392	5,561	9,953
Transportation	0	6,207	0	6,207
Communications	47,070	0	0	47,070
Financial Services	0	2,801	0	2,801
Business services	0	15,833	0	15,833
Other services	0	0	11,661	11,661
Total	47,070	32,493	19,075	98,639

Sources: GTAP; Telecom Advisory Services analysis

Q. ECONOMIC VALUE OF WI-FI IN MEXICO

Wi-Fi has become a critical component of Mexico's telecommunications infrastructure. According to the Cisco Annual Internet Report Highlights Tool 2018-2023, there are approximately 7,070,000 public Wi-Fi access points operating in the country. The Wiman site estimates that there are currently 1,773,371 Wi-Fi sites (of which, 518,000 are in Mexico City, 108,000 in Guadalajara, and 408,000 in Iztapalapa). Given the Wi-Fi access point density, hotspots have become a very important connectivity feature. According to Opensignal[295], Mexican wireless users currently spend 64.0% of their communications time connected to Wi-Fi networks rather than relying on their cellular data connection. The increasing importance of Wi-Fi technology in the digital infrastructure ecosystem results in a significant social and economic impact. This section presents the results and calculations of the economic assessment. The methodology reviewed in section B was used to calculate each source of economic value.

Q.1. Total Economic Value of Wi-Fi in Mexico (2021-2025)

Before considering the additional effect of allocating the 6 GHz spectrum band for unlicensed use, the total economic value of Wi-Fi in Mexico in 2021 will amount to $56 billion. The total economic value in 2021 is comprised of $29.2 billion in consumer surplus, $18.2 billion in producer surplus, and $8.7 billion in contribution to GDP. The 2025 forecast of economic value will reach $109 billion without considering the acceleration effect from Wi-Fi 6 and the allocation of the 6 GHz band. The 2025 forecast of the baseline scenario will be composed of $67.9 billion in consumer surplus, $33.1 billion in producer surplus, and $8.0 billion in GDP contribution (see Table Q-1).

Table Q-1. Mexico: Economic Value of Wi-Fi (Baseline Scenario)

Agent	Source	Economic Value ($Million)					
		2021	2022	2023	2024	2025	Category
1. Free Wi-Fi	1.1. Savings generated by free Wi-Fi traffic offered in public sites	$531	$548	$572	$593	$594	Consumer Surplus
	1.2. Deployment of free Wi-Fi in public sites	$5,893	$5,594	$5,272	$4,925	$4,558	GDP contribution
2. Residential Wi-Fi	2.1. Internet access for home usage of devices that lack a wired port	$20,058	$25,902	$33,269	$42,618	$54,615	Consumer Surplus
	2.2. Avoidance of investment in in-house wiring	$6,694	$7,454	$8,295	$9,213	$10,233	Consumer Surplus
	2.3. Benefit to consumers from speed increases	$108	$210	$337	$493	$684	Consumer Surplus
	2.4. Residential Wi-Fi devices and equipment deployed	$1,796	$1,841	$1,894	$1,867	$1,807	Consumer Surplus
	2.5. Bridging digital divide: use of Wi-Fi to increase	$165	$172	$179	$185	$192	GDP contribution

[295] Khatri, H. and Fenwick, S. (2020). "Analyzing mobile experience during the coronavirus pandemic: Time on Wi-Fi". *Opensignal* (March 30).

Agent	Source	Economic Value ($Million)					
		2021	2022	2023	2024	2025	Category
	coverage in rural and isolated areas						
3. Enterprise Wi-Fi	3.1. Business Internet traffic transmitted through Wi-Fi	$8,238	$8,947	$9,717	$10,553	$11,461	Producer surplus
	3.2. Avoidance of enterprise inside wiring costs	$5,479	$5,743	$6,021	$6,311	$6,616	Producer surplus
	3.3. Return to speed: contribution to GDP derived from an increase in average mobile speed	$96	$177	$270	$1,042	$1,378	GDP contribution
	3.4. Wide deployment of IoT	$2,247	$925	$943	$984	$1,027	GDP contribution
	3.5. Deployment of AR/VR solutions	$129	$207	$281	$416	$580	GDP contribution
4. ISPs	4.1. CAPEX and OPEX savings due to cellular off-loading	$906	$2,660	$4,857	$7,073	$10,385	Producer surplus
	4.2. Revenues of service providers offering paid Wi-Fi access in public places	$80	$79	$65	$89	$121	GDP contribution
	4.3. Aggregated revenues of WISPs	$70	$87	$100	$115	$134	GDP contribution
5. Wi-Fi ecosystem	5.1. Locally manufactured residential Wi-Fi devices and equipment	$2,826	$2,924	$3,027	$2,989	$2,896	Producer surplus
	5.2. Locally manufactured Wi-Fi enterprise equipment	$0	$0	$0	$0	$0	Producer surplus
	5.3. Locally produced IoT products and services	$693	$910	$1,180	$1,313	$1,455	Producer surplus
	5.4. Locally produced of AR/VR solutions	$39	$71	$104	$166	$247	Producer surplus
Total		$56,048	$64,451	$76,383	$90,945	$108,983	

Source: Telecom Advisory Services analysis

In addition to the baseline scenario, the allocation of the 6 GHz spectrum band for unlicensed use and the deployment of Wi-Fi 6 and Wi-Fi 6E devices will trigger a growth of economic value, reaching $8.5 billion in 2025 (see Table Q-2).

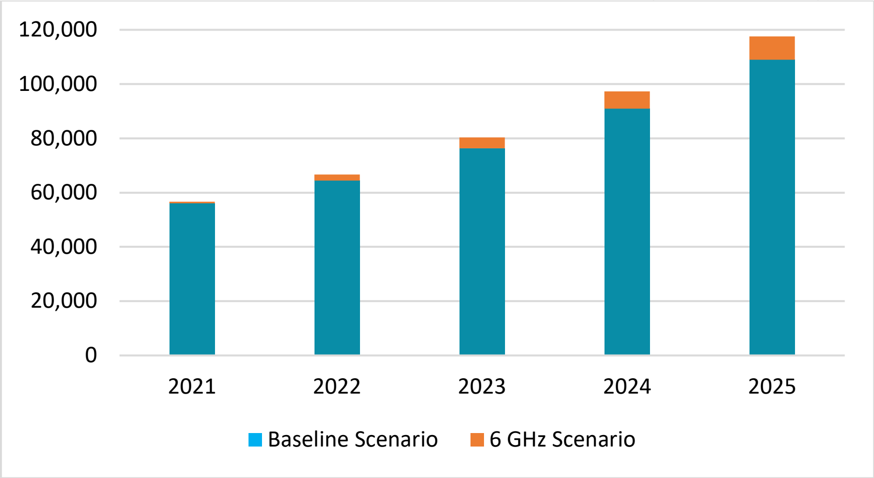
Table Q-2. Mexico: Economic Value of Wi-Fi (only attributed to 6 GHz)

Agent	Source	Economic Value ($Million)					
		2021	2022	2023	2024	2025	Category
1. Free Wi-Fi	1.1. Savings generated by free Wi-Fi traffic offered in public sites	$0	$0	$0	$1	$7	Consumer Surplus
	1.2. Deployment of free Wi-Fi in public sites	$0	$531	$1,000	$1,401	$1,727	GDP contribution
	1.3. Benefit of faster free Wi-Fi with Wi-Fi 6E devices	$0	$67	$130	$198	$264	Consumer Surplus
2. Residential Wi-Fi	2.3. Benefit to consumers from speed increases	$0	$109	$259	$454	$697	Consumer Surplus
	2.4. Residential Wi-Fi devices and equipment deployed	$65	$156	$340	$521	$705	Consumer Surplus
	2.5. Bridging digital divide: use of Wi-Fi to increase coverage in rural and isolated areas	$0	$73	$134	$198	$271	GDP contribution
3. Enterprise Wi-Fi	3.1. Business Internet traffic transmitted through Wi-Fi	$0	$372	$503	$662	$853	Producer surplus
	3.3. Return to speed: contribution to GDP derived from an increase in average mobile speed	$0	$91	$206	$956	$1,406	GDP contribution
	3.4. Wide deployment of Internet of Things	$110	$120	$150	$157	$164	GDP contribution
	3.5. Deployment of AR/VR solutions	$75	$137	$233	$373	$571	GDP contribution
4. ISPs	4.1 CAPEX and OPEX savings due to cellular off-loading	$200	$200	$200	$200	$200	Producer surplus
	4.2. Revenues of service providers offering paid Wi-Fi access in public places	$0	$3	$5	$11	$19	GDP contribution
	4.3. Aggregated revenues of WISPs	$0	$4	$7	$12	$18	GDP contribution
5.Wi-Fi ecosystem	5.1. Locally manufactured residential Wi-Fi devices and equipment	$106	$258	$563	$863	$1,167	Producer surplus
	5.2. Locally manufactured Wi-Fi enterprise equipment	$0	$0	$0	$0	$0	Producer surplus
	5.3. Locally produced IoT products and services	$29	$68	$134	$173	$217	Producer surplus
	5.4. Locally produced of AR/VR solutions	$23	$47	$86	$150	$243	Producer surplus
Total		$608	$2,236	$3,950	$6,330	$8,529	

Source: Telecom Advisory Services analysis

Considering that we forecast that by 2025 only 40% of Wi-Fi traffic will rely on 6 GHz channels, the accelerated effect derived from the new spectrum allocation and latest Wi-Fi technologies will still be far from reaching its maximum potential at this time. However, a visual depiction of the trend provides a perspective of the growing importance of Wi-Fi 6 in the overall economic value (see Graphic Q-1)

Graphic Q-1. Mexico: Economic Value of Wi-Fi (2021-2025)



Source: Telecom Advisory Services analysis

By combining the baseline and the Wi-Fi 6 and 6 GHz scenarios, the overall economic value of Wi-Fi for Mexico will yield $117.5 billion in 2025 (see Table Q-3).

Table Q-3. Mexico: Total Economic Value of Wi-Fi (including Wi-Fi 6 and 6 GHz)

Agent	Source	Economic Value ($Million)					
		2021	2022	2023	2024	2025	Category
1. Free Wi-Fi	1.1. Savings to consumers of free Wi-Fi traffic offered in public sites	$531	$548	$572	$594	$601	Consumer Surplus
	1.2. Deployment of free Wi-Fi in public sites	$5,893	$6,126	$6,272	$6,325	$6,284	GDP contribution
	1.3. Benefit of faster free Wi-Fi with Wi-Fi 6E devices	$0	$67	$130	$198	$264	Consumer Surplus
2. Residential Wi-Fi	2.1. Internet access for home usage of devices that lack a wired port	$20,058	$25,902	$33,269	$42,618	$54,615	Consumer Surplus
	2.2. Avoidance of investment in in-house wiring	$6,194	$7,454	$8,295	$9,213	$10,233	Consumer Surplus
	2.3. Benefit to consumers from speed increases	$108	$319	$596	$946	$1,380	Consumer Surplus
	2.4. Residential Wi-Fi devices and equipment deployed	$1,861	$1,997	$2,233	$2,388	$2,512	Consumer Surplus
	2.5. Bridging digital divide: use of Wi-Fi to increase coverage in rural and isolated areas	$165	$245	$312	$384	$464	GDP contribution
3. Enterprise Wi-Fi	3.1. Business Internet traffic transmitted through Wi-Fi	$8,238	$9,318	$10,220	$11,214	$12,313	Producer surplus
	3.2. Avoidance of enterprise inside wiring costs	$5,479	$5,743	$6,021	$6,311	$6,616	Producer surplus
	3.3. Return to speed: contribution to GDP derived from an increase in average mobile speed	$96	$268	$477	$1,999	$2,785	GDP contribution
	3.4. Wide deployment of IoT	$2,357	$1,045	$1,093	$1,141	$1,191	GDP contribution
	3.5. Deployment of AR/VR solutions	$204	$344	$513	$789	$1,152	GDP contribution
4. ISPs	4.1 CAPEX and OPEX savings due to cellular off-loading	$1,106	$2,860	$5,057	$7,273	$10,585	Producer surplus

Agent	Source	Economic Value ($Million)					
		2021	2022	2023	2024	2025	Category
	4.2. Revenues of service providers offering paid Wi-Fi access in public places	$80	$82	$70	$99	$140	GDP contribution
	4.3. Aggregated revenues of WISPs	$70	$91	$107	$127	$152	GDP contribution
5. IT companies	5.1. Locally manufactured residential Wi-Fi devices and equipment	$2,932	$3,182	$3,589	$3,852	$4,063	Producer surplus
	5.2. Locally manufactured Wi-Fi enterprise equipment	$0	$0	$0	$0	$0	Producer surplus
	5.3. Locally produced IoT products and services	$722	$978	$1,314	$1,486	$1,672	Producer surplus
	5.4. Locally produced of AR/VR solutions	$62	$117	$191	$316	$491	Producer surplus
Total		$56,756	$66,686	$80,331	$97,273	$117,513	

Source: Telecom Advisory Services analysis

The following sections will present in detail the calculation of each source of value, disaggregating the economic contribution under current the spectrum ecosystem and the enhanced effect due to Wi-Fi 6 availability and the 6 GHz band.

Q.2. Value from free Wi-Fi service

The economic value of free Wi-Fi service originates from three contribution sources:

- Savings to consumers by accessing the Internet in free Wi-Fi sites rather than incurring cellular costs
- The use of Wi-Fi to expand broadband coverage to the unserved population
- The return to speed of Wi-Fi compared to the use of cellular service

Q.2.1. Savings incurred by accessing free Wi-Fi in public sites

Free Wi-Fi offered in retail shops, libraries, schools, coffee shops, city halls, and corporate guest accounts allows consumers to save money that would otherwise be spent purchasing cellular service. In addition, free hotspots provide access to the Internet for consumers that cannot afford to purchase broadband service. This last effect has been particularly important in the ongoing pandemic, allowing households to access the Internet for telecommuting and continuing education.

The economic value of free Wi-Fi is measured in terms of consumer surplus, which is by estimating the benefit that flows to consumers as a result of the savings in wireless broadband service acquisition. We start by quantifying mobile Internet traffic. In order to isolate the effect from the increased capacity derived from the 6 GHz allocation, we calculate the portion of free Wi-Fi traffic attributed to current spectrum bands. For this, we relied on the assumption than current traffic levels are already producing congestion in most free Wi-Fi hotspots at times of peak demand. However, as average traffic per hotspot will decline till 2023 (as hotspots will grow faster than overall traffic), we will assume that traffic per hotspot beyond that year will remain at constant levels without considering the allocation of the new bands.

Table Q-4. Mexico: Total Free Wi-Fi Traffic projection (2021-2025)

Variable	2021	2022	2023	2024	2025
Free Wi-Fi traffic (million GB Per year) - considering current trends	521.01	663.92	868.32	1,160.83	1,581.64
Free Wi-Fi hotspots (Million)	2.36	3.13	4.17	5.54	7.36
Traffic per hotspot - considering current trends	221.02	211.88	208.47	209.67	214.91
Traffic per hotspot - capped due to congestion	221.02	211.88	208.47	208.47	208.47
Total traffic (not attributed to 6 GHz) (Million GB)	521.01	663.92	868.32	1,154.23	1,534.27

Sources: Cisco; Wiman; Telecom Advisory Services analysis

We calculate consumer surplus by multiplying the total free traffic (not attributed to 6 GHz) by the difference between what the consumer would have to pay if she/he were to rely on a wireless carrier and the cost of offering free Wi-Fi (incurred by the retailer or public site). To do so, we needed an estimate of the average price per GB of wireless data transmitted by wideband networks, which we calculated by averaging the most economic "dollar per GB" plan of three major wireless carriers (see Table Q-5).

Table Q-5. Mexico: Average Price Per Gigabyte (2020)

Carrier	Plan	Price per GB ($)
Telcel (America Móvil)	Telcel Max Sin Límite 9000	$3.61
AT&T	26 GB	$1.89
Movistar (Telefónica)	6 GB	$2.34

Sources: Websites of cellular operators; Telecom Advisory Services analysis

Historical data allows for a projection of future prices per gigabyte. Based on these prices, we expect the average price per GB will reach an estimated $1.82 in 2025. By relying on the total free Wi-Fi traffic not attributed to 6 GHz allocation shown in Table Q-4 and the average price per cellular gigabyte minus the cost of provisioning Wi-Fi service, we calculated the consumer surplus of free Wi-Fi traffic (see Table Q-6).

Table Q-6. Mexico: Consumer Surplus of Free Wi-Fi Traffic (2021-2025)

Variable	2021	2022	2023	2024	2025
Total Free Traffic (not attributed to 6 GHz) (Million GB)	521.01	663.92	868.32	1,154.23	1,534.27
Price per cellular gigabyte ($)	$2.76	$2.49	$2.24	$2.02	$1.82
Cost per Wi-Fi provisioning ($)	$1.74	$1.66	$1.58	$1.50	$1.43
Consumer surplus per gigabyte ($)	$1.02	$0.83	$0.66	$0.51	$0.39
Total Consumer surplus ($Million)	$531.01	$547.90	$572.02	$592.91	$593.75

Sources: Cisco; Websites of cellular operators; Telecom Advisory Services analysis

As indicated in Table Q-6, consumer surplus of free Wi-Fi traffic in 2021 would reach an estimated $531 million, increasing to $594 million in 2025.

Enhanced free Wi-Fi traffic due to 6 GHz allocation

The allocation of the 6 GHz spectrum band and the technological advances provided by the Wi-Fi 6 standard will remove the above-mentioned bottlenecks assumed for the years after 2023. As a result, the traffic per hotspot will be able to continue growing at its natural rate as determined by the extrapolation of past recent trends. That being said, we must take into account that not all Wi-Fi traffic will benefit immediately from opening the 6 GHz band, as most current devices are not prepared to support the new standards. Thus, we expect the traffic through the 6 GHz channel to gradually increase until reaching a 40% of total free traffic by 2025.

Once computed the additional traffic "above and beyond" the future previsions under current spectrum bands, we will follow a similar approach to calculate the consumer surplus, by multiplying it by the difference between what the consumer would have to pay if he were to utilize a wireless carrier and the cost of offering free Wi-Fi (Table Q-7). As a result, we project an additional consumer surplus of $7.3 million from free Wi-Fi traffic attributed to 6 GHz.

Table Q-7. Mexico: Additional Consumer Surplus of Free Wi-Fi Traffic generated due to 6 GHz (2021-2025)

Variable	2021	2022	2023	2024	2025
Demand not satisfied due to congestion (Million GB)	0.00	0.00	0.00	6.61	47.38
Traffic through the 6 GHz Channel (%)	0%	10%	20%	30%	40%
Total traffic (attributed to 6 GHz) (Million GB)	0.00	0.00	0.00	1.98	18.95
Consumer Surplus (attributed to 6 GHz) ($Million)	$0.00	$0.00	$0.00	$1.02	$7.33

Sources: Cisco; Telecom Advisory Services analysis

Q.2.2. Free Wi-Fi to provide broadband to the unserved population

As explained in section B, deployment of free Wi-Fi provides Internet access to the unserved population. Consumers that do not have broadband at home because they lack the economic means to acquire services can rely on free Wi-Fi to gain Internet access. As a result, more people can be connected, which in turn enhances the economic contribution of broadband.

The calculation of this economic impact starts by calculating which portion of households that lack broadband service are already accessing Internet through free hotspots. We follow a conservative approach and assume that only 5% of unconnected households rely on free hotspots for accessing Internet. After calculating the increase in broadband penetration due to households relying on free Wi-Fi, we rely on the broadband impact coefficient from Katz and Callorda (2018b), for Latin America. As a result, the GDP contribution of this particular effect is expected to amount to $5.9 billion in 2021, reaching $4.6 billion in 2025. The decline is explained as fewer households are expected to remain unconnected in 2025.

Table Q-8. Mexico: GDP contribution due to households relying on Free Wi-Fi (2021-2025)

Variable	2021	2022	2023	2024	2025
Households without Internet	15,099,999	14,596,558	14,021,632	13,369,531	12,634,167
Households that don't buy because access Internet free hotspots (%)	5%	5%	5%	5%	5%
Households served by Free Wi-Fi hot spots	755,000	729,828	701,082	668,477	631,708
Increase in national broadband penetration	3.420%	3.101%	2.795%	2.500%	2.217%
Impact of fixed broadband adoption in GDP	15.75%	15.75%	15.75%	15.75%	15.75%
Increase in the GDP due to the new broadband adoption (% GDP)	0.538%	0.488%	0.440%	0.394%	0.349%
GDP ($Billion)	$1,094.53	$1,145.64	$1,197.86	$1,250.89	$1,305.73
Total impact in GDP ($Million)	$5,893.42	$5,594.44	$5,271.75	$4,924.69	$4,557.60

Sources: INEGI; IMF; Telecom Advisory Services analysis

Enhanced GDP contribution due to 6 GHz allocation

As stated above, Wi-Fi 6 technology enables supporting a high number of devices on a single access point. Accordingly, the improved throughput of free Wi-Fi hotspots under the 6 GHz allocation will allow the possibility of serving additional unconnected households.

The potential universe of additional households that could be served under this effect is enormous, as most unconnected households usually identify that costs are their main barrier for accessing connectivity and thus, may potentially be served by free hotspots as long as they are in proximity to the access point. However, evidence suggests that not many people rely exclusively on free Wi-Fi as their main source of Internet access, so we will follow again a conservative approach and assume that a further 5% of unconnected households will be served through free hotspots under the allocation of the 6 GHz band. On the other hand, we have also considered that the expansion of traffic through the new band will take place gradually, reaching 40% in 2025. All in all, we estimate that additional 239,329 households will be served in 2025 due to free hotspots operating under 6 GHz spectrum, yielding an additional GDP contribution of approximately $1.7 billion (Table Q-9).

Table Q-9. Mexico: GDP contribution due to households relying on Free Wi-Fi due to 6 GHz (2021-2025)

Variable	2021	2022	2023	2024	2025
Households without Internet (not served by free Wi-Fi and not new adopters of WISP)	14,344,999	13,857,450	13,303,335	12,675,142	11,966,433
Potential households that could be served through free Wi-Fi hotspots under increased capacity (% of those not connected)	5%	5%	5%	5%	5%
Traffic through the 6 GHz Channel (%)	0%	10%	20%	30%	40%
Additional households served by Free Wi-Fi hot spots with 6 GHz	0	69,287	133,033	190,127	239,329
Increase in national broadband penetration	0	0.294%	0.530%	0.711%	0.840%
Increase in the GDP due to the new broadband adoption (% GDP)	0.000%	0.046%	0.084%	0.112%	0.132%
Total impact in GDP ($Million)	$0.00	$531.12	$1,000.34	$1,400.67	$1,726.69

Sources: INEGI; IMF; Telecom Advisory Services analysis

Q.2.3. Benefit to consumers for enjoying higher speed from free Wi-Fi if 6 GHz band is allocated

When the 6 GHz band is adopted by free Wi-Fi access points, it will deliver service at faster broadband speeds. Current speeds from free hotspots are quite modest[296]. Thus, the expanded capabilities due to the allocation of 6 GHz spectrum band will enhance free Wi-Fi speeds, and as a result, will increase consumer surplus. We assume that under the 6 GHz allocation, speed from free hotspots will be similar to the Wi-Fi speeds from mobile devices reported by Cisco. After calculating the average speed by considering the expected share of traffic through 6 GHz, we follow Nevo et al. (2016) and calculate the additional consumer surplus per household relying on free Wi-Fi. We expect the consumer surplus resulting from faster speed in free Wi-Fi sites to reach $264 million in 2025 (Table Q-10).

Table Q-10. Mexico: Consumer surplus for enjoying higher speed from free Wi-Fi if 6 GHz band allocated (2021-2025)

Variable	2021	2022	2023	2024	2025
Free Wi-Fi mean speed with no 6 GHz (Mbps)	3.37	3.59	3.83	3.83	3.83
Wi-Fi Speeds from Mobile Device (Mbps)	22.25	26.68	32.00	38.38	46.02
Traffic through the 6 GHz Channel (%)	0.00%	10.00%	20.00%	30.00%	40.00%
Free Wi-Fi mean speed with 6 GHz (Mbps)	3.369	5.903	9.467	14.197	20.710
Demand for average download speed	29.74	31.30	32.92	33.65	34.40
New Demand for average download speed	29.74	38.27	45.89	52.85	59.68
Additional Monthly Consumer surplus	$0.00	$6.97	$12.97	$19.20	$25.29
Additional Yearly Consumer Surplus	$0.00	$83.59	$155.66	$230.43	$303.46
Households that rely on Free Wi-Fi	755,000	799,115	834,115	858,604	871,037
Consumer surplus ($Million)	$0.00	$66.80	$129.84	$197.85	$264.33

Sources: Cisco; Nevo et al. (2016); Telecom Advisory Services analysis

[296] Given the lack of reliable data on free Wi-Fi speed in Mexico, we made an estimation based on U.S. data, and applying the percentual differential between both countries in terms of fixed broadband speed. Then, we estimate free Wi-Fi speed in Mexico to reach 3.2 Mbps in 2020.

Q.3. Residential Wi-Fi

The economic value of Wi-Fi in consumer residences is the result of five factors:

- Provision of connectivity to the home network for devices that lack an Ethernet port;
- Cost avoidance of ethernet inside wiring;
- Consumer surplus resulting from faster broadband speeds relative to cellular networks;
- Consumer surplus derived from usage of home devices connected to the home network; and
- Provision of Internet access to consumers located in rural and isolated areas.

Q.3.1. Home Internet access for devices that lack an Ethernet port

The underlying premise of this analysis is that in the absence of Wi-Fi, users of devices lacking an Ethernet port would have to depend on the cellular network to gain Internet access. For this reason, estimating value would first measure the traffic generated by these devices at home and then multiply it by the average price charged by cellular carriers.

To estimate the traffic of smartphones and tablets, we relied on Cisco estimates for the period 2017-22 and extrapolated those growth rates to 2025. In addition, we have to consider that according to Cisco IBSG (2012), 43.12% of use time of devices that lack an Ethernet port occurs at home. Therefore, the portion of said traffic generated at home will reach 7,258 million gigabytes in 2021 (see Table Q-11).

Table Q-11. Mexico: Total Mobile Internet Traffic (2021-2025) (million gigabytes)

Variable	2021	2022	2023	2024	2025
Total Annual traffic – Smartphones	13,698	19,657	28,020	39,812	56,593
Total Annual traffic - Tablets	3,135	4,488	6,424	9,196	13,164
Share of traffic at Home	43.12%	43.12%	43.12%	43.12%	43.12%
Total Traffic at Home - Smartphones	5,906	8,475	12,082	17,166	24,401
Total Traffic at Home - Tablets	1,352	1,935	2,770	3,965	5,676
Total Traffic at Home	7,258	10,411	14,852	21,131	30,078
Average Price per GB ($)	$2.76	$2.49	$2.24	$2.02	$1.82
Price per home traffic ($Million)	$20,057.55	$25,902.49	$33,269.30	$42,618.05	$54,614.59

Sources: Cisco; GSMA; Telecom Advisory Services analysis

If this traffic had to be transported by cellular networks, at the average price per GB estimated, it would result in costs of $20.1 billion in 2021, before reaching $54.6 billion in 2025.

Q.3.2. Avoidance of inside wiring investment

Residential Wi-Fi allows consumers to avoid paying for wiring to connect all home devices (printers, laptops, storage units, etc.). Considering that 91% of connected households will have Wi-Fi in 2021[297], and the wiring cost estimated for households[298], the avoidance costs of inside wiring over 20 million households yields a total of $6.7 billion. By 2025, almost all connected households are expected to have adopted Wi-Fi, so the savings would have reached $10.2 billion (Table Q-12).

Table Q-12. Mexico: Consumer surplus from avoidance of investment in in-house wiring (2021-2025)

Variable	2021	2022	2023	2024	2025
Total Wiring Cost	$333.21	$340.59	$348.13	$355.84	$363.72
Households with Internet	22,077,453	23,531,826	25,082,008	26,734,310	28,495,459
Households with Wi-Fi (%)	91%	93%	95%	97%	99%
Households with Internet and Wi-Fi	20,090,482	21,884,598	23,827,908	25,892,293	28,135,532
Inside Wiring Costs ($Million)	$6,694	$7,454	$8,295	$9,213	$10,233

Sources: INEGI; Telecom Advisory Services analysis

Q.3.3. Benefits derived from speed increase

As described before, consumer surplus is increased if users enjoy faster Internet speeds. Thus, the welfare of residential Wi-Fi customers is expected to benefit from faster services than those provided by cellular networks. After weighting the corresponding broadband speeds with the percentage of traffic carried out through Wi-Fi at home, we calculated the average speed advantage of using Wi-Fi in comparison to cellular networks. By applying the parameters determined in Nevo et al. (2016), the expected consumer surplus will yield $108 million in 2021, being increased to $684 million in 2025.

[297] Assumed equal to Brazil.

[298] We took as a reference the value from United States and adjusted it for Mexico considering the differences in PPP between both countries.

Table Q-13. Mexico: Consumer surplus from faster speed in households (2021-2025)

Variable	2021	2022	2023	2024	2025
Average Speed in households if Wi-Fi traffic were carried through mobile networks (Mbps)	24.08	27.92	32.37	37.51	43.44
Average Speed in household with Wi-Fi (Mbps)	24.87	29.56	35.14	41.79	49.72
Demand for average download speed	56.75	60.09	63.54	67.10	70.79
New Demand for average download speed	57.20	60.88	64.71	68.69	72.81
Additional Monthly Consumer surplus	$0.45	$0.80	$1.18	$1.59	$2.02
Additional Yearly Consumer Surplus	$5.37	$9.58	$14.13	$19.03	$24.30
Households with Internet and Wi-Fi	20,090,482	21,884,598	23,827,908	25,892,293	28,135,532
Impact ($Million)	$108	$210	$337	$493	$684

Sources: Cisco; Nevo et al. (2016); Telecom Advisory Services analysis

Additional benefit to consumers from speed increase due to 6 GHz

The welfare of residential Wi-Fi customers is expected to receive further benefit from the 6 GHz allocation due to faster Internet service under Wi-Fi 6E. As previously described in Chapter III, only households acquiring a 150 Mbps (or faster) fixed broadband line will be affected due to current router bottlenecks, and hence, the speed experienced will not be equivalent to that delivered by the fixed network. We estimated the percentage of broadband connections above 150 Mbps by relying in data by speed tiers reported by local regulator IFT. After calculating the difference in average speed attributed to 6 GHz, the additional consumer surplus will yield $697 million in 2025.

Table Q-14. Mexico: Consumer surplus from faster speed in households if 6 GHz allocated (2021-2025)

Variable	2021	2022	2023	2024	2025
Households that have connections over 150 Mbps (%)	3.35%	3.79%	4.29%	4.86%	5.50%
Percentage of household traffic that goes through Wi-Fi	61.95%	63.16%	64.35%	65.53%	66.68%
Traffic through the 6 GHz Channel (%)	0.00%	10.00%	20.00%	30.00%	40.00%
Share of traffic affected due to 6 GHz (%)	0.00%	0.24%	0.55%	0.95%	1.47%
Average speed with no 6 GHz (Mbps)	24.87	29.56	35.14	41.79	49.72
Average speed with 6 GHz (Mbps)	24.87	30.44	37.43	46.16	57.05
Demand for average download speed	57.20	60.88	64.71	68.69	72.81
New Demand for average download speed	57.20	61.30	65.62	70.15	74.88
Additional Yearly Consumer Surplus	$0.00	$4.98	$10.88	$17.53	$24.76
Households with Wi-Fi	20,090,482	21,884,598	23,827,908	25,892,293	28,135,532
Impact ($Million)	$0	$109	$259	$454	$697

Sources: IFT; INEGI; Cisco; Nevo et al. (2016); Telecom Advisory Services analysis

Q.3.4. Residential Wi-Fi devices and equipment

The difference between market prices and locally manufactured costs of Wi-Fi enabled products represents the manufacturer's margin and, consequently, producer surplus. It is assumed, following Milgrom et al. (2011), that the consumer surplus is roughly equal to producer surplus. As detailed before in Chapter III, we identified seven consumer products which are intrinsically linked to Wi-Fi: smart home devices and systems such as Wi-Fi speakers and home security systems, home networking systems, Wi-Fi tablets, access points, external adapters, routers, and gateways.

The estimation of economic value begins by compiling local revenues of global manufacturers for each product category in Mexico. This has been done by interpolating data from the United States and Worldwide markets, and assuming a level for Mexico according to the corresponding GDP share. After that, we applied the prorated margin estimated by CSI markets which yields an estimated producer surplus for these particular products of $1.8 billion in 2021. As mentioned above, it is assumed that the consumer surplus is of the same magnitude. This methodology was also used to calculate the consumer surplus up to 2023. However, the gradual adoption of Wi-Fi 6 devices is forecast to reduce the sales and economic value from the devices relying on the 2.4 GHz and 5 GHz spectrum bands. Non 6 GHz consumer devices shipments are expected by IDC to decrease by 1.2% in 2024 and 3.1% in 2025. Based on this estimate, we extrapolated the consumer surplus from non 6 GHz reliant residential Wi-Fi devices and equipment between 2021 and.

In addition, we calculated the consumer surplus attributable to tablets bought by local consumers. Starting with CTA/Statista worldwide tablet revenue estimates, we interpolated the revenue figures for Mexico (by weighting by the country's share on global GDP), and extrapolated the evolution of local revenue till 2025 by considering Cisco estimates of tablet evolution for the period. We reviewed the data on tablet prices for the market leader (taking as a reference the Apple iPad 10.2 Inch 128 GB, as Apple has 50% of the Mexican market share in tablets[299]) and for the rest of the market (taking as a reference the Samsung Wi-Fi tablet 128 GB), and assumed consumer willingness-to-pay levels in a similar percentage above prices as in the U.S. average. Combining all that information, we were able to estimate a consumer surplus attributable to tablets of $77 million in 2021, expected to reach $459 million in 2025 (Table Q-15).

Table Q-15. Mexico: Economic Value of Wi-Fi enabled consumer products (2021-2025)

Variable	2021	2022	2023	2024	2025
Consumer surplus (exc. tablets) ($Million)	$1,718	$1,770	$1,827	$1,805	$1,749
Tablet consumer surplus ($Million)	$77	$71	$66	$63	459
Total consumer surplus ($Million)	$1,796	$1,841	$1,894	$1,867	$1,807

Sources: Consumer Technology Association; ABI Research; CS Markets; IDC; Telecom Advisory Services analysis

[299] Source: Gs StatCounter

Consumer surplus derived from Wi-Fi enabled residential equipment for 6 GHz

As discussed above, sales of residential Wi-Fi devices and equipment operating in the 6 GHz band are expected to gradually replace those of former generations. According to IDC, global shipments of consumer devices operating in the 6 GHz (802.11ax standard) will represent 40% of sales from prior generations. As a result, if the shipments ratio reaches 40% in 2025, we can expect that, at least, the consumer surplus derived from 6 GHz devices will represent 40% of that of former technology residential devices. As a result, our estimates for consumer surplus attributed to 6 GHz residential devices amount to $705 million in 2025 (see Table Q-16).

Table Q-16. Mexico: Economic Value of Wi-Fi enabled consumer products attributable to 6 GHz (2021-2025)

Variable	2021	2022	2023	2024	2025
Ratio consumer 6 GHz / no 6 GHz	3.76%	8.83%	18.59%	28.86%	40.30%
Total consumer surplus ($Million) – 6 GHz	$64.69	$156.36	$339.60	$520.74	$704.62

Sources: IDC; Telecom Advisory Services analysis

Q.3.5. Bridging the digital divide: use of Wi-Fi to increase coverage in rural and isolated areas

Wi-Fi is an appropriate technology to offer Internet access in rural and isolated areas. Based on the data provided by IFT in subscriptions by technology, we can estimate at least 215,666 WISP subscriptions in 2021. However, it is possible that this number is downward biased, given the fact that only 300 WISP operators have been formally registered, with much more expected to be providing services without registration[300]. The growing relevance of WISPs to bridge the digital divide has been highlighted in the local press[301], and an association grouping these operators was constituted, the WISP MX. The calculation of the Wi-Fi contribution to the reduction of the digital divide must subtract the direct impact of WISPs (Section 4.4.3.) to avoid double counting. On the other hand, we assume that 10% of WISP potential connections may be theoretically served by other technologies (i.e. satellite) covering the same isolated footprint. Thus, we can conservatively expect 50% of broadband subscriptions in remote locations exclusively attributed to WISPs. Once this is done, we calculate the impact on GDP by relying on the coefficient estimated by Katz and Callorda (2018b) through regression models that links increase in broadband penetration to economic growth. The contribution to GDP materializes through multiple effects: creation of new businesses, increasing productivity of existing enterprises, and growth of average income per household. We expect a GDP contribution of $165 million in 2021, which will increase until reaching $192 million in 2025 (see Table Q-17).

[300] Mendieta, S. (2019): "WISP, las pymes que pueden dar conectividad a todo el país", *Milenio* (July 21st)
[301] Lucas, N. (2019): "¿Qué son los WISP y cómo pueden ayudar a AMLO para llevar Internet a los mexicanos?", *El Economista* (August, 11th)

Table Q-17. Mexico: Estimation of GDP Contribution derived from reducing the digital divide (2021-2025)

Variable	2021	2022	2023	2024	2025
WISP subscribers	215,666	228,730	242,585	257,280	272,864
Additional broadband penetration due to WISP	1.00%	1.00%	1.00%	1.00%	1.00%
Impact of fixed broadband adoption in GDP	15.75%	15.75%	15.75%	15.75%	15.75%
GDP ($Billion)	$1,095	$1,146	$1,198	$1,251	$1,306
WISP TOTAL impact ($Billion)	$1.72	$1.80	$1.89	$1.97	$2.06
WISP Revenues ($Billion)	$0.07	$0.09	$0.10	$0.12	$0.13
Share that exist because WISP	10.00%	10.00%	10.00%	10.00%	10.00%
WISP spillovers on GDP ($Million)	$165.34	$171.67	$178.59	$185.42	$192.18

Sources: IFT, IMF; Telecom Advisory Services analysis

Economic impact of enhanced coverage and affordability due to 6 GHz

The allocation of the 6 GHz band to unlicensed use would allow WISPs to potentially increase their subscriber base within their same coverage footprint. Therefore, a first effect derived from the allocation of the new spectrum band is related to additional households served due to additional coverage. We will follow a cautious approach and consider that the expanded coverage will yield a gradual increase on WISP subscribers, from 2% in 2022 to 5% in 2025 over the figures projected without assuming the additional spectrum allocation. In addition, an increase of the user base would allow service providers to lower their operating costs. Thus, by assuming stability in prices, affordability would increase as GDP per capita grows as economic growth resumes. Finally, we assumed a similar household sharing rate for WISP subscriptions as in Brazil. All in all, we can expect an overall increase in almost 36,000 WISP connections in 2025, contributing to an increase of 0.09% in national broadband penetration. Considering the impact coefficient of broadband on the economy, which will yield a GDP contribution equivalent to $271 million.

Table Q-18. Mexico: GDP Contribution derived from reducing the digital divide due to 6 GHz (2021-2025)

Variable	2021	2022	2023	2024	2025
New subscribers due to expanded coverage (%)	0%	2%	3%	4%	5%
New subscribers due to expanded coverage	0	4,575	7,278	10,291	13,643
New WISP adoption after price decrease (% households)	1%	1%	1%	1%	1%
Traffic through the 6 GHz Channel (%)	0.00%	10.00%	20.00%	30.00%	40.00%
Sharing %	45%	49%	54%	58%	62%
Increase in WISP connections due to lower prices (considering households that share the connection)	0	4,706	9,937	15,621	22,382
Overall increase in WISP connections due to 6 GHz	0	9,280	17,214	25,912	36,025
Increase in national broadband penetration	0.00%	0.02%	0.04%	0.06%	0.09%
Impact of fixed broadband adoption in GDP	15.75%	15.75%	15.75%	15.75%	15.75%
Increase in the GDP due to the new broadband adoption (% GDP)	0.000%	0.006%	0.011%	0.016%	0.021%
Total impact in GDP ($Million)	$0.00	$73.19	$133.84	$198.36	$271.43

Sources: IFT; IMF; Telecom Advisory Services analysis

Q.4. Enterprise Wi-Fi

Beyond the impact on consumers, Wi-Fi also contributes significant economic value in the Mexican enterprise segment. This section provides estimates in five areas:

- Support of business Internet traffic;
- Avoidance of campus and enterprise facilities inside wiring;
- Contribution to GDP resulting from Wi-Fi speed faster than cellular connections;
- Deployment of IoT solutions; and
- Implementation of business focused AR/VR use cases.

Q.4.1. Business Internet traffic transmitted through Wi-Fi

Wi-Fi enterprise savings results from wireless traffic that is routed through Wi-Fi access points. Considering Cisco 2016-21 projections, we estimate that total business Internet traffic will reach 6,5 billion GB in 2021, of which 3 billion GB would have been transported through Wi-Fi access points. Considering the average price per GB transported by cellular, savings from Wi-Fi will reach $8.3 billion, an addition to the producer surplus. By 2025, this benefit will reach $11.5 billion (see Table Q-19).

Table Q-19. Mexico: Savings in business wireless traffic (2021-2025)

Variable	2021	2022	2023	2024	2025
Share of Business Internet Traffic by Wi Fi	46.00%	44.72%	43.47%	42.25%	41.07%
Total Business Internet Traffic (Million GB)	6,480.20	8,041.60	9,979.21	12,383.69	15,367.52
Total Wi-Fi enterprise traffic (Million GB)	2,980.89	3,595.81	4,337.57	5,232.35	6,311.71
Average Price per GB	$2.76	$2.49	$2.24	$2.02	$1.82
Economic Impact ($Million)	$8,237.87	$8,946.73	$9,716.59	$10,552.69	$11,460.73

Sources: Cisco; Telecom Advisory Services analysis

Enhanced business Internet traffic transmitted through Wi-Fi due to 6 GHz

The deployment of the latest enterprise applications will generate an exponential growth in data traffic that will be handled by devices operating in unlicensed spectrum, through the combination of the existing bands and the 6 GHz band. In 2019, an updated Cisco traffic forecast based on the explosion of IoT and AR/VR applications, among other factors, increased total business Internet traffic previsions from the previous 2016-21 estimates from 2018. As in the case of the U.S., we assume that part of the growth was driven by "natural" growth, and another portion was triggered by Wi-Fi traffic stimulated by changes in 6 GHz. The sum of the difference due to broader Wi-Fi traffic will reach $853 million in 2025 (see Table QI-20).

Table Q-20. Mexico: Savings in business wireless traffic due to 6 GHz (2021-2025)

Variable	2021	2022	2023	2024	2025
Total value of business Wi-Fi traffic 2016-21 ($Million)	$8,237.87	$8,946.73	$9,716.59	$10,552.69	$11,460.73
Total value of business Wi-Fi traffic 2017/22 ($Million)	$10,681.35	$12,394.98	$14,383.51	$16,691.08	$19,368.84
Difference between the 2 estimations ($Million)	$2,443	$3,448	$4,667	$6,138	$7,908
Difference because natural growth ($Million)	$2,289	$3,077	$4,164	$5,477	$7,056
Difference due to 6 GHz ($Million)	$0.00	$371.73	$503.10	$661.73	$852.51

Sources: Cisco; Telecom Advisory Services analysis

Q.4.2. Avoidance in enterprise building inside wiring

Similar to residential Wi-Fi savings due to capital investment avoidance in inside wiring, we assume that the total number of business establishments are equipped with Wi-Fi access points and multiply this value by a standard cost of deploying a CAT 6 network (from U.S., adjusted by PPP) (see Table Q-21).

Table Q-21. Mexico: Savings in business wiring CAPEX (2021-2025)

Variable	2021	2022	2023	2024	2025
Total Wiring Cost	$1,110.71	$1,135.30	$1,160.43	$1,186.13	$1,212.39
Number of Establishments	5,085,445	5,215,401	5,348,678	5,485,361	5,625,537
Establishments with Wi-Fi (%)	97%	97%	97%	97%	97%
Establishments with Wi-Fi	4,932,882	5,058,939	5,188,218	5,320,800	5,456,771
Inside Wiring Costs ($Million)	$5,479	$5,743	$6,021	$6,311	$6,616

Sources: INEGI; Telecom Advisory Services analysis

Q.4.3. Return to speed: contribution to GDP derived from an increase in average mobile speed

Since Wi-Fi accessibility allows, in general, faster access to the Internet than cellular networks do, higher speeds have a positive contribution on the economy in terms of increased overall efficiency and innovation. This contribution is measured in terms of economic growth. As described in section Q.2.3 for the case of consumer surplus, we start with the quantification of the average broadband speed if cellular networks transported all Wi-Fi traffic, and compare it with the presence of Wi-Fi technology (see Table Q-22).

Table Q-22. Mexico: Estimation of speed differential for total traffic (2021-2025)

Variable	2021	2022	2023	2024	2025
Average Download Speed if Wi-Fi traffic were carried through mobile networks (Mbps)	24.08	27.92	32.37	37.51	43.44
Average Speed with Wi-Fi (Mbps)	24.87	29.56	35.14	41.79	49.72
Speed increase (%)	3%	6%	9%	11%	14%
Impact of speed in GDP	0.26%	0.26%	0.26%	0.73%	0.73%
Increase in GDP	0.01%	0.02%	0.02%	0.08%	0.11%
GDP ($Billion)	$1,094.53	$1,145.64	$1,197.86	$1,250.89	$1,305.73
GDP increase ($Million)	$96	$177	$270	$1,042	$1,378

Sources: Cisco; IMF; Telecom Advisory Services analysis

Having calculated the speed increase percentage, we then apply this percentage to the coefficient derived from the model developed by Katz and Callorda (2019) to gauge the potential impact on GDP from Wi-Fi enhanced speed. Table Q-22 indicates that the economic value of Wi-Fi in terms of increasing the speed of transporting wireless will account to $96 million in 2021, before being increased to $1.4 billion in 2025.

Return to Speed additional effect due to 6 GHz

As previously described, only those broadband connections above 150 Mbps will be affected due to current router bottlenecks, and hence, the speed experienced will not be equivalent to that delivered by the fixed network. Thus, the allocation of the 6 GHz band will remove those barriers, increasing broadband speed. After calculating the difference in average speed attributed to 6 GHz, the additional GDP contribution will yield $1.4 billion in 2025 (Table Q-23).

Table Q-23. Mexico: Estimation of speed differential due to 6 GHz (2021-2025)

Variable	2021	2022	2023	2024	2025
Mean speed with no 6 GHz (Mbps)	24.87	29.56	35.14	41.79	49.72
Mean speed with 6 GHz (Mbps)	24.87	30.44	37.43	46.16	57.05
Speed increase due to 6Ghz (%)	0%	3%	7%	10%	15%
Impact speed on GDP	0.26%	0.26%	0.26%	0.73%	0.73%
Increase in GDP (%)	0.00%	0.01%	0.02%	0.08%	0.11%
GDP increase ($Million)	$0	$91	$206	$956	$1,406

Sources: Cisco; IMF; Telecom Advisory Services analysis

Q.4.4. IoT deployment

IoT adoption has a contribution to GDP growth through the multiplicity of use cases that improve efficiency in processes such as preventive maintenance, production monitoring and the like. To estimate this, we rely on a coefficient of GDP impact calculated through an aggregate simple production function which estimates that a 10% rise in M2M connections results in annual increases in GDP of between 0.3%

and 0.9%[302]. Following a conservative approach, for Mexico we assume a 0.3% GDP increase after a 10% raise in M2M.

Starting with a 2021 installed base of 11.6 million M2M devices, we estimate the growth that can be exclusively attributed to the allocation of additional spectrum to indoor Wi-Fi devices. Thus, by subtracting the growth in M2M attributed to 6 GHz, it is estimated that the IoT impact for 2021 according to the natural growth would reach $2.2 billion (see Table Q-24).

Table Q-24. Mexico: GDP Contribution of IoT Deployment Boost (2021-2025)

Variable	2021	2022	2023	2024	2025
Connections, Cellular M2M	11,610,297	11,963.389	12,327,219	12,702,114	13,088,411
Growth Rate (%)	7.51%	3.04%	3.04%	3.04%	3.04%
Natural Growth Rate (%)	6.84%	2.69%	2.62%	2.62%	2.62%
Impact of 1% M2M Growth on GDP	3.00%	3.00%	3.00%	3.00%	3.00%
Impact on GDP (%)	0.21%	0.08%	0.08%	0.08%	0.08%
GDP ($Billion)	$1,095	$1,146	$1,198	$1,251	$1,306
Impact ($Million)	$2,246.85	$924.84	$942.57	$984.30	$1,027.45

Sources: GSMA Intelligence; Frontier Economics; IMF; Telecom Advisory Services analysis

Accelerated effect of IoT due to 6 GHz

As described above, a share of the M2M growth can be attributed to 6 GHz developments. According to the data in Table Q-25, cumulative impact of enhanced IoT deployment driven by 6 GHz spectrum proposals will reach $164 million by 2025.

Table Q-25. Mexico: GDP Contribution of IoT Deployment Boost caused by 6 GHz (2021-2025)

Variable	2021	2022	2023	2024	2025
Growth due to 6 GHz (%)	0.67%	0.35%	0.42%	0.42%	0.42%
Level of development of new bands (%)	50%	100%	100%	100%	100%
Impact on GDP (%)	0.01%	0.01%	0.01%	0.01%	0.01%
Impact ($Million)	$110.26	$120.40	$150.31	$156.96	$163.84

Sources: GSMA Intelligence; Frontier Economics; IMF; Telecom Advisory Services analysis

Q.4.5. Deployment of AR/VR solutions

The adoption of AR/VR among Mexican businesses will in turn have a spillover effect on productivity, thereby contributing to the growth of GDP. Estimating spillover effects of AR/VR is a not a trivial exercise considering the embryonic adoption of some of these use cases. Since the objective is to estimate the spillover effect of AR/VR sales by local firms in the domestic market, we will take as points of departure the estimate by PwC of the total GDP contribution of AR/VR, and the sales of AR/VR components as estimated by ABI Research. The extrapolation of these two parameters allow estimating the indirect (spillover) contribution of AR/VR to the local economy for the period under analysis.

[302] See Frontier Economics (2018)

Starting values are reduced by the proportion that can be attributed to the impact of the 6 GHz spectrum bands. To do so, we took as a reference a ratio of AR/VR product developments according to each technology. Assuming an indirect to direct multiplier of one, we calculate the total spillovers (see Table Q-26). Total spillover value of AR/VR in Mexico in 2021 will account for $129 million and is expected to increase by 2025 to $580 million.

Table Q-26. Mexico: GDP contribution resulting from AR/VR spillovers (2021-2025)

Variable	2021	2022	2023	2024	2025
AR/VR total contribution to GDP ($Billion)	$1.22	$1.26	$1.31	$1.35	$1.40
Share attributed to Wi-Fi (excluding 6 GHz)	0.13	0.21	0.28	0.42	0.58
Portion of GDP contribution attributed to Wi-Fi (excluding 6 GHz) ($Billion)	$0.51	$0.49	$0.42	$0.42	$0.41
Direct impact (sales) attributed to Wi-Fi (excluding 6 GHz) ($Billion)	$0.13	$0.21	$0.28	$0.42	$0.58
Indirect/Direct multiplier	1.00	1.00	1.00	1.00	1.00
Indirect impact ($Million)	$128.51	$207.35	$280.87	$415.58	$580.37

Sources: PwC, ABI; Telecom Advisory Services analysis

Wider deployment of AR/VR solutions (accelerated effect due to 6 GHz)

Higher throughput enabled by the allocation of the 6 GHz band is expected to spur the adoption and use of AR/VR among enterprises, hence increasing the associated spillover effects. By relying on the ratio built from 5 GHz and 6 GHz AR/VR related products, we were able to isolate the specific economic contribution of the new spectrum allocation. Following a similar procedure as that described above, spillovers from AR/VR in Mexico attributed to 6 GHz in 2021 will account for $75 million and are expected to increase by 2025 to $571 million (Table Q-27).

Table Q-27. Mexico: GDP contribution resulting from AR/VR spillovers due to 6 GHz (2021-2025)

Variable	2021	2022	2023	2024	2025
AR/VR total contribution to GDP ($Billion)	$1.22	$1.26	$1.31	$1.35	$1.40
Share attributed to 6 GHz (%)	24.58%	25.59%	26.64%	27.73%	28.87%
Portion of GDP contribution attributed to 6 GHz ($Billion)	$0.30	$0.32	$0.35	$0.38	$0.40
Direct impact (sales) attributed to 6 GHz ($Billion)	$0.08	$0.14	$0.23	$0.37	$0.57
Indirect/Direct multiplier	1.00	1.00	1.00	1.00	1.00
Indirect impact ($Million)	$75.17	$136.73	$232.53	$373.22	$571.45

Sources: PwC, ABI; Telecom Advisory Services analysis

Q.5. Internet Service Providers

In addition to the economic value generated by the sources analyzed above, Wi-Fi will also contribute to either producer surplus or GDP of Internet Service Providers. This section will assess the economic value in three sources:

- Producer surplus of cellular operators resulting from CAPEX savings incurred in network deployment
- Revenues of Wi-Fi carriers offering service in public spaces

- Revenues of Wireless ISPs (this effect differs from the GDP impact of WISPs as a result of their deployment in rural and isolated areas analyzed in section Q.3.5.)

Q.5.1. Cellular network savings by off-loading traffic to Wi-Fi

The estimation of CAPEX savings starts by considering the GSMA Intelligence aggregate projected investment by wireless carriers in Mexico, which amounts to $17.7 billion between 2019 and 2025. Considering the total CAPEX required to deploy 5G in Mexico, and the incremental 5G coverage between 2021 and 2025 we are able to interpolate the 5G CAPEX for each year of the period considered. It is assumed that all the CAPEX invested during the period would be dedicated to 5G deployment.

Based on the simulation model developed to forecast the impact of Wi-Fi off-loading in 5G deployment, we estimate that the savings of deploying carrier-grade Wi-Fi complementing the rollout of 5G to accommodate future traffic growth would amount to 32.9% of CAPEX, while the OPEX savings are $2.82 for each dollar saved in CAPEX. This would result in a total producer surplus (adding CAPEX and OPEX savings) of $906 million in 2021, increasing to $10.4 billion in 2025, when 5G coverage will reach 73% (see Table Q-28).

Table Q-28. Mexico: Savings due to traffic off-loading (2021-2025)

Variable	2021	2022	2023	2024	2025
5G coverage	18%	24%	34%	50%	73%
CAPEX without saving ($Million)	$721.03	$2,116.22	$3,864.72	$5,627.64	$8,263.00
CAPEX reduction due to Wi-Fi off-loading ($Million)	$237.2	$696.2	$1,271.5	$1,851.5	$2,718.5
OPEX reduction due to Wi-Fi off-loading ($Million)	$669.0	$1,963.4	$3,585.6	$5,221.2	$7,666.2
Total Cost of Ownership ($Million)	$906	$2,660	$4,857	$7,073	$10,385

Sources: GSMA; Telecom Advisory Services analysis

Enhanced capability for cellular off-loading if 6 GHz allocated

The complementarity between Wi-Fi and cellular networks for Wi-Fi 6E and 5G, adds further potential gains derived from the savings in capital and operating expenses required to accommodate exploding data traffic. The key objective is to estimate the savings in capital investment as a result of an increase in traffic offloading with Wi-Fi benefits from the additional spectrum allocated, particularly, due to the ability to leverage 160 MHz within single contiguous channels.

The estimation of CAPEX savings starts by considering the GSMA Intelligence aggregate investment estimates of 5G deployments. By relying again on the geographic disaggregation of Oughton and Frias, we estimate that CAPEX can be split in urban, suburban and rural geographies. To estimate the percentage of population living in urban areas, we considered the information provided by the INEGI. We conservatively assume that Wi-Fi 6 will not be critical in sustaining investment in urban areas, but that it will play a significant role beyond those geographies. Based on the cost advantage of carrier grade Wi-Fi, we assume that it will become effective for a portion of the suburban (approximately 15%) and rural network (approximately 5%) deployment. Therefore, this will yield yearly CAPEX savings of $200 million.

Q.5.2. Wi-Fi carrier revenues

The value of Wi-Fi carriers includes the sum of revenues through paid public Wi-Fi access. In order to estimate those aggregated revenues, we start by calculating the number of paid Wi-Fi hotspots in Mexico. According to Cisco, in 2021 there will be 9.4 million public Wi-Fi hotspots in the country, although that figure includes home spots (such as the guest account service provided by cable operators). By subtracting the home spots from the public Wi-Fi estimates of Cisco, we calculated a total of 260,000 paid Wi-Fi hotspots for 2021, which will increase until reaching 350,000 in 2025. On the other hand, based on revenue figures per hotspot from Boingo for the U.S., by adjusting by PPP we were able to estimate a figure for the case of Mexico. Then, we estimate total revenues generated by this sector in Mexico: $80 million in 2021, gradually reducing to reach $121 million in 2025 (Table Q-29).

Table Q-29. Mexico: Revenues of Wi-Fi carriers (2021-2025)

Variable	2021	2022	2023	2024	2025
Public Wi-Fi hotspots (Million)	9.39	12.49	16.60	22.07	29.33
Home spots (Million)	9.14	12.24	16.40	21.80	28.98
Pay Wi-Fi hotspots (Million)	0.26	0.25	0.20	0.27	0.35
Revenue per hotspot ($)	$312.39	$319.31	$326.38	$333.60	$340.99
Revenue ($Million)	$80.44	$78.79	$65.28	$88.69	$120.50

Sources: Cisco, Boingo, Telecom Advisory Services

Increased revenues of Wi-Fi carriers in public places due to 6 GHz

The allocation of the 6 GHz spectrum band offers an opportunity for pay Wi-Fi carriers to enhance their business. As Wi-Fi 6E developments will allow up to 1,500 connected devices per access point, Wi-Fi carriers will have the possibility of adding more clients without quality limitations due to congestion. By considering a conservative potential increase of 40% in the number of connected devices in public venues and weighting that figure by the gradual expansion of the latest technology, we expect pay Wi-Fi carriers to increase their user base by 16% in 2025. If the revenue per hotspot increases in the same amount, that will yield an increase in overall revenues for the sector of an additional $19 million by 2025 (Table Q-30).

Table Q-30. Mexico: Revenues of Wi-Fi carriers due to 6 GHz (2021-2025)

Variable	2021	2022	2023	2024	2025
Potential increase in connected devices in public venues	40.00%	40.00%	40.00%	40.00%	40.00%
Traffic through the 6 GHz Channel (%)	0%	10%	20%	30%	40%
Increase in connected devices due to 6 GHz	0%	4%	8%	12%	16%
Revenue per hotspot if 6 GHz allocated ($)	$312.39	$332.08	$352.49	$373.64	$395.55
Revenue if 6 GHz allocated ($Million)	$0.00	$3.15	$5.22	$10.64	$19.28

Sources: Boingo; Telecom Advisory Services analysis

Q.5.3. Wireless ISPs revenues

The 2021 GDP contribution related to the WISP industry was calculated as a function of the number of subscribers and the ARPU (from U.S., adjusted by PPP), yielding a total of $70 million (Table Q-31).

Table Q-31. Mexico: WISP revenues (2021-2025)

Variable	2021	2022	2023	2024	2025
Subscribers (Million)	0.22	0.23	0.24	0.26	0.27
Revenues ($Million)	$69.90	$87.09	$100.09	$115.36	$134.08

Sources: IFT, Telecom Advisory Services

Increased revenues of WISPs due to 6 GHz

As described in section Q.2.5, the allocation of 6 GHz spectrum band will potentially increase the WISP user base by 2025, due to expanded coverage and better affordability. Thus, by assuming the same ARPU values as described above, the new subscriptions will amount to an additional $18 million in revenues in 2025 (Table Q-32).

Table Q-32. Mexico: WISP revenues due to 6 GHz (2021-2025)

Variable	2021	2022	2023	2024	2025
WISP annual ARPU ($)	$324.11	$380.73	$412.60	$448.38	$491.40
New subscribers if 6 GHz allocated (Million)	0.00	0.01	0.02	0.03	0.04
New revenue ($Million)	$0.00	$3.53	$7.10	$11.62	$17.70

Sources: IFT; Telecom Advisory Services

Q.6. Wi-Fi ecosystem

The economic value of Wi-Fi ecosystem companies is calculated based on the following three sources:

- The producer surplus (i.e. margins) of residential Wi-Fi devices and equipment manufactured in Mexico;
- The producer surplus of local firms providing products and services in the IoT ecosystem (hardware, software and systems integration) in Mexico; and
- The producer surplus of local firms providing products and services in the AR/VR ecosystem (hardware, software and content) in Mexico.

Q.6.1 Locally manufactured residential Wi-Fi devices and equipment

Mexico has a strong hardware industry, however there are no reliable datasets regarding the revenues of Wi-Fi enabled products from local manufacturers. Thus, we had to rely in a proration from U.S. data in order to calculate the producer surplus for local manufacturers. As a result, we were able to estimate a total economic value of $2.8 billion in 2021, which we expect to slightly increase to $2.9 billion in 2025 (Table Q-33).

Table Q-33. Mexico: Producer Surplus from locally manufactured residential Wi-Fi devices and equipment (2021-2025)

Variable	2021	2022	2023	2024	2025
Total producer surplus ($Million)	$2,826	$2,924	$3,027	$2,989	$2,896

Sources: Consumer Technology Association; ABI Research; CS Markets; Telecom Advisory Services analysis

Locally manufactured Wi-Fi 6 devices and equipment for residential use

As mentioned above, devices for 6 GHz are expected to gradually replace those of prior generations. According to IDC, global shipments of consumer devices linked to 6 GHz spectrum (802.11ax) will represent 40% of the shipments of those from previous generations in 2025. Therefore, we expect the producer surplus attributed to 6 GHz devices to yield $1.2 billion in economic value by 2025 (see Table Q-34).

Table Q-34. Mexico: Producer Surplus from locally manufactured residential Wi-Fi 6 devices and equipment (2021-2025)

Variable	2021	2022	2023	2024	2025
Consumer 6 GHz / no 6 GHz	3.76%	8.83%	18.59%	28.86%	40.30%
Producer surplus 6 GHz devices ($Million)	$106.38	258.29	$562.50	$862.53	$1,167.10

Sources: IDC; Telecom Advisory Services analysis

Q.6.2. Firms belonging to the IoT ecosystem

According to Frost & Sullivan, we expect total industrial IoT revenue in Mexico to amount $3.0 billion in 2021, that can be split into two main segments: hardware; and software, contents, and services. By weighting those amounts by the share of local production and the assumed margins, we can estimate the overall producer surplus. However, to that economic value we should extract the share attributed to 6 GHz developments. To do so, we estimated a natural growth rate, by subtracting the corresponding share attributed to 6 GHz according to the growth rates indicated in Table Q-34. Thus, we estimate a producer surplus not attributed to 6 GHz of $693 million in 2021, expected to reach $1.5 billion in 2025 (Table Q-35).

Table Q-35. Mexico: IoT ecosystem direct contribution (2021-2025)

Variable	2021	2022	2023	2024	2025
IoT revenue - Hardware ($billions)	$1.33	$1.65	$2.05	$2.15	$2.26
IoT revenue - Software, Contents, Services ($billions)	$1.70	$2.11	$2.62	$2.75	$2.89
Total Industrial IoT revenue in ($Billion)	$3.04	$3.77	$4.67	$4.90	$5.15
Local production (%) - Hardware	24%	24%	24%	24%	24%
Local production (%) - Software & Services	45%	50%	55%	60%	65%
Margins (%) - Hardware	39%	39%	39%	39%	39%
Margins (%) - Software & Services	77%	77%	77%	77%	77%
Margins - IoT Hardware revenue	$0.13	$0.16	$0.20	$0.21	$0.22
Margins - Software, contents and services IoT revenue	$0.59	$0.82	$1.12	$1.28	$1.45
Producer surplus ($Million)	$722.18	$977.51	$1,313.82	$1,486.09	$1,672.29
Growth rate (%)	39.50%	35.35%	34.41%	13.11%	12.53%
Growth rate not attributed to 6 GHz (%)	35.97%	31.28%	29.67%	11.31%	10.81%
Producer surplus not attributed to 6 GHz ($Million)	$693.07	$909.87	$1,179.87	$1,313.29	$1,455.22

Sources: Frost & Sullivan, CSI, Telecom Advisory Services analysis

Wider deployment of Internet of Things under 6 GHz

Following the previous analysis, we were able to estimate which portion of IoT producer surplus growth can be attributed to 6 GHz. As Table Q-36 indicates, we expect the additional IoT surplus generated by 6 GHz to account for $217 million in 2025.

Table Q-36. Mexico: IoT direct contribution attributed to 6 GHz (2021-2025) ($Million)

Variable	2021	2022	2023	2024	2025
Producer surplus	$722.18	$977.51	$1,313.82	$1,486.09	$1,672.29
Producer surplus not attributable to 6 GHz	$693.07	$909.87	$1,179.87	$1,313.29	$1,455.22
Additional surplus due to 6 GHz	$29.11	$67.63	$133.96	$172.80	$217.08

Sources: Frost & Sullivan, CSI, Telecom Advisory Services analysis

Q.6.3. Firms belonging to the AR/VR ecosystem

Following a similar procedure as with the case of IoT, we can estimate the direct contribution of this ecosystem to the local economy. Starting with the local spending in AR/VR by category (hardware, software, and contents), and weighting those figures by the respective shares of local production and margins, we were able to estimate the total producer surplus. By relying on a ratio built from 5 GHz and 6 GHz AR/VR related products, we were able to subtract the specific contribution attributed to 6 GHz from the surplus corresponding to current bands. Then, we expect by 2021 a direct contribution from the AR/VR ecosystem of $39 million, which will increase until reaching $247 million by 2025 (Table Q-37).

Table Q-37. Mexico: AR/VR ecosystem direct contribution (2021-2025)

Variable	2021	2022	2023	2024	2025
Spending in AR/VR - Hardware $Billion	$0.05	$0.09	$0.14	$0.23	$0.38
Spending in AR/VR - Software, Contents, Services ($Billion)	$0.26	$0.45	$0.73	$1.11	$1.60
Total Spending in AV/VR ($Billion)	$0.31	$0.53	$0.87	$1.35	$1.98
Share of local production - Hardware	24.40%	24.40%	24.40%	24.40%	24.40%
Share of local production - Software, Contents, Services	45.00%	50.00%	55.00%	60.00%	65.00%
Local production for local consumption - Hardware ($Billion)	$0.01	$0.02	$0.04	$0.06	$0.09
Local production for local consumption - Software, Contents, Services ($Billion)	$0.11	$0.22	$0.40	$0.67	$1.04
Local Producer Surplus - Hardware ($Billion)	$0.00	$0.01	$0.01	$0.02	$0.04
Local Producer Surplus - Software, Contents, Services ($Billion)	$0.09	$0.17	$0.31	$0.52	$0.81
Total Producer Surplus	$0.09	$0.18	$0.32	$0.54	$0.84
Share attributable to Wi-Fi (excluding 6 GHz)	42.02%	38.80%	32.18%	30.88%	29.32%
Producer Surplus attributed to Wi-Fi (not including 6 GHz) ($Million)	$39.42	$70.60	$104.30	$166.49	$247.19

Sources: PwC, ABI; Telecom Advisory Services analysis

Wider deployment of AR/VR solutions if 6 GHz allocated

By relying on a ratio built from 5 GHz and 6 GHz AR/VR related products, we were able to isolate the specific economic contribution of the new spectrum allocation.

Following a similar procedure as that described above, the direct contribution from AR/VR ecosystem in Mexico attributed to 6 GHz in 2025 will yield $243 million.

Table Q-38. Mexico: AR/VR direct contribution attributed to 6 GHz (2021-2025)

Variable	2021	2022	2023	2024	2025
Spending in AR/VR ($Billion)	$0.31	$0.53	$0.87	$1.35	$1.98
Share attributed to 6 GHz	24.58%	25.59%	26.64%	27.73%	28.87%
Spending in AR/VR attributed to 6 GHz ($Billion)	$0.08	$0.14	$0.23	$0.37	$0.57
Local production for local consumption 6 GHz ($Billion)	$0.03	$0.06	$0.12	$0.20	$0.33
Local Producer Surplus ($Million)	$23.06	$46.56	$86.35	$149.51	$243.39

Sources: PwC, ABI; Telecom Advisory Services analysis

Q.7. Wi-Fi contribution to employment

The estimation of employment generated is calculated by relying on the total GDP contribution resulting from the effects analyzed above and using that as an input in the communications sector of an input/output matrix of Mexican economy. Table Q-39 presents the GDP contribution enabled by Wi-Fi projected for the period 2021-2025.

Table Q-39. Mexico: Wi-Fi enabled GDP contribution (2021-2025)

Year	GDP contribution enabled by Wi-Fi ($Million)		
	Attributed to current bands	Attributed to 6 GHz	Total
2021	$8,680	$185	$8,866
2022	$7,241	$959	$8,200
2023	$7,109	$1,736	$8,845
2024	$7,756	$3,108	$10,864
2025	$7,991	$4,177	$12,167

Source: Telecom Advisory Services analysis

These inputs generate the following annual employment effects based on the input/output matrix for the Mexican economy (Table Q-40).

Table Q-40. Mexico: Wi-Fi generated Annual Employment

Variable	2021			2025		
	Current bands	6 GHz	Total	Current bands	6 GHz	Total
Direct jobs	78,611	1,679	80,291	72,366	37,828	110,194
Indirect jobs	35,239	0,753	35,991	32,439	16,957	49,396
Induced jobs	12,406	0,265	12,671	11,420	5,970	17,390
Total	126,256	2,697	128,953	116,225	60,754	176,979

Source: Telecom Advisory Services analysis

According to the contribution to GDP, Wi-Fi will generate approximately 129,000 jobs in 2021 and is expected to generate almost 177,000 in 2025. Job estimates include direct jobs (those jobs created by the specific Wi-Fi contribution), indirect jobs (those jobs created by suppliers to the Wi-Fi sector) and induced jobs (those jobs created by spending of direct and indirect workers).

The sector breakdown of 2021 employment (including the additional jobs created by 6 GHz) is as follows (Table Q-41).

Table Q-41. Mexico: Sector Breakdown of Wi-Fi generated annual employment (2021)

Sector	Direct	Indirect	Induced	Total
Agriculture	0	0	93	93
Extractive industries	0	0	50	50
Manufacturing	0	2,874	212	3,086
Construction	0	172	0	172
Trade	0	5,520	7,374	12,893
Transportation	0	2,189	0	2,189
Communications	80,291	0	0	80,291
Financial Services	0	2,464	0	2,464
Business services	0	22,773	0	22,773
Other services	0	0	4,942	4,942
Total	80,291	35,991	12,671	128,953

Source: Telecom Advisory Services analysis