



Accelerating the 5G transition in Europe

**How to boost investments
in transformative 5G solutions**



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Accelerating the 5G transition in Europe: How to boost investments in transformative 5G solutions

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Foreword by EIB Vice President Teresa Czerwińska

In a modern world so often characterised by small, incremental improvements, a technological innovation that promises to make a current practice or process up to 100-times faster is rare. The move from 4th to 5th generation—or 5G—mobile communications is just such an innovation, and will enable greatly accelerated digitalisation by producers and consumers far beyond what we have experienced to date, even during the enforced and rapid adoption of digital means during the current pandemic. Mobile communications have dramatically changed our lives, and 5G promises to accelerate this rate of change.

The immense potential for innovation in downstream applications stemming from the increased speed and reliance and lower latency of 5G mobile technology could greatly increase the resilience of Europe's SMEs, enhance their growth prospects and support employment. 5G technology will also support the European Union's drive towards carbon neutrality under the European Green Deal, as well as the climate action objectives under the Climate Bank Roadmap of the European Investment Bank (EIB). For this reason, 5G is of high strategic importance to the EIB and I am thankful to the European Commission for its leadership on a topic that combines the priorities of innovation, the green transition, technological sovereignty, privacy and cyber security on a continental scale.

The EIB Group is already supporting the roll-out of 5G mobile networks across the European Union, in line with its historical mandate of delivering the benefits of hard infrastructure to the continent's citizens. However, as this report makes clear, the EIB and the European Investment Fund can play a vital role in advancing the scale and effectiveness of financial instruments adapted to the challenge of 5G adoption and innovation by European SMEs. As few 5G consumer devices are currently available and many 5G industrial applications are still on the drawing board, it is essential that the EIB positions itself now on what is the defining digital challenge of the next decade.

I would like to express my sincere thanks to Director-General Roberto Viola and his team for their exemplary cooperation with the EIB Group in this market study, which seeks to address the risks and opportunities of this emerging technology.

I look forward to seeing the fruits of this collaboration in the homes and workplaces of our citizens as Europe reclaims its leadership role—evident in the deployment of 3G and 4G networks—in a key sector of the digital data age.

Foreword by DG CONNECT Director General R. Viola

The COVID-19 pandemic has made everybody fully aware of the need for advanced connectivity. Without such connectivity, many administrations, businesses and educational establishments would not have been able to continue to operate. At the same time, the pandemic also highlighted the enormous potential of connectivity for our future economy.

Responding to this crisis, we now have the true means to invest in Europe's connectivity. For instance, last June, European Heads of State put together an impressive stimulus package, with a total budget of €750 billion to combat the economic downturn stemming from the COVID-19 pandemic. Twenty percent of this amount is earmarked for digital investments, providing a once-in-a-lifetime opportunity to accelerate the digital transformation of our society.

Fibre and 5G infrastructure investments have been identified as one flagship area in this context, and these massive public investments will hopefully unlock additional private and venture capital to fuel innovation in services that rely on connectivity.

This is especially important, since many 5G use cases are of immense societal value – in particular, through the fostering of the digital transformation in vertical industries such as transport, health and manufacturing.

Public and private investments in research and development alone are not sufficient without an effective venture capital strategy. We need this to ensure that innovative European companies in key areas can emerge and scale up to provide their long-lasting benefits for European society.

A lack of adequate growth capital to help our start-ups to achieve a strong market position, or avoid losing their independence, is putting their innovative and disruptive potential at risk, as well as their contribution to the general wellbeing of European citizens.

Therefore, a gradual increase in venture capital activities is essential for achieving 5G leadership in Europe, and the results of this study will inform our discussions and help us to create opportunities for venture capital in Europe.

In particular, we need to leverage private investments with public funding to fill the VC investment gap, like other regions globally, building on European and national funding programmes such as the COVID-19 stimulus package and InvestEU.

We also need to promote advisory services to create appropriate expertise around 5G ecosystem investments. Last but not least, we should direct some venture capital actions specifically towards innovative small and medium-sized enterprises that are potential users of secure and advanced 5G connectivity and could help to create lead markets.

We are looking forward to working with all stakeholders to make this 5G venture capital vision a reality.

Executive Summary

The 2020 global pandemic crisis has forced many societies to adapt their ways of work and life. The proliferation of remote working has demonstrated the potential of the digital revolution and the increased resilience it brings to businesses and customers, thus accelerating the shift towards a more digital economy.

As countries are going through multiple lockdowns, it is becoming clear that the definition of the workplace may have changed permanently. The newly found confidence in remote working gives extra relevance to applications aiming to improve telepresence: from virtual or augmented reality all the way to remote surgeries. One can hardly imagine circumstances that would more urgently demonstrate the need for continued and accelerated digitalisation.

This study discusses why the "fifth generation" of telecommunication systems, or 5G, is integral to digitalisation efforts, and how its roll-out will be one of the most critical building blocks of the European digital economy and society in the next decade. We examine the transformative properties of this technology and explore how we can ensure that Europe remains a relevant, competitive and strategically autonomous player on the global scene. Primarily, we focus on European small and medium-sized enterprises (SMEs) that are active in the 5G domain, and propose a set of recommendations for improving their access to funding.

What is 5G and why it matters for Europe

5G is a set of communications technologies **that brings unique functionalities**, starting with **up to 100 times faster data transfer speeds** (up to 10 Gbps vs. up to 100 Mbps with today's 4G technology¹). More importantly for new business models, 5G will bring **ultra low latency (the transmission time for a packet of data), and the possibility for real-time communication among massive numbers of connected devices simultaneously**. The conjunction of these features gives 5G the potential to not only replace 4G as a faster technology but also enable business innovation across multiple

¹ See <https://ec.europa.eu/digital-single-market/en/blog/eu-funded-project-breaks-available-mobile-network-speed-record-delivering-new-technology-5g-0>

industries (e.g. automotive, virtual reality, healthcare and agriculture), with potentially significant social and economic benefits.

There are several reasons why **5G is strategic for Europe** and why it is urgent to address the issues limiting the financing and development of companies active in 5G communications and developing 5G applications:

5G is central to a large-scale technological, industrial and innovation transition globally, which represents a significant opportunity for Europe. 5G will enable many business applications with significant potential for economic growth and innovation across a variety of sectors including healthcare, mobility, urban development, agriculture and media. The development of 5G technologies, both for equipment and applications, is a key vector of innovation where the winners of tomorrow are decided today. This calls for attention to the success factors and potential bottlenecks currently facing 5G companies and innovators;

5G technologies are a driver of European strategic digital autonomy. European businesses developing 5G technologies, equipment and applications compete in a global market. Maintaining a strong position in this market will be key to ensuring a diversity of choice for telecom operators deploying 5G equipment, thus supporting Europe's autonomy and role in the sector;

5G can make European supply chains and industrial ecosystems more efficient and resilient. It can be deployed not only by traditional operators but also by industrial players, for example to cover specific industrial sites. This could offer new communications possibilities to support industrial processes, potentially adding efficiency and unlocking new ways of doing business, while also providing enhanced security features;

5G will enable SMEs to participate more actively in the communications ecosystem, because communications in a 5G future will see an increasingly important role for software compared to hardware ("softwarisation"²), and a more distributed networking approach relying on mobile devices for computing and performing tasks ("cloudification"³). These

² Softwarisation: Network functionalities that were traditionally implemented via dedicated hardware will, in the future, be implemented

via software modifications. This will enable frequent updates and immediate deployment of specific functionalities in parts of the

network where they are needed. The lower capital expenditure associated with deploying functionalities via software rather than

hardware increases the chances of SMEs developing solutions.

³ Cloudification: This refers to moving data and services to the internet (the cloud). As one of the key concepts in 5G, it will allow network

technological evolutions are expected to open the market to new players, in contrast to the current domination of the sector by traditional players of the telecommunications industry, such as network operators and technology providers. SMEs will play a particularly crucial role in the success of 5G by contributing to the development of 5G-based applications and technologies that support telecom network roll-outs, delivering benefits to citizens and companies;

5G may play help our societies to digitalise further and become more resilient in the face of potential future pandemics, helping people and businesses stay connected and operate as closely as possible to normal even during lockdowns. In a global context where other world regions have already seized the opportunities brought by this technology, it is critical to ensure a rapid transition to 5G in Europe to further the European Union's economic strength and competitiveness.

For these reasons, 5G is strategically important for Europe and its development needs to be supported through a combination of private and public funding sources. 5G may be one of the areas supported under the next Multiannual Financial Framework (MFF). This would help to mobilise market support across different funding stages and financing channels.

This report specifically focuses on examining the needs of small businesses and the issues they may face in developing 5G-related applications, particularly regarding access to financing to fund their activities.

The road to 5G

The deployment of **5G functionality will be gradual**. Initially, it will focus on increasing data transfer speeds and handling large volumes of traffic. Over time, a growing number of functionalities will become available, such as those necessary for ultra low latency communications, connecting large numbers of devices, and enabling more open and distributed networking capabilities.

operators to limit the quantity of data transferred through the mobile network, with data instead transferred from the cloud directly to devices.

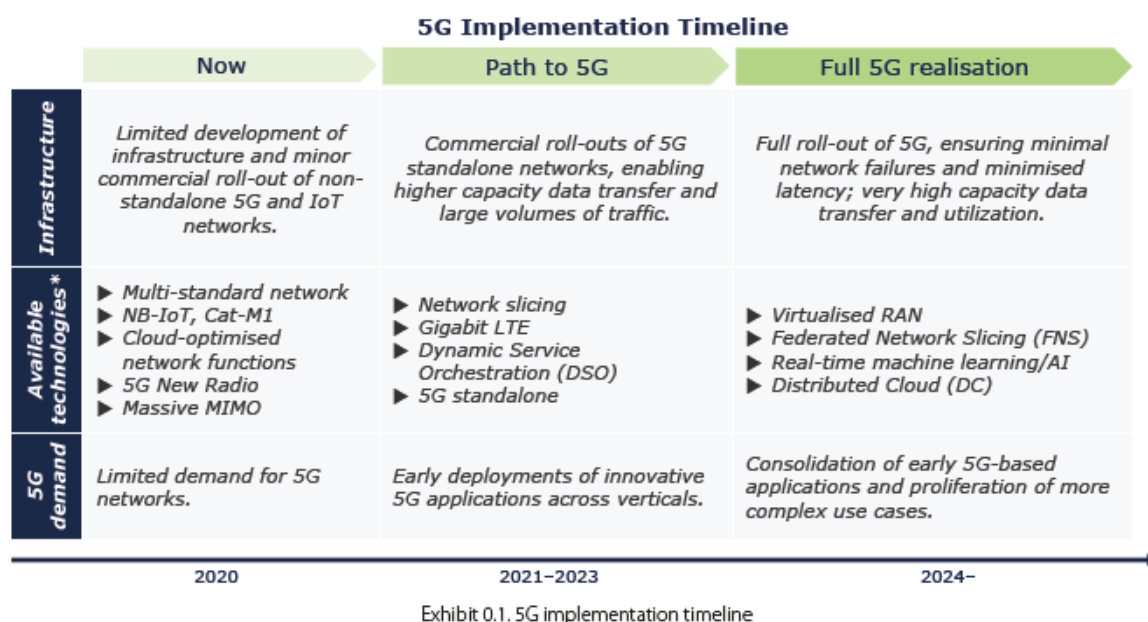


Exhibit 0.1. 5G implementation timeline [Source: Axon Consulting]

In terms of applications, **continued deployment of the more cutting-edge 5G functionalities in telecommunications networks will enable the development of progressively more advanced 5G applications and disruptive innovations and business models.** For example, advanced 5G features will be key to supporting highly autonomous vehicles, remote surgeries, remote factory operations and robotic applications, as well as advanced 3D/holographic communications in the workplace and beyond. In the interim, earlier 5G functionalities will enable applications such as smart meters, consumer IoT⁴ and enhanced media applications. Later in this report we describe such application areas with examples of companies developing them.

⁴ Internet of things, referring to connected consumer devices.

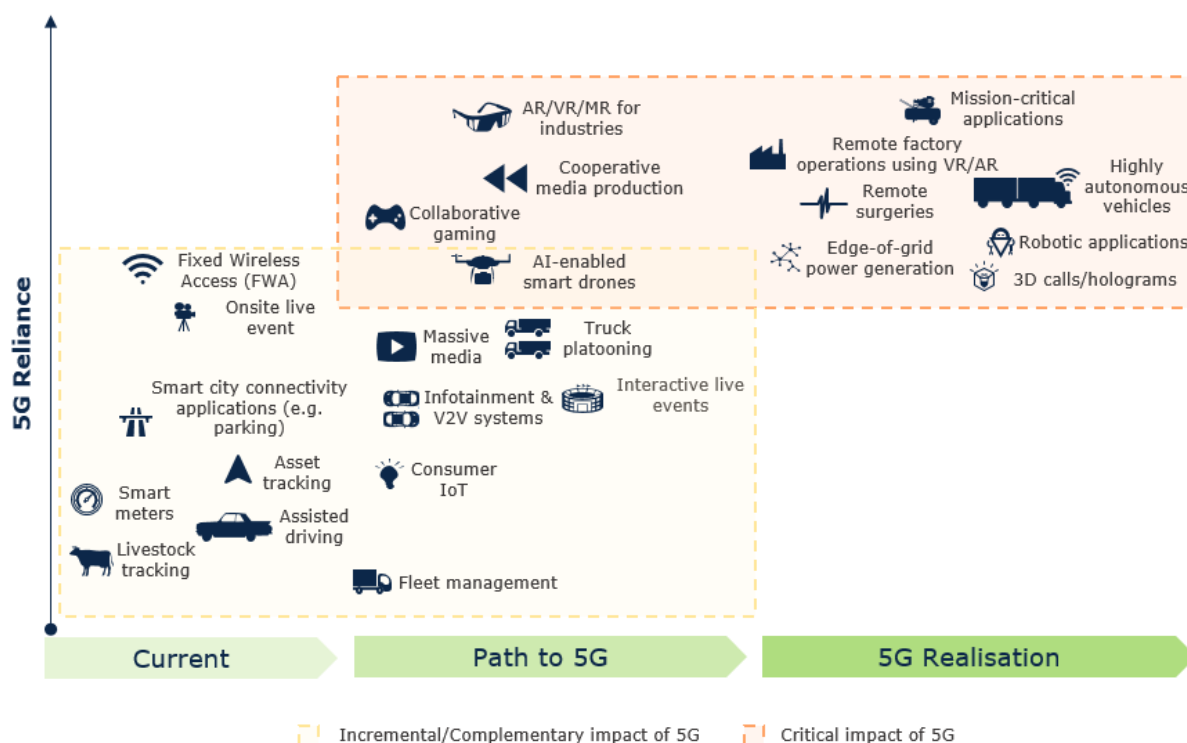


Exhibit 0.2. 5G implementation timeline [Source: Axon Consulting]

Why is there a funding gap for SMEs developing 5G applications?

Most SMEs developing business cases associated with 5G are, at the time of writing, at the early stage of development. They typically depend on public instruments and equity, generally from angel investors or venture capital (VC) firms. Over time, some of these SMEs will develop and also rely on “growth-stage” funding sources with typically larger investment tickets to finance the scaling up of their activities.

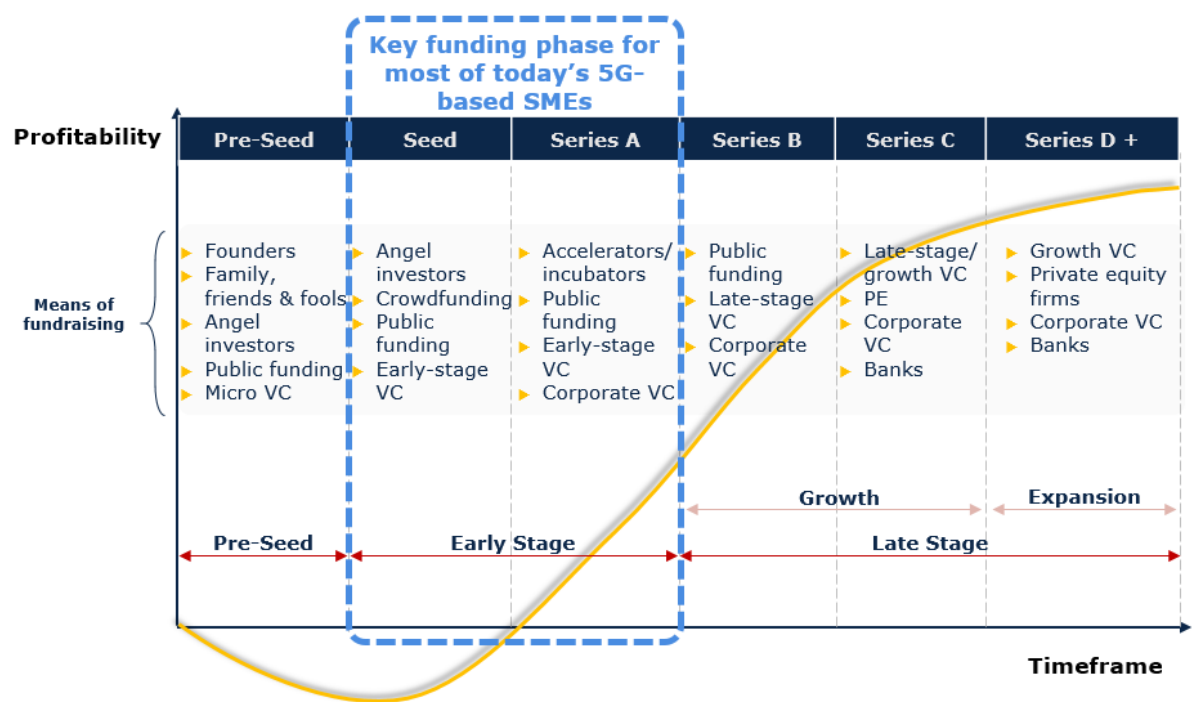


Exhibit 0.3. Funding lifecycle and the key funding phase of typical 5G-focused SMEs
[Source: Axon Consulting]

Based on interviews with SMEs and industry players and research – together with our own and third-party research – we observe **an important funding gap for these SMEs**. In Europe, the gap for 5G-related business models could amount to €4.6 billion and up to €6.6 billion annually. This gap could represent a major challenge for the evolution of 5G in Europe, and poses the risk of Europe being left behind in the race for 5G leadership. The interviews conducted for this study suggest that most of the funding gap is at the early stage of development for 5G-enabled businesses. However, feedback from companies and investors also stresses the importance of growth-stage financing, particularly for successful companies with growing investment needs that typically have difficulty securing commitments from Europe-based VC funds (due to ticket sizes).

Among the various challenges facing SMEs, **the perceived high-risk profile of their businesses emerges as a key constraint**. Several factors explain the current high-risk profile, such as uncertain demand or counterparty/ecosystem dependency. This perception is further aggravated by information asymmetries: the complexity of these SMEs’ business models and the underlying technologies can be difficult to understand for generalist investors, thus limiting their ability to evaluate the risk factors of 5G ventures.

Further, **traditional business angels and VCs** tend to invest in well-understood business models within industries (e.g. IoT applications for agriculture), rather than in underlying

technologies (e.g. NarrowBand IoT⁵ vs. 5G). Hence, these investors have largely held off from prioritising investment in 5G.

Access-to-finance issues are also apparent in the area of **public funding**. Even though EU and Member State funding remains crucial for SME development from a very early stage, there are currently no dedicated 5G-focused programmes available at European level. Many of the SMEs consulted had to rely on general innovation programmes and reported that application processes can be time-consuming with perceived low and/or uncertain chances of success, which may discourage potential applicants.

In summary, both private (VC, CVC, angel investors) and public financing can be difficult to access for SMEs developing 5G-related applications and business models. As SMEs are expected to play an important role in the 5G ecosystem, it is vital for Europe to consider taking actions to help them make a significant impact and drive 5G innovation. The mobilisation of combined public and private resources could become a key lever for accelerating 5G deployment in Europe. The steps taken by other regions in this area, notably the United States and China, reinforce the urgency for support actions for 5G from both public and market sources.

To attract more private VC investment to support the development of 5G-related applications, a particularly important role could be played by **corporate VCs** (CVCs). In contrast to most VCs, CVCs are showing explicit interest in 5G businesses. They tend to bet on innovations that fit with the strategy of their corporate parent. As such, beyond simply maximising the financial return on their investments, CVCs' objectives are also driven by strategic considerations. For example, the involvement of telecom companies in the 5G CVC field is driven by strategic incentives and potential synergies. Beyond telecom-based CVCs, 5G is also being pursued by a much broader set of corporate and industrial players, for example in the advanced manufacturing, aerospace and agricultural sectors, which are all demonstrating interest in innovative 5G use cases.

In addition, CVC players' evident interest and their unique capabilities and industry knowledge could be leveraged to support both public and private funding programmes:

⁵ NarrowBand IoT is a radio technology standard designed to enable low-cost, low-power communication (mostly indoors) among a high number of connected cellular devices. Examples includes the connection of low-powered sensors in smart cities, street lighting, waste management, etc.

here, CVCs could contribute to selecting quality companies, thereby effectively de-risking the funding portfolio.

How can Europe support 5G-related SMEs?

Europe has a number of key strengths and the necessary market structure to create a thriving 5G ecosystem. Within Europe's active 5G infrastructure market, technology providers, connectivity service providers, service enablers and civil infrastructure providers together create a strong supply side of the ecosystem. On the demand side of 5G connectivity, Europe's leading industries and entrepreneurial environment represent clusters of high potential for 5G uptake.

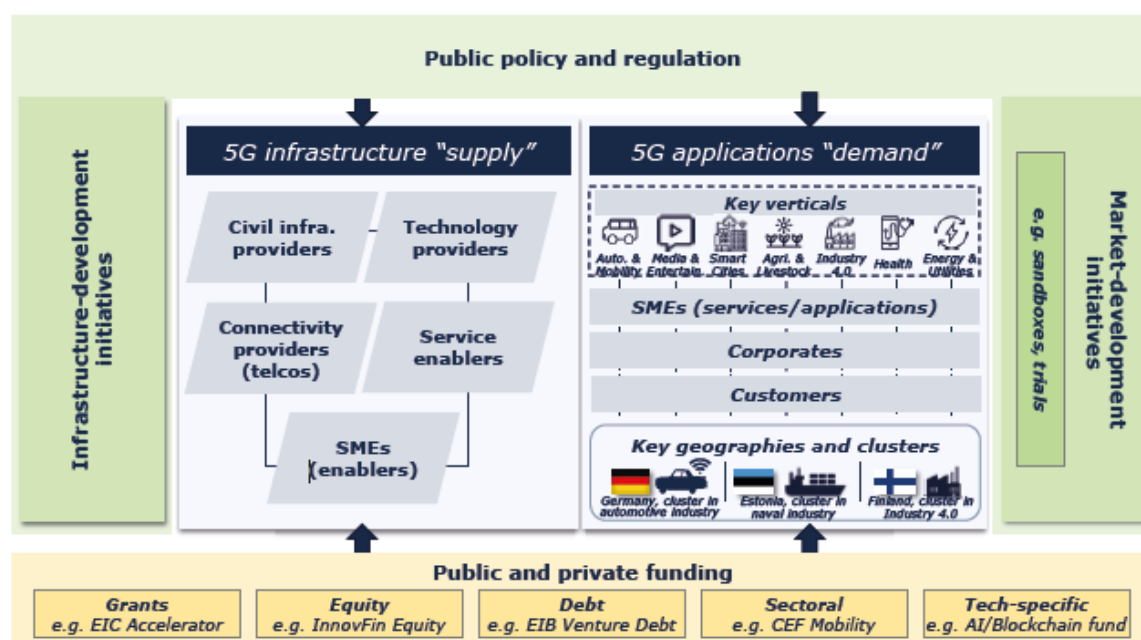


Exhibit 0.4. 5G ecosystem and vision [Source: Axon Consulting]

The following recommendations offer suggestions on how these unique European advantages could be leveraged in the coming transitional years and how the 5G ecosystem could be inclusive of SMEs. The table below provides an overview of our recommendations, highlighting funding programmes and extra measures that could help improve 5G-related access to finance for European SMEs.

Recommendations	Objectives	Actions
Recommendation 1: Allocate public capital to support 5G	Target the funding gap by mobilising financing support from several actors.	Catalyse private investment through public funding programmes.
Recommendation 2: Introduce non-financial means of supporting early-stage activity through public-private initiatives	Target very-early-stage SME development through strategic engagements.	Use key areas of exchange between 5G supply and demand to accommodate interaction between relevant stakeholders.
Recommendation 3: Overcome information asymmetry around 5G	Improve investors' understanding and awareness of 5G technology. Improve companies' awareness of funding programmes available to them.	Roll out industry events, use of digital materials, and create a searchable database to disseminate information.
Recommendation 4: Reduce cross-border challenges by promoting homogeneity and standardisation	Ensure a homogeneous landscape enabling the scalability of 5G businesses across Europe.	Strengthen policies and cross-sectoral regulations to be future-oriented, pro-investment and pro-innovation.

Exhibit 0.5. Objectives and rationales of the recommendations [Source: Axon Consulting]

Recommendation 1: Allocate public capital to support 5G

The European Commission and the EIB Group have a number of programmes that can be used to successfully support SMEs active in the 5G domain in Europe. In the sections below, we will discuss how the existing programmes could be adapted and/or complemented by new, dedicated programmes to create funding instruments that would most benefit SMEs.

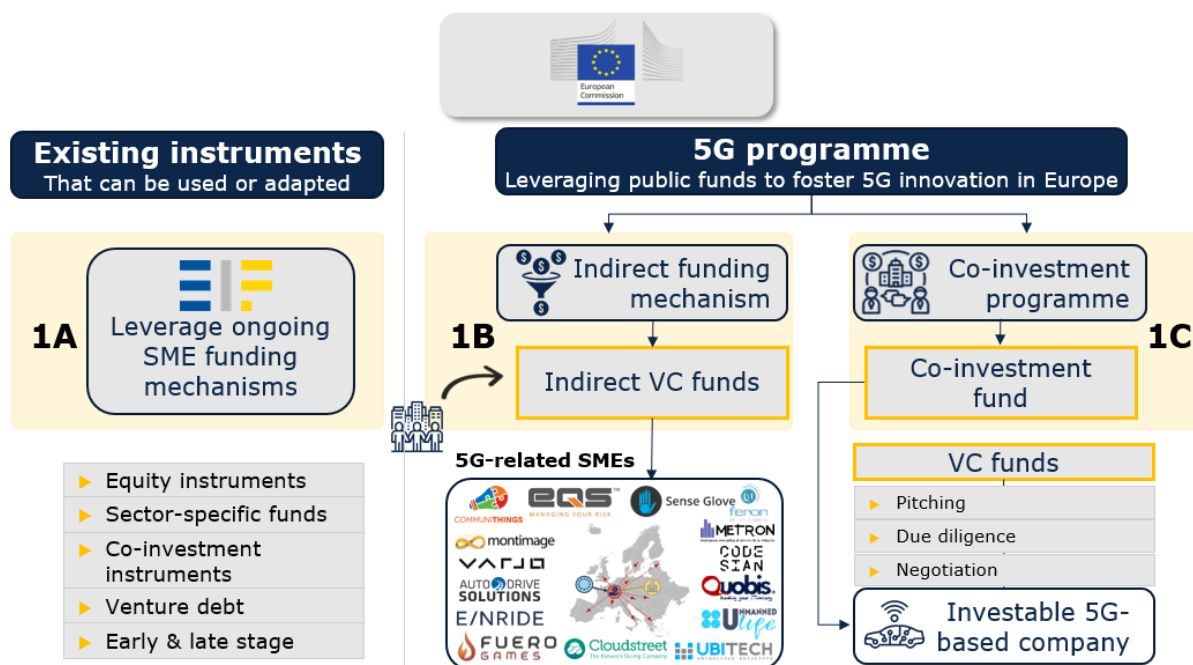


Exhibit 0.6. Scheme of Recommendation 1 and its three pillars

Recommendation 1A – Repurpose existing and planned funding mandates

The European Commission supports innovation through several funding programmes. Some wellknown funding instruments with successful track records could be reused or adapted, at least partially, to help innovative SMEs in the 5G/advanced-connectivity space to transition from seed to growth stage. Future mandates such as InvestEU, which will come into effect in 2021, can be well-suited to this purpose. For example, **dedicating specific budget envelopes within MFF 2021–2027 programmes to SMEs working on 5G/advanced-connectivity solutions** could be effective for facilitating access to finance. Such programmes could cover both public funding vehicles (such as the European Innovation Council) and repayable forms of support (such as under InvestEU), both for the purpose of **encouraging private market participation in addition to public support**. In practice, one could draw from **recent experience in the setup of targeted fund-of-funds envelopes** such as the artificial intelligence (AI) and Blockchain pilot programme implemented by the European Investment Fund, which deployed €100 million to catalyse an overall investment of more than €700 million in eligible companies⁶.

Furthermore, for certain 5G applications, existing instruments such as the Connecting Europe Facility (CEF), particularly CEF Transport for 5G mobility solutions, are already well-suited to supporting the roll-out of infrastructure linked to 5G. **Ensuring the continuity of such programmes would help to promote 5G-enabled mobility applications**, particularly if an explicit reference to 5G-enabled applications were included in eligibility criteria. This approach could potentially also be used as a blueprint for similar funding instruments under this mandate, within other relevant application areas beyond mobility.

Recommendation 1B – Launch an indirect funding programme mobilising venture capital and corporate investment

Another potential means to support European SMEs developing 5G-based applications could be the creation of an indirect investment mechanism. Such a mechanism would focus on **making targeted investments in venture capital (VC) funds that finance early-stage SMEs developing advanced-connectivity applications**. The funds could be

⁶ https://www.eif.org/what_we_do/equity/news/2020/six-funds-backed-innovfin-artificial-intelligence-blockchain-technology.htm

deployed with a thematic focus to eligible fund managers (for example making investments in specific industries) and to SMEs of a particular level of maturity.

Such programmes have already been deployed successfully in the form of fund-of-VC funds. A specific characteristic of this proposed funding programme would be the requirement and opportunity to enlist **telecom or other corporate VCs to participate as limited partners** in the capital structure of individual fund beneficiaries. Bringing in corporate VCs as lead investors or anchors would add significant value, know-how and confidence, thereby encouraging other private investors to participate in the selected funds. This structure would also make it possible to steer the programme's investments to strategic industries through the combined engagement of VCs and corporate players. **Adequate governance would be required to support and encourage knowledge exchanges and strategic input from corporate partners, while leaving full investment discretion to private fund managers** (thereby minimising any perceived conflicts of interest for corporate players). The programme mechanics are overviewed in Exhibit 0.8.

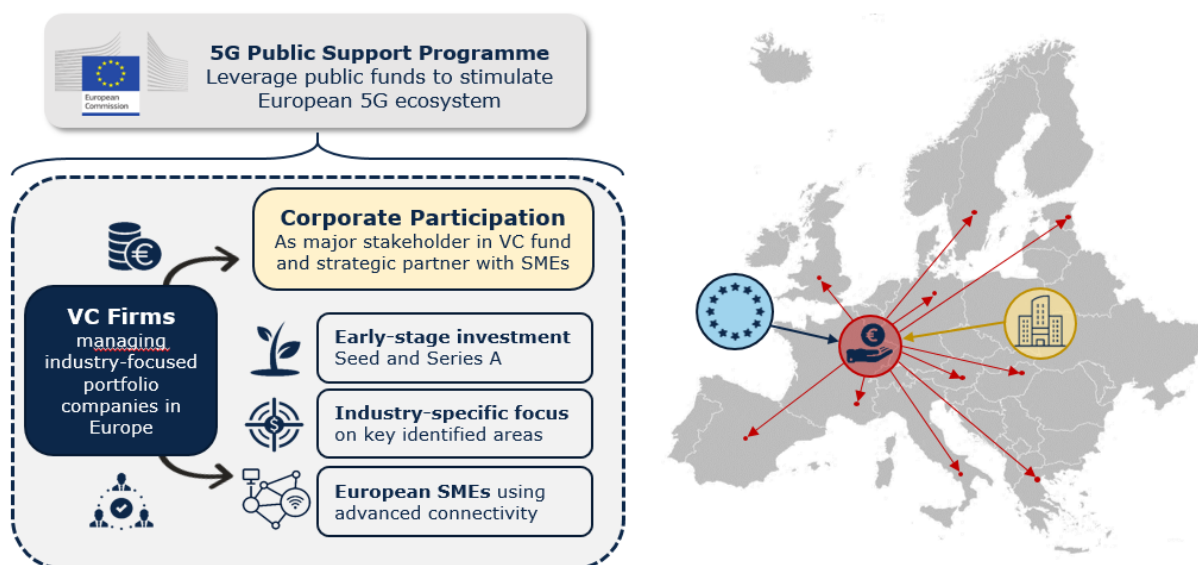


Exhibit 0.7. Overview of Recommendation 1B [Source: Axon Consulting]

Overview of programme mechanism with illustrative figures	
	Programme makes investments into a VC-led fund , for example contributing ~33% of total fund size, with an upper investment limit.
	One or several corporate/telecom anchors are required to contribute extra 20–40% of total fund size.
	VCs must contribute the remaining share with their own or private investment , therefore providing ~33% of total fund size.
	Funds would invest predominantly in early-stage companies with focus on advanced-connectivity applications .
	Funds are “thematic,” covering a specific, or multiple, predefined industries with the tied corporate anchor having a strategic interest in the fund theme.

Exhibit 0.8. Mechanism of the programme [Source: Axon Consulting]

Recommendation 1C – Develop a 5G-focused co-investment platform for VC funds

A dedicated 5G co-investment platform would be another highly effective way for public capital to catalyse private investment. In this case, deal sourcing, negotiation and execution would remain in the hands of private investors, but by co-investing on an equal footing with them, public capital **could make larger deal sizes feasible, allowing SMEs to engage in larger investments**. This would help address a **gap in growth financing** for European SMEs involved in 5G technologies and applications, helping these companies to finance more of their growth in Europe, rather than seeking funding from larger foreign VCs.

Such a co-investment platform would not, in principle, actively engage in company management. This would instead be handled by the private partner investors able to de-risk their investment by acquiring larger stakes in SMEs for less capital. This approach would facilitate private management of SMEs funded by the co-investment programme, creating the conditions for value creation and attracting further capital from private investors for SMEs operating in sectors related to 5G.

A fund prequalification approach could further increase the efficiency of the co-investment programme. As deal-by-deal evaluation of co-investment opportunities is time-consuming and labour-intensive, an alternative that has already been successfully tested would involve delegating co-investment opportunity evaluation to the fund manager. By creating fund prequalification criteria and an open tender for VCs to participate in the platform, the programme would enable the best partners to be selected and offer them quick deal-by-

deal execution. However, to adopt a fund prequalification approach in this context, the alignment of public and private interests would need to be addressed.

Details of the co-investment platform		
 A qualified third-party VC identifies an opportunity benefitting from advanced connectivity	 Execution of the public-private agreement, incentivising VCs to pursue similar deals	 Three beneficiaries of the co-investment fund
An independent VC firm applies for the co-investment programme If requirements are met -> prequalified status VC finds investment opportunity in an advanced-connectivity-based SME and negotiates the potential deal	Prequalified VC fund submits a request for the public body to co-invest on an equal footing Prequalified VC is able to receive fast approval once the opportunity is reviewed VC receives full control, management fees on the co-invested amount and carried interest on exit, if applicable	The target SME, which receives the full funding amount from a joint public-private source The VC, which increases its assets under management and has a partner to de-risk the individual investment The public body, which boosts the 5G ecosystem by leveraging its investment with private capital

Exhibit 0.9. Overview of the co-investment platform [Source: Axon Consulting]

Adopting all three recommendations (1A, 1B and 1C) would deliver optimal outcomes, as their implementation would constitute three pillars for allocating public capital to support 5G tools and applications.

Due to the nature of the risk taken, partnering with traditional VC would be a suitable way to effectively deploy public funding. In this tried and tested model, professional general partners would be called upon to identify the best financing opportunities and how to finance them, and would actively support companies through their growth – all while complying with the strategic criteria predefined by the provider of public funds.

The above-mentioned **InvestEU** and **CEF** are both good examples of mandates that could be used to enhance investments in 5G infrastructure and broader ecosystem-building at pan-European level within the **priorities of the EU Digital Strategy**; this should be explored further with the European Commission. At a national level, the **Recovery and Resilience Facility** is another mandate where closer cooperation and coordination between Member States and the European Commission could promote the further integration of 5G infrastructure and innovation-ecosystem-building programmes. In addition, with the support of EU Member States, **the European Commission and the EIB Group could set up a dedicated financial instrument** to enhance access to equity and growth finance for the scale-up of companies focused on developing 5G solutions, and

to support the adoption of 5G-enabled technologies across all sectors of the economy. In the following sections, we will describe how these measures should be complemented by other measures, including skills

development and advisory programmes to strengthen the adoption of 5G technologies in Europe, and how this would support the priorities of the **Digital Europe Programme**.

Recommendation 2: Introduce non-financial means of supporting early-stage activity through public-private initiatives

This recommendation promotes the **potential to involve telecom and other corporate players** as relevant partners in the 5G ecosystem, **beyond their role as potential investors**.

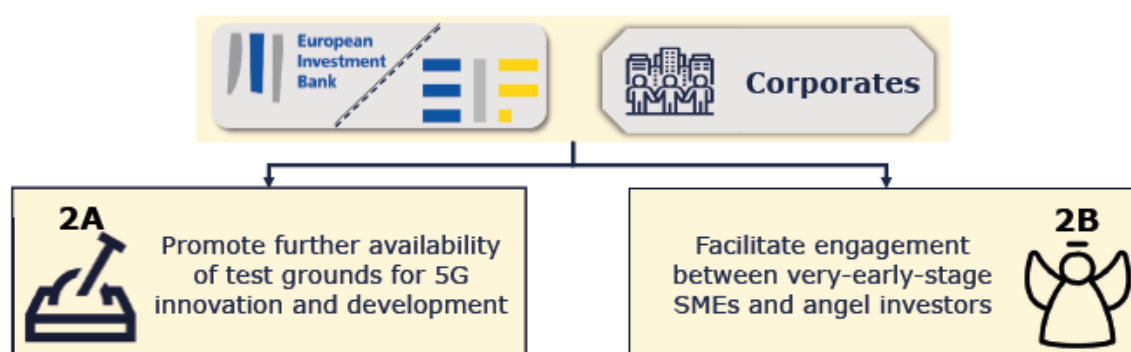


Exhibit 0.10. Overview of Recommendation 2 [Source: Axon Consulting]

Recommendation 2A – Promote further availability of test grounds for 5G innovation and development

One of the most promising non-financial mechanisms for supporting the sector is to **increase the availability of testing facilities**, so-called sandboxes, where multiple players can interact and test the latest iterations of 5G technology. In the 5G corridors initiative⁷, the European Union and its Member States are already committed to developing

⁷ The 5G corridors are projects designed to provide seamless 5G connectivity to vehicles even as they cross borders, thereby paving the way for autonomous driving on main road, train and maritime routes. See: <https://5gobservatory.eu/info-deployments/pan-eu-5gcorridors/>

large-scale testing sites for connected and automated driving, turning a large area of Europe into an experiment zone for 5G technology. Such initiatives could be complemented by increasing active support for localised sandboxes – these would serve as areas of shared interest between the supply and demand sides of the 5G ecosystem, and thus form a key space for engagement between them. Numerous interviewees expressed a need for more sandboxes, as they allow the parallel testing of equipment, processes/systems and proof-of-concepts, and demonstrations of technical innovations. This, in turn, enables fast prototyping, development and proofing of technology, and provides favourable conditions for collaboration, demonstration and open innovation.

Recommendation 2B – Facilitate engagement between very-early-stage SMEs and angel investors

In addition to public grants, very-early-stage SMEs are often supported by angel investors, who provide early equity financing. To promote private investment in very-early-stage SMEs, dedicated events could be organised with the primary objective of **bringing together investors and SMEs**. A particularly helpful type of interaction could involve the **demonstration of 5G technology capabilities** – such events could also educate angel investors on the potential impact of 5G on industries from an investment perspective, thereby enhancing their understanding of these technologies. These events could be complemented by tailored funding schemes to attract investments into such projects by angel investors. In addition, advisory services could also contribute to matching companies with relevant investors, and such services could be delivered through local/regional innovation agencies or digital innovation hubs.

Recommendation 3: Overcome information asymmetry around 5G

Information asymmetry was identified during interviews as a key hindrance of investment in 5G and its wider adoption, with the complexity and potential of underlying 5G applications and technologies often not understood by VCs. This information asymmetry is apparent in two areas: (i) knowledge of the transformation potential of 5G technology, and (ii) awareness of existing financing options that could support SMEs developing 5G applications.

Recommendation 3A – 5G Monitor: Disseminate information around 5G and advanced-connectivity-enabled business cases and their potential impact

Knowledge of the potential and future capabilities of 5G technology is crucial for VCs to conduct realistic risk assessments and thereby minimise the possibility of negative biases. Increased confidence in the potential business impact could drive industry adoption of 5G applications. Industry-focused events could provide a good platform to discuss the impact and importance of 5G within specific industries. In addition, digital content such as blogs, podcasts and articles could help to disseminate information on the potential of 5G technology in multiple industries through key channels, including industry-specific channels. The current COVID-19 crisis provides a particularly good opportunity to demonstrate the usefulness of 5G technology and, therefore, the full potential of its use cases.

Recommendation 3B – Provide clarity on financing options through advisory services

European SMEs generally lack vital information about the available financing opportunities, and this not only in the 5G sector; in many cases, this is further compounded by limited understanding of how to structure a financeable investment plan. Education and easy access to relevant information on a single platform would increase transparency and potentially provide an early opportunity to connect capital seekers and capital providers in a more productive way. To this end, creating a database-style portal would help to collate financial and business model information from startups and investment funds. On such an information platform, investors would find relevant data on SMEs in a searchable database of investment opportunities. **Advisory services** will also be key to addressing this need by **raising awareness** of available financing instruments. Awareness raising opportunities include **direct engagement** with specific companies, the **organisation of relevant events** matching companies and investors, and other **market-development initiatives** to bring public finance solutions closer to where they are needed. Such awareness initiatives should also build on existing events, ranging from the Mobile World Congress and Web Summit to more tailored events specifically focused on 5G and related applications.

Recommendation 4: Reduce cross-border challenges by promoting homogeneity and standardisation

Although focused primarily on financing bottlenecks for SMEs active in the 5G domain, this study also revealed various non-financial issues related to regulation, standards and homogeneity in the European market for digital services. SMEs and investors both noted the **lack of homogeneity and standardisation** as potentially having a **severe impact on the scalability of 5G-related business models**; in turn, this could harm the valuation of SMEs and the level of investments.

The European Commission has correctly identified the most relevant barriers, notably 5G spectrum allocation and the need to facilitate network deployment (particularly small cell deployment), which should be addressed by the European Electronics Communications Code. The Commission has also established deployment targets, initially in the 5G for Europe Action Plan, which were further developed as part of the Gigabit Society broadband targets. On the technology and applications side, some projects under the 5G Public-Private Partnership initiative, such as those related to 5G corridors, should also contribute to future network coverage and functionality homogenisation.

Further efforts should target the effective implementation of already developed improvement measures, as well as the increased homogenisation of deployments, in terms of not only general coverage but also the specific capacity and functionality of those networks (required levels of basic metrics such as throughput and latency, and of functionalities implemented). Otherwise, the high level of degrees of freedom of 5G deployment could lead to significant diversity among networks, making it impossible to deploy highly innovative applications in certain markets where networks comply with the regulations but lack the most advanced features.

From a regulatory standpoint, specific verticals (e.g. drones, autonomous driving) also depend on increased regulatory clarity across Europe. These issues call for specific efforts from the respective regulatory bodies.

Further harmonisation and coordination on these issues are a key enabler and should be encouraged. These drivers can help to maximise the potential of the European Digital Single Market and facilitate the scale-up of European SMEs. This is especially important in light of the expected impact of 5G on a wide range of industries; ensuring true cross-sectoral policy and regulation will be essential to fully realising the benefits of the 5G technology for these industries and its transformative potential.

1. Introduction

The next generation of wireless connectivity, 5G,⁸ has been identified as a game-changing technology of great importance to the progress of European industry and society. The digitalisation of the industrial economy, the connection of private, public and industrial objects to the internet, and demand for sending high quantities of processed data from the cloud to the edge (users) will require vast connectivity capabilities. To this end, 5G is set to deliver a seamless, ubiquitous network that will cater to the increasing connectivity requirements of both individuals and industrial players.

5G has been identified as a game-changing technology of great importance to the progress of European industry and society

5G network infrastructures will be a key asset to support societal transformation in Europe, enabling the Fourth Industrial Revolution (Industry 4.0) and impacting multiple industries (automotive, healthcare, utilities, agriculture, etc.). The functionalities that 5G is expected to bring will enable players in these industries to enhance existing, and develop new, products and services. Therefore, ensuring a rapid and broad-based transition to 5G in Europe is key to promoting the European Union's economic strength and competitiveness.

Beyond the typical players of the telecommunications industry, such as network operators and technology providers, 5G will allow small and medium-sized enterprises (SMEs)⁹ to participate more actively in the whole ecosystem, hence increasing the impact of technology on the economy. SMEs are an important pillar for new, advanced forms of connectivity such as 5G, as they contribute to developing technologies supporting telecommunications network roll-out and the services and applications that will deliver benefits to users and industries.

5G will allow SMEs to participate more actively in the whole ecosystem, hence increasing the impact of technology on the economy

This study, titled "**Assessment of access to finance to support investments in 5G service innovation and take-up,**" focuses on such

⁸ A brief contextualisation of 5G technology, as well as its potential role in the key trends of the ICT sector, is provided in Annex B.

⁹ SMEs are defined in EU Recommendation 2003/361. The main factors determining whether an enterprise is an SME are i) staff headcount and ii) either turnover or balance sheet total. The thresholds applied to these factors to determine SME status are detailed on the following website: https://ec.europa.eu/growth/smes/business-friendly-environment/sme-definition_en.

SMEs and especially their access to financing to unlock the potential of advanced forms of connectivity such as 5G.

The study's **main objectives** are to:

- ▶ Analyse the access-to-finance conditions of SMEs in order to ensure the optimum development of innovative services and business models triggered by the emergence of advanced forms of connectivity such as 5G technology.
- ▶ Provide a set of actionable recommendations on how to develop funding models to stimulate the development of such services and business models associated with 5G.

To achieve these objectives, the scope of the work undertaken for this study includes the following main tasks:

1. Assessment of the 5G ecosystem
2. Interviews with SMEs
3. Interviews with key financial investors
4. Identification of SMEs' key limitations in terms of access to finance
5. Development of recommendations to support 5G investments

The above tasks are described in Exhibit 1.1:



Exhibit 1.1. Overall methodology for the study [Source: Axon Consulting]

This study combined broad desk research with interviewing representatives of European SMEs from several distinct verticals, multiple European countries and different positions within the 5G ecosystem value chain (mainly technology enablers and application/service providers). In particular, we interviewed 28 SMEs, 12 venture capital (VC) and corporate venture capital (CVC) firms, and 6 industry experts from within the European 5G ecosystem.¹⁰ The interviewed representatives of SMEs from distinct backgrounds, industries and countries presented consistent insights. Similar positioning on 5G-related matters was observed between the interviewed financial players (both VC and CVC). Such consistency levels allowed us to extract conclusions and develop recommendations that can be extrapolated to the entire ecosystem.

This study's **conclusions and recommendations** will be used to address the challenges identified for developing the service innovations and new business models enabled by advanced forms of connectivity such as 5G, thus supporting the creation of a successful technological ecosystem that spreads innovation to all industrial and economic sectors.

The remainder of this study is structured as follows:

- ▶ **5G in Europe: current situation and perspectives (Section 2)**, in which we explore the current situation surrounding 5G and describe the main global ICT trends that affect 5G, before exploring the main findings and perspectives associated with access to finance for SMEs in the 5G ecosystem.
- ▶ **Vision and way forward (Section 3)**, which discusses the vision for the European 5G ecosystem, provides key recommendations to advance the access-to-finance conditions for SMEs in the advanced-connectivity space, and highlights opportunities to best stimulate public and private investment in this area.

This study's conclusions and recommendations will be used to address the challenges identified for developing the service innovations and new business models enabled by advanced forms of connectivity such as 5G

¹⁰ The methodology for identifying and selecting the interviewed stakeholders is provided in Annex A.

2. 5G in Europe: current situation and perspectives

The next generation of wireless connectivity, 5G, has been identified as a game-changing technology of great importance to the progress of European industry and society. To enable the digitalisation of the industrial economy, the connection of private, public and industrial objects to the internet, and demand for sending high volumes of data between the cloud, the edge and billions of end devices of all kinds, vast connectivity capabilities will be required. 5G is set to deliver a seamless, ubiquitous network that will cater to these increasing connectivity requirements of both individuals and industrial players.

5G network infrastructure will be a key asset to support societal transformation in Europe, enabling the Fourth Industrial Revolution and impacting multiple industries, such as automotive, healthcare, utilities, and agriculture.

The functionalities that 5G is expected to bring will enable players in these industries to enhance existing, and develop new, products and services. 5G is expected to make possible innovative use cases such as remote surgery, augmented reality (AR) and virtual reality (VR) applications, and factories of the future. The economic impact of these innovations, through both direct and indirect applications, will be significant. Therefore, ensuring a rapid, broad-based transition to 5G in Europe is key to promoting the European Union's economic strength and competitiveness.

Beyond the typical players of the telecommunications industry (e.g. network operators, technology providers), 5G will allow SMEs to participate more actively in the whole ecosystem. SMEs are an important pillar for new, advanced forms of connectivity, such as 5G, since they contribute to developing technologies supporting telecommunications networks roll-out and the services and applications that will deliver benefits to users and industries.

5G will be a game-changing technology of great importance to the progress of European industry and society

Ensuring a rapid, broad-based transition to 5G in Europe is key to promoting the European Union's economic strength and competitiveness

In this section, we explore the 5G ecosystem in Europe and analyse the main challenges it poses to SMEs.¹¹

2.1. The European 5G landscape

The 5G ecosystem is driven and influenced by a number of stakeholder groups. Telecommunication ecosystems are becoming significantly complex and there is no universal way to picture their value chain. Moreover, the value chain's structure differs according to each player's perspective, and players can function in more than one link. Exhibit 2.1 presents the value chain structure followed in this report.¹²

The 5G ecosystem is driven and influenced by a number of stakeholder groups

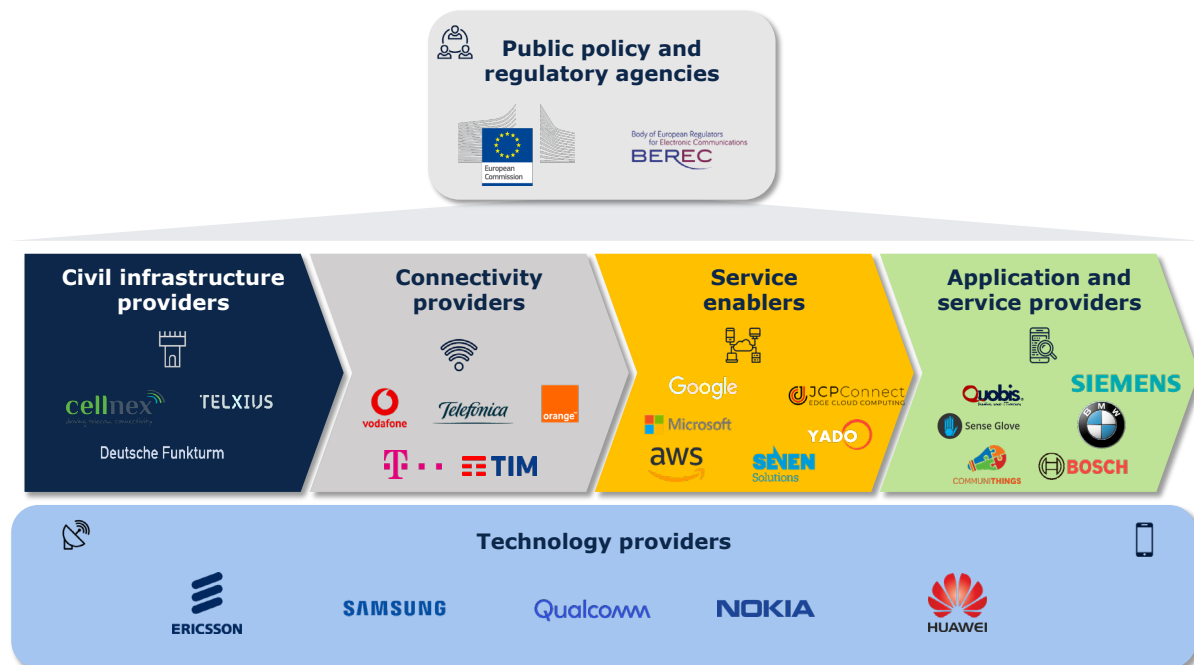


Exhibit 2.1. Main stakeholders involved in providing 5G services [Source: Axon Consulting]

Civil infrastructure providers

Civil infrastructure providers offer operators access to the passive infrastructures (e.g. towers, masts) through which connectivity is provided. Although traditional connectivity providers, such as mobile network operators

¹¹ This section is further supplemented by research on the current status of 5G development in Europe, as outlined in Annex C.

¹² Exhibit 2.1 shows only those stakeholders of relevance to this study. There are more stakeholders involved in the overall ecosystem, such as standardisation bodies or associations.

(MNOs), have typically tended to deploy their own passive infrastructure, a trend of disposing of these assets and outsourcing the passive infrastructure operations can be observed around the world, including in Europe. For instance, Vodafone recently spun off its tower infrastructure into a new organisation, Vantage Towers,¹³ which became operational in July 2020. As explained below, this trend is likely to become even more relevant in the 5G era.

Many infrastructure elements required to provide 5G services will be built on top of existing infrastructures. This means that civil infrastructure providers can take an evolutionary approach to infrastructure investment, by upgrading the capacity of their existing 4G deployment.

This evolutionary approach will be the natural path for most civil infrastructure providers due to the high costs of replacing current infrastructure with entirely new 5G infrastructure. This will allow them to minimise investment while the incremental revenue upside of 5G, derived from the migration of previous technologies, remains uncertain.

When upgrades to existing infrastructures can no longer support the increasing demand for services (especially mobile data), there will ultimately be a need for new infrastructure (e.g. telecoms sites). The point in time where existing infrastructures reach their capacity limit will vary by site and country. The time it takes for such a shift will be the primary driver behind major infrastructure cost increases as the providers will need to build-out new access nodes to accommodate 5G demands.

In comparison to the current macro sites, upcoming 5G deployment is likely to be driven by the following infrastructure-related factors:

- **Densification of the access network:** Providing 5G services with high capacity and high data rates per user will likely necessitate densifying the access network, meaning an increase in the deployment of access nodes.¹⁴ Civil infrastructure providers are expected to eventually rely on adding small cell solutions to their networks to cater for very high

¹³ Vodafone, July 2020; Available at: <https://www.vodafone.com/news/press-release/vantage-towers>

¹⁴ Enterprise IoT Insights, November 2016; Available at: <https://enterpriseiotinsights.com/20161109/5g/network-densification-5g-taq31-taq99>

frequency band use.¹⁵ This will likely be most prominent in highly populated areas, mainly due to a higher concentration of traffic.¹⁶ Hence, small cells are expected to be installed primarily in high-traffic, urban areas to overcome the bottlenecks of macro cell networks, such as limited network capacity. The extent to which this will take place and its timing are still being discussed within the wider industry.

- **Upgrade to fibre of the transmission network:** To improve transmission, large-scale upgrades to fibre networks will be required. In addition to helping networks meet capacity and latency requirements for 5G, switching to fibre technology will be instrumental in supporting small cell deployment in urban areas.

The expected situation of multiple MNOs seeking to deploy their networks in a single site suitable for small cell solutions may prove challenging, given the need to reach agreements on access to private sites (e.g. procuring asset rights from public entities and homeowners) and the practical difficulties of providing power and backhaul to each site. From the MNOs' perspective, these are significant obstacles that can undermine their core operations. Hence, there may be opportunities for new players upstream of traditional MNOs to provide access to such infrastructures. These players can strive to simplify the installation and deployment models, allowing the profitable delivery of services such as site acquisition, construction and integration.

Although the future need for dense access networks and upgrading transmission networks to fibre presents possible opportunities, it is currently unclear whether civil infrastructure providers will be able to develop sustainable business models for cell densification or whether only MNOs will be able to bear the high investment required to cope with the needed granularity of access nodes.

Nevertheless, it is possible that the need to obtain suitable sites, conclude deals with site owners and then interconnect and backhaul a large number of small cells could create opportunities for civil infrastructure providers of wholesale services (acting as neutral hosts). For example, **Cellnex**,¹⁷ with

¹⁵ 5G will make use of several frequency bands that have never been used for mobile services. Although these bands will massively increase network capacity, they also have limited propagation characteristics and are unable to travel through buildings and other obstacles.

¹⁶ As measured by traffic load per square kilometre.

¹⁷ See <https://www.cellnextelecom.com>

infrastructures already in place across several European countries (Spain, France, Italy, Netherlands, Switzerland and the United Kingdom), is aiming to position itself as a key European leader in this segment.

Connectivity providers

Traditionally, MNOs have been in charge of providing connectivity to their users. However, the technological capabilities of 5G create possibilities for offering a larger number of differentiated services. This may facilitate changes to the traditional model of offering standardised, undifferentiated “mobile broadband” services to customers in the form of a “minutes and data” package for a subscription fee, or charges on a per-device basis based on data use.

Although traditional MNOs will preserve the largest stake in the connectivity market, 5G technology will support the development of new dimensions within the connectivity layer. For instance, 5G is set to drive progress across internet of things (IoT) and machine-to-machine (M2M) use cases, thereby impacting a number of verticals and players. Therefore, there may be a role for new players in identifying new applications or models for providing 5G connectivity, as they may have specialist knowledge of the connectivity requirements of particular sectors.¹⁸

To date, Europe’s most active traditional MNOs¹⁹ in providing connectivity for 5G services have been **Vodafone, Deutsche Telecom, Orange, Telefónica, Telia and TIM**. Traditional MNOs are likely to move down the value chain (e.g. by partnering with service enablers and with application and service providers) to capture a potential revenue upside on top of traditional connectivity revenues. Some examples of trials carried out by these MNOs, including some partnerships with players downstream in the value chain, are discussed in Annex C.

Regarding potential new players, we note the example of **Airspan**,²⁰ which recently acquired spectrum in the Irish 3.6 GHz auction, apparently with a view to deploying small cell solutions and offering wholesale connectivity

There may be a role for new players in identifying new applications or models for providing 5G connectivity, as they may have specialist knowledge of the connectivity requirements of particular sectors

¹⁸ The industries that can benefit from 5G are further explained in Annex C.2.

¹⁹ Based on the number of trials and pilots reported by the European 5G Observatory: <https://5gobservatory.eu/5g-trial/major-european-5g-trials-and-pilots/>

²⁰ <https://www.airspan.com>

(thus becoming a connectivity provider). This is one example of a potential player that can move up the value chain to provide both civil infrastructure and connectivity.

There may also be room for new players to focus on **niche services** such as providing 5G connectivity within indoor spaces to serve the particular demands of an industry (e.g. providing 5G connectivity in factories or warehouses).

Service enablers

On top of the connectivity provided by the above-mentioned stakeholders, service enablers provide horizontal platforms or enabling technologies/systems to facilitate onboarding new ecosystem partners and launching new services. Service enablers could be able to provide as-a-service offerings including billing, security and data analytics.

In this ecosystem, besides traditional service enablers or even connectivity providers moving down the value chain (e.g. Microsoft, Amazon Web Services, Predix, and Google), there may be room for SMEs to capture a market stake by providing niche services to their customers. Examples of such niche services include data analytics, network slicing, communication security and network optimisation.

There may be room for SMEs to capture a market stake by providing niche services to their customers

This layer of the 5G ecosystem is one of the most rapidly changing environments due to high offerings, constant evolution and the emergence of new services, which allow entry to multiple smaller competitors with niche knowledge and strengths.

Application and service providers

Application and service providers (often also called service creators) offer services directly to end users. Service creators' ultimate role is providing customers with digital services spanning a wide variety of use cases or applications.

Such services can be provided by three groups of companies, briefly described below:

- ▶ **Traditional MNOs:** MNOs typically provide pure connectivity to users, by means of mobile broadband services through smartphones, laptops and other devices. 5G will, therefore, extend their existing value provision.
- ▶ **SMEs:** Fast-growing existing and start-up SMEs leverage or provide advanced connectivity to create high-value innovations for businesses and end users. 5G-enabled use cases developed by SMEs will offer services in industries, such as healthcare or public safety, and these SMEs will coexist, compete or partner with larger corporations.
- ▶ **New providers:** Services can also be provided by technology-driven companies such as Bosch, BMW and Siemens, offering services based on 5G technology embedded in their solutions' portfolio. For instance, a car manufacturer can use 5G technology to power solutions such as infotainment services and emergency call features.

5G-enabled use cases developed by SMEs will offer services in industries, such as healthcare or public safety, and these SMEs will coexist, compete or partner with larger corporations

Technology providers

Technology providers supply equipment and software solutions to all stakeholders across the ecosystem, including connectivity providers (e.g. telecommunications equipment, network virtualisation tools) or 5G enablers (SMEs developing connectivity hardware and/or software solutions).

Regarding the equipment for providing connectivity, the most active players²¹ to date in Europe have been **Ericsson, Huawei and Nokia**.

Several 5G basebands²² have already been announced and are already being integrated into devices. According to information provided by the European 5G Observatory, the most active 5G basebands manufacturers in Europe are **Qualcomm, Huawei and Samsung**, having reached agreements with several device vendors, such as **Samsung, LG, Xiaomi, OPPO, OnePlus and Motorola**.

Technology providers, as well as connectivity providers, are also coping with the increasing softwarisation, virtualisation and cloudification of networks.

²¹ Based on the number of trials and pilots reported by the European 5G Observatory: <https://5gobservatory.eu/5g-trial/major-european-5g-trials-and-pilots/>

²² Baseband processors are pieces of hardware that manage the radio functions and connect to mobile networks. See: <https://www.ericsson.com/en/news/2020/6/new-ericsson-baseband-makes-5g-easier>

The use of such networks is considered necessary for implementing 5G at scale while maintaining CapEx and OpEx efficiencies.

In this environment, initiatives such as **OpenRAN**²³ are currently gaining momentum and are forecast to have a significant transformative impact on the industry in the longer term. Such an impact can be explained primarily by the following core principles of open radio access networks (RANs)²⁴:

- ▶ **Openness:** Open interfaces are crucial to enabling vendors and operators to introduce their own services or customise the network to suit their own needs. They enable multivendor deployment, and thus a more competitive and vibrant supplier ecosystem. Similarly, open source software and hardware reference designs enable faster, more democratic and permission-less innovation.
- ▶ **Intelligence:** Networks are becoming increasingly complex with the advent of 5G, densification, and richer and more demanding applications. Hence, the network must be able to operate on its own, leveraging new learning-based technologies to automate operational network functions and reduce costs.

The above ecosystem is expected to create opportunities for smaller players, including SMEs, to innovate on certain network functions, or even particular processes and subfunctions of network operations, and to create new functionalities tailored for new use cases. Therefore, OpenRAN initiatives will allow SMEs to contribute to, and gain a piece of, the technology vendors market through their ability to compete with traditional players.

²³ OpenRAN is an ongoing project focused on developing an open ecosystem of vendor-neutral RAN solutions based on general purpose processing platforms. See: <https://telecominfraproject.com/openran/>

²⁴ These principles are outlined by the O-RAN Alliance, which was founded by operators to define requirements and help build a supply chain ecosystem to realise the objective of evolving RANs around the world. See: <https://www.o-ran.org/>

Public policy and regulatory agencies

Public policy and regulation will play a key role in shaping the upcoming roll-out of 5G. Agencies must ensure the availability of suitable spectrum, while other regulatory decisions may help or hinder the 5G roll-out. To encourage the significant investment required for deploying a dense and granular network carrying 5G services, there should be a stable and proportionate regulatory framework for all stakeholders. The return on investments in 5G-related initiatives could be longer term, so support from regulatory agencies will likely play a key role in stakeholders' decisions.

Public policy and regulation will play a key role in shaping the upcoming roll-out of 5G

Consequently, these agencies will be crucial in ensuring the smooth development of a pro-investment, competitive 5G ecosystem, as well as in addressing, within the scope of their competence, any potential barriers and obstacles facing stakeholders.

Overall, in our view, 5G regulation will have to address the following issues:

- ▶ **Release suitable spectrum** in the appropriate bands, in sufficient amounts, with the right licence conditions and at affordable prices. Spectrum assignment should follow a well-planned and transparent process, within the shortest time possible, aiming to allow connectivity providers to maintain the right balance between the spectrum fee level and their coverage obligations and innovative schemes. This will incentivise connectivity providers to also deploy 5G in areas of lower commercial priority (e.g. rural areas, certain lower-traffic transport corridors).
- ▶ **Encourage and allow infrastructure sharing**, especially in the passive layer of access networks (e.g. towers, small cells) to allow operators to reduce their deployment costs.
- ▶ **Provide access to public locations** for the deployment of 5G infrastructures (e.g. street furniture, social housing roofs), thus removing a significant hurdle to cell deployment.
- ▶ **Enable small cell deployment** by streamlining the request and approval processes for equipment installation.
- ▶ **Facilitate the deployment of fibre** transmission infrastructure, which is expensive and takes a long time to build, while right-of-way permits tend to be difficult to obtain. New entrants and mobile-only operators are

particularly disadvantaged as they have limited fibre in their networks compared with incumbents and integrated operators.

- ▶ **Ensure true cross-sectoral regulation** to future-proof coordination between the telecoms regulatory authority and other industry regulators. For example, the presence of unmanned aerial vehicles (commonly called drones) is likely to require actions from both the telecoms regulator and aviation authority.
- ▶ **Consistency of regulatory actions at EU level**, as a paramount factor for cross-border alignment to build the Digital Single Market.

These regulatory actions could produce major benefits for downstream products and applications in terms of cost reduction, easily accessible infrastructure and faster connectivity, alongside a more homogeneous landscape across countries.

Summary of main challenges for key stakeholders in the 5G era

Exhibit 2.2 summarises the most critical challenges that 5G may entail for the above-mentioned key stakeholders.

Stakeholder	Description
Civil infrastructure providers 	▶ Meet new demand with existing or new infrastructure with high efficiency and at the most affordable price ▶ Gain positioning in new infrastructure models, such as small cell solutions
Connectivity providers 	▶ Capture a potential revenue upside on top of traditional connectivity revenues ▶ Monetise investments through new services and new segments (especially in the case of enterprises) ▶ Establish the right partnerships with key stakeholders across the value chain
Service enablers 	▶ Identify the right platforms and tools to facilitate onboarding new ecosystem partners ▶ Cope with the dynamic offering, constant evolution and emergence of new services
Application and service providers 	▶ Be at the forefront of innovation ▶ Identify potential applications and services to meet connectivity demands
Technology providers 	▶ Adapt to the increasingly dynamic technological environment, including softwarisation, virtualisation and cloudification of networks

Stakeholder	Description
Public policy and regulatory agencies 	▶ Ensure the smooth development of a pro-investment, competitive 5G ecosystem ▶ Address any barriers and obstacles potentially facing stakeholders

Exhibit 2.2. Summary of main challenges for key stakeholders in the 5G era**[Source: Axon Consulting]**

2.2. Unlocking the potential of 5G

Compared with 4G-based networks, 5G brings a number of enhancements, including higher bandwidth, lower latency, enhanced reliability, higher energy efficiency and greater terminal device densities. These improvements will enable the evolution of a broad range of services and applications across various industries and verticals, such as automotive, Industry 4.0, gaming and media.²⁵ Beyond specific applications, 5G will also create new possibilities in business model design, which could result in more disruptive and transformational innovation. Exhibit 2.3 illustrates the potential impacts of 5G across a selection of key use-case clusters:

5G brings a number of enhancements that will facilitate the evolution of a broad range of applications and services across various industries

Use-case clusters (non-exhaustive)	Key 5G enabling capabilities
Real-time automation This brings autonomous applications, often mission critical, that leverage data from sensors in real time to perform specific autonomous actions. Verticals involved: Agriculture, energy & utilities, Industry 4.0, healthcare	▶ Ultralow latency will ensure real-time responsiveness. ▶ Availability and reliability of 5G will meet the requirements of being constantly connected.
Connected vehicles These involve applications to provide moving vehicles with robust nationwide connectivity services. Verticals involved: Automotive, smart city & public safety, healthcare	▶ Higher bandwidth of 5G will enable faster access to data and dynamic shifting of computing workloads. ▶ Low latency and high reliability of 5G will support advanced safety services and vehicle platooning.
AR	

²⁵ The benefits that 5G could potentially bring across various industries are explained in Annexes C.2 and C.3.

Use-case clusters (non-exhaustive)	Key 5G enabling capabilities
AR use cases involve applications that augment the live view of a real-world environment through visual and audio aids. Verticals involved: Media & entertainment, healthcare, agriculture, Industry 4.0, automotive	▶ Peak data rates and flexibility offered by 5G will support using AR in live, outdoor environments. ▶ High connection density of 5G will allow instant interaction between large numbers of devices and users to support AR implementations.
Autonomous robotics With minimal human intervention, autonomous robotics applications are based on machines/sensors that perform tasks and behave autonomously. Verticals involved: Industry 4.0, healthcare, retail	▶ High bandwidth and high speed provided by 5G will enable a smoother, safer exchange of information between the cloud, the robot, and its attached systems. ▶ Ultrareliable low-latency communication capabilities of 5G will enable the performance of robotic applications in a fluid, fast and synchronous manner.
Remote operations Remote operations comprise applications that enable remote control of machinery or vehicles from any location, under human supervision. Verticals involved: Public safety, Industry 4.0, healthcare, media & entertainment, agriculture	▶ High uplink capacity, mobility and low latency of 5G will enable equipment, machinery, devices, etc. to be controlled and managed remotely. ▶ High availability and low latency of 5G will be transformative for critical applications such as remote surgery and remote control of heavy machinery.

Exhibit 2.3. Selection of use-case clusters and the impact of 5G [Source: Axon Consulting]

With new areas of opportunity being opened by the prospect of 5G connectivity, SMEs have a potentially significant role to play, with the chance to compete with corporates head on for new niches and emerging market gaps.

This study's interviews revealed that a significant portion of SMEs see 5G as a relevant topic for their business (Exhibit 2.4).

Interviewed SMEs	Example use cases
Number of SMEs considering 5G to have significant importance for their business models 23 <i>out of 28</i>	 VR gaming  Aerial drones  Autonomous trucks  Smart parking  Haptic gloves

Exhibit 2.4. Appetite shown by interviewed SMEs for 5G-based business models [Source: Axon Consulting, based on interviews]

The technical development and adoption of 5G technology will progress in a staged manner. As with previous generations of wireless connectivity, 5G technology will coexist with and complement existing and new technologies over the years, with more complex and impactful capabilities being realised in the long term. Demand for 5G capabilities will develop alongside infrastructure and connectivity roll-out, unlocking increasingly advanced use cases as infrastructure is rolled-out and new technical capabilities are implemented. As such, it is the demand for advanced connectivity such as 5G that will grow, as companies offer ever more advanced combinations of existing and new connectivity capabilities.

5G technology will coexist with and complement existing and new technologies over the years, with more complex capabilities being realised in the long term

"5G will be a hot topic for investing in the future. Industries like automotive (for self-driven cars) or healthcare (for mission-critical remote interventions) will benefit from it and act as major pushers driving innovation to many other sectors."

– SME (5G enabler)

Most of the interviewed SMEs see strong potential benefits to their offerings from using 5G. This is well highlighted by one focal SME, which emphasised the manner in which it plans to adapt to new 5G capabilities as they become relevant (Exhibit 2.5).

Interview case study - SME		
Headquarters 	Foundation year 2014	# Employees 10–50
Vertical focus Smart City Enabler		Application group Smart city management
Company description Provides smart parking solutions to alleviate urban mobility while also optimising operational efficiencies across cities and companies. Uses an IoT platform, a network of sensors, enriched services and extensive analytics towards improving the urban-planning ecosystem.		
Key insights from the interview	▶ The company currently delivers its products with 4G-LTE connectivity in 20+ cities in Europe. ▶ They will adopt 5G in their business model when it is ready (1–2 years), as they see it can enhance their offerings or add new features.	

Exhibit 2.5. Case study on SME [Source: Axon Consulting, based on interviews]

As illustrated in Exhibit 2.6, we identify three major stages of the implementation of 5G. Starting with the current situation, advanced connectivity will begin to make an impact in existing industries and business models mainly by enhancing current operations and services. This will be followed by a stage of increasing capability and greater availability of 5G, catering for the emergence of progressively advanced 5G applications. Finally, full realisation of 5G will usher in the most complex use cases that fully utilise 5G technologies through widely deployed networks.

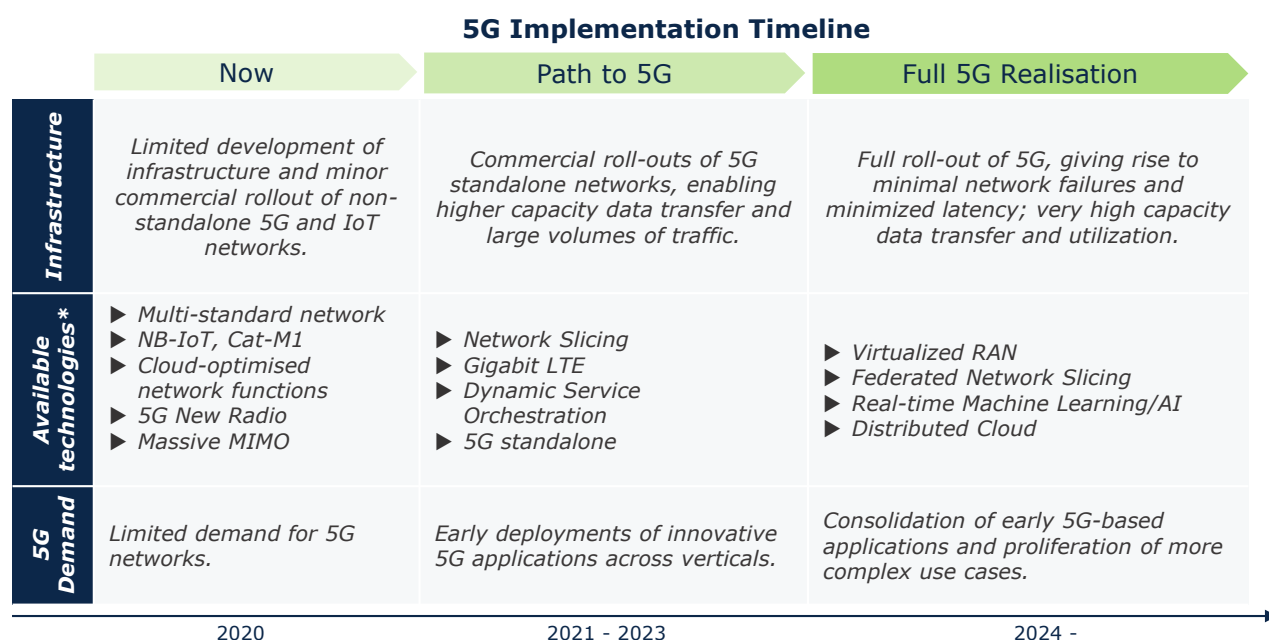


Exhibit 2.6. Implementation timeline of 5G [Source: Axon Consulting]

(*) **Note: Illustrative and non-exhaustive list.**

Europe already has a number of early-stage 5G networks up and running.²⁶

As of November 2019, 23% of European cities with a population of more than 400 000 had some form of early-stage 5G network in operation. However, other jurisdictions have achieved broader deployments of 5G networks in the same timeframe, including 56% of US cities with a population over 400 000 and 100% of cities of that size in South Korea.²⁷

As the 5G environment takes shape, use cases will progressively maximise the full capabilities of 5G, as illustrated in Exhibit 2.7.

As of November 2019, 23% of European cities with a population of more than 400 000 had some form of early-stage 5G network in operation, compared to 56% in the United States and 100% in South Korea

²⁶ According to the European 5G Observatory, at the end of 2019, 5G commercial services had been deployed in 10 EU countries.

²⁷ According to Northstream, RCRWireless and internal elaboration.

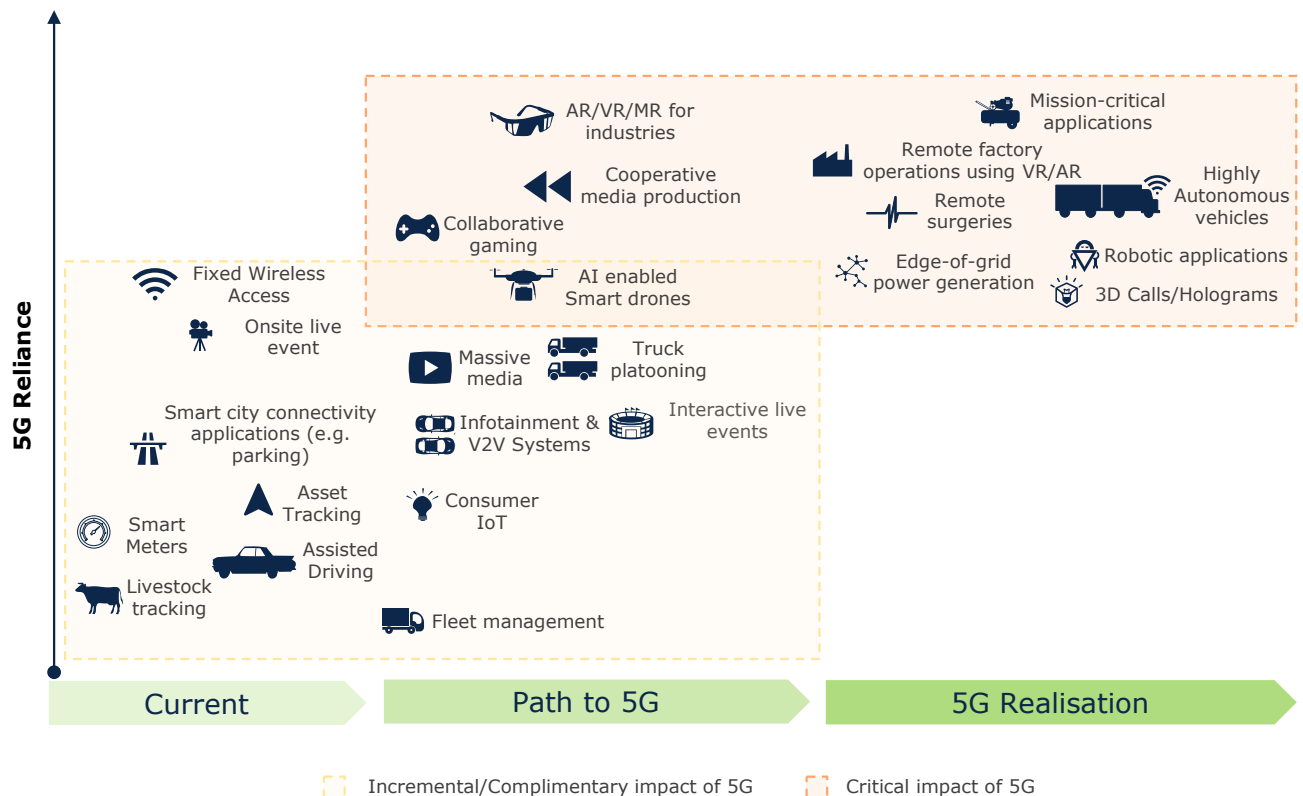


Exhibit 2.7. 5G reliance and expected timeframe of major use cases
[Source: Axon Consulting]

The rate at which advanced connectivity developments and applications occur across Europe will ultimately depend on various factors, including:

- ▶ Roll-out of networks that allow testing and realisation of new business models;
- ▶ Availability of technology supporting 5G-enhanced capabilities (notably virtualisation, slicing, latency and reliability) that enable the emergence and deployment of new use cases;
- ▶ Capacity of companies to develop new use cases and demand for their adoption.

It is important for Europe to align such factors to fully capture the economic and social opportunities presented.

The rate at which 5G innovations occur across Europe will ultimately depend on various factors

2.3. 5G innovation through European SMEs: a need to act

As outlined previously, this study focuses on the role of SMEs within the 5G and advanced-connectivity ecosystem. SMEs can become key players in defining the technologies that make 5G networks viable (enablers), as well as developing the applications and business cases that capture the benefits of advanced connectivity across European industries (service providers).

From both the supply and demand sides, we investigated the main challenges facing SMEs in accessing finance for the development of applications and business cases using new forms of advanced connectivity. Our aim was to form a set of actionable recommendations for funding models that stimulate the development of such services and business cases across Europe.

Within the 5G ecosystem, SMEs play an important role as either providers of advanced-connectivity use cases or developers of technologies that enable networks and use cases. As such, these SMEs are vital to the growth in demand for advanced connectivity within Europe.

At present, most SMEs developing advanced-connectivity technology, applications and businesses associated with 5G are at the early stage of development. Many depend on public instruments and equity investments, generally from angel investors or VC firms. Nevertheless, the prospects of current 5G-based companies are set to achieve growth phases in the future. Exhibit 2.8 illustrates the funding lifecycle and key funding phases of typical 5G-related SMEs:

This study analyses the main challenges faced by SMEs in accessing finance for the development of 5G-related applications and business cases

Most 5G-based SMEs are at the early stage of development

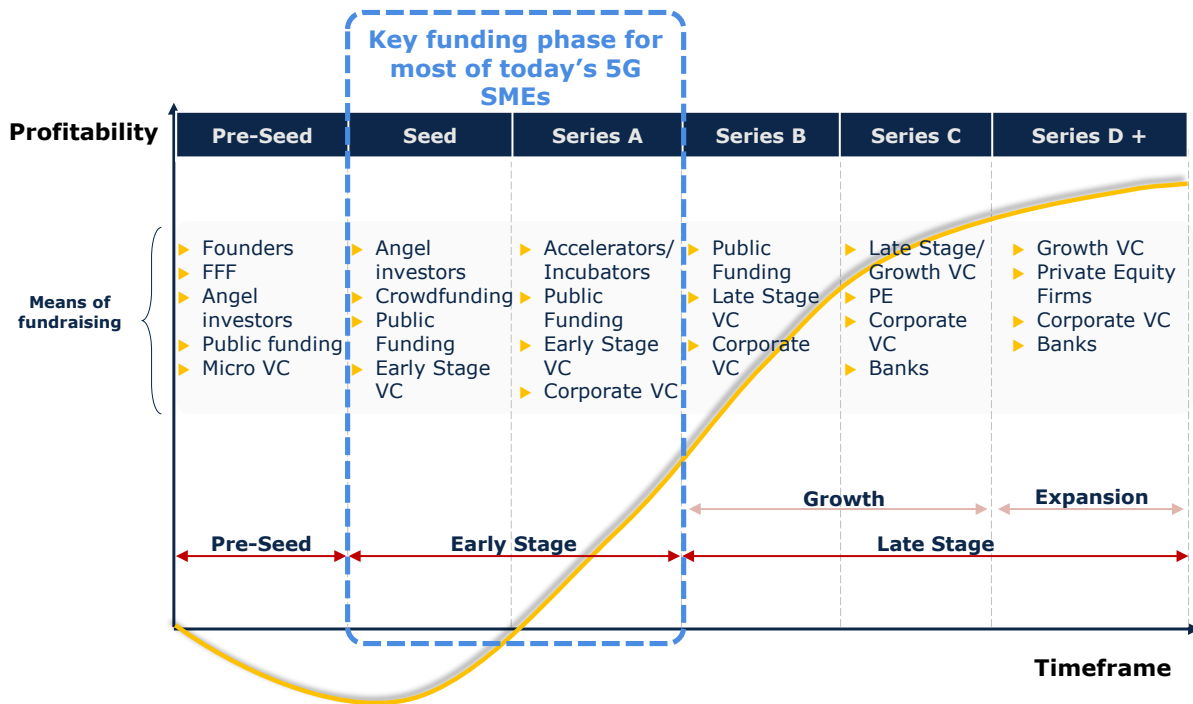


Exhibit 2.8. Funding lifecycle and key funding phase of typical 5G-based SMEs
 [Source: Axon Consulting]

For these SMEs, accessing external fundraising²⁸ from such financing mechanisms poses several challenges. Consequently, many SMEs struggle to find the correct investment to advance their projects at this especially crucial stage. Around 70% of interviewed SMEs rated their overall access to finance as very difficult or difficult. This points to a need for public help in mobilising 5G investment from the private capital market to enable Europe to compete globally.

Based on our interviews with SMEs and industry players, and through field research using investment data from key industries, we identified a funding gap for investments into SMEs using or enabling advanced connectivity, which could represent a major challenge for the evolution of 5G in Europe. The gap between supply and demand for finance of these SMEs is difficult to accurately quantify because granular information on investments in 5G-related ventures is lacking. Nevertheless, we observe a relevant gap between

The challenges faced in accessing finance leave a funding gap for investments into SMEs developing 5G-based applications and use cases, so 5G-based SMEs could be supported through early-stage equity financing

²⁸ Financing mechanisms for SMEs in Europe are explored in Annex C.4.

Europe and the United States in investment in advanced-connectivity-related SMEs that could amount to €2.5–7.2 billion annually.²⁹

According to our research and market consultation, among the multiple challenges facing SMEs, the perceived high-risk profile of advanced-connectivity-dependent businesses emerges as a current constraint on investments and capital mobilisation. The main factors that explain these SMEs' perceived risk profile are as follows:

- ▶ **Demand risk.** Novel innovations are usually prone to demand risk, since there are limited data with which to anticipate demand and perhaps even limited accessibility to the product or service.

Advanced-connectivity use cases, especially in the medium to long term, involve more complex and advanced offerings that will only be unlocked when fully fledged 5G technology becomes available. These innovations may have high potential but tend to present high demand risk because their product–market fit remains unproven and there is still uncertainty around user access to 5G capabilities. This risk could be somewhat mitigated by creating environments that support demand development, such as previous major initiatives like the 2018 trial projects of the 5G Corridor, which provides 5G networking capability along a number of highway corridors across Europe.

- ▶ **Counterparty/ecosystem risk.** Business models of advanced-connectivity use cases tend to be complex and involve multiple stakeholders. Therefore, SME development often depends on partnerships or commercial agreements with other players, which increases complexity and management costs.

Counterparty dependency in advanced-connectivity use cases can be high for several reasons. During the development phase, companies are often forced to partner with connectivity providers for research and development (R&D) purposes. Consequently, use cases depend on the roll-out of necessary infrastructure and connectivity—something that remains outside the control of most SMEs. In more advanced use cases, the nature of SMEs' offerings may also require building complex arrangements between multiple public and private parties. For example,

5G business models carry a high-risk profile with regards to investment, which poses challenges to create the right incentives

²⁹ The methodology used for this calculation is described in Annex C.5.

a smart city service such as autonomous first response would require complex arrangements between connectivity providers, hardware providers, local governments, local emergency services, hospitals, etc.

- ▶ **Technology risk.** Any advanced-connectivity use case has a technology-intensive business model and, hence, an inherent technology risk. Moreover, most use cases depend on the functionality of complementary technologies developed by other providers, such as haptic devices for VR systems. For instance, in the agricultural sector, use cases have a twofold technology dependency—on the functioning of connectivity technology and on individual sensing technologies—to add value to the agricultural process, such as through monitoring/analysis or automation.
- ▶ **Regulatory risk.** The regulatory risk for advanced-connectivity-based business models is twofold. First, the roll-out of 5G infrastructure, the backbone of the use case's connectivity provision, is highly dependent on the regulatory framework and its timely implementation (e.g. spectrum availability) within a market. Second, 5G enables many new business models across several industries that are subject to heavy regulation (e.g. aerospace, security, health). This high-level exposure to regulatory and public-policy decisions brings uncertainty on product development and commercial possibilities for many ventures. For example, autonomous driving or air mobility innovators face an uncertain demand outlook due to regulatory developments, or lack thereof, across potential end markets.
- ▶ **Fragmentation risk.** Differences in EU Member States' situation and policies towards 5G (e.g. spectrum allocation, connectivity readiness) may result in a fragmented 5G landscape as regards international operations. This can cause issues for SMEs trying to achieve scale, as accessing Member States with the same solution may be problematic. This limits commercial expansion across territories, and requires incremental costs to manage cross-country differences. It also disadvantages EU companies compared to companies operating in large single-market countries such as the United States and China.

Such a high-risk profile is accentuated by information asymmetries. The complexity of such business models and underlying technologies can be difficult to understand for generalist investors. This lack of knowledge or technological/sector understanding can limit investors' ability to evaluate the risk factors of 5G ventures such as those outlined above. Accordingly, 5G investment could be promoted through de-risking initiatives and improving communication on the technology and related opportunities.

The inherent risk profile is further accentuated due to information asymmetries

"The risks associated with early-stage investments are generally very high, perhaps higher in the case of 5G as it requires a large volume of infrastructure to be developed. In addition, many of the current start-ups are developing hardware solutions, which are even riskier due to high CapEx costs."

– VC firm

Because of the above-mentioned risks and other factors, traditional business angels and VCs have not prioritised investment in 5G and advanced-connectivity-related projects. The case study outlined in Exhibit 2.9 illustrates how 5G investments are conceived by VCs. The VC firm in question notes an apparent absence of interest in direct 5G investment over the short term because of low market visibility and the uncertainty of the value that future 5G-based use cases could bring.

As VCs tend to allocate capital to industries or business cases, rather than the underlying technology, there is room to mobilise private capital for 5G investment via an industry focus

Interview case study – VC			
Headquarters		Foundation year 1993	# Employees 1–10
Role	Venture capital	Focus	Generalist
Company description			
A VC firm that invests in hi-tech companies from Central and Eastern Europe with meaningful prospects of scaling internationally, including sectors like cybersecurity, fintech, artificial intelligence & machine learning, VR & AR and IoT.			
Key insights from the interview	▶ There is not enough expertise and visibility in the market. Consequently, this VC firm does not currently have an investment strategy for 5G. ▶ One reason they do not consider 5G as an investment topic is because the applications and their value are not yet clear.		

Exhibit 2.9. Case study on VC firm [Source: Axon Consulting, based on interviews]

According to the majority of interviewed VC investors, VCs tend to allocate capital to well-understood industries or business cases, rather than general underlying technologies. For instance, in the agricultural sector, there may be appetite to invest in IoT applications, such as crop-monitoring sensors, but this focus has little regard for the technologies that support such applications. The reported behaviour suggests there is room to leverage private VC investment towards advanced-connectivity use cases, using an industry focus to target applications and business cases associated with highly advanced wireless capabilities.

In contrast to most traditional VCs, CVCs³⁰ are showing explicit interest in investing in 5G-enabled businesses, partly for strategic reasons. CVCs usually aim to find innovations that fit within the strategy of their corporate parent, aiming to eventually integrate the technology or business model into group operations. As such, CVCs have objectives beyond those of VCs, which prioritise generating a financial return on their investments. CVCs are, therefore, less deterred by certain risk factors, making 5G a much higher priority for investment from a technological and strategic standpoint.

5G is recognised as important to corporate strategy, so corporates are showing explicit interest in 5G investments

Investing in 5G-related ventures allows corporations to increase their exposure to such innovation and familiarise themselves with its advantages. Apart from gaining exposure to the technology, corporates may also strategically prioritise expanding their geographical footprint in markets outside their regional reach. The interviews with both CVCs and European Investment Fund (EIF) representatives revealed the favourable circumstances that 5G presents to corporates to enlarge their geographical presence and position themselves as holders of cutting-edge technology. Furthermore, since these corporations tend to have, at an institutional level, a deeper, more technical understanding of 5G and its potential uses, they may face more limited information asymmetries compared to VCs.

The interviews also revealed that some CVCs are treating 5G as an explicit investment theme within their strategy. The involvement of telecom companies in this field is primarily driven by strategic incentives (e.g. incentivising the demand for services provided by telecom companies, such as connectivity) and the potential synergies from ownership of such SMEs. For example, as outlined in the exhibit below, Hubraum, the VC arm of Deutsche Telekom, is treating 5G as a key investment area, and currently has 20 SMEs involved in two 5G-focused programmes.³¹

There is space for CVCs to be actively involved within the European 5G ecosystem through key investments and partnerships

³⁰ As part of their innovation strategy, a number of corporations (e.g. telecom operators, technology providers) engage in venture capital activity, usually through specific CVC arms.

³¹ <https://www.hubraum.com/programs-hub/>

Interview case study – CVC		
Headquarters 	Foundation year 2012	# Employees 11–49
Vertical focus 5G, AI and IoT		Role Tech incubator and CVC arm
Company description A tech incubator that predominantly accelerates and invests in start-ups within the geographical footprint of its corporate parent (mostly Europe, but also Israel, the United States and Asia).		
Key insights from the interview	▶ The CVC scouts start-ups implementing solutions enabled by 5G through specific incubation programmes. ▶ They adopt an ecosystem approach instead of concentrating on specific projects, allowing SMEs to try different applications and take higher risks when innovating.	

Exhibit 2.10. Case study on CVC [Source: Axon Consulting, based on interviews]

Besides telecom companies, the wider corporate ecosystem (e.g. manufacturing, agriculture, healthcare) is also set to be affected by new and disruptive 5G use cases. Hence, corporates such as Robert Bosch³² and Daimler Technology³³ are also showing explicit interest in the 5G domain.

Due to this explicit interest from corporates, and because CVCs outside telecoms remain largely untapped, CVC and general corporate investment from wider industries can be mobilised to drive further investment in 5G

³² Qualcomm Technologies and Bosch announced in 2019 a research collaboration agreement on 5G for Industrial IoT (<https://www.qualcomm.com/news/releases/2019/02/25/qualcomm-technologies-and-bosch-announce-research-collaboration-5g-nr>).

³³ Daimler is collaborating with Telefónica and Ericsson to establish the world's first 5G mobile network for automobile production in its "Factory 56" in Sindelfingen (<https://www.daimler.com/innovation/production/5g-network-production.html>).

across industries and to scale the strategic push into 5G of key European corporates.

In addition to the private mechanisms outlined above, public funding remains important for developing and supporting SMEs from the very early stage. About 80% of the interviewed SMEs have, at some point, relied on public investments in the form of R&D grants or business plan grants, with just a small portion relying exclusively on private investment. This illustrates the critical role of this type of fundraising for start-up financing.

Public support³⁴ and financing is one of the key contributors to growing the European innovation ecosystem.³⁵ Large-scale public programmes such as Horizon 2020 (H2020) and the European Fund for Strategic Investments (EFSI)—soon to be succeeded by Horizon Europe and InvestEU, respectively—help support SMEs at different funding stages and with different financial mechanisms (e.g. grants, equity, hybrid/debt) tailored to companies' needs.

However, no specific 5G-focused programmes are currently available at the European level. Consequently, advanced-connectivity-based SMEs must rely on general innovation support programmes. Such programmes are often instrumental in allowing companies to progress through the initial stages of developing their solutions.

Receiving public funding is challenging for SMEs. For example, grant application processes may be time-consuming due to the application requirements, and awarded amounts may be too low to sustain long-term company development plans. According to interviewed SMEs, the process of receiving a grant from a public institution can take up to 18 months.³⁶ These processes also typically entail significant competition from a wide range of verticals, applications and technologies,³⁷ making pursuit of a grant a

***Although also
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European
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development of 5G-
based SMEs from
very early stage
onwards***

³⁴ The role of relevant public stakeholders, such as the 5G PPP, 5G IA and NetWorld2020, in the 5G arena is further elaborated in Annex C.1,

³⁵ Between 2014 and 2020, the European Union provided almost €80 billion in research funding. With hundreds of regional, state and European-level programmes operating simultaneously across the continent, public financing in Europe has proved essential for supporting the SME ecosystem as a whole, with governments and public institutions strongly promoting entrepreneurship.

³⁶ Particular case of an Energy & Utilities SME raising capital from Horizon 2020.

³⁷ Technologies and sub-industry groups like 5G, Fintech, IT systems or hardware manufacturers compete for the same public funds.

resource-intensive yet quite uncertain scenario for advanced-connectivity-based SMEs.

Interview case study - SME		
Headquarters 	Foundation year 2015	# Employees 1–10
Vertical focus Automotive and Mobility		Application Group C-V2X communications
Company description The company leverages and promotes software-defined radio technology for designing, developing, measuring, analysing and optimising contemporary and future radio communication technologies and networks across many industries.		
Key insights from the interview	▶ Unsuccessful in raising funds through VCs and angel investors, mostly due to three factors: limited local (Greek) market interest; requirement to produce at least two existing customer contracts; slow adoption/lack of focus on 5G. ▶ Successfully raised public grants but this was “difficult” due to the highly competitive and time-consuming nature of the process.	

Exhibit 2.11. Case study on SME [Source: Axon Consulting, based on interviews]

In summary, for advanced-connectivity-based SMEs at the early stage, both private (VC, CVC, angel investors) and public financing can be challenging to access. However, we believe that public capital could add substantial value if blended with private capital, perhaps with a specific focus on SMEs developing advanced connectivity and/or its applications. Blended finance enables a layering of private capital on top of public funding, thus extending the impact of public programmes. Promoting such coupled investments also brings further benefits from both sides: on the public side, the signalling effect of European institutions; on the private side, the incentives for mobilising capital and the expertise in efficiently managing investment portfolios.

The advantages of public and private financing mechanisms can be leveraged to help SMEs foster 5G innovation across Europe

Mobilising capital is key to driving innovation around 5G in Europe. Although it is rather premature to estimate overall 5G investment activity in Europe or internationally, other international jurisdictions are already taking important steps in that direction.

Other international jurisdictions are already taking important steps in promoting their VC/CVC ecosystem

The United States and China, which are characterised by strong **VC and private equity (PE) ecosystems**,³⁸ are already mobilising private capital for industries that can develop 5G downstream applications, such as healthcare, mobility and manufacturing.³⁹ For example, Beijing-based VC Winreal Investment has successfully raised an RMB 1 billion 5G investment fund.⁴⁰ In America, Clear Ventures has started to consider 5G in its investment thesis, and closed its \$180 million Clear Ventures II fund—focused on Industry 4.0, with 5G, Artificial Intelligence (AI) and IoT as three key focal areas—in April 2019. In Europe, as outlined in Exhibit 2.12, VCs are showing appetite for a wide range of industries that may eventually benefit from 5G, but without explicit focus on the technology to date.

³⁸ VC and CVC activity has been greater in the United States and Asia than in Europe over recent years. According to CB Insights, overall VC activity (in terms of deal value) during 2014–2018 was 5.5 times larger in the United States and 3.6 times larger in Asia, relative to Europe, while overall CVC activity was 6.1 and 2.3 times larger, respectively.

³⁹ Deloitte, “5G: Reshaping the industries,” 2018.

⁴⁰ <https://en.pingwest.com/w/5383>

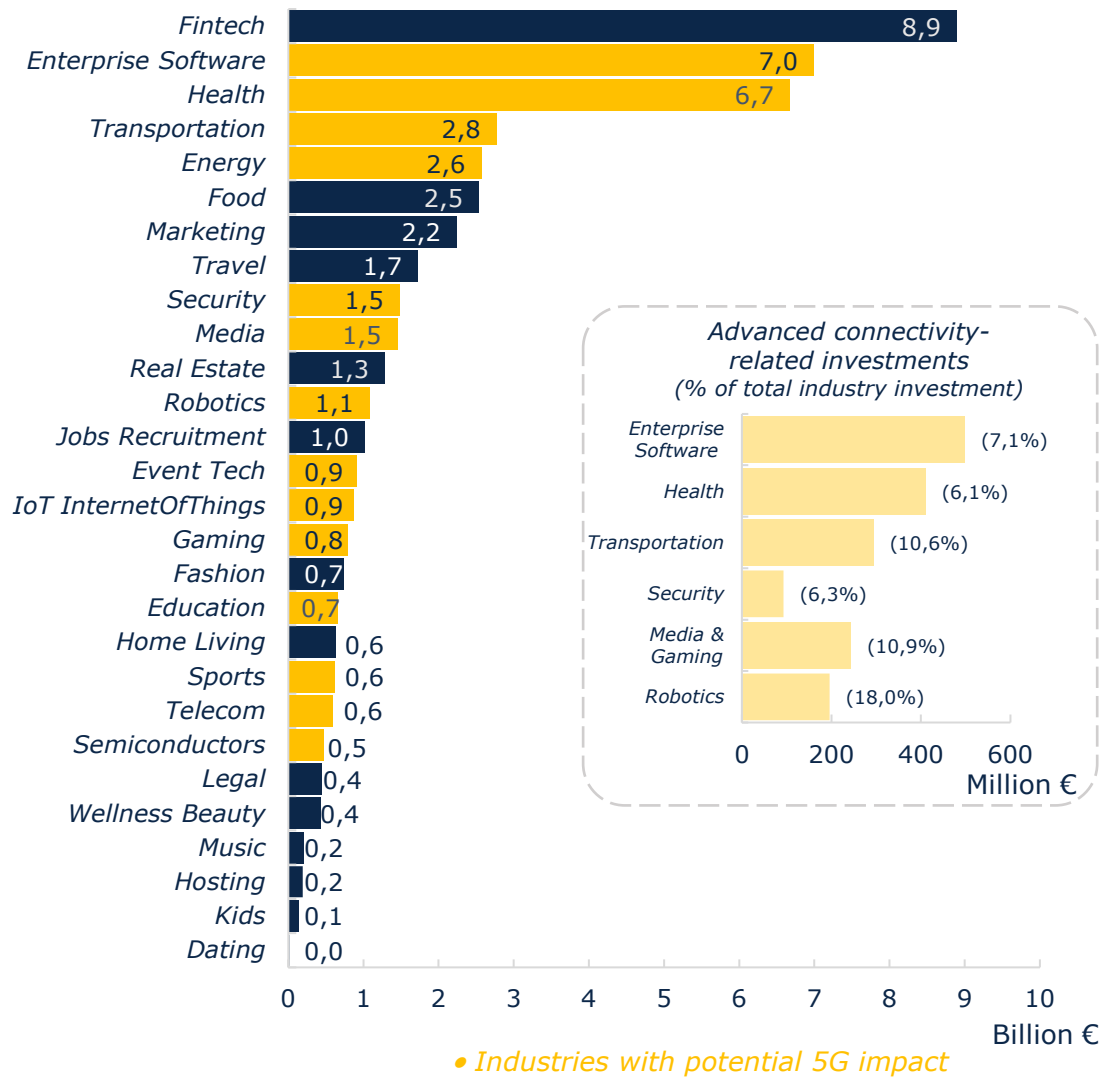


Exhibit 2.12. European VC total investments and advanced-connectivity-related investments by industry in 2019 [Source: Axon Consulting, based on information from Dealroom]

As Exhibit 2.12 shows, investments within individual industries already have some overlap with advanced-connectivity-related businesses. This indicates a potential appetite within the European VC community to invest in this kind of technologies. For example, 10.6% of investments (almost €300 million) in the transport industry are linked to advanced-connectivity-related technologies, as are 6.1% in healthcare (over €400 million) and 10.9% in media & gaming (over €150 million). These figures suggest that there is money available from European VCs for advanced technologies, that is potentially capturable through 5G innovation.

CVC activity related to 5G is also gaining traction in the international landscape. In 2019, Qualcomm announced the launch of the Qualcomm

Ventures 5G Ecosystem Fund to invest up to \$200 million.⁴¹ The fund focuses on start-ups developing new and innovative 5G use cases. In Japan, the telecommunications company KDDI has partnered with a local VC firm to establish KDDI Open Innovation Fund 3, which will invest \$186 million in innovative technologies and 5G-based businesses over a five-year period.⁴² As pointed out above, European CVCs are also showing explicit interest in 5G investments.

⁴¹ <https://www.qualcomm.com/news/releases/2019/10/24/qualcomm-launches-200m-5g-investment-fund>

⁴² <https://www.rcrwireless.com/20180406/5g/kddi-vc-fund-invest-5g-tag23>

3. Vision and way forward

While there is evidence of investment in 5G from European CVCs, and some interviewed SMEs have successfully achieved VC-backing, such successes must be amplified for Europe to realise the full potential of its 5G ecosystem. It is, therefore, important to address the financial challenges facing the private sector. Otherwise, Europe runs the risk of being left behind in the race for 5G leadership.

As SMEs will play an important role in the 5G ecosystem, Europe should seize the opportunity to devise actions and mechanisms to help SMEs make a significant impact and drive 5G innovation. This would support positioning the European Union as a global leader in 5G, leveraging its core strengths, and exploiting the opportunities this strategic technology can bring to society overall. In this scenario, mobilising both public and private resources becomes key to accelerating 5G innovation in Europe.

Europe has a number of key strengths and the necessary market structure to create a thriving 5G ecosystem. A burgeoning 5G infrastructure market comprising European technology providers, connectivity service providers, service enablers and civil infrastructure providers forms the supply side of the ecosystem. Europe's leading industries, corporates and customers and the continent's entrepreneurial environment represent clusters of high potential for 5G uptake, forming the demand side of 5G connectivity. SMEs in particular are a key stakeholder to lead innovation and competition around 5G, benefitting the ecosystem both economically and collaboratively (with other industry players), and ultimately helping to pave the way for future industries and their leading companies.

These two sides of the ecosystem are reinforced by public policy and regulatory bodies, which are helping to shape the environment through infrastructure and market initiatives. The interplay of supply and demand regarding 5G is an especially important but complex area, with each side depending on the other for viability. We consider this to be a key domain for government support to spur action or even collaboration.

Important steps have been taken in this direction by bodies such as the European Commission, Body of European Regulators for Electronic Communications (BEREC) and 5G Infrastructure Public Private Partnership

Europe should seize the opportunity to devise actions and mechanisms to help European SMEs make a significant impact and drive 5G innovation

Mobilising both private and public resources is key to accelerating 5G innovation in Europe

(5G PPP). For example, large-scale European initiatives have been implemented, such as the 5G Action Plan for Europe (5GAP), which defined a roadmap for public and private spending on 5G infrastructure across the Digital Single Market, focused on developing European 5G networks and the surrounding economy. Furthermore, the Pan-EU 5G corridors initiative was developed to foster a true 5G ecosystem for the timely roll-out and development of 5G infrastructures and services, and to create the necessary testbeds for developing new use cases. This form of pan-European cooperation around 5G development, especially between providers and users, is and will continue to be indispensable for realising a leading 5G vision in Europe.

The European Commission continues to provide extensive funding to both the supply and demand sides of the 5G environment, aiming to drive R&D and innovation across the board, while the European private capital market has the potential to complement this funding with further support. A conceptual view of the European 5G market ecosystem, gathering all the elements explored in the preceding paragraphs, is represented in Exhibit 3.1 below:

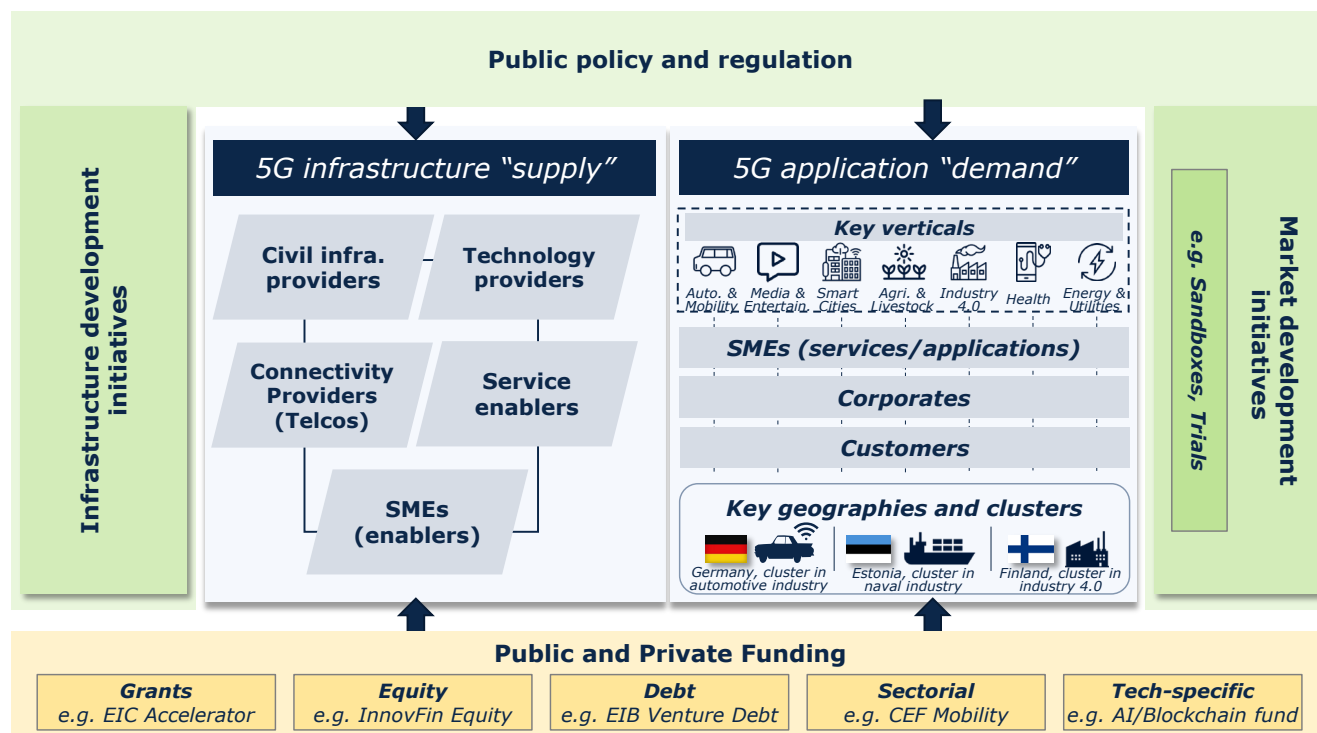


Exhibit 3.1. 5G ecosystem and vision [Source: Axon Consulting]

With all of the required ingredients for this ecosystem already present in Europe, it is essential to take the right steps to encourage the various stakeholders to engage fully in order to advocate for a promising 5G future in the Union. By stimulating the underlying ecosystem, Europe could reduce reliance on external products or services (e.g. network equipment) and increase reliance on, and support for, domestic providers. The European Commission has already taken certain steps in that direction, highlighting the critical importance of the European Union's technological sovereignty.

Europe holds the key strengths and appropriate markets to create a thriving 5G ecosystem

To achieve this objective, we have developed a set of recommendations to strengthen Europe's 5G ecosystem from the perspective of SMEs' access to finance. These recommendations are detailed in the following subsections.

3.1. Recommendation 1: Allocate public capital to support 5G

Objective: Target the funding gap in SMEs developing use cases, applications and enabling technologies by spurring financing support from several actors.

Rationale: Mobilise private capital for advanced-connectivity use cases through purpose-built public funding programmes that stimulate participation from VC, CVC and private investment.

Based on our analysis in this report, we believe there is a strong case for making strategic, public investment into the 5G ecosystem, aiming to address the identified funding gap in Europe. Public capital should be used to finance funds and investments in areas that will have the greatest overall impact on the European 5G economy. Public capital can be used to not only directly fund European R&D and SMEs but also draw private money into 5G, under a European Commission-defined scope and leveraging so-far untapped European resources such as VC, angel investors and CVC.

Public capital can be used to draw private money into 5G, leveraging so-far untapped European resources

This kind of public investment can serve as a strategic tool for the European 5G project by targeting innovation in and the development of specific industry verticals where higher impact is expected. In our view, specific factors can be used to assess the impact and/or strategic relevance of 5G within verticals under the scope of this recommendation. These factors include:

- ▶ Economic relevance of the industry, such as market potential, gross domestic product (GDP) contribution, employment rate or share of public budgets. For instance, the industrial sector should be a key contributor to economic growth in Europe.
- ▶ Propensity of the industry to adopt innovative technologies or innovations across its processes and operations. For instance, verticals already used to relying on innovative technologies (such as the automotive industry) may deliver quicker results, while those with lower levels of technology adoption (such as agriculture) may have more margin for improvement in the long term.
- ▶ Existence of entry barriers that inhibit SMEs developing applications within the industry. These can take the form of capital requirements, regulatory restrictions, existing large players, etc. For example, the healthcare industry is generally associated with high R&D expenditures and rigid regulatory requirements.

To support 5G SMEs, we recommend that the European Commission and its financing partners, such as the European Investment Bank (EIB) and EIF, allocate dedicated funding for the sector, either by adapting existing instruments to ensure their resources are deployed accordingly, or by creating new funding programmes to support advanced-connectivity-related SMEs. Specific options to achieve this operationally are summarised in Exhibit 3.2.

It is recommended that the European Commission allocate dedicated funding toward the sector, either by adapting existing instruments to ensure resources under those are deployed accordingly, or by creating new funding programmes in support of advanced connectivity-related SMEs

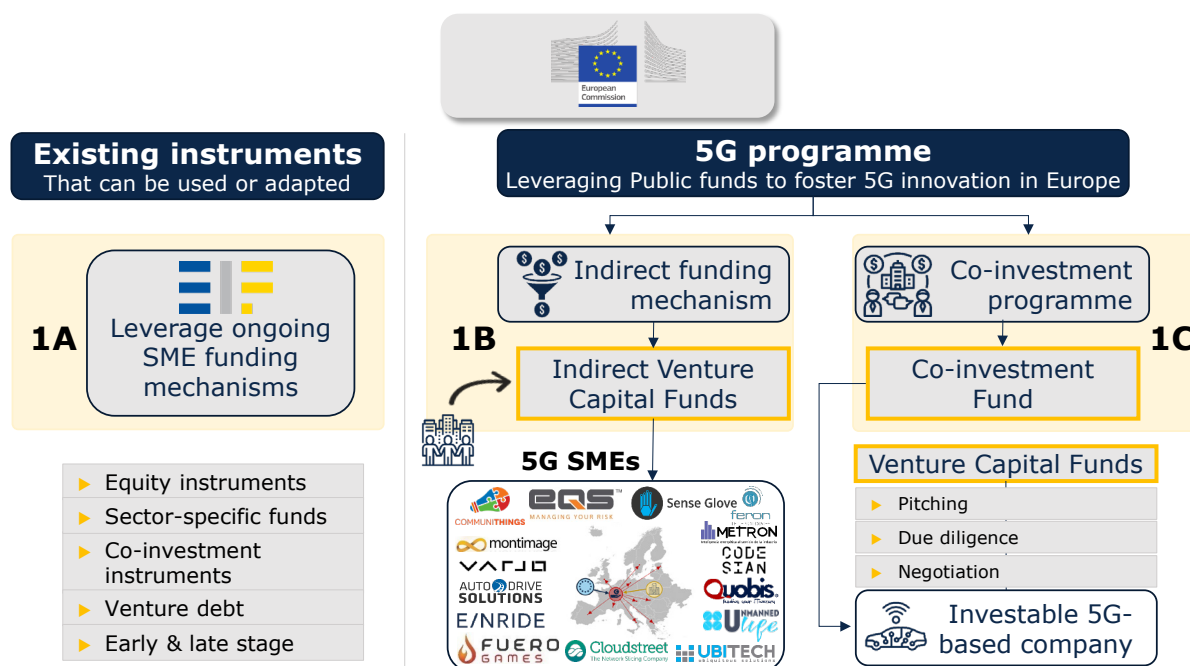


Exhibit 3.2. Scheme of Recommendation 1 and its three streams [Source: Axon Consulting]

Recommendation 1A – Repurpose existing and planned funding mandates

The European Commission provides strong support to European innovation through a number of programmes. Well-known funding instruments with successful track records can be reused or tailored, at least partially, to support European SMEs providing or enabling advanced-connectivity use cases and help them transition from pre-seed to growth stage. Reinjection of capital or more specific adaptability to 5G-related projects are two potential measures that the European Commission could undertake to leverage ongoing mechanisms and address the uncertainty of future prospects and funding gaps.

Recently, public grant programmes have successfully helped European early-stage SMEs to develop their advanced-connectivity solutions. Although there is no purely 5G-specific, pan-European grant initiative in place, existing mandates can be well suited to this purpose:

- ▶ The European Innovation Council (EIC) Accelerator (formerly the SME Instrument): Within its €0.5–2.5 million grants scheme, specific calls could be focused on advanced-connectivity applications. The EIC Accelerator is a particularly interesting mandate because, for more mature SMEs, it also offers blended finance instruments with a portion of equity to top-up the grant received. This concept may prove particularly

Well-known funding instruments with successful track records can be re-used or tailored to support European SMEs from pre-seed to growth stage

convenient for advanced-connectivity-based SMEs that are scaling towards more advanced stages.

- **InnovFin Equity:** This programme targets investment into VC funds that provide funding to H2020 sectors. As 5G was not an important theme when the H2020 framework was conceived, it was not included within the industry scope of the umbrella instrument. Therefore, tighter focus would be needed on specific industries where new enabling transversal technologies such as 5G are targeted, so as to overcome the mismatch in budget allocation.

The opinions given here apply to both the programmes in their current form and potential successor programmes (e.g. InvestEU) assumed to be consistent with current operating principles. As it may be too late to repurpose existing mandates as sector-specific, we consider that focusing on future mandates such as InvestEU, which comes into effect in 2021, will allow for better planning and an increased margin of manoeuvre. A potentially very effective strategy is to create vertical-specific products within the InvestEU umbrella that focus on advanced-connectivity solutions.

Focusing on future mandates such as InvestEU, which comes into effect in 2021, will allow planning and an increased margin of manoeuvre

There are existing programmes that aim to support SMEs within particular industries. Ongoing programmes, such as the AI/Blockchain equity pilot within InnovFin Venture Capital, could be replicated to support 5G-enabled and advanced-connectivity-based businesses.

Regarding applications, instruments such as the CEF Future Mobility Facility can support the roll-out of alternative mobility infrastructure, which may be linked to 5G. Ensuring the continuity of such a programme, and perhaps adding an explicit reference to 5G-enabled applications into its eligibility criteria, could help promote 5G-enabled clean mobility applications. Such an approach could also provide a blueprint for another funding instrument under the same mandate, targeting innovative advanced-connectivity applications within key industries.⁴³

⁴³ Apart from CEF Transport, the other late-stage mechanisms with an industry focus are CEF Telecom and CEF Energy, both also under the Connecting Europe Facility.

Furthermore, established co-investment mechanisms between individual EU Member States and the EIF, on a *pari passu* basis (same risk, same reward), have effectively boosted VC support for SMEs. Examples include the ERP-EIF Co-Investment Growth Facility,⁴⁴ partnering with the Federal Ministry for Economic Affairs and Energy (BMWi) for growth-phase companies in Germany, or the Dutch Growth Co-Investment Programme, a joint equity scheme with the Netherlands Investing Agency for SMEs beyond the start-up stage. Both instruments can potentially be adapted to providing funding for advanced-connectivity projects. However, refocusing would be needed to position the programme to support only SMEs yet to reach the expansion stages.

Established co-investment mechanisms between individual EU countries and the EIF, on a *pari passu* basis (same risk, same reward), have also demonstrated their effectiveness in boosting VC support for SMEs

Although most SMEs developing solutions enabled by advanced connectivity are at the early stage, some are starting to evolve towards more developed and robust business models, and many more will do so in the medium to long term. The EIB Group actively supports businesses scaling up towards the late stage via venture debt products guaranteed by the EFSI,⁴⁵ which has proven to be an effective funding instrument for many high-growth innovative businesses, including in the ICT sector. This mainly generalist programme, or its successor, would likely need commensurate budget resources and the definition of specific policy priorities favouring 5G SMEs to achieve the stated objective.

Recommendation 1B – Launch an indirect funding programme mobilising VC and corporate investment

Another potential means to support European SMEs developing 5G-based applications could be the creation of an **indirect investment mechanism**, focused on overcoming the challenges in access to finance for these SMEs.

⁴⁴ ERP: European Recovery Programme.

⁴⁵ European Fund for Strategic Investments.

As illustrated in Exhibit 3.3, the new mechanism would focus on making targeted investments into **VC funds** that provide funding to **early-stage** SMEs utilising **advanced connectivity** within one or more identified, **relevant industries**. Funds can, therefore, be thematic, based on an EIF-determined scope, for example covering different industries or subject to other targeting criteria. The programme could also require participating VCs to tie **corporate participation** to the programme as a potential requisite for each individual fund as limited partners.

The programme will allow the European Commission to indirectly target key 5G impacted industries while also mobilising two key supporting actors of the 5G ecosystem

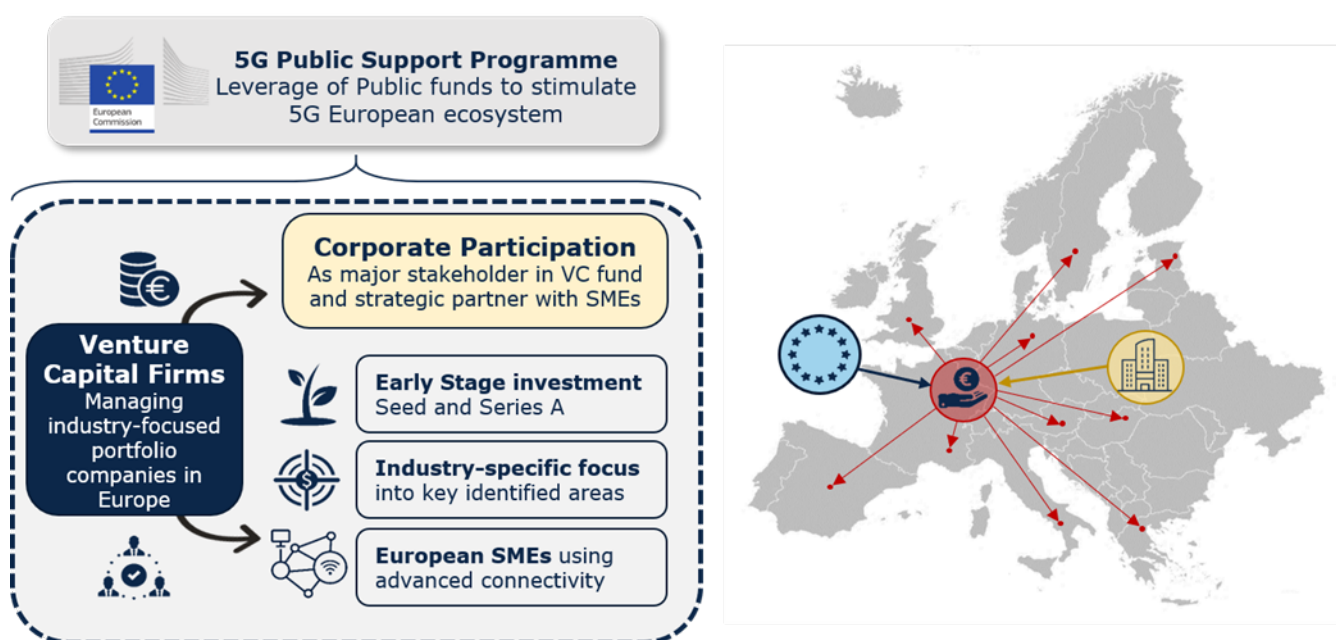


Exhibit 3.3. 5G public indirect programme structure and participants
[Source: Axon Consulting]

To encourage 5G-related private investment, we believe it might be beneficial for the programme to target **VC firms** within Europe, incentivising them to invest in key areas that can spur the evolution of European 5G. Independent VCs are generally able to identify better investment opportunities by selecting the best companies from a financial standpoint, and are strong stakeholders to bring into the 5G ecosystem and drive investment into the best SMEs.

"The best stimulus for the market would be to provide more capital through VCs as they are a lot more efficient. The role of public institutions is hence vital, as they should give the funds to the right VCs who can inject capital into the right companies."

– Corporate finance expert

Most SMEs developing advanced-connectivity solutions are currently at the early stage. This fact supports the proposition that the programme should **focus on early-stage (seed, Series A)** investments, paying due to the greater current demand for capital from this segment. It would also allow the support of a larger number of projects due to the lower average ticket sizes and capital needs in the early stages of company developments. However, such a programme should be created with a potential to support later stage investments in the future once the 5G evolution is further underway, helping to target the late-stage funding gap for SMEs that have progressed further.

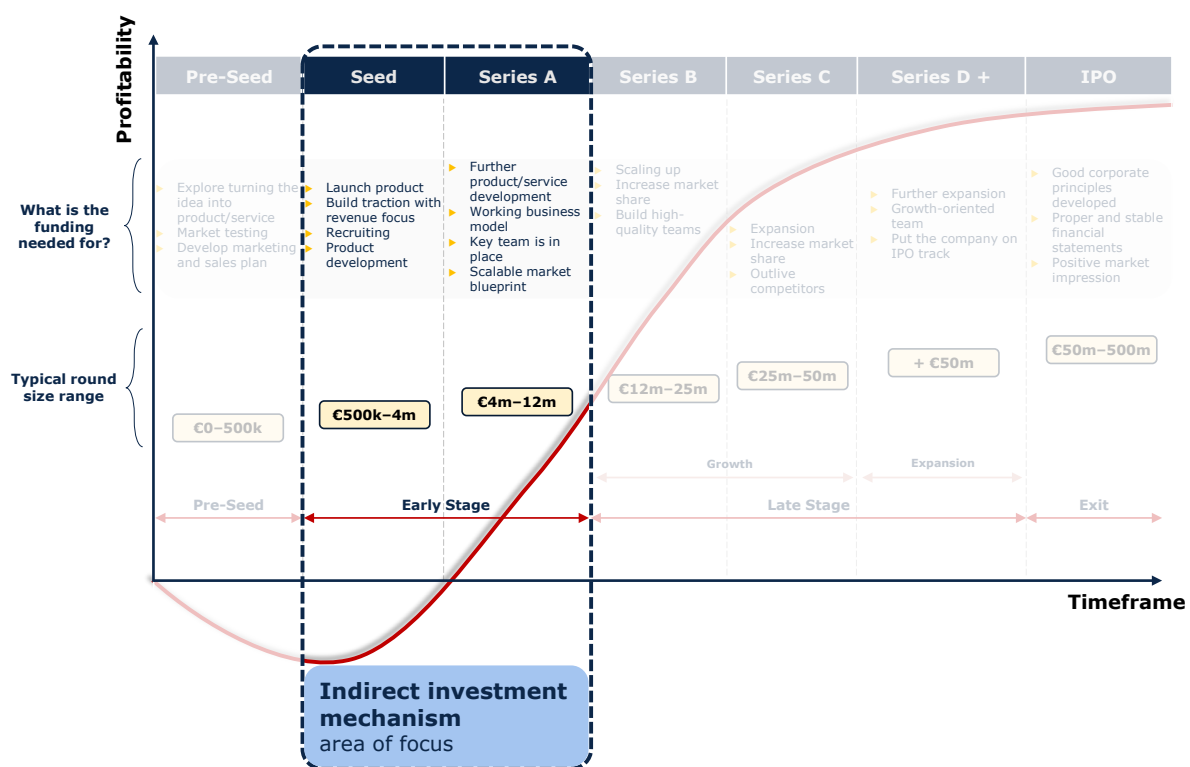


Exhibit 3.4. Indirect investment programme entry point in the lifecycle chart

[Source: Axon Consulting]

We consider that bringing in corporates as lead investors or anchors would add significant value, experience and confidence, thus encouraging other private investors to participate in the selected funds. This would also unlock an extra source of private capital. Apart from gaining exposure to the

technology, corporates will benefit from greater geographical presence in markets outside their regional reach, coupled with appealing fund conditions. We believe that such actions would also allow the European Commission to indirectly target strategic industries while engaging VCs and leveraging corporates / industry players to support them, thereby mobilising two key players in the 5G ecosystem.

"There is not enough money in venture capital alone. As such, corporates should be encouraged to initiate programmes using their venture arms, especially with regards to late-stage funding, or should bolster VC funds by investing in them, as 5G requires much more capital compared to other technologies."

– VC firm

Much like the EIF's current activity, the indirect funding mechanism would serve as a **fund-of-VC-funds with a multisector focus**, supporting funds focused on individual industries. Such a mechanism could incentivise private fund managers to take a more active, 5G-focused role by providing public capital as an anchor investment. Additionally, to increase participation and mobilise another area of private capital, it would be beneficial to structure the programme to direct corporate investment into individual funds. We therefore recommend that the programme requires the VC fund manager to include one or more sector-focused corporate investors to match the proposed public investment. The fund's remaining capital requirements could be met by other private investors (e.g. institutional investors, pension funds, family offices), providing an overall leverage on public capital of, for example, 1:2. Thus, public money can be invested into early-stage 5G and advanced-connectivity-related projects, while incentivising private capital and expertise to follow.

The main mechanisms for the proposed programme are summarised in Exhibit 3.5.

Overview of programme mechanics with illustrative figures	
	Programme makes investments into a VC-led fund at, for example, ~33% of total fund size, with an upper investment limit (e.g. €20–35m); 20–40% is the necessary leverage to attract corporates to the fund.
	One or several corporate anchors are required to contribute 20–40% to a fund. The fund is attractive to corporates for R&D and innovation, for expanding geographical presence and increasing exposure to other VCs outside the local market. However, the investment may also provide extra incentives for their participation.
	VCs must raise the remaining funding required with their own or private investment , therefore providing the remaining share (e.g. ~33%) of total fund size. The public and corporate anchors make the fund attractive to investors.
	Funds invest predominantly in early-stage companies focused on advanced-connectivity applications.
	Funds can be “thematic,” covering a specific, or multiple, predefined industries, with the tied corporate anchor having a strategic interest in the fund theme.
	The programme must make investments into multiple funds to cover all predefined, 5G-impacted industry verticals.

Exhibit 3.5. Key details of indirect investment mechanism [Source: Axon Consulting]

The suggested equity product could explore using a sector-specific, rather than technology-specific, focus and would require corporate participation in the target funds. Because greater private participation would be required in these funds (through corporates and private investment), certain thresholds would be slightly lower than in the InnovFin product: for example, maximum share per fund participant at around 40%, rather than 50%. Moreover, assuming a similar overall fund size, maximum programme investment for the recommended programme would be around €20–35 million, compared to €50 million for InnovFin equity. Exhibit 3.6 shows commonalities and differences between the proposed mechanism and the general InnovFin approach to investment:

Indirect Investment Approach	Feature	General InnovFin Equity Approach
Highly innovative European SMEs	Target company beneficiary	Highly innovative European SMEs
5G and advanced-connectivity applications	Areas of focus	ICT, Life Science, Clean Energy Technology, etc.
Multisector pan-EU	Geographical focus	Generic pan-EU
€20–35m	Maximum investment	€50m
~33% of total commitments	European Commission/EIF share	~25% of total commitments
40%	Maximum share per fund participant	50%
Acting as fund manager / general partner	VC engagement	Acting as fund manager / general partner
One or more, 20–40% of total commitment as limited partners	Corporate engagement	No engagement
5–15 years	Investment timeframe	5–15 years

Exhibit 3.6. Suggested investment programme contrasted with InnovFin Equity
[Source: Axon Consulting]

Extra incentives may be required to encourage corporates to participate as lead investors or anchors in the selected funds. One potential approach is to offer the corporates, and other non-public investors, an option to buy out the public body within a predefined time window (e.g. five years of fund establishment) and at a fixed price set in terms of internal rate of return (IRR; e.g. 10%). Such and other similar incentives are already used by development banks and other public institutions around Europe, such as Fond-ICO in Spain.⁴⁶ The foreseen incentives architecture is represented in Exhibit 3.7:

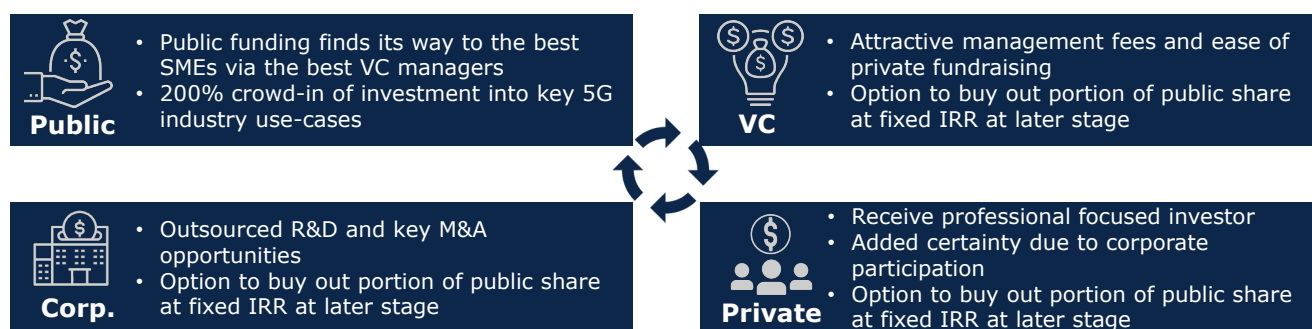


Exhibit 3.7. Incentives scheme for the indirect funding mechanism
[Source: Axon Consulting]

In summary, we believe that such an initiative will facilitate the engagement of several key actors in the 5G ecosystem: VC and private investment from the financial side, and corporates and SMEs from the 5G demand side. It is worth remembering that corporates are attracted not only by the potential financial returns but also by greater exposure to technology and increased presence in other regions. Additionally, there should be flexibility in the total commitment ratio between corporates, EIF and private investors, so as to optimally align interests. This instrument might help drive demand for 5G by requiring private investors to commit up to, for instance, 200% of the public investment amount of each individual fund, depending on the finalised programme structure.

Recommendation 1C – Develop a 5G-focused co-investment platform for VC Funds

We also consider that a dedicated 5G co-investment platform, prioritising ease-of-use, would be another highly effective way to leverage public

⁴⁶ Fond-ICO Global, the first Spanish fund-of-funds, invests in companies at all stages of development, focusing especially on early-stage investment and innovation. In its 13th call, it invested €329 million in 15 qualified VC funds (out of 40 applicants), which are committed to reinvesting €1,220 million in Spanish SMEs.

investment with private capital. By entrusting private investors with deal sourcing, negotiation and execution and by co-investing, *pari passu*, with them, public capital can be used to create extra dealmaking possibilities from larger investments, where necessary by giving public support to prequalified VCs. This, in turn makes larger tickets in advanced-connectivity-based SMEs more attractive for VCs.

The programmes mentioned above, such as the ERP-EIF Co-investment Growth Facility and the Dutch Growth Co-investment Programme, highlight the potential of such an approach. Based on these existing programmes, the details of the recommended co-investment platform are given in Exhibit 3.8.

Details of the co-investment platform		
 A qualified third-party VC identifies an opportunity benefitting from advanced connectivity ▶ An independent VC firm applies for the co-investment programme ▶ If requirements are met -> prequalified status ▶ VC finds investment opportunity in an advanced-connectivity-based SME and negotiates the potential deal	 Execution of the public-private agreement, incentivising VCs to pursue similar deals ▶ Prequalified VC fund submits a request for the public body to co-invest <i>pari passu</i> ▶ Prequalified VC can receive fast approval once the opportunity is reviewed ▶ VC receives full control, management fees on the co-invested amount, and carried interest on exits, if applicable	 Three beneficiaries of the co-investment fund ▶ The target SME, which receives the full funding amount from a joint public-private source ▶ The VC, which increases its assets under management and has a partner to de-risk the individual investment ▶ The public body, which boosts the 5G ecosystem by leveraging its investment with private capital

Exhibit 3.8. Overview of the co-investment programme [Source: Axon Consulting]

A co-investment platform will not be actively engaged in company management, which is instead entrusted to the private partner/s, who will be able to maintain control of larger investments by acquiring larger stakes in advanced-connectivity-based SMEs for less capital, sharing the risk for individual investments. This creates an attractive incentive and stimulus for VCs to carefully evaluate opportunities driven by advanced connectivity. Using the example of an SME looking to raise a €10 million Series B round,

The co-investment platform creates an attractive incentive and stimulus for VCs to evaluate opportunities driven by advanced connectivity

an individual VC may be unable or unwilling to invest the entire amount, or unable to find other private investors that can add value. Instead, the VC may offer a co-investment opportunity to the public body while retaining control and charging an extra management fee.

Similar to the proposed approach, current EIF practice involves co-investments with VC funds in which the EIF is already an investor and a relationship of trust has been nurtured over the years, with a common vision and strong alignment of interests. Normally, the EIF makes a 1-to-1 matching contribution with the VC into the target company/ies, although the ratio is always set on a case-by-case basis. Additionally, the EIF avoids co-investment opportunities that may, in any way, artificially affect the performance of the fund or a given investment. Overall, the process can be rather quick, with the entire EIF-VC-investment operation accomplished in 40–60 days. Exhibit 3.9 showcases two examples of on-going co-investment programmes in Europe:

Case studies of active co-investment programmes in Europe	
ERP-EIF Co-Investment Growth Facility	Launched in 2016 to boost VC support for growth-phase SMEs and mid-caps in Germany, the facility provides qualified fund managers with co-investment pockets of €20–60 million across an investment period running until 31 December 2021. It is a €500m equity scheme, funded with €330m from the BMWi, on behalf of the ERP, and €170 million from the EIF.
Dutch Growth Co-Investment Programme	A €100m equity co-investment instrument managed by the EIF and developed in partnership with the Netherlands Investment Agency, contributing 50% each. Launched in fall 2017, the programme aims to provide support to SMEs and small-caps with a strong growth profile in the Netherlands. The programme offers co-investment funding to fund managers with an established relationship with the EIF.

Exhibit 3.9. Existing co-investment mandates in Europe
[Source: Axon Consulting, based on public information]

To increase the efficiency of the suggested co-investment programme, we propose a fund prequalification approach. Deal-by-deal evaluation of co-investment opportunities is time-consuming and labour-intensive, so we suggest that the fund should be evaluated instead. By creating fund prequalification criteria and an open tender for VCs to participate in the platform, the public body will be able to identify the best partners and offer them quick deal-by-deal execution. As such, the selected co-investment partners will be able to request co-investment in an advanced-connectivity-driven SME via a simplified process, thus significantly reducing execution time and risk for VC investors working with the public body. We believe that such ease-of-use will further increase the platform's attractiveness for participating VCs.

To further encourage private participation in the co-investment platform, the implied control incentive may be complemented by other tools. One such tool is return enhancement through capped public returns. For example, a capped IRR of 8% would allow the manager and other limited partners to benefit from excess return while still providing sufficient return to the public body. Another possible tool is downside-protection measures, whereby the public body takes the first loss where the investment loses value. Both tools may prove highly effective in encouraging VCs to participate in the platform. However, the exact approach should be defined consensually with potential participants during platform formation.

Overview of recommendations in the funding lifecycle

As illustrated in Exhibit 3.10, the proposed funding mechanisms mainly affect SMEs in the early stage but can also be repurposed to support late-stage SMEs in the medium to long term. The chart also shows a non-exhaustive sample of existing programmes and their stage of action.

As a solution to increase the efficiency of the suggested co-investment programme, we propose a Fund Prequalification Approach. This form of "ease-of-use" will further increase the attractiveness of the platform for participating VCs

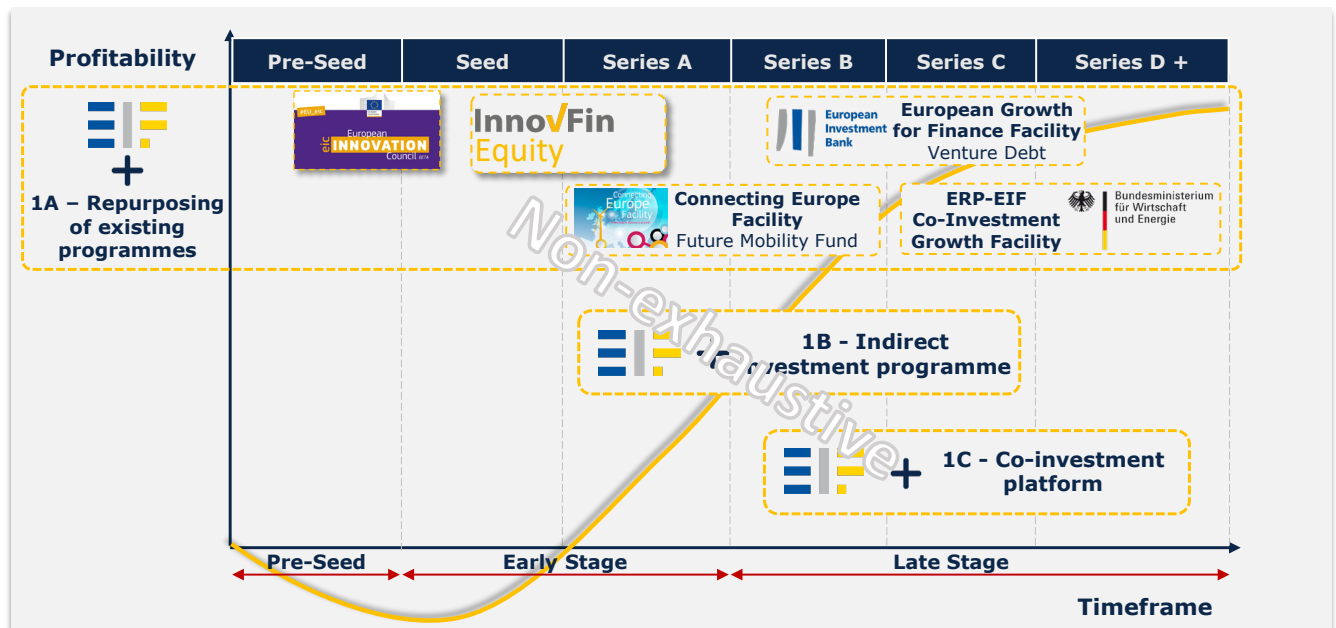


Exhibit 3.10. Overview of Recommendation 1 actions in the funding lifecycle
 [Source: Axon Consulting]

3.2. Recommendation 2: Introduce non-financial means of supporting early-stage activity through public-private initiatives

Objective: Target very-early-stage SME development through engagements with various actors in the ecosystem.

Rationale: Using key areas of exchange between 5G supply and demand, such as sandboxes, to accommodate interaction between various stakeholders, including financial actors and corporate customers.

To address another part of the funding gap, very-early-stage (pre-seed/seed) SMEs can also be supported through special initiatives. In our opinion, the European Commission has the opportunity to leverage corporate players as relevant partners contributing more than investment to the advanced-connectivity SME ecosystem. Public-private initiatives can be used to provide development and investment opportunities for 5G and advanced-connectivity projects. Exhibit 3.11 below shows the general approach of Recommendation 2:

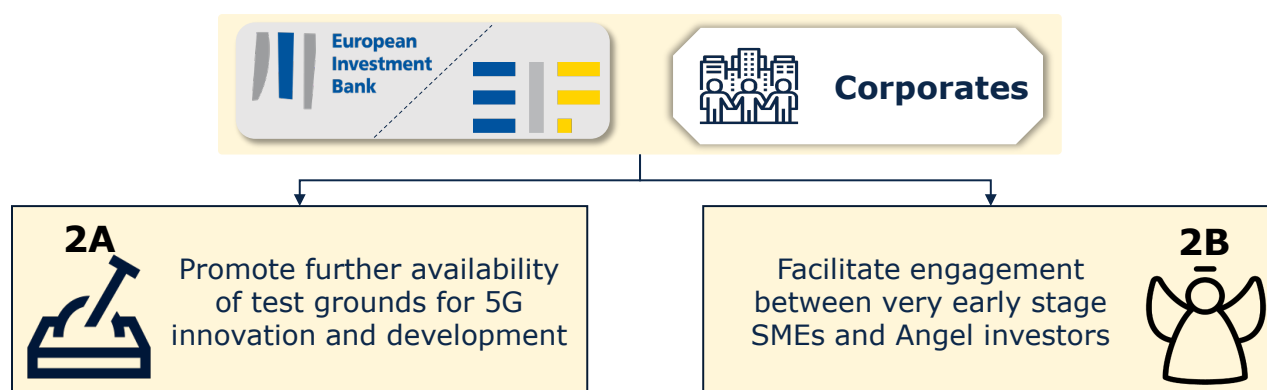


Exhibit 3.11. Scheme of Recommendation 2 [Source: Axon Consulting]

Recommendation 2A – Promote further availability of test grounds for 5G innovation and development

Sandboxes serve as areas of shared interest between various stakeholders in technology development, and thus support engagement between the supply and demand sides of the 5G ecosystem. They allow parallel testing of equipment, processes/systems and proof-of-concepts, and demonstrations of technical innovations. This, in turn, allows fast prototyping, development and proofing of technology, and also provides favourable conditions for collaboration, demonstration and open innovation.

In Europe, much work has been devoted to innovation hubs and regulatory sandboxes as sites where 5G development and innovation can take place. Projects such as the H2020-financed 5G-VINNI (Verticals Innovation Infrastructure) in Norway, the 5G-PPP-backed 5Growth in Spain and 5G-EVE (European Validation platform for Extensive trials) in Italy, and the 5GTNF (Test Network Finland) are facilities that cater for multistakeholder technology and/or use case development for 5G.

In our view, it would be beneficial to pursue mechanisms for increasing the availability of facilities such as sandboxes in which multiple players can interact on current developments of 5G and related technologies.

Specifically, it is important that SMEs can interact in this regard with other players, including investors.

We recommend exploring mechanisms such as funded programmes between private and public bodies to create and run testbeds. Furthermore, multiple actors in the 5G ecosystem (e.g. SMEs, corporates, investors, policymakers) should be encouraged to collaborate in technology-focused development programmes.

Sandboxes serve as areas of shared interest between various stakeholders in technology development, and thus support engagement between the supply and demand sides of the 5G ecosystem

Alternatively, or in parallel to such an initiative, the promotion and use of existing testbeds outside government-led programmes can be explored as a means to facilitate engaging players from both the supply and demand sides of 5G, and also supporting financial actors (e.g. angel investors).

Recommendation 2B – Facilitate engagement between very-early-stage SMEs and angel investors

Very-early-stage (pre-seed/seed) SMEs will most likely not qualify for the equity products presented in Recommendations 1B and 1C. However, companies at this stage also form part of the identified funding gap, so steps should be taken to address their funding needs in parallel with those of early-stage SMEs.

Beyond public grants, very-early-stage SMEs are often supported by angel investors, who provide early equity financing. In this respect, the European Commission might be well placed to encourage interaction between young, advanced-connectivity-based SMEs and angel investors, and to break down barriers between these two types of actors in the ecosystem. This can be done through funding-based and non-funding-based initiatives.

We suggest organising events such as demonstrations to bring together angel investors and very-early-stage advanced-connectivity-based SMEs in interactions such as demonstrations. This will serve to educate angel investors on the potential impact of 5G within industries from an investment perspective, while also boosting their understanding of advanced-connectivity-based technologies. This approach can be combined with the sandbox initiative highlighted in Recommendation 2A.

This initiative can potentially be complemented by funded schemes that increase the attractiveness to angel investors of investing into such projects. The most straightforward example of such a funding mechanism would be a small co-investment platform, similar in shape to that described in Recommendation 1C, that provides de-risking for investors but without prequalification. Such a mechanism would provide smaller degrees of investment matching for angels' investments (less than 1-to-1 contribution) but require more work from the public body in evaluating whether each investment qualifies.

The European Commission might be well placed to encourage interaction between young, advanced-connectivity-based SMEs and angel investors, and to break down barriers between these two types of actors

This initiative can potentially be complemented by funded schemes that increase the attractiveness to angel investors of investing into such projects

3.3. Recommendation 3: Overcome information asymmetry around 5G

Objective: Improve clarity, understanding and awareness around 5G for both the supply and demand sides to achieve prosperous business interactions.

Rationale: Rolling out industry events, using digital materials and creating a searchable database to spread information about advanced connectivity for SMEs and investors.

A key issue hindering investment in and adoption of 5G is information asymmetry. The limited understanding of investors and industry players leads to an elevated perception of risk in 5G investments and to a slower uptake of advanced-connectivity-based solutions in industry. Furthermore, limited understanding of financing options and the best ways to secure them causes entrepreneurs to miss out on optimal ways to fund their developments. We therefore recommend that actions be taken at the European level to reduce this knowledge gap.

A key issue hindering investment in and adoption of 5G is information asymmetry

Recommendation 3A – 5G Monitor: Disseminate information around 5G and advanced-connectivity-enabled business cases and potential impact

It is crucial that Europe promotes educational initiatives to reduce knowledge barriers and facilitate understanding of 5G. From an investor perspective, these initiatives should serve to reduce the disproportionate risk perception resulting from low understanding of advanced-connectivity technologies and/or their implementation. This obstacle was reported to have discouraged potential investments in 44% of the interviewed SMEs. By raising awareness of the technical and business-case aspects of 5G applications, this gap in investor knowledge might be reduced, leading to superior decisionmaking. From an industry-adoption perspective, these initiatives should serve to increase confidence in the industry impact and time-to-adoption of 5G.

From an investor perspective, these initiatives should serve to reduce the disproportionate risk perception caused by limited understanding of 5G

"I see a generalised educational barrier regarding 5G knowledge. Many investors are simply not convinced that the need for 5G exists now. It does not help that when we dig deep into SMEs, most companies have not developed a study on whether they really need 5G or not."

– 5G technology expert

Since broader industries, rather than the technology itself, should be the focus of engagement around advanced connectivity, we believe that industry-focused events should be created to discuss the impact and importance of 5G within specific industries. These events could coincide with initiatives such as the angel-investor event in Recommendation 2B.

It is also our opinion that digital materials such as blogs, podcasts, and articles could be used to spread information on the 5G future within multiple industries through industry-specific and other key channels. This information could include the potential of advanced-connectivity-enabled business cases and the work being done to support companies developing such solutions. We consider that such actions will help by educating potential investors and connectivity-reliant SMEs, and by providing extra confidence and guidance to the market, which could encourage a further increase in participation from private investors.

To help investors understand 5G technology and its opportunities and shortcomings, they could be targeted by a tailored information campaign comprising technical articles, short videos, case studies and the contact details of experts in the field. Advisory networks may also be useful in this regard, whereby 5G technical and/or investment experts can provide support to European investors through an EU-pioneered initiative. Targeting investors specifically would help alleviate some of their difficulties in understanding the underlying technology and relevance of 5G, thereby also lowering their reluctance to invest.

Developments from other initiatives, such as sandboxes and testbeds, could also be used to offer insights into industry effects and timelines.

From an industry-adoption perspective, the initiatives should serve to increase confidence in the industry impact and time-to-adoption of 5G

Recommendation 3B - Provide clarity on financing options through advisory services

Many SMEs and investors alike lack vital information about the financing opportunities within the 5G ecosystem. A further asymmetry we observed within the 5G industry is SMEs' lack of understanding of how to create financeable projects and deals. We see an opportunity to create a more active and streamlined VC-SME ecosystem around advanced connectivity by targeting these knowledge gaps.

We believe that consolidating access-to-finance information and advice into a single resource will improve transparency in the market and provide an early opportunity to productively connect capital seekers and providers. For example, the European Commission could use existing and new digital spaces to create information hubs for SMEs to identify relevant public programmes and private investor networks, and learn how to access such funding.

Platforms such as the European 5G Observatory⁴⁷ already contain extensive information on the technical development of 5G technology. However, financing aspects affecting 5G-based SMEs and their development are not comprehensively covered on this platform. Digital innovation hubs that help companies to better understand financial/commercial challenges may also be viable forums for providing access-to-finance information and advice. The information should include the typical financing stages of high-risk ICT projects and the role of specific public programmes in the project lifecycle.

We also recommend creating a database-style portal to combine financial and business-model information from start-ups and investment funds. Such a platform would give investors relevant data on SMEs, acting as a searchable database of investment opportunities. This would offer transparency regarding existing and future financial instruments, thus benefitting SMEs and investors.

The platform could also be extended to incorporate some of the activities included in Recommendation 3A, and could be used to particularly focus on transparency around initiatives such as those of Recommendation 1. This

The European Commission could use existing and new digital spaces to create information hubs for SMEs to identify relevant public programmes and private investor networks, and learn how to access such funding

A database-style portal could be created to combine financial and business-model information

⁴⁷ www.5gobservatory.eu

would allow investors and SMEs to find definitive information on how engage to with and benefit from such initiatives.

3.4. Recommendation 4: Reduce cross-border challenges by promoting homogeneity and standardisation

Objective: Ensure a homogeneous landscape that enables the scalability of 5G businesses across Europe.

Rationale: Strengthen policies and cross-sectoral regulations to be future-oriented, pro-investment and pro-innovation.

Active support in additional public policies and regulations to promote further digital homogeneity across EU Member States is recognised as essential to achieve the desired future outcome of the European Union becoming a reference in 5G.

In particular, to facilitate the adoption of 5G across Europe, the European Commission and Member States must coordinate even further and encourage the unification and homogenisation of the various technical and regulatory ecosystems spread across Europe, aiming to address the challenges noted by SMEs and investors alike.

Although the European Commission has taken significant steps towards creating a unified Europe from a digital perspective (the Digital Single Market), we believe there is still room to strengthen existing regulations and policies. Areas such as rights of way (to enable faster deployment of new sites, notably small cells) and infrastructure sharing are domains for which homogeneous policies can go a long way towards fostering 5G development throughout the European Union.

Areas such as spectrum allocation, rights of way, infrastructure sharing regulations, among others, are points where homogeneous policies can go a long way towards fostering 5G development throughout the EU

"The regulatory aspect, although strict in the field of spectrum allocation in Europe, should not serve as a pretext for 'doing nothing.' At a non-economic level, efforts to find talent trained in 5G should be made. In the end, we must move away from short-termism and foster in-house investments to help bridge the market fragmentation to benefit us all."

– Serial tech entrepreneur and 5G expert

Because a wide range of industries will be impacted by 5G, ensuring true cross-sectoral policy and regulation becomes essential. Such policies and regulations must be future-oriented, pro-investment and pro-innovation, and they have to embrace all relevant stakeholders. For example, with autonomous cars and unmanned drone flights on the horizon, policymakers have an opportunity to create homogeneity from an early stage with respect to health & safety and commercial regulation. Such activity will serve to future-proof the European Union with regards to the transformational changes brought by 5G in the medium to long term.

3.5. Indicative timeline for the proposed recommendations

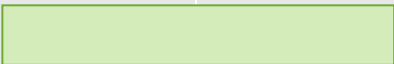
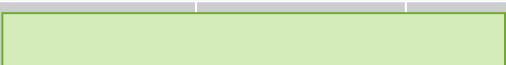
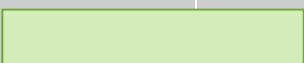
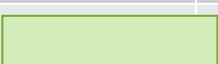
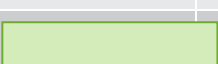
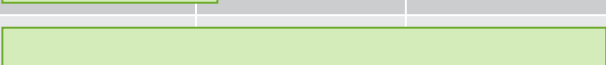
Initiative	< 1 year	< 3 years	> 3 years	Sponsor/s
1A – Repurposing of existing funding mandates				
1B – Indirect funding programme				
1C – Co-investment programme				
2A – Promote availability of test grounds for 5G innovation				
2B – Engage very early stage SMEs with Angel investors				
3A – Distribution of information around 5G-enabled use cases				
3B – Provide clarity surrounding financing options				
4 – Promote homogeneity and standardisation				

Exhibit 3.12. Indicative timeline for each recommendation
[Source: Axon Consulting]

Annex A. Methodology for identifying and selecting SMEs and financial actors

As part of this study, we interviewed relevant stakeholders within the following groups:

- ▶ **SMEs** developing and providing services that use or enable the use of 5G;
- ▶ **Financial actors** that are investing or could invest in SMEs developing and providing services that use or enable the use of 5G.

We also interviewed several experts in 5G technology, on both the demand and supply sides, to obtain an unbiased 360-degree view of the 5G ecosystem and evolution. These experts span the ICT value chain, including technology providers, mobile operators, technical experts, financial experts, and mergers & acquisitions experts, and so could offer broad perspectives and provide feedback on the study's main findings.

We designed a structured methodology to identify an extensive list of stakeholders⁴⁸ and shortlist interviewees. This methodology is summarised in Exhibit A.1.

Key steps	Description	SMEs	F. Players
1. Extraction	▶ Perform a broad range research using recognised industry sources, such as Dealroom and Crunchbase, and Axon's network in order to identify players and financial actors	~ 300 entries	~ 70 entries
2. Screening	▶ Review the preliminary list of entries in order to remove any entity that is not related to the scope of the study or that is not actually active in the EU	~ 200 entries	~ 60 entries
3. Qualitative filtering	▶ Select the most relevant companies in terms of how their business description and operations are related to 5G projects	~ 150 entries	~ 50 entries
4. Segmentation	▶ Classification of entities based on the segmentation criteria (details in following sections). Segmentation has been applied to be able to assess and sample entities based on main characteristics	~ 150 entries	~ 50 entries
5. Final filtering	▶ Shortlist entities for further analysis and interviews, based on their interest and to ensure sampling of the different geographies and segmentation criteria under analysis	~ 50 entries	~ 30 entries
6. Validation and agreement	▶ Final agreement with the EIB on the stakeholders that will be subject to the interviews	~ 30 entries	~ 15 entries

Exhibit A.1. Methodology for identifying and shortlisting the SMEs, corporates and financial actors
[Source: Axon Consulting]

⁴⁸ The selection is intended to be a sample of relevant stakeholders in the European Union, and so is not a full list of stakeholders within these groups.

The above methodology was applied consistently to the groups described above. However, due to the different nature of the groups, we had to tailor the **segmentation criteria** for each one. These criteria are described below.

A.1. Segmentation criteria

The main objective of the segmentation process is to group stakeholders based on their most relevant characteristics. Such segmentation is instrumental to ensuring that the sample selected for interview is sufficiently representative to enable reliable conclusions about access to finance in the European Union's 5G ecosystem.

SMEs

The following dimensions were used to categorise SMEs during the extraction and screening phases:

- ▶ **Role in the value chain:** This dimension indicates the firm's relevant financial characteristics and needs. In particular, we classified the identified SMEs into the following categories:
 - Developers of **hardware** for 5G connectivity;
 - **Enablers** allowing companies to develop solutions associated with 5G connectivity;
 - Companies using 5G connectivity (**users**).
- ▶ **Development and financing stage:** This criterion also provides a broad indication of the firm's financial needs, which helps, in turn, to identify potentially interested capital providers. We classified SMEs into the following categories (see Exhibit A.2 for further clarification on the funding lifecycle structure for start-ups):
 - Pre-product / **pre-seed**: Companies in the very-early/project stage seeking the first round of financing;
 - Product (pre-revenue) / **early stage**: Companies with early proof of concept seeking additional funding. Seed-stage companies fall within this category;
 - Maturing (revenue) / **late stage**: SMEs starting to be profitable that are looking to scale up and further expand their business. This stage encompasses two categories:
 - Pre-profit / growth: Companies with proven product-market fit looking to grow their existing business;
 - Profit / expansion: Companies already generating significant revenues and seeking business expansion internationally or into additional business lines.

- ▶ **Geography:** Categorisation based on the headquarters location and area of operations helps in identifying relevant financing gaps in specific countries and/or regions. It also demonstrates the relative development dynamics in different geographical regions of Europe.
- ▶ **Vertical and application group:** Identifying the vertical and application group in which the SME operates is essential to identifying potentially interested financial- and strategic-capital providers.

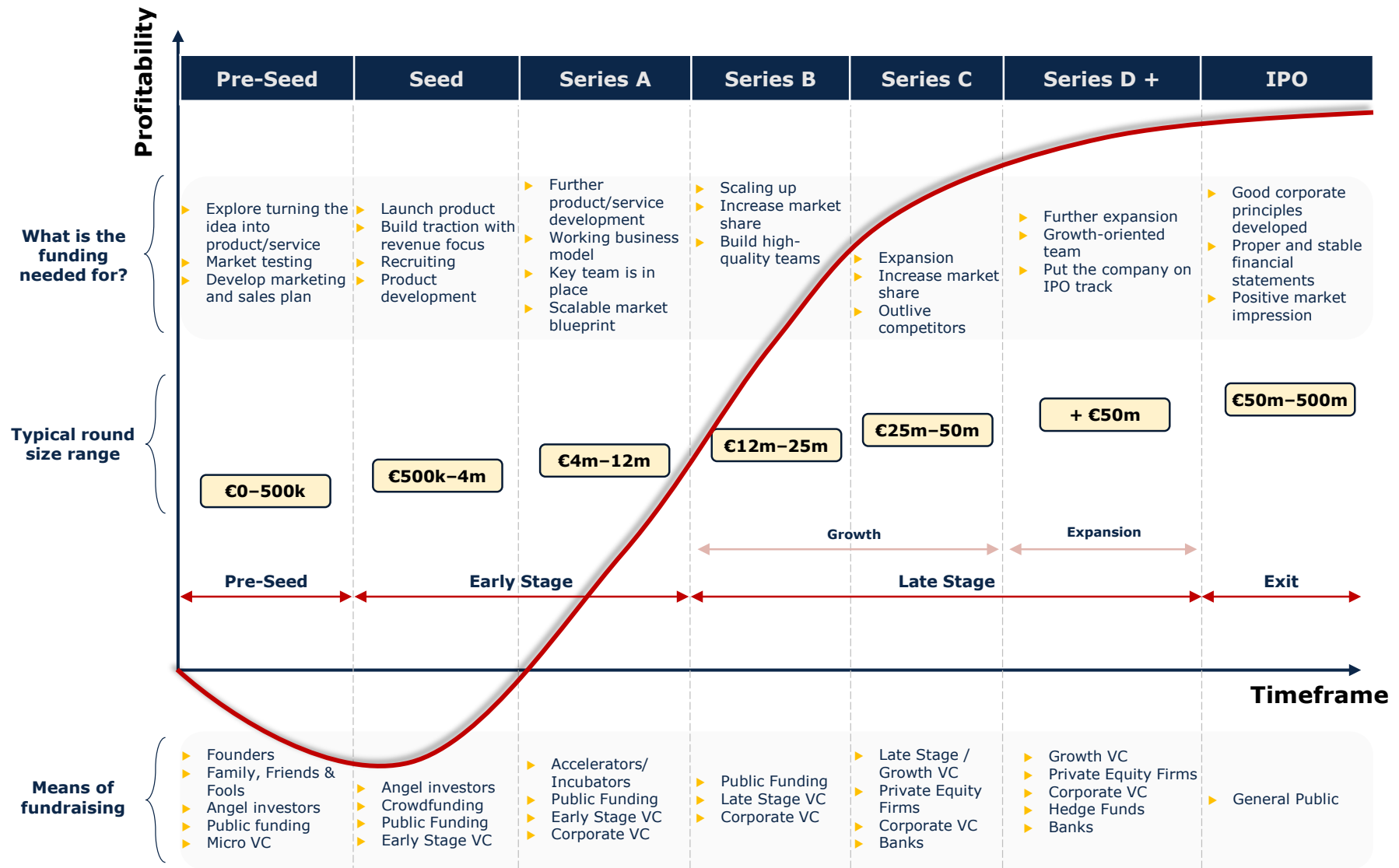


Exhibit A.2. Typical funding lifecycle structure for start-ups: stages, target funding size, objectives and potential investors [Source: Axon Consulting]

Financial actors

The following dimensions were used to categorise financial actors (both public and private) during the extraction and screening phases:

- ▶ **Institution or investor type**, distinguishing the following groups:
 - Private investors, including VC/PE, CVC and banks;
 - Multilateral organisations, including entities such as the International Finance Corporation, EIB or EIF;
 - Public organisations, including national-level institutions such as Bpifrance, BBB (UK) and ICO (Spain).
- ▶ **Focus on specific part(s) of the value chain** (if any), based on the same categorisation used for SMEs, namely hardware, enablers and users.
- ▶ **Geographical focus**, in terms of country, countries or regions in which they are expected to invest.
- ▶ **Stage of focus**, based on the following categories:
 - Pre-product / **pre-seed**: First round of financing;
 - Product (pre-revenue) / **early stage**: Second round of financing (seed, Series A);
 - Maturing (revenue) / **late stage**: Later rounds of financing (growth: Series B/C) and final stage of development (expansion: Series D and beyond).
- ▶ **Types of instruments used**, including:
 - Equity: Instruments providing financing in exchange for equity;
 - Debt: Instruments providing financing in exchange for a promise to repay the principal and interest on the borrowed capital;
 - Hybrid: Instruments combining the characteristics of equity and debt;
 - Grants: Financing given to a person or organisation for a particular purpose without obligation to repay.

A.2. Overview of participants

This section overviews the stakeholders that participated in each of the relevant segmentation groups.

SMEs

A total of **28 SMEs were interviewed for this study**, representing different industry verticals, geographies, financial stages and roles in the value chain.

- ▶ Regarding **role in the value chain**, the majority of interviewed SMEs were users, and the minority enablers. Exhibit A.3 shows the distribution.

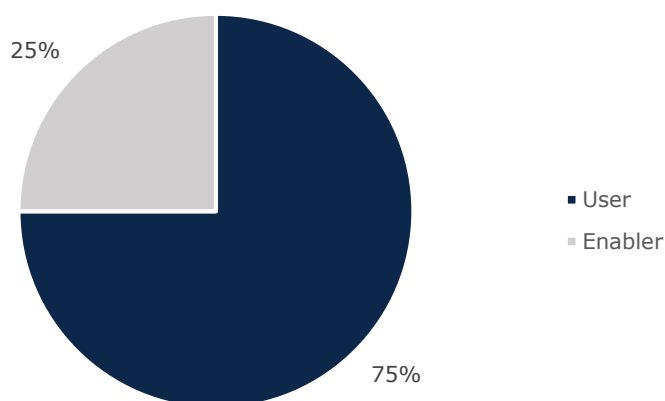


Exhibit A.3. Interviewed SMEs by roles in the value chain

[Source: Axon Consulting, based on interviews]

- ▶ Regarding the **financing stage**, the sample is split between early-seeds (pre-seed and early seeds), early stage (seed and Series A), and late stage (Series B and beyond). Exhibit A.4 shows the distribution.

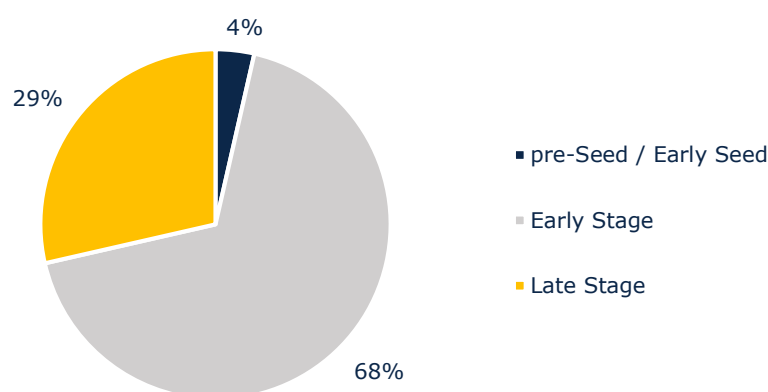


Exhibit A.4. Interviewed SMEs by financing stage

[Source: Axon Consulting, based on interviews]

- ▶ In terms of the **verticals**, the interviewed SMEs are distributed largely evenly between cross-vertical use cases (applications generically related to the telecommunications market) and specific vertical use cases. Exhibit A.5 shows the distribution.

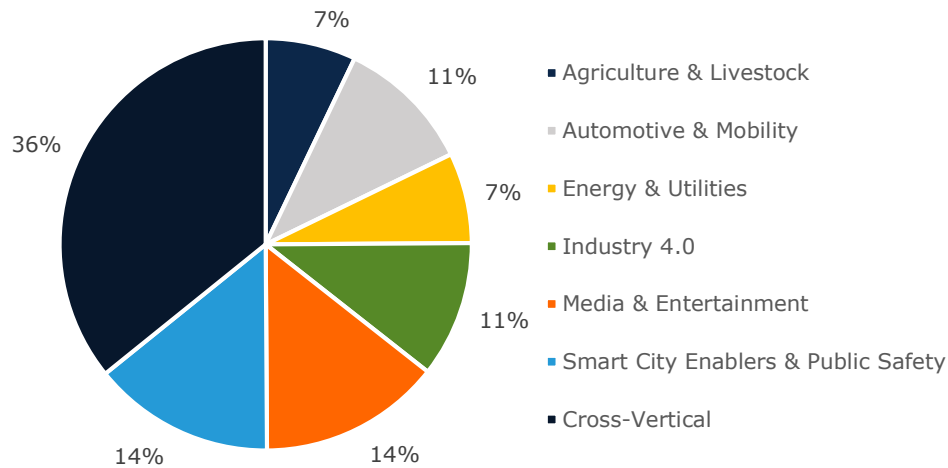


Exhibit A.5. Interviewed SMEs by industry verticals

[Source: Axon Consulting, based on interviews]

- ▶ Regarding **geography**, the sample is split between Zone A (Nordics), Zone C (Balkans and Eastern Europe) and Zone D (Southern Europe); Zone B (Central Europe plus United Kingdom) has the largest number of interviewed SMEs. Exhibit A.6 shows the distribution

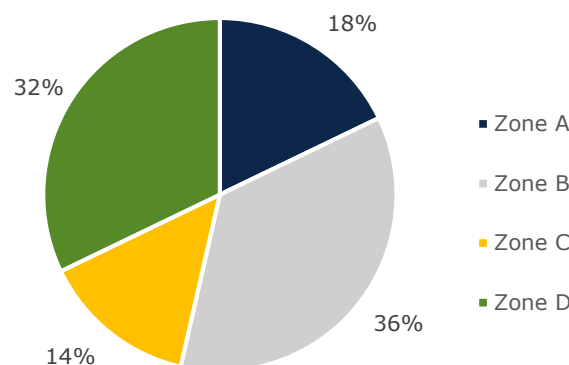


Exhibit A.6. Interviewed SMEs by geographical segmentation

[Source: Axon Consulting, based on interviews]

Financial actors

A total of **12 private financial institutions were interviewed for this study.**

- ▶ None of the financial actors had a specific industry focus, so they can be assumed to operate across industries. In terms of **geographical origin**, Zone B (Central Europe plus United Kingdom) featured most prominently among the interviewed VCs and CVCs, followed by Zone D (Southern Europe), Zone C (Balkans and Eastern Europe) and Zone A (Nordics). There was also one participant from the United States. Exhibit A.7 shows the distribution.

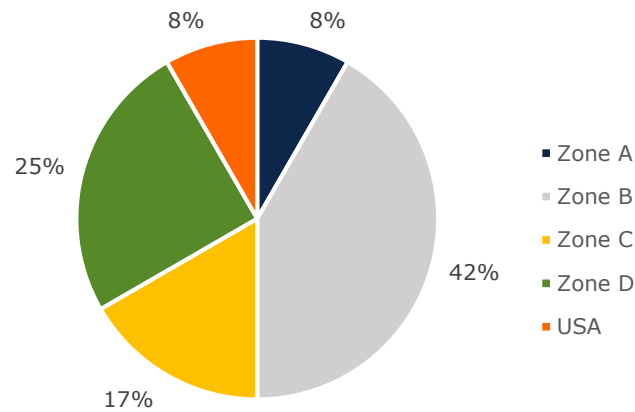


Exhibit A.7. Interviewed VCs/CVCs by geographical area
[Source: Axon Consulting, based on interviews]

- ▶ Regarding **company profile**, less than half of the sample were VCs while the majority had a CVC role. In this context, two CVC arms of major telcos were categorised as incubators/accelerators. Exhibit A.8 shows the distribution.

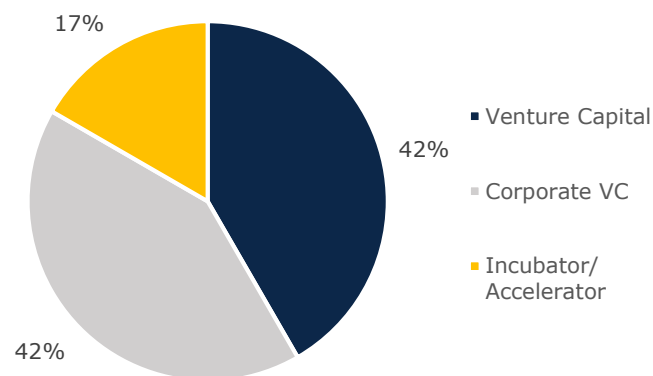


Exhibit A.8. Interviewed VCs/CVCs considering their company profile
[Source: Axon Consulting, based on interviews]

- ▶ In terms of **stage of focus**, the distribution is quite broad, as many of the interviewed financial actors target companies at different stages. However, we could see a general interest towards seed- and early-stage SMEs, with fewer investors focusing on late-stage SMEs. Exhibit A.9 shows the distribution.

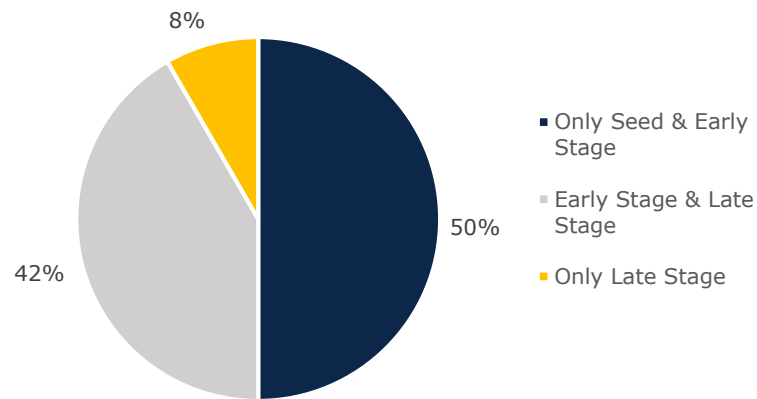


Exhibit A.9. Interviewed VCs/CVCs considering the funding stage of focus
[Source: Axon Consulting, based on interviews]

Workshop attendees

As part of this study, a focused workshop was organised between the EIB Group, the European Commission and multiple stakeholders from the European investment and 5G-related scene. This workshop's 30+ attendees included representatives of VC firms, CVC and corporate stakeholders from telecommunications and other industries, and representatives from European SMEs. The workshop provided a forum to gather feedback on the study's main findings and recommendations.

Annex B. Background on 5G

This annex provides a brief introduction to 5G (Annex B.1) and discusses the key drivers for developing 5G (Annex B.2).

B.1. Introduction to 5G

5G is the term used to describe the next (and fifth) generation of wireless networks, beyond current 4G-LTE⁴⁹ networks. With the first version of the 5G technical standards already available,⁵⁰ 5G networks are expected to build on, and smoothly integrate with, the legacy of previous generations of wireless networks. Principally, 5G represents an evolution of existing wireless communication technologies.

The deployment of 5G networks is key for telecom operators to address the expected growth in mobile data traffic in a sustainable way. 5G greatly exceeds the performance of previous generations of wireless networks in all metrics, most notably access to extra frequency bands, spectral efficiency, energy efficiency, latency, and enhanced resilience and security. These advantages can drive access to a broad range of applications and services, and open opportunities for new business models within the telecommunications sector and, most importantly, key verticals.

Improvement on existing mobile broadband services by providing enhanced mobile broadband (eMBB) is just one pillar of 5G. In particular, there is general agreement on the main families of use scenarios and applications that 5G will support.⁵¹ The three main families are illustrated in Exhibit B.1.

⁴⁹ Long-Term Evolution.

⁵⁰ In June 2018, 3GPP finalised "Release 15," which was the first standalone release of 5G (<https://www.3gpp.org/release-15>). A pre-standard release of 5G was made available at the end of 2017, enabling the industry to work on tests and trials. However, while this standard used 5G New Radio, it relied on an existing LTE network to function.

⁵¹ ITU-R, "Recommendation ITU-R M.2083. IMT Vision – Framework and overall objectives of the future development of IMT for 2020 and beyond," 2015 (https://www.itu.int/dms_pubrec/itu-r/rec/m/R-REC-M.2083-0-201509-I!!PDF-E.pdf)

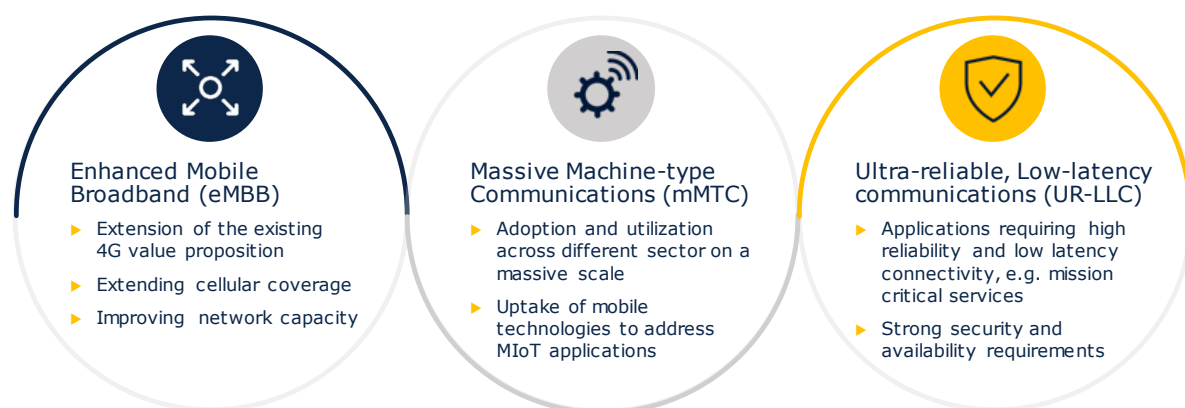


Exhibit B.1. The main families of use scenarios and applications that 5G is expected to support
[Source: Axon Consulting]

The three families of use cases and their evolution in the 5G era are briefly described below:

- ▶ Massive mobile connectivity, which will enable **enhanced mobile broadband** (eMBB). As an extension of existing 4G services, eMBB-based use cases will be the early adopters that rely on commercial 5G services. This set of data-driven use cases, requiring high data rates across a wide coverage area, can be seen as the first phase of 5G. The evolution towards enhanced connections has already begun and is being commercialised in several countries, thereby initiating the transition to 5G.
- ▶ Connectivity of millions of devices, which will enable **massive machine-type communications** (mMTC). These use cases are seen as the essential drivers for scaling up IoT applications, from their current limited use in the consumer market to significant relevance for enterprises, public entities, and governments. These use cases will employ 5G to extend existing IoT applications that require low-cost devices, low power use, and a large number of connected edge devices in a given area. As a mere software update should enable most existing mMTC use cases to take advantage of some enhanced capabilities of 5G, enterprises should be able to transition their applications from 4G to 5G without much hassle. Thus, some businesses are currently pursuing such IoT applications knowing that they will be able to quickly update them to benefit from 5G enhancements when they become available.
- ▶ Resilient, instantaneous connectivity, which will enable **ultrareliable low-latency communication** (URLLC). In addition to the previous two evolutionary advancements, 5G will also deliver a significant leap forward in the capabilities of cellular technologies. 5G's ability to provide low-latency, high-reliability and fast transfer rates will drive applications such as factory automation, smart grids, and autonomous vehicles, as well as vertical business cases not yet conceived.

As Exhibit B.2 illustrates, 5G connections across the world are expected to grow significantly, with eMBB connections forecasted to account for 90% of global 5G connections by 2025.⁵²

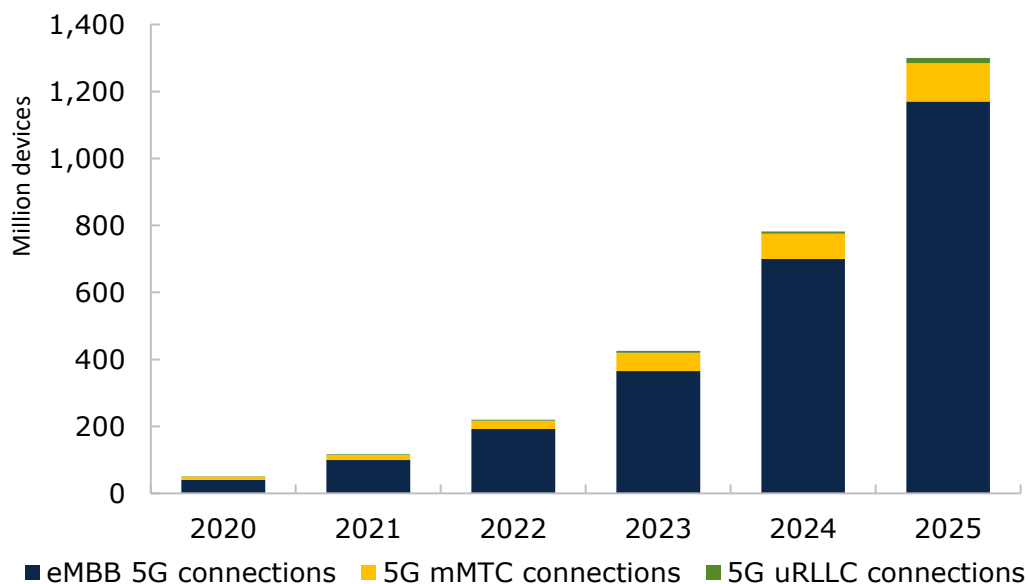


Exhibit B.2. Global 5G connections estimates for 2020–2025 by use-case family
[Source: Axon Consulting, based on IDATE DigiWorld 2019]

Overall, 5G is expected to provide not only an enhanced value proposition relative to traditional mobile broadband services but also tailored connectivity to meet the demands of different user groups, including innovative use cases for particular industries (verticals), such as automotive, energy and healthcare.

The business transformations driven by advances in technologies and digital capabilities are expected to lead to massive investments across the major industry verticals. These investments are expected to increase yearly and benefit ICT players across the globe. Global revenues for ICT players are forecast to be around \$2.5 trillion by 2025 and \$3.8 trillion by 2030.⁵³ 5G is expected to capture up to \$1.5 trillion worldwide by 2030, representing approximately 40% of overall ICT revenues. The ability of 5G players to assume a role in the value chain will vary by industry and depend on further factors, such as the speed of disruption, geographical significance, and the level of complexity in the use cases addressed. Of the \$1.5 trillion in revenue forecast to be captured by 2030, the total value of the global addressable, 5G-enabled market for service providers across major

⁵² Cisco Visual Network Index, "Forecast and Trends, 2017-2022 White Paper" (<https://www.cisco.com/c/en/us/solutions/collateral/service-provider/visual-networking-index-vni/white-paper-c11-741490.pdf>)

⁵³ Ericsson, "5G for business: a 2030 market compass," October 2019 (<https://www.ericsson.com/en/5g/forms/5gforbusiness-2019-report>)

industry verticals is projected to be \$700 billion of new, additional revenue streams (i.e. beyond mobile broadband).

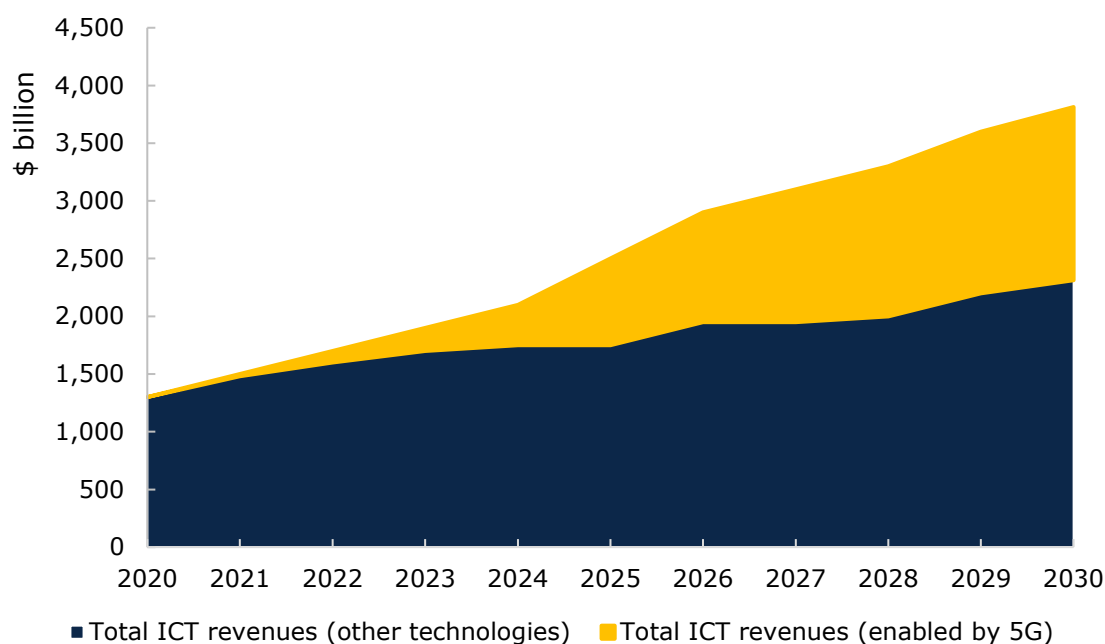


Exhibit B.3. Total ICT revenue forecast split between 5G-enabled and other technologies
 [Source: Axon Consulting elaboration on Ericsson report⁵³]

In addition to its expected business impact, 5G equally has the potential for significant social impact. As part of a long-term project to drive social change and make lives better globally, the European Commission is committed to the United Nations' 17 Sustainable Development Goals (SDGs) and is working towards them through multistakeholder participation as part of the 2030 Sustainable Development Agenda.

Several international bodies, such as the International Telecommunications Union (ITU) and the World Economic Forum, are increasingly studying how 5G can contribute to achieving the SDGs. In particular, according to the ITU, 5G will be used to "accelerate the achievement of all 17 Sustainable Development Goals."⁵⁴ 5G connectivity will allow this by providing new ways to tackle the focal problems and through aligning this possibility with offerings from the private sector. The exhibit below summarises a few examples of how the SDGs can be positively impacted by 5G use cases.

⁵⁴ <https://www.itu.int/en/mediacentre/backgrounders/Pages/5G-fifth-generation-of-mobile-technologies.aspx>

SDG	5G impact	Example use case
2. Zero Hunger 	The powerful combination of IoT and 5G is enabling many use cases across verticals. For agriculture, 5G can potentially provide connectivity to underserved rural areas, thus enabling interconnectedness of agricultural systems.	 DS Instruments⁵⁵ is an early-growth-stage SME from France that enables urban and rural ecosystems to adapt to and mitigate climate change by relying on new ICT. Services such as those provided by DS Instruments can use advanced connectivity to tackle some of the biggest challenges to agriculture globally.
3. Good Health and Well-being 	5G-enabled applications such as remote surgery, advanced remote medical training and remote diagnostics can potentially enable healthcare services and life-saving education in rural or remote areas or in underserved countries, helping to serve billions of people without access to safe surgical services.	FUNDAMENTALVR FundamentalVR⁵⁶ is a London-based SME providing a surgical platform that uses VR and AR to deliver surgical training. This represents a cost-effective way to provide knowledge and skills development for surgeons.
4. Quality Education 	5G can potentially enable or amplify educational services by incrementing the quantity and quality of media used by or transferred remotely to end users, en-masse.	RosieReality RosieReality is a seed-stage SME from Switzerland that is creating AR technologies⁵⁷ for early childhood education.

⁵⁵ <https://dsinstruments.fr/>

⁵⁶ <http://www.fundamentalvr.com/>

⁵⁷ <https://techcrunch.com/2019/04/26/rosiereality/>

SDG	5G impact	Example use case
9. Industry Innovation and Infrastructure 	Industry 4.0 is set to experience a wealth of innovation through 5G. Smart factories and smart infrastructure are just two of the ways that 5G can enable IoT and autonomous solutions to work in combination to drive this goal.	 Stockholm-based SME Imagimob⁵⁸ uses edge computing to combine IoT sensors and data analytics tools for real-time Industry 4.0 use cases, such as predictive maintenance and manufacturing. Such offerings could be amplified in scale, speed and data quality through implementing 5G capabilities.
11. Sustainable Cities and Communities 	5G can unlock the potential of smart cities by allowing the vast connection of connected devices and citizen interaction, among other technologies. Smart city applications will increase the safety, connectedness and ease of living within modern cities.	 MyBus⁵⁹ is a German SME providing telematic solutions for public transport in smart city environments. 5G can enable such services to send vast amounts of data through smart transport networks at high speeds within cities.

Exhibit B.4. 5G impact on SDGs [Source: Axon Consulting, based on research]

B.2. Key trends in the ICT sector and the role of 5G

In recent years, some relevant and disruptive trends have appeared in the ICT sector. These trends have driven rising demand for global connectivity, digitalisation and enhanced communication services.

⁵⁸ <https://www.imagimob.com/#>

⁵⁹ <https://www.mybus.gmbh/en.html>

Exhibit B.5 sets out the key digital trends in the ICT sector that are likely drivers of growth, innovation and disruption across industries. It is expected that 5G will play a significant role in leveraging these trends or driving them forward in the coming years.

Key trend	Potential role of 5G
 Demand for ubiquitous connectivity <i>Increase in the number of devices, amount of content, and volume of data traffic</i>	▶ Meet the demands of use cases requiring continuous connectivity while assuring minimal latency through edge-computing capabilities. ▶ Handle growth demands in a cost-effective, energy-efficient, high-speed manner.
 Softwarisation, virtualisation and cloudification of networks <i>Ability to integrate novel computing functions</i>	▶ 5G's service-based architecture is cloud native and extensively uses advanced software-defined networking, network function virtualisation, and edge-computing technologies to provide advanced functionalities such as network slicing.
 Internet of things (IoT) <i>Increase in the number of connected devices</i>	▶ 5G can support connecting everything from smart-home devices, buildings and waste bins to traffic systems, self-driving cars and robots. ▶ Reduced latency in IoT networks compared to 4G systems, for example in Industry 4.0 applications, where this requirement is vital.
 Demand for low latency <i>Industry applications and use cases that require minimal delays</i>	▶ To support high-demanding use cases such as factory automation, self-driving cars, gaming and other tasks demanding quick response times. ▶ To meet the low-latency demands of AR and robotics applications, which can be adopted in a multitude of industries.
 Global smart city deployments <i>Major global initiatives to place cities at the forefront of using data, sensors and connected devices to improve services and quality of life</i>	▶ 5G wireless infrastructure can enable the installation of connected devices and sensors required for smart city projects, such as smart traffic management, smart waste management and connected vehicles.

Key trend	Potential role of 5G
 Digitalisation and advanced analytics <i>Achieving maximum value from each customer</i>	▶ Digitalise and overhaul the business models of telecom and adjacent industries. ▶ Collect larger amounts of relevant data in real time to feed into data analytic algorithms that accurately segment and generate maximum value from each customer.
 Proliferation of value-added services and over-the-top (OTT) players <i>Telecom operators adapting to changes in service and content provisioning</i>	▶ Support evolution of richer content types such as 4K and 8K resolution, VR, AR and 360° videos. ▶ Enable telcos to gain access to markets currently dominated by OTT players, through partnerships and quality offerings.
 Fixed wireless access (FWA) technology <i>The great wireless migration</i>	▶ Utilise much higher frequency bands (and bandwidths) than current 4G networks. ▶ Solve the last mile problem.⁶⁰

Exhibit B.5. Major trends in the ICT sector and the roles of 5G [Source: Axon Consulting]

The above trends are further explained in the following subsections.

B.2.1. Demand for ubiquitous connectivity

Demand for connectivity has grown significantly, driven by smartphones (and other connected devices) becoming a channel for consuming content such as music and video, running many applications (including payments and e-commerce), and remotely controlling various types of devices. Long-run growth in data volumes is expected to also result from new services, including connected devices communicating directly, machine-to-machine. As seen in Exhibit B.6, total mobile data traffic is expected to be four times higher in 2025 compared with 2019.⁶¹

⁶⁰ Last mile is the portion of the network that reaches the user's premises. The bulk of the costs and most of the complexity in fixed access deployments are associated with the last mile.

⁶¹ Ericsson Mobility Report, November 2019 (<https://www.ericsson.com/4acd7e/assets/local/mobility-report/documents/2019/emr-november-2019.pdf>)

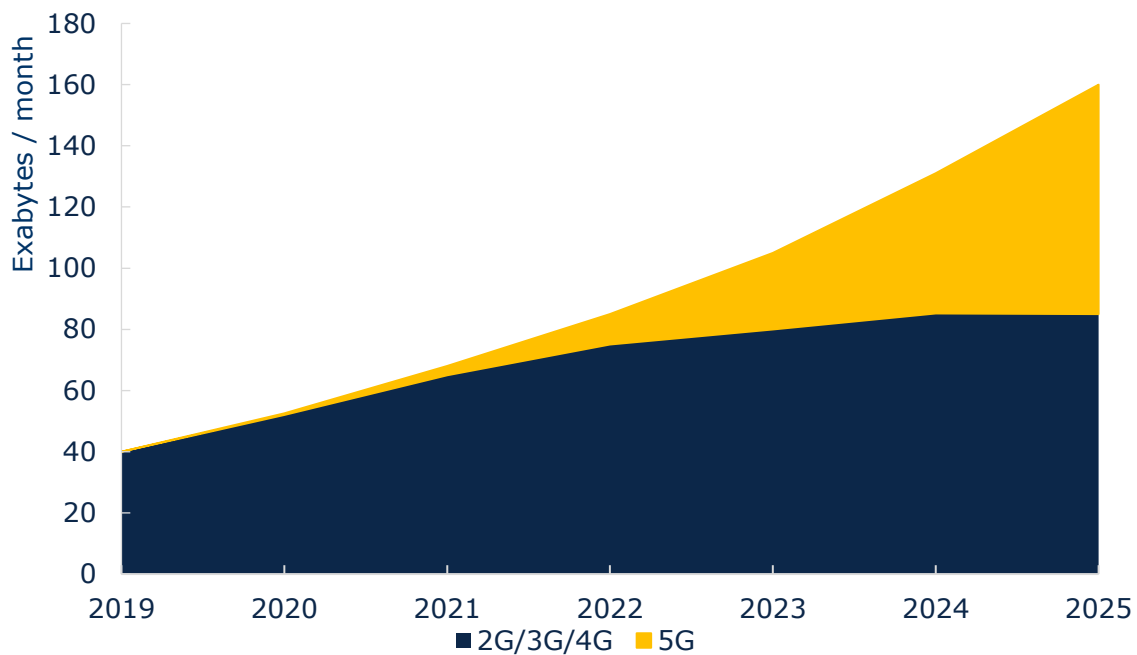


Exhibit B.6. Global evolution of mobile data traffic consumption
 [Source: Axon Consulting, based on Ericsson report⁶¹]

5G is expected to contribute to meeting this growing demand by delivering eMBB and opening up new opportunities that will serve industries by improving their coverage network capacity.

The improvements offered by 5G will create a new ecosystem of applications that require the **ubiquitous presence** of this technology. Unlike the present requirements of the 4G ecosystem, 5G applications are expected to rely on continuous connectivity. This dependence primarily comes from some characteristic needs of these applications, such as low latency, network reliability and resource efficiency.

B.2.2. Softwarisation, virtualisation and cloudification of networks

In line with the increasing digitalisation experienced across all industries over recent decades, the Technology, Media & Telecom (TMT) industry is also becoming digitalised in new ways. The virtualisation and softwarisation of telecoms networks and/or their functions are trends allowing operators to scale the capacity of their services while minimising the associated costs. This is occurring at both the network core and its edge.

Regarding 5G, the use of virtual or software-based networks is considered necessary for implementing 5G at scale while maintaining CapEx and OpEx efficiencies. Concepts such as network slicing, which involves building multiple logical networks across one physical

network, will enable the customisation of services for various 5G use cases, such as advanced media, connected cars and IoT. As such, distinct and virtual networks (layers) will be created to serve the specific performance needs of each use case separately in every dimension/metric (e.g. latency, coverage, capacity). Operators can, thereby, provide these separate networks over a shared infrastructure.

Cloudification is another key concept in 5G. Through the cloud, network operators can create system architectures in which logical infrastructures can be effectively scaled or downsized rapidly and on-demand. The cloud can also be used to create open platforms for third-party integration with the network through the creation of common network applications.

In this environment, initiatives such as OpenRAN are currently gaining momentum and are expected to have a significant transformative impact on the TMT industry in the longer term.

Such an impact is primarily explained by the following core principles that characterise these radio access networks:

- ▶ **Openness:** Open interfaces are crucial to enabling vendors and operators to introduce their own services or customise the network to suit their own needs. They also enable multivendor deployments, and hence a more competitive and vibrant supplier ecosystem. Similarly, open source software and hardware reference designs enable faster, more democratic and permission-less innovation.
- ▶ **Intelligence:** Networks are becoming increasingly complex with the advent of 5G, densification, and richer and more demanding applications. Hence, a network must be able to operate on its own, with the ability to leverage new learning-based technologies to automate operational functions and reduce costs.

The above ecosystem is expected to create an opportunity for smaller players to innovate on certain network functions or particular processes and subfunctions of network operations, and even create new functionalities tailored for new use cases.

B.2.3. Internet of things (IoT)

Besides the ever-growing consumer demand for faster internet, a primary driver of 5G is the **growth of connected devices** in industrial settings, from agriculture to pharmaceuticals and automotive manufacturing. These industries increasingly rely on connected devices to gather and analyse data, make business processes more efficient,

enhance productivity and continuously improve products and services for customers. This ecosystem of connected devices is commonly referred to as the **IoT**.

The number of IoT devices connecting through cellular networks is expected to reach 5 billion in 2025, up from 1.3 billion at the end of 2019,⁶¹ as Exhibit B.7 illustrates.

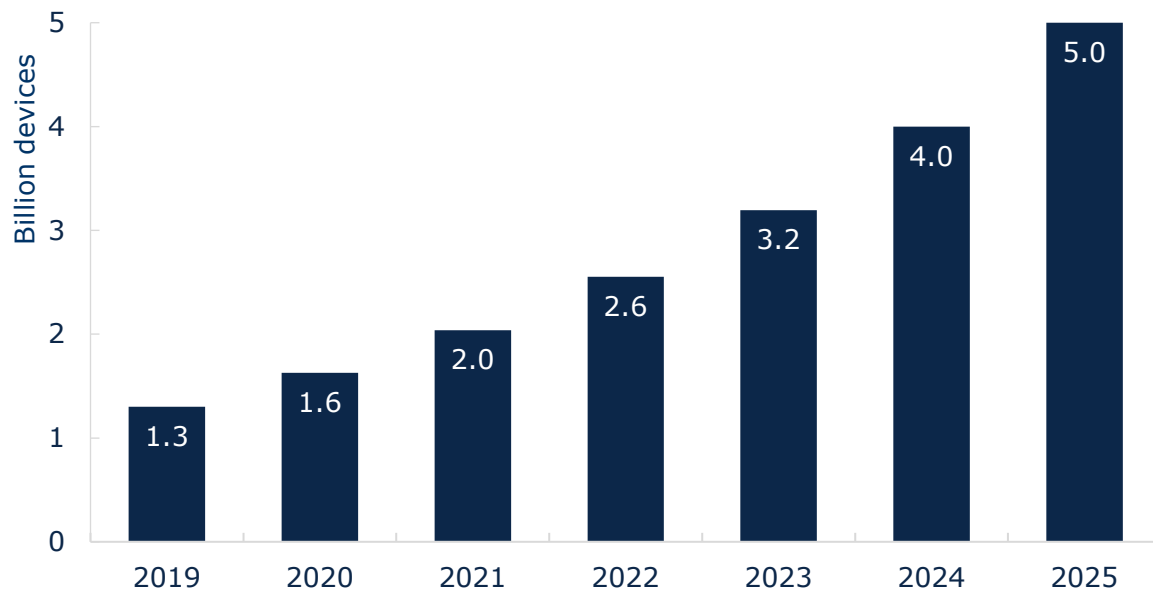


Exhibit B.7. Worldwide evolution of cellular IoT connections
 [Source: Axon Consulting, based on Ericsson report⁶¹]

Revenue from IoT is expected to reach \$242 billion (€210 billion) in Europe in 2025, up from \$53 billion (€47 billion) in 2017.⁶² Europe will, therefore, experience a compound annual growth rate (CAGR) of 21% over that period and account for 22% of total global revenue from IoT in 2025.

One of the most important implications of IoT development will be the growing need to handle large volumes of data within a reduced time frame, which will stretch the capabilities of existing connectivity infrastructures. With connectivity central to industry transformation, 5G will have a key role to play—not just in the evolution of communication but also in the transformation of businesses.

Among the most important cellular technologies sustaining IoT communications so far have been narrowband IoT (NB-IoT) and LTE for machines (LTE-M). These technologies have allowed the creation of numerous new use cases but currently appear inadequate in certain

⁶² GSMA, “The Mobile Economy Europe 2018” (<https://www.gsma.com/mobileeconomy/europe/>). NB. Stats updated since publication.

areas, such as scalability (devices per square kilometre), efficiency (e.g. in terms of energy consumption), performance (e.g. throughput) and security, which are indispensable to unleashing the full capabilities of IoT. 5G is expected to meet such requirements in a flexible manner, enabling different use cases with very specific connectivity needs.

B.2.4. Demand for low latency

5G networks will also enable ultralow-latency communications, a concept expected to open up and drive a multitude of use cases across some key industry verticals. Lower latency signifies faster response times and real-time interactivity for services, and are critical attributes in some use cases.

Some of the key applications expected use 5G's low-latency capabilities are as follows:

- ▶ **Factory automation:** As Industry 4.0 involves broader capabilities, reduced delays can enable multiple industry machines to be independently and remotely controlled, with comparable levels of latency as a wired connection. Ericsson⁶³ has been carrying out multiple initiatives on this front, with three factories in Sweden, Estonia and China being fast-tracked to implement 5G and industrial IoT solutions such as AR troubleshooting in their manufacturing environments.
- ▶ **Self-driving cars and traffic systems** are latency-sensitive applications that will rely on the combination of edge computing and 5G. Edge computing⁶⁴ enables faster response times for task processing by moving computing aspects from central servers out to 5G base stations. One 5G initiative that relies on low-latency characteristics is the collaborative project between Scania and Ericsson,⁶⁵ whose main objective is to develop a 5G system architecture for autonomous driving and platooning. The low latency in such wireless connections will allow vehicles to transmit information to one another in situations where speed and reliability are vital, like braking or turning.
- ▶ **Drone/robot applications** can improve significantly in terms of object recognition, flight duration and other functions through a low-latency 5G network enabling fast links to base stations. In Spain, Telefónica⁶⁶ has recently carried out a successful pilot project with drones for the early detection and prevention of forest fires.

⁶³ <https://www.ericsson.com/en/cases/2017/smartfactory>

⁶⁴ Edge computing is based on bringing data storage closer to the location where the data are needed (e.g. analysing the most important data immediately after collection and before long-time storage).

⁶⁵ <https://www.scania.com/group/en/scania-links-up-with-ericsson-to-test-5g-mobile-technology/>

⁶⁶ <https://www.telefonica.com/web/press-office/-/telefonica-successful-conducts-pilot-with-drones-based-on-iot-solutions-for-early-fire-detection>

- ▶ **Healthcare applications**, such as remote surgery, require real-time interaction and control of robotic arms. On this front, Deutsche Telekom⁶⁷ is already piloting use cases that involve real-time emergency care, enabled over a high-throughput, low-latency 5G connection with an edge cloud infrastructure. This type of use case involves remote collaboration between a paramedic in the field and a hospital specialist, and employs a futuristic medical probe for diagnosis.
- ▶ **AR** applications should particularly benefit from low-latency connections because they can deliver the instant imagery necessary for operation. In Finland, Telia and Stora Enso (a pulp and paper manufacturer) have tested a 5G-based AR application in the forest industry, particularly in the operation and maintenance of mills.⁶⁸
- ▶ **Games**, which will effectively be driven by VR, AR and 3D in the future, stand to benefit significantly from the lower latency that 5G can deliver. Low latency can ensure that VR/AR headsets deliver a superior gaming experience, eliminating challenges associated with jarring and nausea. For instance, during the 2019 Mobile World Congress, Telefónica presented 5G connectivity applied to eSports, using gaming consoles and a 5G router connected to the internet.⁶⁹

B.2.5. Global smart city deployments

Based on current rates of urbanisation, two-thirds of the world's population are forecast to reside in cities by 2050.⁷⁰ Countries and governments are initiating major projects to build smart cities in collaboration with major telcos, technology providers, and other stakeholders. 5G offers superior wireless speeds and better energy-efficiency capabilities compared to 4G, which can be utilised to develop and deploy real-time sensor grids and a multitude of connected technology applications across cities. These applications usually include smart traffic management, smart water and electricity meters, smart homes, connected vehicles, dynamic lighting systems and maintenance systems.

The major implications of 5G in smart city deployments are as follows:

⁶⁷ <https://www.telekom.com/en/company/details/5g-experience-514526>

⁶⁸ <https://www.teliacompany.com/en/news/news-articles/2018/stora-enso-5g-ar/>

⁶⁹ <https://www.telefonica.com/en/web/press-office/-/telefonica-presents-movistar-riders-on-5g-the-first-european-demonstration-of-esports-at-maximum-mobile-speed>

⁷⁰ Ernst and Young, "The upside of disruption, Megatrends shaping 2016 and beyond" (<https://www.ey.com/gl/en/issues/business-environment/ey-megatrends-urban-world>).

- ▶ **Enabling smart transport and traffic management:** 5G can gather and mine vast data sets from sensors deployed across cities, thereby helping to pinpoint major challenges with respect to traffic and transport;
- ▶ **Enhancing emergency and public-safety services:** The capabilities offered by 5G will enable cities to upgrade their critical communication networks and deliver superior public-safety services;
- ▶ **Conserving energy:** 5G networks, along with the connected devices and sensors, will enable smart cities to be more environmentally friendly and target sustainable growth by delivering energy-efficient, instantly responsive solutions.

According to the 5G Infrastructure Association's (5G IA) 2018 report on 5G Pan-European Trials,⁷¹ 63 trials had been implemented in 38 cities. Examples of such pilot projects include the Telia Company's 5G Finland⁷² developed in Helsinki, Tampere and Oulu, and TIM's 5G metropolitan trials in Turin for driverless cars, drone environmental monitoring, connected robots and NB-IoT.

B.2.6. Digitalisation and advanced analytics

Digitalising business operations and implementing analytics tools is expected to make companies more productive and improve customer satisfaction, which should lead to increased revenues. However, current communication technologies are expected to fall short in meeting data collection and processing needs in the coming years. Among the most relevant factors inducing this change are:

- ▶ **The substantial generation of data** fostered by extensive sensor deployment and the exponential rise of data generated by each device;
- ▶ **Data-driven strategies** powered by companies' increasing reliance on data-processing strategies. As data increasingly drives decisionmaking processes and forecasting, effective treatment of data is becoming pivotal for enterprises.

Advanced analytics can allow businesses to segment customers and predict their behaviour, thus deriving more value from each customer. 5G's ability to support data collection and distributed processing through edge computing is expected to assist

⁷¹ See: https://5g-ppp.eu/wp-content/uploads/2018/11/5GInfraPPP_TrialsWG_Roadmap_Version4.0.pdf

⁷² See: <https://www.telia.fi/business/5g/5g-finland>

important aspects of data analytics and digitalisation (such as massive data transmission) and empower future digital and analytics tools.

The role of 5G in digitalisation and advanced analytics can take multiple forms. One example, as proposed by Ericsson,⁷³ is the digitalisation of industries fostering 5G-IoT applications which provides new business models of digital service providers with the ability to create network slices with 5G (e.g. network resource orchestration, new analytics capabilities, automation of business operations).

B.2.7. Proliferation of value-added services and over-the-top (OTT) players

Recently, OTT players have been conquering and acquiring traditional services like messaging, voice and video. The irruption of 5G will allow OTT players to take an incumbent position on these traditional services (by cannibalising mobile operators' legacy systems) and on the newest services, such as on-demand video and music and livestreaming, without owning or operating any physical networks.

The main implications expected in the broadcasting and OTT ecosystem due to the emergence of 5G networks are as follows:

- ▶ **Implications for the OTT business model:** Although OTT players (e.g. Netflix, Spotify) have been gaining momentum in recent years, the attractiveness of their offerings is limited by their dependence on a proper internet connection. At present, especially in the video segment, most consumers rely on fixed broadband connectivity, therefore limiting the value proposition of such OTT players. However, with the high speeds and adjacent capabilities that 5G will potentially offer, content providers will be able to reach target customers directly, and with higher reliability and quality than before, thereby largely eliminating the need to rely on fixed lines. Hence, OTTs will be able to deploy directly to consumers both new services and richer content types, such as 4K, 8K, VR, AR and 360-degree videos. 5G thus has the potential to impact the OTT business model by opening up attractive new revenue streams (e.g. by offering new types of services that were previously constrained by technical capabilities). This change does not necessarily create direct competition between operators and OTT services; rather, it presents opportunities for collaboration through concepts such as

⁷³ Ericsson, "A guide to capturing the 5G industry digitalization business potential," 2019 (<https://www.ericsson.com/en/networks/trending/insights-and-reports/5g-challenges-the-guide-to-capturing-5g-iot-business-potential>)

bundling, which entail economies of integration. For example, in 2018, Telefónica and Netflix announced a global partnership to integrate Netflix's service into Telefónica's TV and video platforms.

- ▶ **Implications for consumer choices:** 5G brings increased bandwidth availability and reliability, and so will significantly alter how users consume content. In effect, any consumer will be able to stream OTT content without using fixed lines.

B.2.8. Fixed wireless access (FWA) technology

FWA technology can provide broadband access to homes via a wireless network instead of traditional fixed lines. It may become an alternative to traditional very-high-capacity networks currently provided via fixed-access infrastructures. The increased spectrum availability (in terms of bandwidth) and the technical properties offered by 5G will be key to affordably providing equivalent services. From a technical standpoint, however, FWA will require massive deployments of fibre access networks to backhaul 5G base stations.

FWA could enable the establishment of a relatively quick and cheap broadband service, even in areas lacking ready access to fixed-line home broadband. It does not require any civil infrastructure works at the customer end: only customer-premises equipment (CPE) is needed, which can be readily self-installed by the user.⁷⁴

Some European telecom operators have been testing the feasibility of FWA networks over recent months. According to Ericsson, 5G will enable eMBB-based cost-efficient FWA solutions on a large scale, which is especially pertinent with up to 50% of the world's population still awaiting reliable broadband access.⁷⁵

⁷⁴ Nevertheless, CPE is often outdoors equipment requiring a technician to install for FWA implementation.

⁷⁵ <https://www.ericsson.com/en/networks/offerings/fixed-wireless-access>

Annex C. 5G ecosystem in Europe

This section describes the current status of 5G in Europe (Annex C.1), the verticals that can benefit from 5G (Annex C.2) and the business potential of 5G in the digitalisation of European industry (Annex C.3). It then presents a synopsis of the financing ecosystem for SMEs in Europe (Annex C.4), before finally assessing how Europe is performing against other international regions in rolling out 5G (Annex C.5).

C.1. Current status of 5G development in Europe

5G commercialisation is set to be strong in Europe

According to the GSMA,⁷⁶ mobile market penetration is higher in Europe than in any other region, with 469 million unique mobile subscribers at the end of 2019, representing 86% of the population. This is forecast to grow to 481 million by 2025, covering 88% of the population and representing a CAGR of 0.4% for the 2019–2025 period. This superior penetration rate means that the saturation point for mobile users is closer in Europe than anywhere else in the world.

Although 4G is still expected to grow further in many markets, the first 5G launches by European mobile operators took place in 2019. For example, Vodafone initiated the commercial roll-out of 5G in Spain⁷⁷ and the United Kingdom⁷⁸ in June and July 2019, respectively. In Spain, Vodafone has deployed 5G in 15 cities, with approximately 50% coverage in each, while in the United Kingdom partial 5G coverage reached 92 cities by the end of 2020. At the end of 2019, 5G commercial services had been deployed in eight other EU countries (Austria, Estonia, Finland, Germany, Hungary, Ireland, Italy and Romania), some of which already have more than one 5G service provider. It is important to note, however, that these initial commercial roll-outs usually target traditional broadband consumers, and not 5G-based innovative use.

Some forecasts indicate that 5G will account for approximately 231 million connections in Europe by 2025, corresponding to a 34% share of total connections in the continent.^{76,79} Together, 4G and 5G are forecast to account for 92% of total connections in Europe by

⁷⁶ GSMA, "The Mobile Economy Europe 2018" (<https://www.gsma.com/mobileeconomy/europe/>). NB. Stats updated since publication.

⁷⁷ http://www.saladeprensa.vodafone.es/c/notas-prensa/np_5g_comercial/

⁷⁸ <https://5g.co.uk/coverage/vodafone/>

⁷⁹ Total connections refers to the total number of SIM connections across Europe, excluding licensed cellular IoT.

2025. The evolution of all types of mobile connections from 2019 to 2025 is depicted in Exhibit C.1.

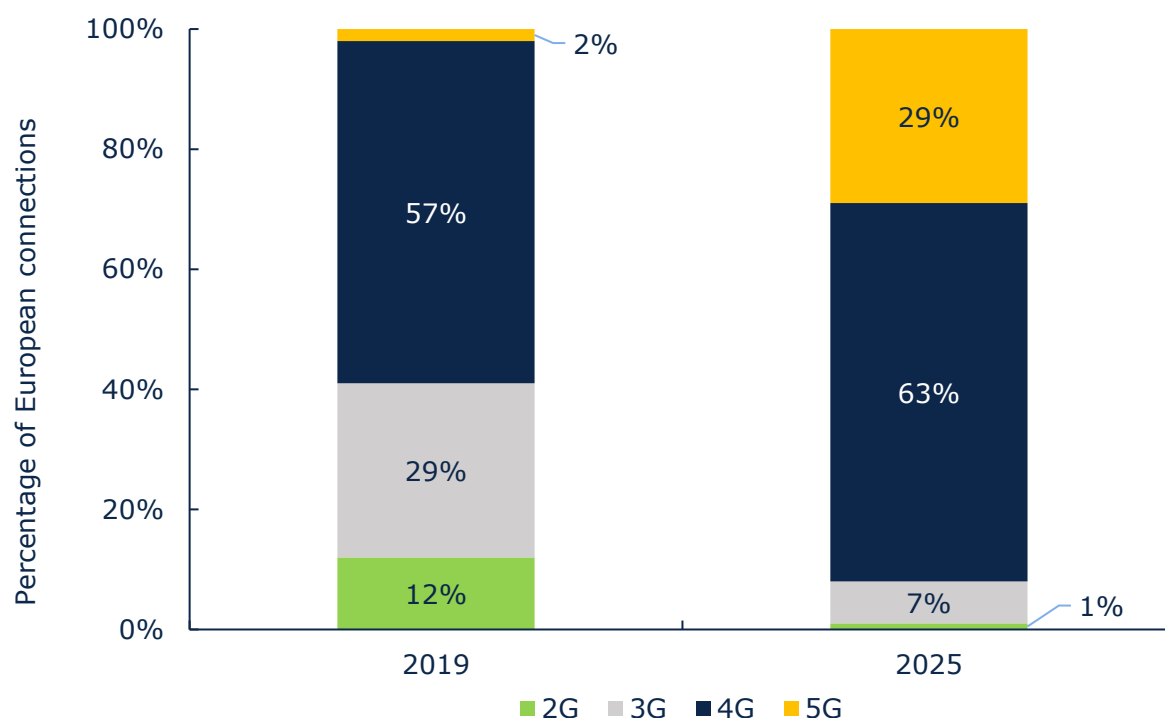


Exhibit C.1. Forecast evolution of mobile connectivity types, 2019–2025

[Source: Axon Consulting elaboration on the GSMA's report]

Although Europe's mobile ecosystem is forecast to account for over 4% of the region's GDP by 2022,⁸⁰ a proper ecosystem of investment and regulatory actions will be pivotal to positioning Europe as a global 5G leader and establishing a genuine Digital Single Market. Thus, the evolution of the mobile market, and cellular connectivity in general, is expected to be a driving force in Europe in the coming years.

5G is an important factor for the European economy, so public bodies are taking an active role in its development

5G is a topic of strategic interest in Europe, with ambitious goals being set at EU level since 2016. Europe sees 5G as a major opportunity to improve not only the ICT sector but also the entire economy, contributing to the digital transformation of businesses and societies. The European Commission identified 5G standards as one of the five key priority areas of the "Digitising European Industry" initiative.⁸¹ The 5G vision encompasses a whole

⁸⁰ See the GSMA forecast: <https://www.gsma.com/newsroom/press-release/5g-to-power-economic-growth-in-europe-finds-gsma-study/>

⁸¹ See: <https://ec.europa.eu/digital-single-market/en/policies/digitising-european-industry>

ecosystem and the integration of digital communications into everyday life by supporting different public and industrial sectors. The European Commission's strong commitment to 5G has led to the adoption of a challenging target for 5G deployment,⁸² the definition of detailed initiatives for implementing 5G projects, and the proposal of legislative measures aimed at facilitating 5G development.

Exhibit C.2 highlights some of the major pan-European public initiatives, innovation hubs and stakeholders fostering 5G development in Europe.

5G Initiatives and Stakeholders	Description
5G Action Plan 	The 5GAP targets ensuring commercial roll-out of 5G in at least one major city in every Member State by the end of 2020 and uninterrupted coverage of all urban areas and major terrestrial transport paths by 2025. This plan sets a clear roadmap for public and private 5G investments in the European Union.
European Electronic Communications Code (EECC) 	Following a recent review of the EU regulatory framework for electronic communications, the new EECC entered into force in December 2018. The Code includes measures to stimulate investment in and take-up of very-high-capacity networks in the European Union, as well as new spectrum rules for mobile connectivity and 5G. EU Member States have two years to transpose it into national law, which will give a strong push to 5G and high-speed broadband networks. Also, BEREC has made 5G a key focus of its 2020 Work Programme. Within the scope of its competence, BEREC intends to continue actively and closely following the development of 5G and will, where relevant, collaborate with other EU bodies to identify potential obstacles to the smooth and timely implementation of 5G in Member States. In 2019, BEREC focused on the mandatory work assigned to it under the EECC, namely enabling 5G and promoting technological innovation. This remains a key objective for BEREC, but

⁸² To ensure early deployment of 5G infrastructure in Europe, the European Commission adopted in 2016 the 5GAP, aiming to start launching 5G services in all EU Member States by the end of 2020, followed by a rapid build-up to ensure uninterrupted 5G coverage in urban areas and along main transport paths by 2025. See: <https://ec.europa.eu/digital-single-market/en/news/communication-5g-europe-action-plan-and-accompanying-staff-working-document>

5G Initiatives and Stakeholders	Description
	it committed to also work on coverage information for 5G deployments and the security of 5G networks during 2020.
5G Infrastructure Public Private Partnership (5G PPP) ⁸³ 	A joint initiative between the European Commission and European ICT industry, the 5G PPP brings together ICT manufacturers, telecommunications operators, service providers, SMEs and research institutions. The 5G PPP is expected to deliver solutions, architectures, technologies and standards for the ubiquitous next-generation communication infrastructures of the coming decade.
5G Infrastructure Association (5G IA) 	Within the 5G PPP, the 5G IA represents the private side and the European Commission the public side. The 5G IA is committed to advancing 5G in Europe and building global consensus on 5G. Towards this aim, the association brings together a global industry community of telecoms & digital actors, such as operators, manufacturers, research institutes, universities, verticals and SMEs.
5G Observatory 	The EU 5G Observatory ⁸⁴ monitors market developments , including trials and other actions taken by industry stakeholders and Member States in the context of 5G roll-out in Europe. The observatory will assess the progress of the 5GAP and take action to fully implement it.
NetWorld2020 	NetWorld2020 ⁸⁵ is the European Technology Platform for communications networks and services that supports the vision to develop mobile, fixed and satellite communications at European and national levels. The platform gathers players in the communications networks sector, including industry leaders, innovative SMEs, and leading academic institutions.

Exhibit C.2. Selection of major 5G initiatives, innovation hubs and stakeholders in Europe
[Source: Axon Consulting]

⁸³ <https://5g-ppp.eu/>

⁸⁴ <https://5gobservatory.eu/>

⁸⁵ <https://www.networld2020.eu/>

Overall, these EU-wide initiatives and stakeholders are contributing to the development of 5G across Member States.

As of December 2019, 11 Member States had published national 5G roadmaps, including spectrum strategies to drive towards 5G deployments (Austria, Denmark, Estonia, Finland, France, Germany, Luxembourg, Netherlands, Spain, Sweden, and the United Kingdom). The national strategies adopted to date have a number of facets, including concrete targets, defined priority areas and milestones. Overall, 26 EU Member States have launched public consultations on 5G spectrum/strategy.

5G trials involving multiple stakeholders remain essential to 5G development in Europe

European operators have been working closely with technology providers and vertical players on various trials to validate 5G capabilities. According to the 5G Observatory, more than 220 trials in Europe had been reported at the end of December 2019, up from 164 in December 2018.⁸⁴

Such trials have various aims, such as technical stress-testing, examining proof of concept, and analysing the commercial feasibility or disturbance of certain aspects of 5G. They are also conducted for a range of different verticals, beyond commercial mobile users. Consequently, trials often involve collaboration between entities, such as public-sector agencies, operators, network providers and SMEs, with each stakeholder gaining something from the test.

The main verticals trialled across Europe with regards to 5G include:

- ▶ Automotive and Mobility⁸⁶
- ▶ Smart City Enablers and Public Safety⁸⁷
- ▶ Industry 4.0⁸⁸
- ▶ Healthcare
- ▶ Energy and Utilities
- ▶ Media and Entertainment
- ▶ Agriculture and Livestock

⁸⁶ "Automotive and Mobility" includes projects addressing automotive, transport and mobility industries.

⁸⁷ "Smart City Enablers and Public Safety" includes projects addressing smart cities, smart homes, smart buildings and public safety.

⁸⁸ "Industry 4.0" includes projects addressing manufacturing industry and factories of the future.

Although most trials in Europe and across the world are focused on these industries, a considerable number of companies and stakeholders are building cross-vertical (i.e. industry-agnostic) 5G solutions. Ultimately, prominent verticals thereby gain ubiquitous access to a wide range of 5G solutions. These represent an attempt to provide the technology, connectivity, infrastructure, hardware, and other elements that can drive 5G deployment or solutions for various verticals. For instance, companies that develop solutions based on connectivity, coverage, communications, and mobile network infrastructure are not generally limited by industry and are capable of addressing the needs of multiple use cases. Accordingly, our analysis paid particular attention to identifying such industry-agnostic application groups, given their significant relevance to the 5G ecosystem and this study.

The previously mentioned verticals provide a useful basis for categorising the different trials related to 5G technology. For this study's purposes, we considered 5G pre-commercial trials⁸⁹ conducted as part of the 5GAP. These include commercial trials and demonstrations as well as national initiatives, based on 5G technology, with a clear focus on activities revolving around EU cities. Exhibit C.3 presents the categories of 5G trials taking place across the main verticals in Europe as of December 2019.

⁸⁹ 5G pre-commercial trials are conducted across the European Union and are defined under Pan-European 5G Trials Roadmap by the 5G PPP: <https://5g-ppp.eu/5g-trials-roadmap/>

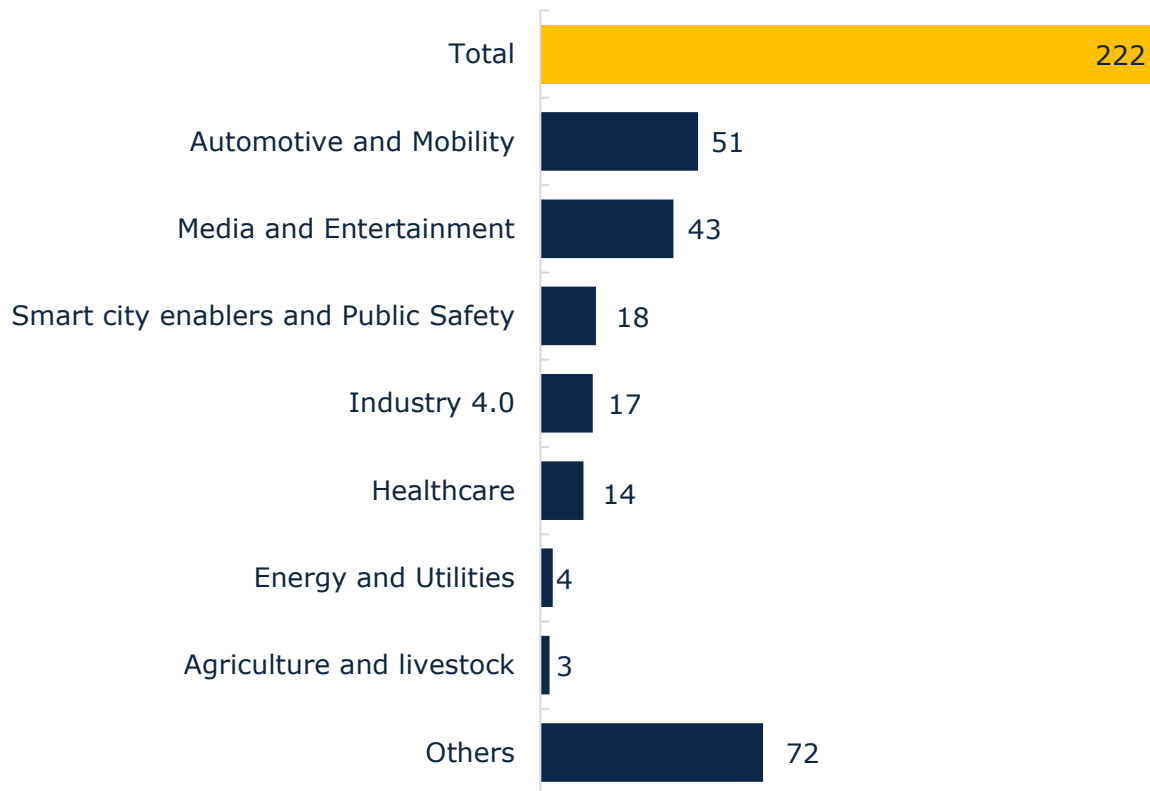


Exhibit C.3. 5G trials conducted across verticals in Europe⁹⁰
[Axon Consulting, based on data from European 5G Observatory⁹¹]

5G trials are also a field of interest for SMEs, which have begun conducting pilots throughout Europe by collaborating with large telcos. To illustrate such activity, Unmanned Life successfully demonstrated in 2018 the necessity of URLLC by deploying autonomous control and management of a fleet of drones in London on a dedicated 5G network slice within BT's network. The drones had been launched in America by Verizon, whereas the 5G technology, together with virtualized network functions, were provided by Ericsson.

Most European countries are already running 5G trials across their territories. As Exhibit C.4 shows, Spain, France, Germany, Italy and the United Kingdom are leading the way, accounting for 52% of the trials using 5G's advanced capabilities. Pursuant to the 5GAP target of 5G commercial roll-out in one major city of every Member State by 2020, several European cities announced their plans to become "5G Trials Cities." For instance, 20 Trials Cities were announced in nine Member States⁹² in 2018. With other cities implementing

⁹⁰ It takes into account 222 trials organised in 30 countries (181 in EU Member States; 41 in Russia, San Marino, Norway, Turkey and Switzerland)

⁹¹ European 5G Observatory, "Quarterly Report 6," December 2019 (http://5gobservatory.eu/wp-content/uploads/2020/01/90013-5G-Observatory-Quarterly-report6_v16-01-2020.pdf)

⁹² Amsterdam, Aveiro, Barcelona, Bari, Berlin, Bristol, Espoo, Ghent, L'Aquila, London, Madrid, Malaga, Matera, Milan, Oulu, Patras, Prato, Stockholm, Tallinn and Turin.

5G pilots and 5G-live services, the total number of 5G-enabled cities in the EU-28 reached 138 by the end of December 2019. All these advancements promote European H2020 objectives.

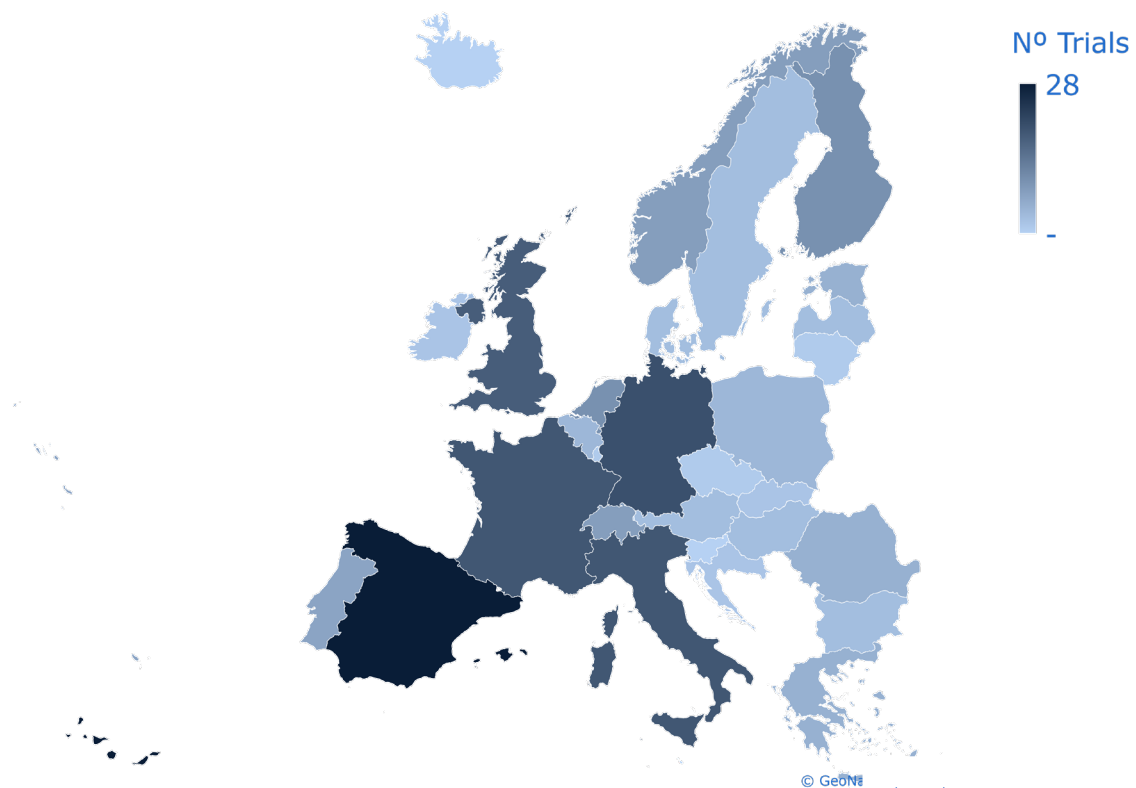


Exhibit C.4. Number of major 5G tests and trials conducted across Europe⁹³ as of December 2019
[Source: Axon Consulting, based on data from European 5G Observatory]

Additionally, Member States have aligned interests by creating interconnected platforms and facilities in which tests and pilots of specific 5G use cases can be performed. This encourages various stakeholders of the ecosystem to make the right steps towards bringing their applications into reality. Projects such as 5G-VINNI (Norway), 5Growth (Spain), 5G-EVE (Italy) and 5GTNF (Finland) cater for multistakeholder technology and/or use-case development for 5G, as Exhibit C.5 illustrates.

⁹³ To keep consistency with the information provided by the European 5G Observatory, Exhibit D.20 shows information for not only the EU 28 Member States but also Norway, Switzerland, and San Marino.

5G Trial Initiatives	Description
5G-VINNI  5G-VINNI	Working as a group of interconnected site facilities, 5G-VINNI ⁹⁴ aims to accelerate 5G uptake in Europe by providing an end-to-end facility that lowers the entry barrier for vertical industries to pilot and test specific applications as the infrastructure evolves. The main facility sites are in Norway, the United Kingdom, Spain, and Greece, while the experimentation facility sites are in Portugal and Germany (Munich, and Berlin).
5G-EVE  5G EVE	5G EVE ⁹⁵ is the 5G European Validation platform for Extensive trials, rooted in the idea of further developing and interconnecting existing European sites in Italy, Greece, Spain, and France to form a unique 5G end-to-end facility.

Exhibit C.5. Interconnection facilities for 5G trial initiatives across the European Union [Source: Axon Consulting]

However, running trials is just one of many ways in which EU Member States are strongly working towards success in the 5G era. Therefore, the current 5G maturity of a particular country is not necessarily strictly related to the number of 5G trials conducted there. Some studies analysing 5G readiness or maturity thus consider other relevant factors, such as economical, operational and social elements.⁹⁶

Regional differences in Europe may lead to discrepancies in 5G deployment

According to the "Europe 5G Readiness Index" prepared by Incites, which provides a 5G readiness score for each European country,⁹⁷ there is a significant gap between Western and Eastern Europe, with countries in the former category being, on average, more ready to introduce 5G.

Exhibit C.6 presents an overview of the overall 5G readiness score for each country.

⁹⁴ <https://www.5g-vinni.eu/>

⁹⁵ <https://www.5g-eve.eu/>

⁹⁶ Examples include the Europe 5G Readiness Index prepared by Incites (https://www.incites.eu/incites-map/Europe_5G_Readiness_Index_Report.pdf) and the 5G Maturity Index prepared by Nokia (<https://networks.nokia.com/services/5g-acceleration-services/maturity-index>).

⁹⁷ This index comprises six categories: "Infrastructure and technology," "Regulation and policy," "Innovation landscape," "Human capital," "Country profile" and "Demand."

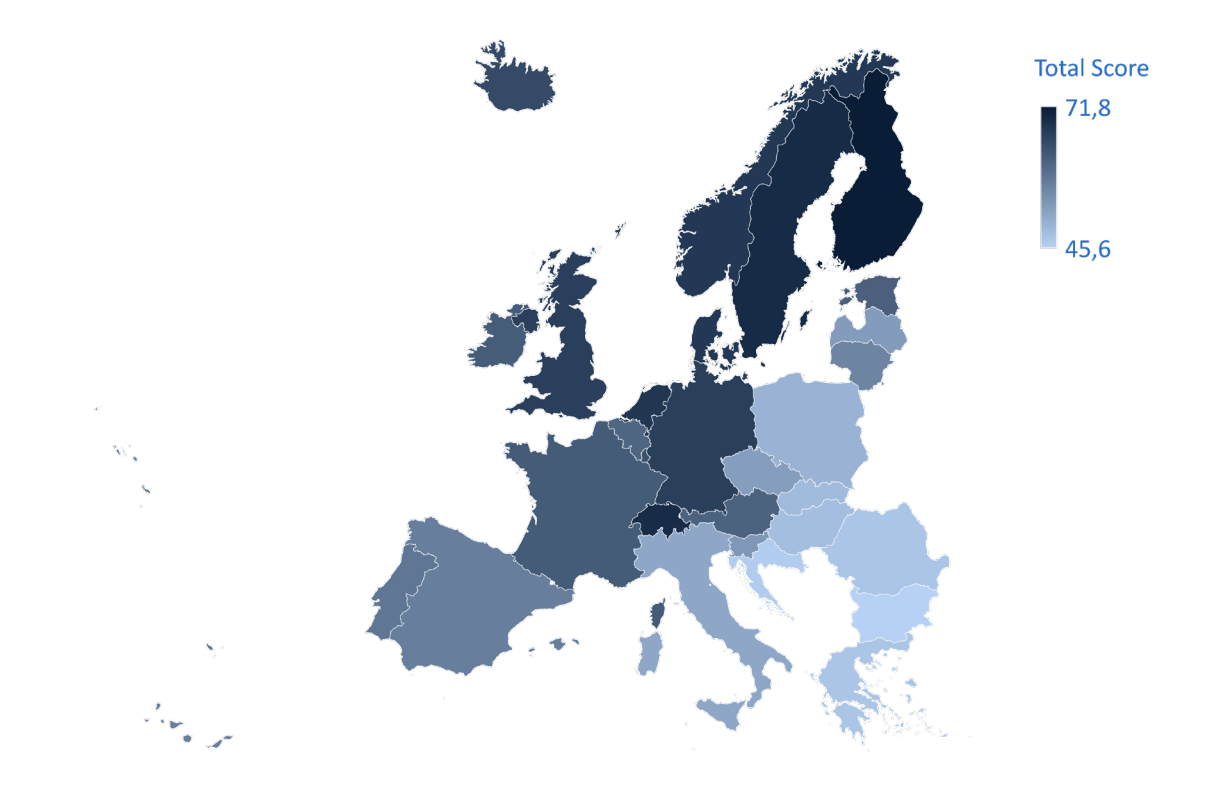


Exhibit C.6. Overall 5G readiness score in European countries
[Source: Axon Consulting, based on Incites report] Error! Bookmark not defined.

We note, however, that this and similar indexes tend to analyse overall 5G readiness, thus reflecting the extent to which countries are able to initiate commercial roll-outs of 5G, which usually target traditional broadband consumers.

5G has exciting potential impacts across many verticals that are already being pursued today

Overall, 5G has the potential to span across industry verticals and drive forward existing and new business cases. Trends in Europe also point towards convergence, as witnessed by the pilots and initiatives carried out across Member States. Exhibit C.7 shows some of the use cases currently being implemented across our focal industry verticals in Europe.

Key vertical	Example use case	Description
Automotive and Mobility	Stakeholder 	
	Geography 	

Key vertical	Example use case		Description
	Use-case family	URLLC	DenseAir and Airspan have developed autonomous vehicle solutions intended to reach the market by 2022 . Having deployed a hyper-dense small cell network of 89 base stations, trials were conducted using a McLaren sports car travelling at speeds above 250 km/h. ⁹⁸
	Use case	Autonomous vehicles	
Media and Entertainment	Stakeholder		forwARdgame, a mixed-reality gaming company, will use the ultralow latency of 5G to deliver immersive real-time-response experiences by 2020 . ⁹⁹
	Geography		
	Use-case family	eMBB	
	Use case	Gaming and AR	
Smart City Enablers and Public Safety	Stakeholder		Phillips has developed a "smart street pole" that houses cellular gear for 4G and 5G phone and broadband services while also connects lighting and other smart city operations to those networks .
	Geography		
	Use-case family	mMTC	
	Use case	Smart lighting	

⁹⁸ <https://www.airspan.com/> and <http://denseair.net/>

⁹⁹ <https://www.forwardgamear.com/>

Key vertical	Example use case		Description
Healthcare	Stakeholders		Hospital Clinic of Barcelona used Vodafone's 5G network in Spain to conduct remote robotic surgery early in 2019. They plan to extend this practice from 2020 onwards when critical 5G standalone capabilities are fully deployed .
	Geography		
	Use-case family	URLLC	
	Use case	Remote surgery	
Agriculture and Livestock	Stakeholder		Gamaya, a precision-agriculture SME, provides intelligent solutions for optimising crops based on drone and satellite images captured by a hyperspectral camera. They started selling their cameras in 2020 . ¹⁰⁰
	Geography		
	Use-case family	URLLC	
	Use case	Crop surveillance	
Industry 4.0	Stakeholder		Bosch is currently undertaking 5G factory trials : the factory has sensors for preventive maintenance and real-time feedback, and uses data analytics to predict any potential failures. Bosch is targeting revenue of over €1 billion in this area as early as 2022 .
	Geography		
	Use-case family	mMTC	
	Use case	Industry maintenance	

¹⁰⁰ <https://gamaya.com/>

Key vertical	Example use case		Description
Energy and Utilities	Stakeholder(s)		BeeBryte, an energy intelligence company , develops an IoT gateway, which leverages 5G connectivity and capacity to reach up to 40% savings in heating, ventilation, air conditioning and energy in a real-time optimisation . ¹⁰¹
	Geography		
	Use-case families	eMBB, mMTC	
	Use case	Energy efficiency	

Exhibit C.7. Examples of 5G-based use cases across industry verticals in Europe
 [Source: Axon Consulting]

C.2. Developing 5G-based applications and assessing their potential

C.2.1. Clustering of use cases among verticals

When trying to pursue cost-competitiveness, addressing verticals separately and selecting use cases independently might not optimise synergies on market entry. The power to encounter segments with similar characteristics across industries makes it possible to identify application-based clusters, thus creating a secondary classification that can maximise revenue potential and reduce deployment challenges. Compared to addressing use cases individually, the cluster approach allows for shared investment, better prioritisation of opportunities and better allocation of resources through increased revenue volume while scaling across multiple industries. Therefore, it enables risk sharing and rewarding across a wide range of applications and verticals.

¹⁰¹ <https://beebryte.com/>

As explained by Ericsson,¹⁰² more than 200 use cases in which 5G is expected to play an important role can be grouped into nine clusters, accounting for almost 90% of 5G business opportunities. The nine clusters are defined as follows:

- ▶ Real-time automation
- ▶ Enhanced video services
- ▶ Monitoring and tracking
- ▶ Connected vehicle
- ▶ Hazard and maintenance sensing
- ▶ Smart surveillance
- ▶ Remote operations
- ▶ Autonomous robotics
- ▶ AR

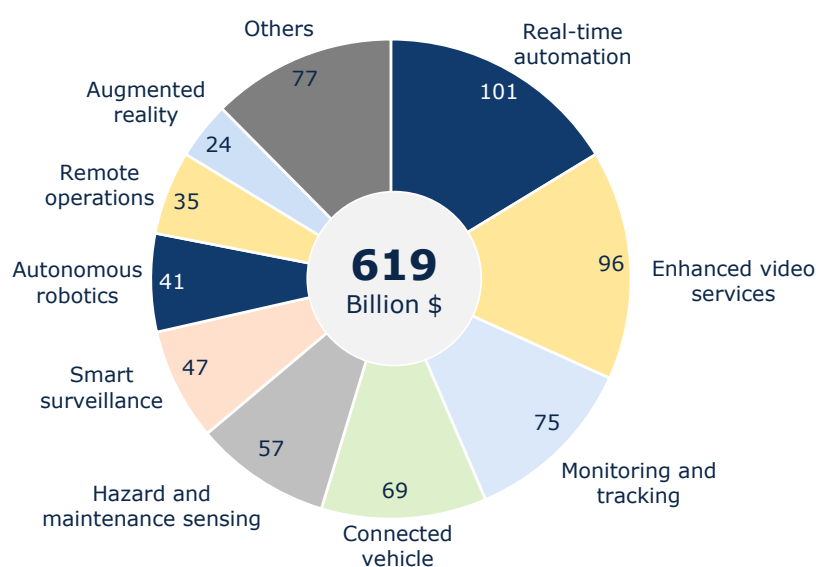


Exhibit C.8. Use-case clusters methodology and 2026 revenue potential in \$ billion
[Source: Axon Consulting elaboration on Ericsson report¹⁰²]

Each cluster of use cases covers between two and six industries. Verticals such as manufacturing and healthcare feature in several clusters. Therefore, operators might need to consider the combination of industry verticals and the opportunities they entail from a clustering perspective within their home markets, so as to leverage every angle.

Success in maximising the potential and capturing the benefits of use-case clustering will depend on the ambition of operators and stakeholders in the deployment of technical capabilities and on the prospect of market launch. Therefore, go-to-market and operator

¹⁰² Ericsson, "A guide to capturing the 5G industry digitalization business potential," 2019 (<https://www.ericsson.com/en/networks/trending/insights-and-reports/5g-challenges-the-guide-to-capturing-5g-iot-business-potential>)

deployment are the two main challenges faced by this 5G clustering approach, with difficulties such as latency, reliability, broadband, regulation and ecosystem complexity affecting all key verticals for 5G.

Cluster description	Potential use cases	Key factors
Real-time automation As the largest cluster, real-time automation brings autonomous applications—often mission critical—that leverage data from sensors in real time to perform specific autonomous actions. Verticals involved: Agriculture, energy & utilities, Industry 4.0, healthcare	▶ Management and distribution of energy resources ▶ Virtual power plants (VPP) ▶ Cutting-edge, high-precision medicine ▶ Biotechnology development, accurate pesticides spraying	▶ Ultralow latency, availability and reliability ▶ Key partnerships needed due to significant regulatory challenges ▶ Complexity of market entry
Connected vehicles The connected vehicle cluster includes applications to provide moving vehicles with robust nationwide connectivity services. Verticals involved: Automotive, smart city & public safety, healthcare	▶ Emergency service vehicle connection and notification system ▶ High-speed internet on trains ▶ Vehicle-to-vehicle networks	▶ Wide-area deployment of high-speed mobile broadband ▶ New sales capabilities to deal with a variety of customers (public transport, end-users, etc.) ▶ Connection density, position accuracy, performance
Augmented reality The AR cluster gathers applications that augment the real-world environment with visual and audio aids. Verticals involved: Media & entertainment, healthcare, agriculture, Industry 4.0, automotive	▶ AR for industrial support such as maintenance, construction and repair ▶ Remote live events experience, gaming, video storage and enhanced customer care ▶ AR aiding agriculture ▶ AR as a means to support medical treatment	▶ Need for numerous successful partnerships with hardware/service providers ▶ Broadband data required for correct performance ▶ Go-to-market complexity and need for extensive deployment ▶ Latency, performance and position accuracy are key

Cluster description	Potential use cases	Key factors
Hazard and maintenance sensing This cluster comprises applications that leverage algorithms and sensors to provide signals that help decisionmaking in mission-critical activities. Verticals involved: Smart city & public safety, Industry 4.0, healthcare, energy & utilities, automotive, agriculture	▶ Power plant default detection ▶ Predictive maintenance of machinery and vehicles ▶ Grid infrastructure sensors ▶ Patient remote monitoring	▶ Network availability and reliability for mission-critical applications ▶ Market entry complexity of handling broad ecosystems ▶ Current, upcoming, and potential regulatory constraints
Smart surveillance The smart surveillance cluster will use cameras and sensors to identify and analyse a large number of objects in real time Verticals involved: Public safety, Industry 4.0, healthcare, media & entertainment, automotive	▶ Smart digital billboard marketing ▶ Security monitoring with automatic face detection – crowd control ▶ Real-time person-vehicle surveillance ▶ Traffic/border security control	▶ General privacy and data protection regulation in different markets ▶ Distinguishing between private and public surveillance is a critical legal issue for wider adoption ▶ Low latency and availability needed for fast, accurate monitoring
Autonomous robotics The autonomous robotics cluster includes use cases based on machines/sensors that perform tasks and behave autonomously, with minimal human intervention. Verticals involved: Industry 4.0, healthcare, retail	▶ Automatic inventory-management robots in warehouses ▶ Collaborative robots in closed-loop communication ▶ Smart robots for assisted living ▶ Autonomous delivery robots	▶ Critical deployment challenges: latency, reliability, availability and position accuracy ▶ Significant go-to-market challenges, including capital-intensive developments and extremely high regulatory barriers
Enhanced video services Having the second-largest revenue potential, the enhanced video services cluster allows for next-generation content consumption and video telecommunication. Verticals involved: Media & entertainment, smart city & public safety, healthcare, Industry 4.0, agriculture	▶ Training simulations via VR 4K/8K ▶ Enhanced cloud gaming and large-scale on-demand viewing ▶ Huge number of participants video calling ▶ Immersive video conferencing ▶ Telemedicine	▶ Need for close partnerships among enablers (medical facilities, TV channels, mobile operators, etc) ▶ Access to high quality content is vital, thus negotiation with the content owner ▶ Large-scale deployments and highly complex market entry ▶ Low latency and high broadband connection will be 5G's key enablers

Cluster description	Potential use cases	Key factors
Monitoring and tracking This cluster entails an extensive asset-tracking network and next-generation navigation skills. Verticals involved: Industry 4.0, agriculture, healthcare, automotive, energy & utilities	▶ Fleet and freight management ▶ Hospital asset tracking and health records sharing ▶ Identification and tracking of goods in the value chain ▶ Connected goods	▶ Need to implement accurate positioning, long battery life and robust security, enabled by 5G ▶ Close partnerships between operators and industry experts to develop specific solutions for each target industry ▶ Relatively low deployment challenges
Remote operations This cluster comprises applications that enable remote control of machinery or vehicles from any location under human supervision. Verticals involved: Public safety, Industry 4.0, healthcare, media & entertainment, agriculture	▶ Remote services: drug administration; control of agricultural equipment; control of robots, processes and operations ▶ Telesurgery ▶ Vehicle teledriving ▶ Deep underground and underwater activities (mines, dive equipment maintenance)	▶ Key deployment challenges in verticals require solutions developed by special technology experts ▶ Latency-intensive applications with no chance of failure

Exhibit C.9. Clustering of use cases: description, potential applications and challenges
 [Source: Axon Consulting]

C.2.2. Key verticals expected to drive 5G-based applications

5G is envisioned to be stakeholder driven, enabling a holistic ecosystem for technical and business innovation that integrates networking, computing and storage resources into one programmable and unified infrastructure. 5G network infrastructures will provide key support for societal transformation in Europe, leading to the Fourth Industrial Revolution that will impact multiple sectors. The transformational capabilities that 5G is poised to bring will enable vertical industries to enhance their own capabilities to develop new products and services. Identifying key vertical sectors' requirements, anticipating relevant trends early and mapping them into the 5G design are all fundamental to 5G success. Therefore, close collaboration between vertical industries and 5G civil-infrastructure providers will be mutually beneficial.

The prominent industry verticals considered in this study are discussed in the following paragraphs.

Automotive and Mobility

The vision of advanced driver-assistance systems and, in the longer term, completely autonomous driving promises not only fewer fatal accidents and less traffic congestion in cities but also a wide range of new business opportunities for a broad range of industries, as well as benefits for the environment. 5G will realise this vision by improving cooperative automated driving through the real-time exchange of sensor information between thousands of cars connected in the same area. For example, cooperative collision avoidance sets the prerequisite that communications be operational everywhere, with far higher reliability and performance levels than are currently available. This connectivity should be possible even in areas without network coverage (due to shadowing or other obstructions), for example by relaying signals between vehicles. In addition, 5G is expected to drive the smart mobility segment, which is a rising trend across the world.

The main use-case categories and application groups in this vertical that are expected to leverage 5G technology include:

- ▶ **Cellular-vehicle-to-everything (C-V2X) communications:** Cellular-based technologies will be essential to transforming the entire mobility ecosystem. With a strong evolutionary path to 5G, V2X technology is expected to offer superior performance in communication between connected vehicles and transport infrastructure, leading to less congestion, reduced emissions, and a smoother driving experience. The interconnectivity speed required by such applications implies the need to transmit and receive data in the quickest manner. Thus, the signals should ideally be sent directly, rather than via a base station. Unlike in-vehicle connectivity, which can run off mobile signals when they are available, this technology requires a much-improved out-of-vehicle network connection to work safely. 5G reception for these applications is expected to provide a continuous and reliable signal that does not bounce off moving vehicles, buildings or other surfaces. Use cases such as remotely controlled vehicles and self-driven vehicles will require ultrareliable and very fast communication between different self-driving cars and between cars and infrastructure.
- ▶ **Driver and passenger services:** 5G can also significantly improve the driver and passenger experience in vehicles, generating revenues and cost-saving opportunities for the industry. Infotainment services for passengers require high-capacity and high-mobility mobile broadband, as users will expect a good quality connection regardless of their location and speed.
- ▶ **Vehicle management:** 5G has significant implications for the automotive management, maintenance and damage-control ecosystem. As the number of sensors

in vehicles increases, the data they produce can help manufacturers to improve the design, safety, and maintenance of vehicles.

Exhibit C.10 gives examples of use cases and SMEs developing them within Automotive and Mobility, categorised by application group.

Application group	Use cases	Example company
Automated driving and C-V2X communications	▶ Self-driving cars: Range of use cases that include features such as collision avoidance, emergency breaking and intelligent traffic coordination. ▶ Vehicle to anything (V2X) communications: Use cases that connect vehicles with other vehicles, infrastructures, pedestrians, networks, etc. These use cases are expected to support the move towards autonomous vehicles. ▶ Vehicle platooning: Platooning of vehicles such as delivery trucks equipped with mutually connecting smart technology for reduced fuel consumption, traffic management, etc.	Oxbotica¹⁰³ Oxbotica enables vehicle autonomy by engineering the software that drives them, with total freedom from external infrastructure dependency. Its software can be applied to various vehicles in multiple verticals.
Driver and passenger services	▶ Connected cars: Improvements to provision of services to the vehicle, such as emergency calls, driver-assistance services, and infotainment services. ▶ Driver-assistance services: Include smart applications such as birds' eye view, auto-parking, "see through" the vehicle in front, and in-dash junction cameras.	WayRay¹⁰⁴ WayRay offers novel driving experiences and services by utilising AR technology to create advanced driver-display solutions.

¹⁰³ <https://www.oxbotica.com/>

¹⁰⁴ <https://wayray.com/>

Application group	Use cases	Example company
Vehicle management	▶ On-board diagnostics: Include real-time analytics, predictive maintenance and remote monitoring of vehicles. ▶ Vehicle insurance: Vehicle tracking systems to monitor driving style, estimate premiums, etc.	2Hire¹⁰⁵ 2Hire offers advanced fleet-management solutions by connecting fleet owners to real-time data including vehicle maintenance and use.

Exhibit C.10. Use cases in Automotive and Mobility that are expected to leverage 5G
[Source: Axon Consulting]

Smart City Enablers and Public Safety

Smart cities and smart homes, often collectively termed smart society, will be embedded with dense wireless sensor networks. Smart city technology is expected to benefit transport, healthcare, education, building management, city governance and other domains. The systems associated with smart city project deployments will operate across a vast ecosystem of sensors, mobile devices, communication networks and data centres enhanced by advanced analytics, including AI. Thus, these systems will enable projects such as smart energy harvesting and storage, building automation and smart traffic management—even notifying drivers of available spaces in parking lots. Although 5G is most often hyped for the very fast data rates it is supposed to bring, it could also provide significantly greater coverage density than is currently available. 5G is thus expected to deliver the massive improvements in speed, throughput, device deployment, traffic capacity, latency and spectrum efficiency required by the smart city ecosystem.

The main use-case categories and application groups in this vertical that are expected to leverage 5G technology include:

- ▶ **Smart buildings and smart homes:** These must be embedded with dense wireless sensor networks. Distributed networks of intelligent sensors will identify conditions for cost-efficient and energy-efficient maintenance of the city or home. A similar setup can be deployed in each home, with temperature sensors, window and heating controllers, burglar alarms and home appliances all connected wirelessly. Many of these sensors are typically low data rate, low power and low cost, although real-time high-definition

¹⁰⁵ <https://2hire.io/>

video may be required in some types of surveillance devices. 5G will serve to integrate the management of these very diverse connected devices.

- ▶ **Smart city management:** Use cases in this category address the effective management of various aspects of the city by leveraging 5G networks. Such solutions will include smart traffic, smart waste management, smart parking, and smart pollution control.
- ▶ **Public safety:** Public-safety stakeholders are expected to contribute significantly to the conversation that drives the 5G revolution, aiming to ensure that it meets their needs. Assured, dedicated and efficient cellular connectivity is required for public-safety and mission-critical applications, so as to enable the stakeholders to perform their crucial tasks. Cellular networks will need to be able to function in harsh environments and weather, transmit seamlessly from body cameras, enable warning broadcasts, provide continuous connectivity for drones, and maintain individual privacy.

Exhibit C.11 gives examples of smart city use cases and SMEs developing them, categorised by application group.

Application group	Use cases	Example company
Smart buildings and homes	▶ Smart buildings: Sensor-connected applications to optimise maintenance processes, reduce energy footprint, gain real-time insights, etc. ▶ Smart homes: Connecting appliances and devices throughout the house to be controlled from a central device. ▶ Smart security and surveillance: Live video surveillance and other remote security features for homes and offices.	Yanzi ¹⁰⁶ Yanzi provides a smart building network platform that uses sensor data to create better work and living spaces.

¹⁰⁶ <https://www.yanzinetworks.com/>

Application group	Use cases	Example company
Smart city management	▶ Smart parking: Sensing devices determine occupancy in parking lots, enabling faster, easier and denser parking of vehicles. ▶ Smart street lighting: Lighting systems with intelligent control and remote-communication features to provide monitoring, measuring and control functions. ▶ Smart traffic control: Intelligent management of traffic using smart parking sensors, smart streetlights, smart highways, smart accident assistance, etc. ▶ Smart garbage bins: Sensor-enabled and internet-connected garbage bins to collect information on fill-level, temperature, location, etc.	Teralytics¹⁰⁷ Teralytics is building an intelligent mobility operating system to enable transport infrastructures, mobility services and cities to work together for public benefit.
Public safety	▶ Mission-critical communication: Broad range of critical applications that must work as anticipated, without fail, during emergencies and other similar situations. ▶ Smart emergency vehicles ▶ Body cameras, especially for law enforcement agents, police, emergency workers, defence applications, etc. ▶ Public security management	CTRL4 enviro¹⁰⁸ CTRL4 enviro uses a customised software to analyse video images and integrate, process and publish results in real time.

Exhibit C.11. Use cases in Smart City Enablers and Public Safety that are expected to leverage 5G
[Source: Axon Consulting]

¹⁰⁷ <http://www.teralytics.net/>

¹⁰⁸ <https://ctrl4enviro.com/>

Industry 4.0

An industrial revolution entails seismic change in industrial processes, output and productivity. The Fourth Industrial Revolution, known as Industry 4.0, is characterised by a fusion of technologies that are blurring the lines between the physical and digital spheres. The digitalisation of factories will be a key development of the 2020s and is expected to be fuelled by cyber-physical systems (CPS) and the IoT, which will enable effective, connected and flexible factories of the future. New scenarios are emerging that aim to increase the efficiency of production lines inside the factory, based on the collaborative functions of a new generation of robots. Manufacturers are driving the evolution to data-driven ecosystems by exploiting product lifecycle data from connected goods. Energy-efficient communication schemes and data analytics tools will support these diverse data-collection scenarios. With AR, new remote services are emerging, such as toolmakers that use AR systems to facilitate processes and reduce error rates in complex injection moulding tools, accompanied by vast amounts of data that, adequately postprocessed, can provide effective knowledge sharing in the factory. More generally, future communication solutions are expected to ensure seamless, secure and real-time connectivity between different globally distributed production sites and new actors in the value chain (e.g. suppliers and logistics providers). Thus, stakeholders are betting on 5G to deliver ultralow latency, high bandwidth and reliable communication to realise smart factories. In summary, Industry 4.0 and its design principles are gaining ever more acceptance and will influence present and future 5G requirements.

The main use-case categories and application groups in this vertical that are expected to leverage 5G technology are as follows:

- ▶ **Industrial control and process automation:** To achieve success in the industrial and manufacturing segment, 5G must become embedded in the industrial automation process. First, the functionality of today's wired industrial systems must be replicated to support existing controllers, switches, sensors and actuators. Second, 5G will be integral to the evolution of industrial IoT as machines and production lines are themselves re-designed, improved and automated. Together, 5G solutions will be expected to support zero-defect manufacturing and enable the development of smart factories.
- ▶ **Planning and design systems:** 5G can provide stakeholders with the capabilities to simulate factory processes, deliver training support, detect operational inefficiencies and perform troubleshooting. Wasted time in a factory can translate into not only lost revenue but also missed opportunities for new revenue. The more efficiently processes are designed and planned, the greater the resulting efficiency of accessing, collecting

and aggregating data, leading to highly efficient production units. Additionally, 5G will enable stakeholders to respond to changes in the production lifecycle and the supply chain for smarter, leaner operations.

- **Connectivity and maintenance:** Connectivity is linking manufacturers directly to consumers, thus opening new opportunities for creating revenue-generating services. Connectivity and analytics make it possible to deliver a holistic picture of factory operations to manufacturers, enabling them to lower maintenance costs, increase asset life, and boost factory output. The use cases in this application category primarily target gathering and monitoring data.

Exhibit C.12 gives examples of use cases and SMEs developing them within Industry 4.0, categorised by application group.

Application group	Use cases	Example company
Industrial control and process automation	► Industrial operations and control: Includes connectivity of infrastructure within the factory to assist in monitoring, quality control, fleet management, logistics, traceability, etc. ► Industrial automation: Use of various control devices, such as computers and robotics, for handling and controlling different processes in the factory, such as production line control.	Universal Robots ¹⁰⁹ A Danish company that produces a robotic arm that is flexible and easy to use in day-to-day industrial production.
Planning and design systems	► Industrial design systems: Include use of 3D AR for product design, digital twins for data integration, online simulation, etc. ► Industrial planning systems: Demand and supply forecasting through asset tracking, inventory forecasting, connected fleets, scheduled maintenance, etc.	Vekia ¹¹⁰ Vekia designs and edits predictive planning software that uses the latest research advances to model the complex problems of supply chains.

¹⁰⁹ <https://www.universal-robots.com/>

¹¹⁰ <http://vekia.fr/>

Application group	Use cases	Example company
Connectivity and maintenance	▶ Industrial maintenance: Includes real-time monitoring, descriptive analytics of processes, early warning alarms, predictive maintenance, etc. ▶ Industrial connectivity: Wearable devices for security/control purposes, connected drone fleet, autonomous guided vehicles, etc.	Elmodis¹¹¹ Provides an end-to-end IoT solution that monitors the performance and improves the operating efficiency of industrial machines.

Exhibit C.12. Use cases in Industry 4.0 that are expected to leverage 5G [Source: Axon Consulting]

Healthcare

According to the 5G PPP,¹¹² healthcare accounts for 9–10% of national GDP in Europe, a share that is likely to grow further over the next decades. Containing the budget for healthcare is one of today's biggest socio-economic challenges, and there are high hopes that technologies such as 5G will be instrumental in mobilising efficiency reserves, such as assisted self-management capabilities, and empowering less qualified personnel to conduct routine tasks on behalf of highly qualified professionals. Although the spread of electronic health (e-health) and mobile health (m-health) applications could be instrumental in reducing the societal burden, a 2014 EU public consultation¹¹³ and study showed that their market uptake has been sluggish and lagged far behind expectations. With 5G, there is potential to decentralise the healthcare model and accelerate the industry towards providing care closer to the patient and outside the hospital setting. 5G will support this decentralised healthcare ecosystem by enabling more reliable and accessible medical procedures.

The main use-case categories and application groups in this vertical that are expected to leverage 5G technology are as follows:

- ▶ **Hospital:** 5G has the potential to significantly impact the business models of healthcare facilities in numerous ways, by encouraging incremental improvements and innovations. For instance, 5G can facilitate the speed and exponential computing at the edge that will encourage widespread adoption of telemetry and telemedicine. Further,

¹¹¹ <http://elmodis.com/>

¹¹² 5G PPP, "5G empowering vertical industries" (https://5g-ppp.eu/wp-content/uploads/2016/02/BROCHURE_5PPP_BAT2_PL.pdf)

¹¹³ Public Consultation on the Green Paper on mobile Health: <https://ec.europa.eu/digital-single-market/en/public-consultation-green-paper-mobile-health>

5G is expected to support the extension of healthcare infrastructures beyond hospital premises. One example is the potential use of ambulance drones, with integrated features such as a defibrillator, to provide emergency services.

- ▶ **Patient monitoring and surgery:** 5G can also enable the healthcare industry to deploy patient-centred applications used primarily outside traditional hospital environments. 5G is expected to drive precision medicine and applications to remotely monitor, alert and administer medicines, among other applications. It will enable better connections on mobile devices, increase data-transfer capacity by utilising wider bandwidth, support the transfer of larger data blocks, and enable healthcare workers to provide live and near-real-time remote care.
- ▶ **Medical data management:** Effectively harnessing data in healthcare can potentially lower operational costs and improve efficiencies. Today's key topics in the health domain include the real-time integration of a massive number of "things" (IoT), processing large amount of data (Big Data), integrating data on the fly from different sources and across different networks, and aggregating services across different domains to support integrated care models. The latter topic includes billing and future universal care accounts, through which patients will be able to take control of their care and allocate resources in accordance with their perceived needs. 5G can facilitate faster and highly secure processing of large amounts of data to perform predictive analyses and prevent diseases and complications. Real-time delivery of rich data sets and e-health records are major use cases that 5G can drive in medical data management.
- ▶ **Other healthcare applications:** For instance, 5G can enhance the quality of experience of surgeons using operating robots by cutting latency and allowing remote use from anywhere. Ultralow latency can also support real-time artificial perceptions (audio, vision, haptics), VR and AR. 5G-powered VR/AR can potentially enable doctors and surgeons to more aptly visualise procedures in an engaging and educative manner.

Exhibit C.13 gives examples of use cases and SMEs developing them within Healthcare, categorised by application group.

Application group	Use cases	Example company
Hospital	▶ Assets and interventions management in hospital ▶ Ambulance drones, with integrated features such as a defibrillator, to provide emergency services ▶ Telemetry and telemedicine to provide healthcare services remotely	Qare ¹¹⁴ Qare offers on-demand, online-to-offline, virtual medical practice, providing all the benefits of the French medical system abroad.
Patient monitoring and surgery	▶ Patient monitoring: Includes remote monitoring of patients' health, remote diagnosis and imaging, smart medication, etc. ▶ Remote surgery: Use of robotics to manipulate instruments remotely for performing surgeries	CMR Surgical ¹¹⁵ CMR Surgical has developed Versius, a remote surgery tool that works with the surgeon to improve patient outcomes and deliver value for healthcare providers.
Medical data management	▶ Electronic health records ▶ Predictive analysis to identify and prevent diseases and complications	Preventicus ¹¹⁶ A digital health company that develops and commercialises fundamentally new digital products and services for atrial fibrillation detection.

Exhibit C.13. Use cases in Healthcare that are expected to leverage 5G [Source: Axon Consulting]

Energy and Utilities

The energy sector is facing fundamental changes with the transformation to a user-centric and distributed energy grid. Current communications networks, which cannot be flexibly or temporarily deployed and involve high CapEx, are unable to support this transformation. There are numerous ways in which the technologies introduced by 5G will benefit the energy and utilities sector, bringing higher profitability for suppliers and greater

¹¹⁴ <https://www.qare.fr/>

¹¹⁵ <https://cmrsurgical.com/>

¹¹⁶ <https://www.preventicus.com/>

accessibility for consumers. As a consequence of impacting this vertical, 5G is also expected to positively influence the protection of the environment and natural resources.

The main use-case categories and application groups in this vertical that are expected to leverage 5G technology include:

- ▶ **Smart grids:** Electric power systems are undergoing major changes, as recent natural disasters and power outages drive the growing need for more resilient grids. Accordingly, new “smarter” grids are being developed that require significant upgrading of electronic equipment and communication networks. The smart grid control system demands low latency and high performance of the underlying communication networks. In this regard, 5G technologies will introduce a wave of smart grid features and improve efficiency. For instance, the superior capabilities provided by 5G will enable the provisioning of energy closer to where it is used, thereby improving overall efficiency. The flexible communication architecture provided by 5G can support distributed power generation and storage, which will significantly drive emerging use cases in the energy sector. 5G-powered smart grids will allow users to better understand their energy consumption, forecast their needs and avoid using (and ultimately paying for) unnecessary energy. Energy suppliers will be able to predict energy peaks, support load balancing and avoid waste, allowing them to improve energy distribution and thereby lower costs for consumers. Further, the ability to capture sensitive information from smart grids can enable cities to plan infrastructure spending, thereby reducing downtime and increasing efficiency. Within the smart grids concept, two applications in particular are currently gaining momentum:
 - **Remote monitoring:** Remote energy monitoring is not a new feature for existing energy suppliers. However, as 5G services are introduced, the improved speed of service and vastly improved latency will enable far more detailed information to be collected. For instance, smart meters have already been introduced into many homes around the world using existing telecommunications infrastructure to manage, send and monitor the data they provide. With the introduction of 5G, these services will be much more precise, allowing more data to be sent and received more often, and thus giving much more detailed information to consumers and service providers.
 - **Energy efficiency:** With the imminent arrival of 5G wireless networks, entailing millions more base stations and billions of connected devices, the need for energy-efficient system design and operation will become even more essential. 5G will enable stakeholders to have more control over the environment than ever before, particularly regarding wasted energy. A great example is smart street lighting, a

system expected to rely entirely on 5G connectivity and remote monitoring via integrated sensors to “know” when pedestrians or vehicles are present and alter the lighting accordingly. This will save power, reduce light pollution and increase safety.

Exhibit C.14 gives examples of use cases and SMEs developing them within Energy and Utilities, categorised by application group.

Application group	Use cases	Example company
Smart grids	▶ Smart grid for electrical networks: Use cases to manage power-quality evaluation, synchronised power generation, power flow rerouting, self-healing and fault location, etc. ▶ Smart grids for telecom networks: Real-time control and monitoring of grid access, backhaul and backbone ▶ Smart grids for other networks (e.g. gas, water): Includes management of leak control, automated distribution, etc.	Power Plus Communications¹¹⁷ A European supplier of broadband power-line communication systems; has carried out various projects targeting expansion and further development of the smart grid.
Remote monitoring	▶ Electric vehicle charging stations ▶ Smart meters ▶ Remote monitoring/control of equipment ▶ Fleet energy consumption management	Kunak¹¹⁸ Kunak’s utilities systems monitor environmental parameters and critical points in real time, allowing intelligent and efficient management and remote control of infrastructures and utilities resources.

¹¹⁷ <https://www.ppc-ag.de/>

¹¹⁸ <https://www.kunak.es/en/>

Application group	Use cases	Example company
Energy efficiency	▶ Smart street lighting ▶ Pollution monitoring and prevention ▶ Smart energy management applications for saving energy in residential buildings, factories, etc.	Sonnen¹¹⁹ Sonnen is considered a leader in smart energy-storage solutions, in the form of batteries or virtual power plant software.

Exhibit C.14. Use cases in Energy and Utilities” that are expected to leverage 5G
[Source: Axon Consulting]

Media and Entertainment

The global media industry stands to gain \$765 billion in cumulative revenues from new services and applications enabled by 5G.¹²⁰ This is primarily driven by the profound changes in user habits and expectations relating to media consumption and production. While linear TV on a stationary display (TV set), possibly supported by local caching for non-real-time viewing, will continue to be a very important element, the overall media and entertainment experience for users is broadening and deepening rapidly. This applies to types of services (linear media, on-demand content, user- and semi-professional-generated content, games etc.), conditions of consumption (on the move, at home, etc.) and user devices (e.g. TV sets, smartphones, tablets, wearables, watches and VR devices). Media services face increasing demand in terms of data rates, the number of simultaneously connected users and more stringent quality-of-service requirements. High quality and high-resolution audiovisual services are the most important drivers of increased downlink data rates, whereas user-generated content, including sharing of social media, is the main driver of increased uplink data rates.

5G will seamlessly integrate different network technologies—including unicast, multicast and broadcast—and capabilities (e.g. caching) that may be needed to cover use cases in the media segment. The scalability of 5G networks, with management of rapidly varying traffic conditions in dense use-case scenarios, will be critically important for sustainable business models of network operators and providers of applications, devices and services, and hence for continued device and service innovation. 5G will also foster the innovation ecosystem in media and entertainment by opening simple application programming

¹¹⁹ <https://sonnengroup.com/>

¹²⁰ Ovum, “How 5G will transform the business of media and entertainment,” October 2018 (<https://newsroom.intel.com/wp-content/uploads/sites/11/2018/10/ovum%E2%80%9393intel%E2%80%93935g%E2%80%9393ebook.pdf>)

interfaces, toolkits and environments to adapt network capabilities to content application needs in real time.

The main use case categories and application groups in this vertical that are expected to leverage 5G technology include:

- ▶ **Mobile media and content production:** 5G will substantially transform the video market, bringing economies of scale and a much wider footprint to the TV offerings of network providers, which will compete more intensively with internet protocol TV, cable, and satellite. Mobile media entails the use of paid-for and bundled-in traditional media including video, music, and gaming via 5G networks. 5G-based broadband services could become the primary home internet connection, likely bundled with a TV package. This type of connection is also termed FWA. Further, the demand for high-quality live streaming of major events can be met using the capabilities that 5G will bring.
- ▶ **Immersive and new media:** Immersive media applications include AR, VR, and cloud gaming. Though none of these are new, 5G offers the opportunity to unlock their use by mass markets through its fast responsiveness and delivery of high-resolution, real-time streaming. New media refers to new applications that do not really exist today but will be enabled in the future by 5G. Such use cases include self-driving car entertainment, 3D holographic displays, and connected haptic suits.
- ▶ **Digital advertising:** Advertising is expected to be the media segment whose value proposition will be most impacted by 5G. The advertising market will benefit from the incremental use of services such as video, the emergence of immersive formats enabled by 5G, and resulting social integrations. 5G will play a fundamental role in transitioning traditional display advertising toward social and media immersive experiences. Scale, delivery and measurements are key current challenges for mobile ad campaigns that 5G will help overcome.

Exhibit C.15 gives examples of use cases and SMEs developing them within Media and Entertainment, categorised by application group.

Application group	Use cases	Example company
Mobile media and content production	▶ Enhanced mobile media that allows multicast and broadcast modes over wireless networks ▶ Ultrahigh-fidelity media ▶ Video streaming services	Teyuto ¹²¹ Teyuto offers technology that allows clients to deliver ultrahigh-quality video-on-Demand services.
Immersive applications and new media	▶ Interactive media applications: VR, AR, 3D holographic apps, interactive video, haptic suits, etc. ▶ Cloud gaming, collaborative gaming, AR/VR gaming ▶ Cooperative media production and user/machine-generated content	Gritworld ¹²² Gritworld develops key technologies in graphic visualisation applications for industry. It provides up to real-time industry data simulation and visualisation, including VR media.
Digital advertising	▶ Real-time dynamic measurement of ad effectiveness ▶ VR/AR advertising ▶ In-game and in-streaming advertising	Eyecandylab ¹²³ Eyecandylab builds the toolsets for content creators to generate engaging and interactive AR experiences on video.

Exhibit C.15. Use cases in Media and Entertainment that are expected to leverage 5G
[Source: Axon Consulting]

Agriculture and Livestock

Agriculture is rapidly evolving from an industry entrenched in tradition to one embracing change. Technological innovations are automating labour-intensive tasks and providing farmers with greater knowledge of and insights into their crops and environmental factors, which they can use to increase efficiency and yield. Management of livestock is another key area in agribusiness seeing widespread adoption of technology and connectivity. The agricultural sector has already started to embrace ICT and wireless connectivity to increase

¹²¹ <https://teyuto.com/>

¹²² <https://www.gritworld.com/>

¹²³ <https://augmen.tv/eyecandylab/>

productivity and efficiency. 5G could provide improved capabilities to meet the growing demand for broadband connectivity among the farmer community, for whom alternatives are not currently available or cost effective. 5G can also provide improved bandwidth and a platform for advanced processes such as precision farming and drone-based crop monitoring, which could prove valuable and cost efficient to farmers. Farmers could use 5G to manage their livestock by monitoring health, rumination, fertility, and eating patterns. 5G will enable extremely precise measurements, allowing farmers to track the finest details of a vast number of environmental factors.

The main use case categories and application groups in this vertical that are expected to leverage 5G technology include:

- ▶ **Farm monitoring and analytics:** The use cases under this category primarily use sensors to collect information on soil moisture, fertilisation, weather, etc. The information is then transmitted over a cellular wireless network to a central hub that provides farmers with real-time access to information on and analysis of their land, crops, livestock, logistics and machinery. This enables farmers to improve their farms' operational performance by analysing the data collected and acting upon it in ways that increase productivity or streamline operations.
- ▶ **Automation and robotics:** 5G can enable farm equipment to communicate with other machines in the field by streaming data from vehicle to cloud and back down to machine operators in a short time. 5G-based devices, robots and equipment can automate a number of processes in the farm, as well as enabling analysis of critical information collected from drones and sensors.

Exhibit C.16 gives examples of use cases and SMEs developing them within Agriculture and Livestock, categorised by application group.

Application group	Use cases	Example company
Farm monitoring and analytics	▶ Monitoring assets and conditions: Includes soil and crop monitoring, moisture and temperature control, cold chain monitoring, connected animals, etc. ▶ Advanced analytics for farms: Includes precision farming, AI-enabled smart irrigation, precision livestock farming, mixed reality and AI for crop control and prediction and water management, etc.	XFarm ¹²⁴ XFarm aims to digitalise agriculture, providing innovative tools that can support farmers and food supply chain stakeholders in managing their businesses.
Automation and robotics	▶ Automated and robotics solutions: Include agriculture drones, autonomous tractors, automatic systems (e.g. irrigation), etc.	Tibot Technologies ¹²⁵ Tibot creates robots that automate tasks to improve the working conditions of poultry farmers.

Exhibit C.16. Use cases in Agriculture and Livestock that are expected to leverage 5G
[Source: Axon Consulting]

C.3. Business potential of 5G in the digitalisation of European industry

As explained in the previous sections, despite the transformative possibilities of 5G in the medium to long run, there is currently broad consensus among stakeholders that 5G's initial deployments will continue to be driven by eMBB. This short-term forecast recognises not only uncertain demand from verticals but also the limited availability of 5G technologies.

However, eMBB alone may not create significant extra revenue from 5G, as it is unclear whether customers will be willing to pay more for just an enhanced broadband service, especially at a stage when few applications and services can truly take advantage of its capabilities. Indeed, experience of previous migrations from one mobile technology to the next suggests that mobile operators do not substantially change the price for consumers.

¹²⁴ <https://xfarm.ag/>

¹²⁵ <https://tibot.fr/>

Vodafone has followed this approach when turning on its 5G services in the United Kingdom and Spain in June–July 2019, with customers paying the same price as for 4G.

Therefore, although network operators may be incentivised to deploy 5G to reduce network costs in meeting data growth prospects from mobile broadband services, it is not obvious that providing eMBB to traditional customers can deliver significant incremental net profit.¹²⁶ Rather, incremental revenues are likely to derive from the scalability of 5G to other industries, as discussed in previous sections.

This is demonstrated by the forecast that 5G will create an addressable market of \$700 billion across the major industry verticals by 2030.¹²⁷ The onset and commercialisation of 5G may, therefore, enable a shift in the value chain, with various stakeholders able to address many new vertical use cases. This staged growth that 5G brings to the verticals will be a key driver of the overall development of high-potential and innovative business cases.

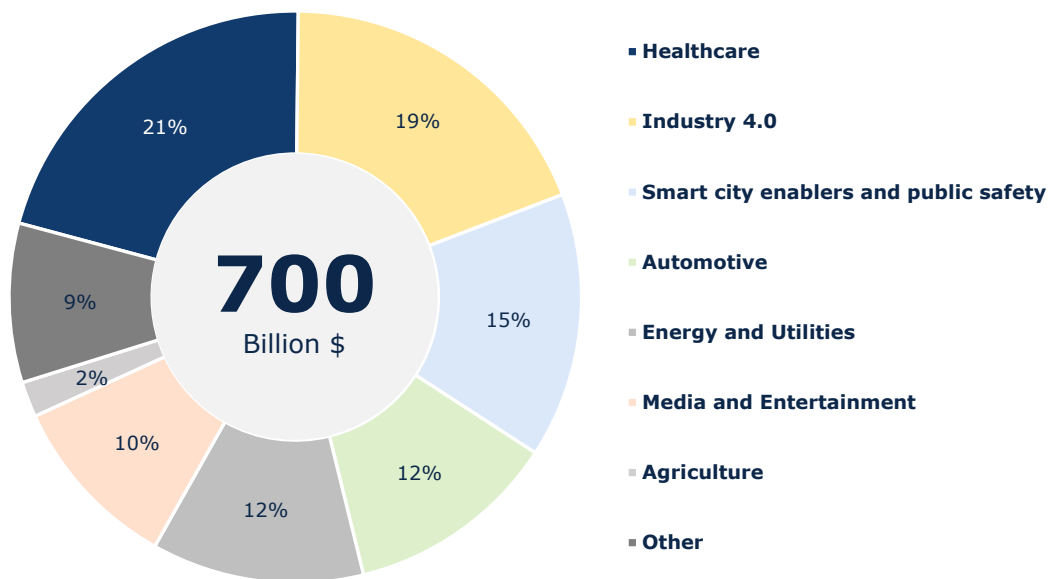


Exhibit C.17. 5G-enabled industry digitalisation breakdown by industry in 2030
 [Source: Axon Consulting, based on Ericsson report¹²⁸]

As Exhibit C.17 illustrates, some industries are expected to benefit more from the adoption or integration of 5G-based digital technologies. However, it should be noted that the

¹²⁶ In terms of extra revenues plus cost savings.

¹²⁷ Ericsson, "5G for business: a 2030 market compass," October 2019 (<https://www.ericsson.com/en/5g/forms/5gforbusiness-2019-report>)

¹²⁸ The category "Other" corresponds to the categories "Retail" and "Financial services" as per the classification in Ericsson's report. The category "Automotive and mobility" corresponds to the categories "Automotive" and "Public transport" in Ericsson's report.

forecast shares of revenue potential are only important consideration for stakeholders when deciding whether to address a certain industry. Factors such as competition, economies of scale and scope, risks and expected returns are key when estimating business viability.

Access to finance poses challenges for many companies seeking funding from a variety of sources, since traditional banks alone are unlikely to fund the total necessary capital. Companies may have to explore other capital solutions to finance the necessary spending. The next section discusses the financing ecosystem in Europe, focusing especially on SMEs (in line with the scope of this study).

C.4. Financing ecosystem for SMEs in Europe

The purpose of this section is to examine the European SME financing ecosystem. We analyse both the demand and supply sides of financing. On the demand side, we consider key factors driving the recent and current success of European tech SMEs (especially start-ups and early-stage companies), such as talent, entrepreneurial mindset, and the development of distinct tech hubs across Europe. On the supply side, we consider both private and public financing, focusing particularly on equity investors, such as VC, angel investors, and CVC—the key capital providers during the early stage of company development. In addition, we briefly address debt-providing institutions and the available instruments for SMEs (which are likely to be less relevant given the development stage of most 5G-related SMEs), as well as the role of public agencies in the innovation ecosystem.

C.4.1. Demand side

The European tech ecosystem has been flourishing in recent years, as shown in Exhibit C.18. European tech companies have gained scale and are growing quickly, with an eightfold increase in the number of +\$1 billion companies since 2012, giving recognition to the solid growth of Europe's entrepreneurial ecosystem. Spotify, Adyen and Zalando are prominent examples of this kind of company.



Exhibit C.18. Companies in Europe with +\$1 billion valuation
[Source: Axon Consulting, based on Dealroom data]

Several key factors have contributed to the prosperous evolution of the entrepreneurial ecosystem in Europe:

- **Fast-growing and top-quality European talent:** Europe possesses an incredible talent pool backed by some of the world's top leading institutions. A useful proxy is the top-ranked computer science universities around the world: as Exhibit C.19 shows, five of the top ten institutions are in Europe.¹²⁹

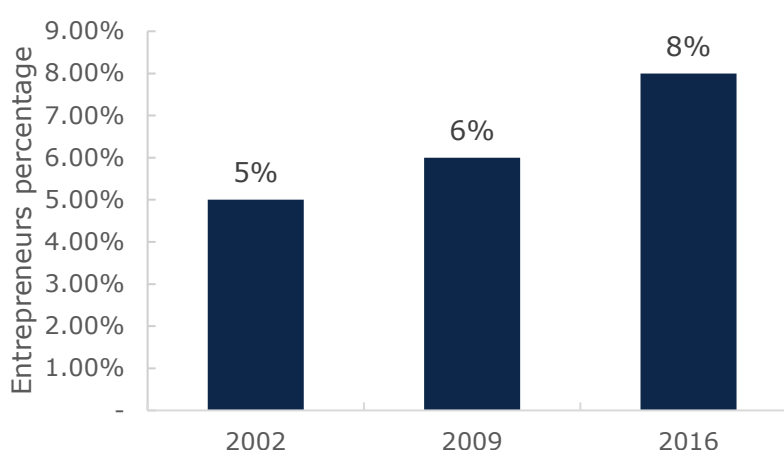
Global rank	Institutions	Location
1		Zurich, Switzerland
3		Oxford, United Kingdom
7		London, United Kingdom
8		Lausanne, Switzerland

¹²⁹ Atomico, "State of European Tech 2019" (<https://2019.stateofeuropeantech.com/>)

Global rank	Institutions	Location
9		Munich, Germany

Exhibit C.19. Europe-based computer science institutions in the global top ten[Source: Axon Consulting, based on Atomico¹²⁹]

- **Shift to entrepreneurial mindset of the younger generations:** In terms of entrepreneurial mindset, Europe is also undergoing a significant transformation as entrepreneurship becomes a widely accepted career path and is now taught in most institutions. This socio-economic shift represents a pivotal point for Europe, as “the dream” is no longer solely American, and younger Europeans are more willing to take risks to pursue their ambitions. This is illustrated by Exhibit C.20, which depicts the number of entrepreneurs as a percentage of the working age population.¹³⁰ This measure has increased 3 percentage points over the 2002-2016 period.

**Exhibit C.20. Number of entrepreneurs as a percentage of working population (European average)**

[Source: Axon Consulting, based on Atomico data]

Development of tech hubs across Europe: Europe’s dispersed tech hubs represent one of the continent’s most significant accomplishments but also one of its biggest financing challenges. The European innovation and tech ecosystem is very different to its equivalents in the rest of the world. In the United States, most tech start-ups, scale-ups and tech-related SMEs are situated in two locations: the San Francisco Bay Area and New York. In Europe, by contrast, tech hubs are much less concentrated, with nearly every European country having its own. This is illustrated in Exhibit C.21, which shows the countries where many well-known European tech companies were founded.

¹³⁰ Atomico, “State of European Tech 2018” (<https://2018.stateofeuropeantech.com/>)

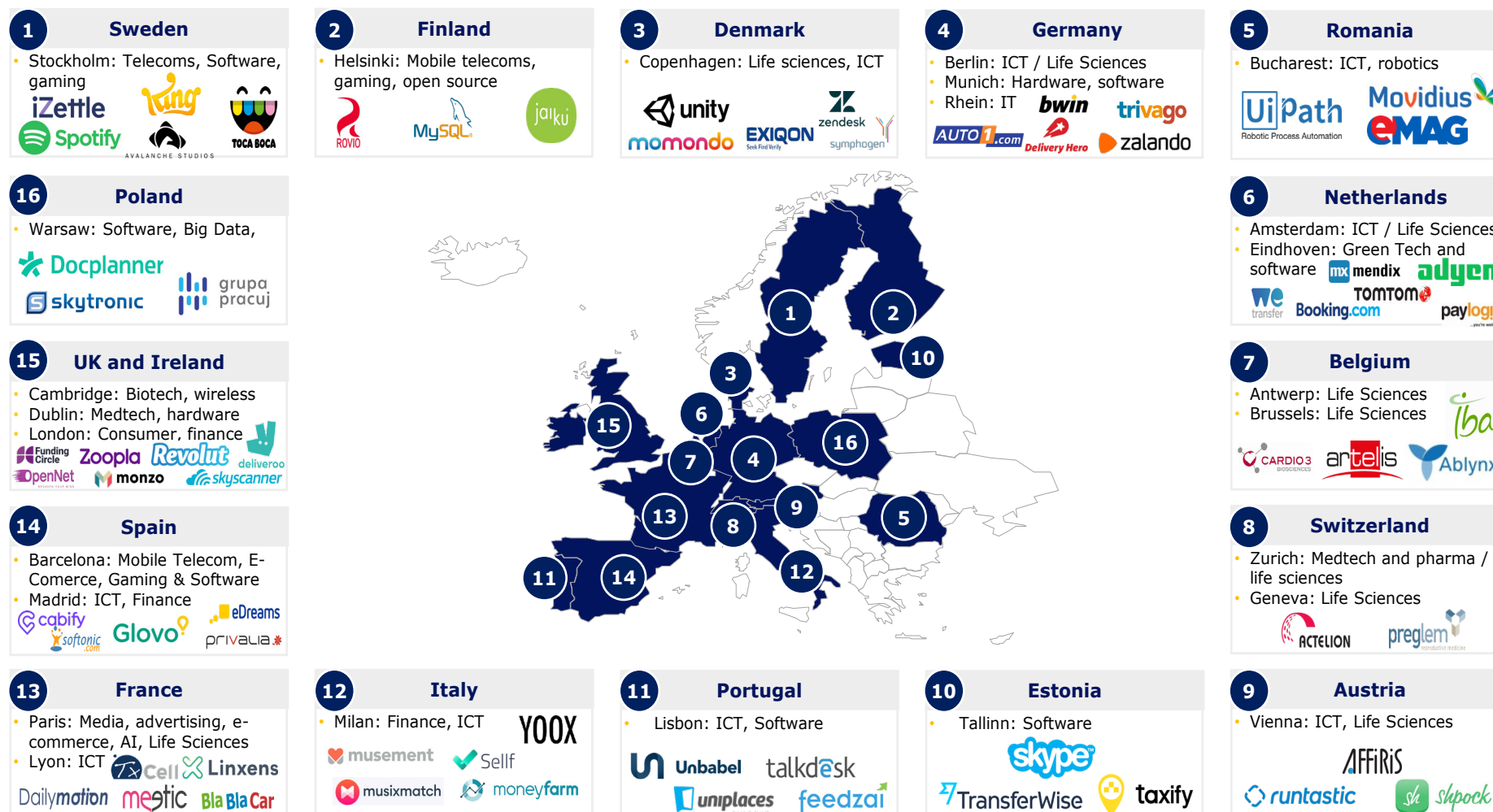


Exhibit C.21. Tech hubs around Europe [Source: Axon Consulting, based on Dealroom data]

However, the formation of so many hubs across Europe poses major financing challenges. For example, in the European VC market, most fund managers focus on a single country or region, rather than the whole continent. For that reason, they remain relatively small and struggle to gain the scale necessary to attract long-term financial investors.

On the aggregate level, Europe can clearly create new tech companies and projects at a greater rate than ever before. The quality of these companies is also becoming significantly higher, as reflected by the number of +\$1 billion European companies that have emerged over the past 10 years (Exhibit C.18): the number of these companies increased from 7 to 172 between 2010 and 2019. Moreover, this significant growth in quality of European start-ups, scale-ups and SMEs indicates an improvement in the level of available financing to support these companies. Nevertheless, in terms of available capital to fuel the growth of SMEs, Europe is still lagging behind other regions.

C.4.2. Supply side

Private financing refers primarily to the capital provided by financial and strategic investors in the private sector, such as PE (more precisely VC) funds, CVC funds and banks. On the public financing side, we address the importance of public agencies in the European innovation ecosystem and give examples of several programmes that directly benefit the 5G ecosystem.

To better understand the current funding gap in Europe, the above financial actors are discussed in the following subsections.

Venture capital (VC)

The financial investment strategy of VC is generally included within the PE asset class. As opposed to buyout (the largest PE strategy), VC focuses on minority-stake investments in fast-growing private companies, rather than acquiring ownership of a company. In terms of assets under management (AuM), VC is the second largest strategy and represents around one-quarter of overall PE AuM.¹³¹ Historically in Europe, VC has been heavily underrepresented and only started to gain relevance after the 2008 financial crisis. Despite robust growth of approximately 22% CAGR between 2009 and 2019,¹³² capital raised by

¹³¹ Preqin, "2019 Preqin Global Private Equity & Venture Capital Report" (sample available at: <https://docs.preqin.com/samples/2019-Preqin-Global-Alternatives-Reports-Sample-Pages.pdf>)

¹³² Pitchbook, "Annual European Venture Report 2019" (<https://pitchbook.com/news/reports/2019-annual-european-venture-report>)

VC funds remains relatively small in Europe when compared to the United States (considered further in Annex C.5).

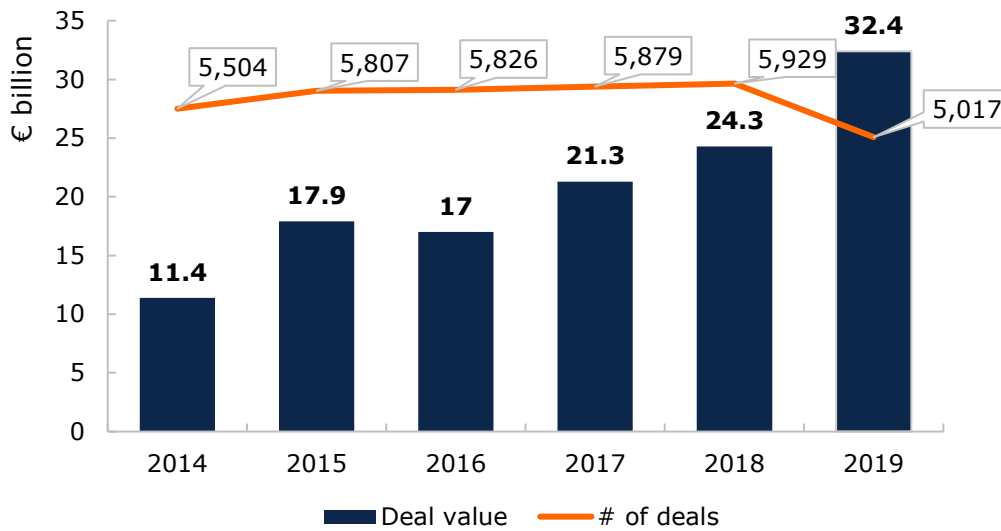


Exhibit C.22. Evolution in Europe of VC amount invested and number of deals
 [Source: Axon Consulting, based on PitchBook report¹³²]

Exhibit C.22 shows the generally increasing trends in European VCs' overall amount invested and number of deals. Regarding the fewer but larger investments recorded in 2019, it is interesting to consider which industries were the major focuses of VC investment in Europe. As Exhibit C.23 illustrates, these include Fintech, Enterprise Software and Health.

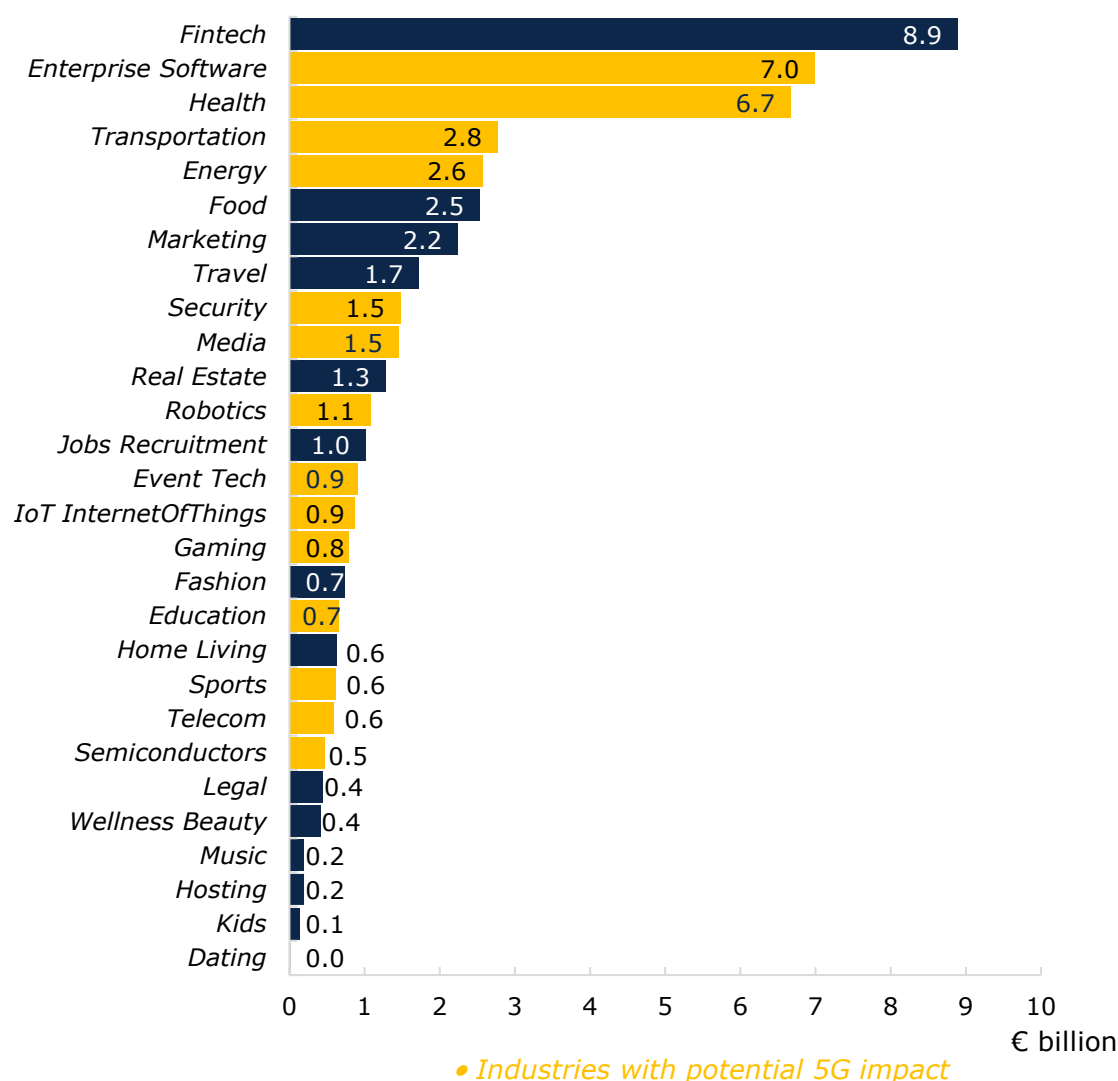


Exhibit C.23. European VC investments by industry in 2019

[Source: Axon Consulting, based on Dealroom data]

The substantial potential impacts of 5G connectivity make certain industries especially attractive to VC funds. In particular, four of the top five VC investment themes in Europe during 2019 are likely to be enhanced by 5G applications. Although not all of the industries highlighted above will benefit from 5G capabilities, it is expected that a strong market share can be captured by 5G-enabled connectivity. As explored in Annex C.2, some verticals, such as Gaming, Health and Security, should see clear benefits from the enhancement brought by 5G, whereas others have not yet envisioned a clear 5G path for the industry, e.g. Legal, Recruitment and Food.

In terms of instruments, VC can provide two types of financing: equity, which is the main form of investment, and (in some cases) hybrid/venture debt.

- ▶ **Equity** investments are relatively simple and usually involve the company raising extra capital to continue/expand its operations. In some cases, the capital injection can significantly dilute the previous ownership structure. For example, a company owned by a single individual that raises €2 million at a €4 million valuation will effectively surrender over 33% of ownership.
- ▶ **Hybrid/venture debt** is a smaller and less common market, especially in Europe, as these instruments are more complex and highly tailored for each transaction. These transactions mostly take the form of either convertible loans or venture debt.
 - Convertible loans allow an investor to provide capital with similar conditions to a normal loan but with an option to convert the debt into equity at a pre-agreed valuation, or lower if the company is not performing as expected.
 - Venture debt is a solution for companies that do not match the profile to meet the application criteria for traditional debt-financing instruments but still seek funding that does not overly dilute ownership and imposes fewer governance requirements. It essentially provides debt funding, but the exact structure is determined on a case-by-case basis, typically including an amount provided as pure debt and an “equity kicker,” which grants an equity stake to the investor in certain predefined conditions. Venture debt amount is usually in the range of 20–35% of the total VC raised, depending on the type of venture debt option: traditional venture debt (bridge financing, short term, €500 000 to €20 million tickets) or growth venture debt (growth-oriented, long term, €5–50 million tickets). In Europe, the EIB is among the largest venture debt providers.

VC is a highly relevant asset class in the SME equity-financing ecosystem: VC trends in Europe indicate not only whether available capital is rising or falling but also the overall attitude of the private sector towards start-ups, scale-ups and SMEs developing new technologies. In our view, the European VC industry is heavily underfunded for various reasons, such that VC activity levels do not fully represent the quality of European SMEs. Moreover, Europe possesses a similar, if not higher, level of talent compared to other continents, and the number of globally successful companies coming out of Europe has increased exponentially over recent years. Thus, it is fair to conclude that despite the rapid growth in European VC AuM, the amount of capital raised by VC funds—and consequently also the amount of VC financing received by European SMEs—remains unjustifiably low.

Angel investors

In the very early stages of the SME funding lifecycle, few VC firms are willing to invest. This gap in equity investment is covered by angel investors, who are generally high-net-

worth individuals willing to spend their time and money supporting companies at this development stage.

Angel investors support SMEs through equity investments generally at the early or very early/pre-seed stage. Usually, angel investors write tickets under €500k to finance the early prototype / product development of these SMEs. As such, they provide a much smaller level of investment than VCs, which corresponds to the funding needs of SMEs at this stage.

Angel investors usually have experience in a given field and/or a track record of success with their own start-ups. As such, they can also provide sound advice to SME founders on the journey to early stage. Angel investors usually exit SMEs around the Series A stage, when VC investors buy out their stake. They often take advisory/board positions in the SMEs they fund and hold these positions until the arrival of institutional investors.

Corporate venture capital

CVC refers to the internal VC branch of large corporations. It typically focuses on strategic targets of the corporate parent, but also has financial goals.

In Europe, CVC has shown a similar pattern to VC over recent years. Following little activity in the early 2000s, there was rapid growth in the number of CVC deals after the financial crisis. As Exhibit C.24 shows, the number of CVC investments in European companies increased from 249 in 2014 to 609 in 2019, with a CAGR of 20%. This large increase in CVC activity was backed by a 42% CAGR of investment levels during the same period, which demonstrates growth in the average deal size.¹³³

¹³³ CB Insights, "The 2019 Global CVC Report" (<https://www.cbinsights.com/research/report/corporate-venture-capital-trends-2019/>)

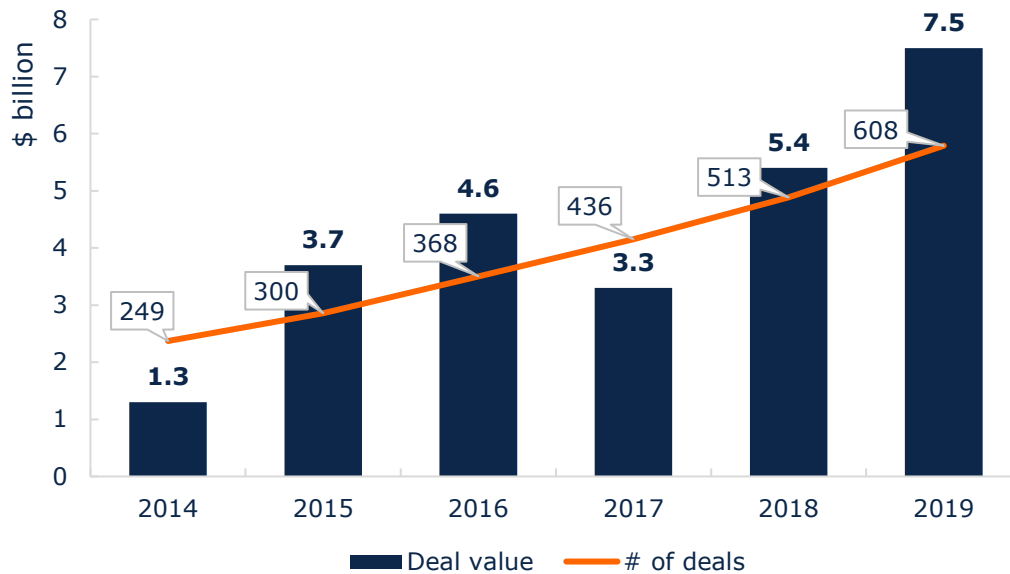


Exhibit C.24. Evolution in Europe of CVC amount invested and number of deals
 [Source: Axon Consulting, based on CB Insights report]

Early-stage CVC investments typically finance various emerging technologies (e.g. VR, blockchain), thus demonstrating corporations' interest in gaining early access to these disruptive technologies and developing the competitive advantage of their businesses.¹³⁴

In Europe, banks are leading the way as the most active CVC investors in the tech ecosystem. In the age of digital transformation, European banks are trying to remain relevant and even stay ahead of their competitors, which drives their increased CVC activity in search of new technologies. An especially prominent example is the French bank BNP Paribas, which participated in 24 investment rounds in 2020, holds a portfolio of 143 European companies, and has exited 22 companies.¹³⁵

One of the most relevant verticals regarding 5G is Automotive & Mobility, specifically the C-V2X communications application group. There has been extensive financing activity in this vertical, with a large increase in CVC investment, both directly and indirectly. One example is Alliance Ventures, operated by Renault, Nissan and Mitsubishi, which created a \$1 billion fund to invest into the Automotive and AutoTech space in late 2018.

Another example is the insurance companies shifting from human liability to product liability, which will lead to insurance costing becoming even more data-driven. Allianz X

¹³⁴ Pitchbook, "VC Valuations Report," 1H 2019 (<https://pitchbook.com/news/reports/1h-2019-vc-valuations-report>)

¹³⁵ Based on information extracted from Dealroom.

(the digital investment unit of Allianz Group) recently increased its fund size to €1 billion and became one of the largest active investment vehicles in Europe. Having initially been established as an in-house incubator, Allianz X has now made 15 CVC deals to date.¹³⁶ The fund is diversified across several verticals, including fintech, health and cybersecurity, but one of its biggest components is mobility.

The healthcare industry is becoming another hotbed for CVC investment in Europe, as shown by the increasing attraction of large corporates to application groups related to patient diagnostics, biotechnology, hospital applications and pharmaceuticals. One clear example of funding growth in this vertical is the allocated budget of M Ventures (the venture arm of Merck), which expanded from €14 million to €300 million over the 2010-2020 period, furnishing its portfolio with investments in healthcare and life sciences.

Exhibit C.25 lists the top ten European corporations most active in European tech. Together, they participated in 127 investment rounds over 2019, financing 368 European companies since inception.¹³⁵

European corporate Investors	Country	Number of rounds in last 12 months	Portfolio size in Europe	Portfolio % in Europe
ZKB - Zürcher Kantonalbank	Switzerland	27	46	98%
Next47 (Siemens)	Germany	22	16	18%
BNP Paribas	France	15	88	93%
Deutsche Telekom Capital Partners	Germany	12	38	51%
Robert Bosch Venture Capital	Germany	10	21	57%
Sabadell Venture Capital	Spain	10	25	100%
Barclays Ventures	United Kingdom	9	40	78%
AXA Venture Partners	France	9	18	44%
Axel Springer	Germany	9	70	48%
Allianz X	Germany	4	6	40%

Exhibit C.25. Top ten most active corporate investors in European tech
[Source: Axon Consulting, based on Pitchbook data]

¹³⁶ Techcrunch, February 2019 (<https://techcrunch.com/2019/02/20/allianz-x-1-billion-eur/>)

Overall, the increase in CVC activity over recent years implies a positive outlook in Europe. Nevertheless, there is still a significant gap in investment activity when compared to the United States, despite the similar level of talent and comparable economic size. In our view, this again indicates a funding gap in Europe.

Banks and lending

Banks have historically been the main source of external funding to traditional SMEs, financing companies through different kinds of debt products, such as a simple credit line or loan. Contrary to the early-stage scenario, banks usually support SMEs that have reached the mid-to-late development stages, when they show consistent revenues, achieve profitability or are demonstrably close to doing so. Companies in early development stages are usually non-profitable and burn cash, making them much less bankable and unable to meet banks' lending criteria. Especially after the 2008 financial crisis, policymakers have tightened the rules for banks, which are now required to hold much more and better quality capital than before. As 5G projects are generally in a very early development phase at the global level, banks may not play an important funding role for them.

Therefore, for innovative, high-growth companies and start-ups, such as 5G-based SMEs, equity financing or venture debt appear more essential than traditional bank debt. In fact, banks' investment in late-stage SMEs is being powered by public institutions through risk-sharing partnerships across Europe, so as to facilitate SMEs' access to debt products. These programmes include products tailored to boost the general funding of SMEs through banks. Initiatives such as Fund KredEx's loan warrant programme (Estonia), the COSME¹³⁷ programme of BGK (Polish Development Bank, supported by EIF) and Finnvera's bond financing programme (Finland) are supporting entrepreneurs to access loans, leases or attractive bank guarantees.

Public financing

Public financing is a key contributor to the explosive growth of Europe's innovation ecosystem. With hundreds of regional, state and European-level programmes simultaneously active across the continent, it is hard to provide a comprehensive view on their scale and effectiveness. Nevertheless, it is clear that public financing is essential for

¹³⁷ Programme for the Competitiveness of Enterprises and Small and Medium-sized Enterprises.

supporting early-stage projects and companies in Europe, and even the SME ecosystem as a whole.

Several large-scale programmes in Europe have delivered substantial financial benefits to SMEs. Existing financial mandates at a pan-European level, offering a variety of instruments (e.g. equity, grants, hybrid/debt) to SMEs at different stages, include the following:

- ▶ **H2020¹³⁸** (2014–2020): a seven-year EU framework programme with a budget of €77 billion, representing the largest research and innovation funding programme ever created in Europe. The funding opportunities available under H2020 are defined in multiannual work programmes prepared by the European Commission. H2020 is built around three priorities: Excellent Science (€24.4 billion), Industrial Leadership (€17.0 billion) and Societal Challenges (€29.7 billion). Within the first three years (2014–2016), a total of 115,235 eligible proposals were submitted, with an overall success rate of 12.6%.
- ▶ **EFSI¹³⁹** (2015–2020): As one of the three pillars of the Investment Plan for Europe (the Juncker Plan), this common initiative launched by the EIB Group and the European Commission is helping to overcome the existing funding gap in the European Union. Some key achievements to date are the €478.4 billion of investment mobilised and the €88 billion of financing approved in more than 1,300 operations, benefitting up to 1.1 million European SMEs. The EFSI focuses on important sectors for the EU economy, such as strategic infrastructure (including digital, transport and energy), renewable energy and resource efficiency.
- ▶ **InnovFin¹⁴⁰** (2014–2020): This joint initiative was established by the EIB Group under H2020. It provides a range of financial products such as guarantees to banks, equity investment into VC funds, or risk sharing via the EIB Venture Debt instrument. Under InnovFin, the EIF provides demand-driven products by allocating 35–50% of the investment cost to selected VC firms to manage the fund, which helps attract other public or private investors. Beneficiaries include small tech start-ups, large research facilities and circular economy companies.

¹³⁸ <https://ec.europa.eu/programmes/horizon2020/en/what-horizon-2020>

¹³⁹ <https://www.eib.org/en/efsi/index.htm>

¹⁴⁰ <https://www.eib.org/en/products/blending/innovfin/index.htm#>

- ▶ **EIC Accelerator¹⁴¹** (2018–2020): As part of the European Innovation Council pilot, this initiative supports high-risk, high-potential innovative SMEs that could drive economic growth and shape new markets or disrupt existing ones in Europe and worldwide. It offers feasibility grants (€50k), R&D grants (€500k–2.5m), equity up to €15m, business coaching and access to acceleration services and facilities.
- ▶ **Connecting Europe Facility¹⁴²** (2014–2020): This key EU funding instrument has a €30.45 billion budget to promote growth, jobs and competitiveness through targeted infrastructure investment at the European level under H2020. It covers three areas of action: CEF Energy (€5.35 billion), CEF Telecom (€1.05 billion) and CEF Transport (€24.05 billion).
- ▶ **VentureEU¹⁴³** (2018–2020): Independently managed by the EIF, this fund-of-funds has a budget of up to €410 million to distribute among selected VC fund-of-funds managers in Europe under H2020. EU participation is capped at 25%, and the manager must raise the remaining 75% from private investors. These funds are helping to finance VC funds across Europe, in turn supporting SMEs developing a range of use cases in several fields, such as ICT, digital, life sciences, medical technologies, and resource and energy efficiency.
- ▶ **Equity Facility for Growth¹⁴⁴** (2014–2020): Under the COSME umbrella and with a €1.3 billion budget, this instrument is expected to provide, through financial intermediaries, equity and mezzanine finance to about 300 stakeholders, aggregating €2.54 billion of overall investment. The instrument is accessible to VC firms that finance expansion- and growth-stage SMEs, and to SMEs settled and operating in one EU Member State and across borders, with a maximum ticket size of €30 million. This private enrolment from VCs attracts co-investments from other public and private participants, resulting in higher financial interactions within the market.
- ▶ **Mezzanine Facility for Growth¹⁴⁵** (until 2020): As a mandate granted by the EIB, this €1 billion fund-of-funds is expected to drive hybrid/debt initiatives across Europe by financing growing tech SMEs into later stages, thereby establishing more mature businesses in the European landscape. In Europe, the EIF is strongly involved in several initiatives to promote regional business development. For example, the EIF has explored public–private collaboration via the Mezzanine “Fund of Fund” for Germany, with €300 million fully hybrid (i.e. debt-equity) programmes co-invested by the CVC

¹⁴¹ <https://ec.europa.eu/easme/en/eic-accelerator-sme-instrument>

¹⁴² <https://ec.europa.eu/inea/en/connecting-europe-facility>

¹⁴³ <https://ec.europa.eu/programmes/horizon2020/en/ventureeu>

¹⁴⁴ https://www.eif.org/what_we_do/equity/single_eu_equity_instrument/cosme_efg/index.htm

¹⁴⁵ https://www.eif.org/what_we_do/equity/mezzanine/index.htm

arms of corporates (e.g. BMWi Ventures) into SMEs and mid-cap companies, with appropriate incentives for the whole team of investors. The Central Europe Fund of Funds has a similar profile, providing VC, PE and mezzanine instruments to bolster innovation in Austria, Czech Republic, Slovakia, Hungary and Slovenia.

Despite their relevance, most of these mandates are reaching their end-of-life. For instance, InnovFin Equity expired at the end of 2020, and the EIC Accelerator stopped receiving applications by fall 2020. The European Commission has reacted by promising new mandates, most prominent of which are the following:

- ▶ **Horizon Europe**¹⁴⁶ (2021–2027): This seven-year EU scientific research initiative is planned to succeed the current H2020 programme, with an increased budget of €100 billion. The European Commission has begun a strategic planning process on how to shape the programme in the first four years of implementation (2021–2024), receiving over 8 000 responses to date.
- ▶ **InvestEU**¹⁴⁷ (2021–2027): This European programme will build on the success of the Juncker Plan for Europe (which ended in December 2020) to mobilise both public and private investments to bolster innovation and access to finance in the European Union. It will bring together the EFSI and 13 other EU financial instruments that are currently available. The programme comprises three bodies: the InvestEU Fund, the InvestEU Advisory Hub and the InvestEU Portal. The InvestEU Fund is responsible for allocating the €38 billion budget between projects in four pillars: sustainable infrastructure (€11.5 billion); research, innovation and digitalisation (€11.25 billion); SMEs (€11.25 billion); and social investment and skills (€4 billion). There will also be financial partners, such as the EIB, that are expected to contribute at least €9.5 billion in risk-bearing capacity. The aim is to conduct crowdfunding with private and public investors to reach at least €650 billion of total investment.

The EIB also acts as a financial partner for the telecoms sector in the European Union. In this role, the EIB undertakes activities to support both the R&D of network technology (via technology providers) and its deployment (via operators). Since 2018, 5G has been a key focus of these activities. As such, the EIB has recently provided loans to several corporates working on R&D of 5G technologies, such as Nokia or Ericsson:

¹⁴⁶ https://ec.europa.eu/info/horizon-europe-next-research-and-innovation-framework-programme_en

¹⁴⁷ https://europa.eu/investeu/home_en

- ▶ Nokia¹⁴⁸: In August 2018, Nokia signed a €500 million loan with the EIB, supported by the EFSI. In relation to this funding, Nokia invested €1.1 billion during 2018 Q1 to further accelerate its research and development of 5G technology.
- ▶ Ericsson¹⁴⁹: In May 2018, Ericsson was granted a €250 million loan by the EIB to boost R&D efforts in 5G. Like Nokia, Ericsson received this funding through the EFSI. In relation to this funding, Ericsson invested €900 million during 2018 Q1 in R&D programmes.

Even from the few outlined examples of public financing within Europe, it is clear that there are many channels through which public agencies are supporting SMEs at different funding stages and with different financial mechanisms (grants, equity, hybrid/debt). Although not all of them specifically target 5G, many will contribute to boosting the ecosystem by enabling 5G-based applications in Europe.

C.5. Worldwide competitive landscape of 5G

Globally, several regions have taken a pivotal role in advancing 5G, at both the technological and deployment levels. It is, therefore, worthwhile investigating their current state of development in comparison with Europe. We primarily examine the United States and Asia. Although it is interesting to explore similarities and differences between the three regions, it should be noted that Asia is a very different market, largely defined by its massive population as compared to the other two major regions. For this reason, the United States will be used as a more comparable market given its parallels in population and economic size to Europe.

This section covers three main topics of interest in determining qualitatively and quantitatively the state of 5G worldwide:

- ▶ Regional 5G network deployments;
- ▶ Talent in the tech ecosystem;
- ▶ Private investment in the VC and CVC fields, plus an inter-continental private investment overview.

¹⁴⁸ European Commission press release: https://ec.europa.eu/commission/news/digital-investment-eu500-million-eu-financing-5g-development-nokia-2018-aug-27_en

¹⁴⁹ Telecoms: <http://telecoms.com/490019/ericsson-lands-e250mn-5g-loan-from-european-investment-bank/>

5G network deployment

Like Europe, other jurisdictions are taking important steps towards early deployment of 5G. **The United States, China, South Korea and Israel** are examples of countries that are taking important roles in the development of 5G. Exhibit C.26 briefly discusses some of their initiatives.

International jurisdiction	Description
United States 	According to the study “5G Deployment – State of Play in Europe, USA and Asia”¹⁵⁰ requested by the European Parliament in April 2019, all major MNOs in the United States (Verizon, AT&T, T-Mobile and Spirit) have launched trials of 5G technologies. In late 2018 and early 2019, only 5G prototype deployments were available but during the second half of 2019, 5G was enabled in the country’s main cities. Launched in 2018, Verizon’s “5G Home” was the first 5G commercial service, aiming to provide speeds from 300 Mbps to 1 Gbps with FWA connectivity in four large cities (in 2018) with a tariff from \$50–\$70 per month. By December 2019, Verizon had also launched mobile 5G in almost 30 cities across the country.
China 	According to a European Parliament study, China has invested in a national action plan to organise 5G deployment by the three state-owned operators (China Mobile, China Unicom, China Telecom). These operators are committed to a commercial launch of 5G by 2020, but the research period has a long time frame (2025–2030 for final developments) due to technical challenges. The physical roll-out is being overseen by China Tower, the world’s largest mobile site operator, rather than the mobile operators. The relevant investments expected until 2030 are estimated to be around €26bn per year. Overall, a slow roll-out is expected, beginning in 2019–2020 and extended until 2030 due to political, economic and technical issues.
South Korea 	South Korea is currently the world leader in 5G deployment and penetration. According to the above-mentioned European Parliament study, the first 5G pilot was conducted at Korea’s Winter Olympics in February 2018. The commercial launch of 5G routers (enabling Wi-Fi connections) followed in December 2018, and the commercial launch of mobile devices took place in Q2-2019. South Korea progressed this roll-out throughout 2019 as a testing laboratory to foster worldwide sales of domestically produced smartphones (by Samsung, LG, etc.). As of December 2019, more than 85 South Korean cities have established operational 5G mobile networks.

¹⁵⁰ European Parliament, “5G Deployment – State of Play in Europe, USA and Asia” ([http://www.europarl.europa.eu/RegData/etudes/IDAN/2019/631060/IPOL_IDA\(2019\)631060_EN.pdf](http://www.europarl.europa.eu/RegData/etudes/IDAN/2019/631060/IPOL_IDA(2019)631060_EN.pdf))

International jurisdiction	Description
Israel¹⁵¹ 	A tender for 5G mobile networks was organised by the Israeli regulator in December 2019, and the frequencies are expected to be allocated to enable the launch of 5G deployments between 2020 and 2023. Despite the presence of nine operators in Israel, only the six main operators are eligible to bid for 5G licences. The Communications Ministry has estimated the cost of 5G deployment, as an extra layer over existing 4G networks, to be around \$529m.

Exhibit C.26. Status of 5G in other jurisdictions
[Source: Axon Consulting, based on public information]

One key driver for 5G network deployment is the availability of spectrum. In this regard, reliance on a centralised structure helps the United States and other single markets to award spectrum in a more harmonised way across the region than Europe, which comprises as many spectrum awarding mechanisms as number of countries.

Europe has a focused on allocating lower frequency bands to 5G (700 MHz to 3.8 GHz), whereas the United States is mostly allocating upper bands of the spectrum for this purpose (6 GHz to 40 GHz). Among the Asian players, South Korea enjoys a well-deployed 5G network nationwide at both lower and upper frequencies (3.5 GHz and 28 GHz bands), which facilitates homogeneity and ease of access to end users.¹⁵²

A further relevant point of comparison is the forecast for when 90% of the population will have 5G coverage. According to a Northstream study¹⁵³ and an RCRWireless article,¹⁵⁴ there are significant differences in the 5G roll-out pace among these regions, with Europe reaching the 90% threshold almost two years later than the United States and three years after South Korea. As of November 2019, and focusing on cities with over 400 000 inhabitants, only 23% of these cities in Europe had an operating 5G network, compared to 56% in the United States and 100% in South Korea, which is leading the way with almost nationwide 5G roll-out in over 85 cities. This disparity will eventually cause Europe to fall further behind in the short to medium term if policymakers do not strive to quickly fix the structural development issue and address the spectrum release and consolidation concern. If Europe invests less in 5G network deployment compared to other jurisdictions, European

¹⁵¹ Reuters, "Israeli regulator delays 5G mobile tender by two weeks," November 2019 (<https://www.reuters.com/article/us-israel-telecoms-5g/israeli-regulator-delays-5g-mobile-tender-by-two-weeks-idUSKBN1XY09A>)

¹⁵² South Korea has been selected as representative of Asia due to its pioneering activity in 5G deployments.

¹⁵³ Northstream, "A 5G Outlook in Europe," September 2019 (http://www.northstream.se/northstreamwp/wp-content/uploads/2019/09/5G_Northstream_Opinion.pdf)

¹⁵⁴ RCRWireless, "How South Korea built 5G, and what it's learning" (<https://www.rcrwireless.com/20190912/5g/how-south-korea-built-5g-and-what-its-learning>)

enterprises may be unable to access the newest connectivity technology and expand innovations at the pace required to compete with their US and Asian counterparts; moreover, consumers in European countries may be unable to fully benefit from the 5G innovation wave.

Topic	Europe	United States	South Korea
Spectrum allocation focus for 5G	Usually below 6 GHz (700 MHz, 1800 MHz, 2.4–2.6 GHz, 3.4–3.8 GHz) with less use in upper bands (24–28 GHz and rarely above)	Tendency for above 6 GHz (4.7 GHz, 24–28 GHz, >36 GHz) with limited allocation to lower bands (600–900 MHz, 2.4 GHz, 3.5–3.8 GHz)	Extended spectrum use, particularly allocated in both the 3.2–3.5 GHz and 24–28 GHz bands
Main cities with actual 5G coverage ¹⁵⁵	+17 (Bucharest, Madrid, London, Rome, etc.)	+28 (Atlanta, New York, Los Angeles, Houston, etc.)	+28 (Seoul, Busan, Daegu, Gwangju, etc.)
Forecast for 5G coverage for 90% of population ^{153, 154}	2023 Q2	2021 Q3	2020 Q2

Exhibit C.27. Status of 5G: comparison between Europe, the United States, and South Korea (as of November 2019) [Source: Axon Consulting, based on public information]

Talent in the tech ecosystem

Europe has one of the highest value digital markets and the largest number of researchers. This is illustrated by the fact that 32% of the most cited research organisations in the cutting-edge sectors of Blockchain and AI are European universities and institutions, surpassing the United States (30%) and China (15%).

It is also interesting to consider Europe's overall number of developers¹⁵⁶ as a measure of highly qualified individuals in the region. As Exhibit C.28 shows, Europe has a higher number of developers than the United States but fewer than Asia.

¹⁵⁵ Cities with a population above 400 000 inhabitants, November 2019.

¹⁵⁶ Number of developers, as well as number of STEM graduates per annum, are common indicators for assessing the quality and quantity of tech-related talent in a given region. Source: <https://stackoverflow.com/>

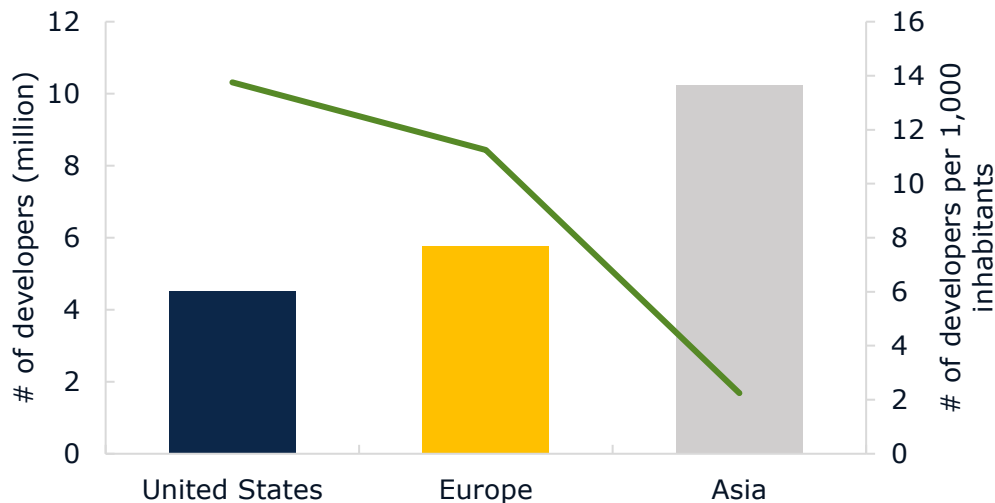


Exhibit C.28. Number of developers per region and per 1 000 inhabitants
 [Source: Axon Consulting, based on Stack Overflow data]

In terms of producing unicorn tech start-ups, Europe lags behind its peers, totalling 63 privately owned companies as of December 2019 (see Exhibit C.29). According to data from Crunchbase, the number of private companies valued at over \$1 billion worldwide is 630, with a total valuation of approximately \$1.9 trillion. In this area, the United States and Asia also lead the way with almost four times more companies founded than in Europe. However, the emergence of European unicorn companies like UIPath (Bucharest) and Farfetch (Lisbon), outside the traditional hubs of London, Stockholm and Berlin, signifies new horizons for Europe. Besides, the fact that almost every city in Europe is becoming a tech hub is getting momentum: there are currently 175+ hubs across the region, hosting tech-related events all year round.

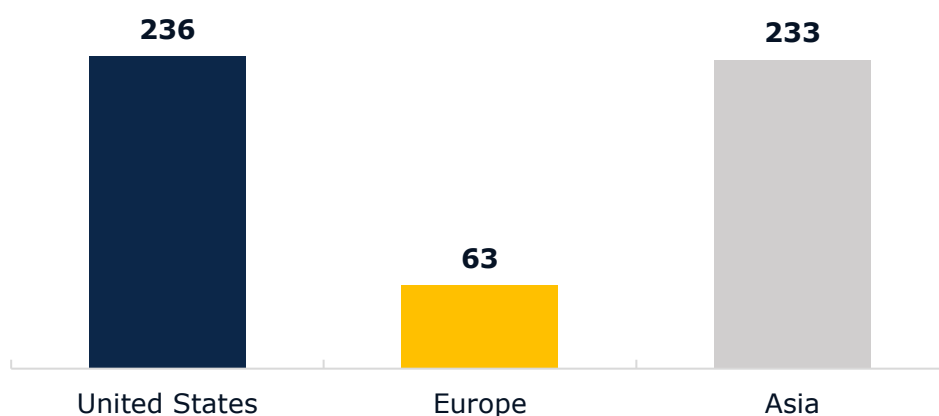


Exhibit C.29. Number of +\$1 billion private start-ups per region (as of December 2019)
 [Source: Axon Consulting, based on Crunchbase data¹⁵⁷]

Despite the difference observed in the chart above, the **European VC ecosystem has grown at an annual rate of 23.5%** over the past 5 years. As mentioned in Annex C.4, the number of +\$1 billion companies in Europe has increased eightfold since 2012, reflecting both European talent and the flourishing performance of EU-based VC funds. As explained in the next subsection, over the same period, tech companies in Europe achieved roughly one-half of the aggregate value of VC-backed exits in the United States with approximately one-quarter of the funding, which indicates huge potential in the European start-up field.¹⁵⁸

Both VC and CVC funding instruments are appropriate mechanisms to assess the private financing ecosystems of Europe, the United States and Asia. The rest of this section compares European characteristics to those of the United States and Asia in an attempt to elucidate the similarities and differences between the three regions. As previously mentioned, Europe and the United States are comparable in terms of GDP, so their economic initiatives should also be similar. By contrast, Asia has a higher GDP and its financing activity has fluctuated considerably in recent years, so its performance cannot be strictly compared to that of Europe or the United States.

Venture capital investment

In terms of **VC** funding, European tech companies received significantly less than their US counterparts in both absolute terms and as a proportion of GDP during 2019; the disparity

¹⁵⁷ The Crunchbase Unicorn Leaderboard: <https://techcrunch.com/unicorn-leaderboard/>

¹⁵⁸ Axon Partners Group, "Participation of institutional investors in European Venture Capital," 2019.

with their Asian counterparts was significant in absolute terms but fairly small as a proportion of GDP.^{159,160}

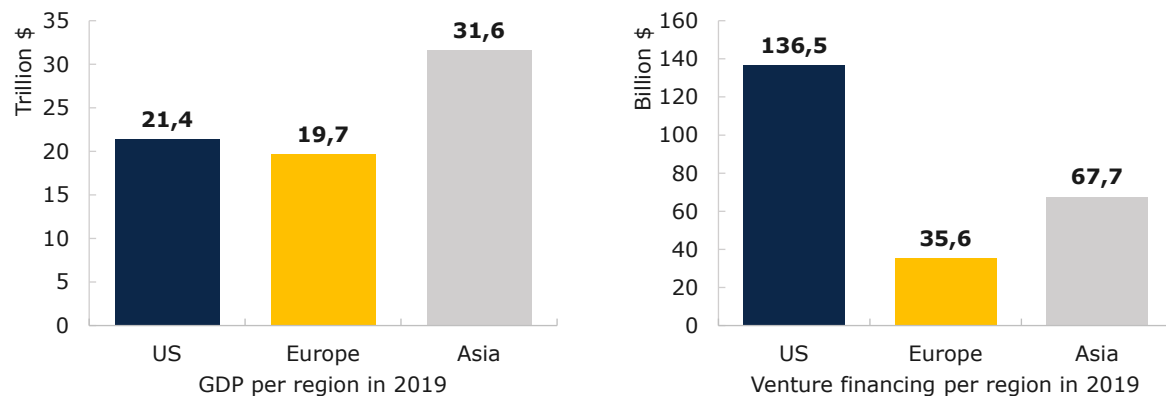


Exhibit C.30. GDP levels and VC financing in tech companies per region in 2019

[Source: Axon Consulting, based on International Monetary Fund, Pitchbook and KPMG reports]

Although the reasons for the relatively lower VC fundraising activity in Europe will not be analysed in depth, it is interesting to compare quantitative data regarding VC between Europe and the United States. Despite the two regions' similar GDP levels, European VC funds consistently raised significantly less on an annual basis than US VC funds, by 4.1x less capital in 2019 (see Exhibit C.30).

¹⁵⁹ International Monetary Fund, World Economic Outlook Database 2020:

<https://www.imf.org/external/pubs/ft/weo/2020/01/weodata/index.aspx>

¹⁶⁰ KPMG Venture Pulse, Q4 2019: <https://assets.kpmg/content/dam/kpmg/xx/pdf/2020/01/venture-pulse-q4-2019-global.pdf>

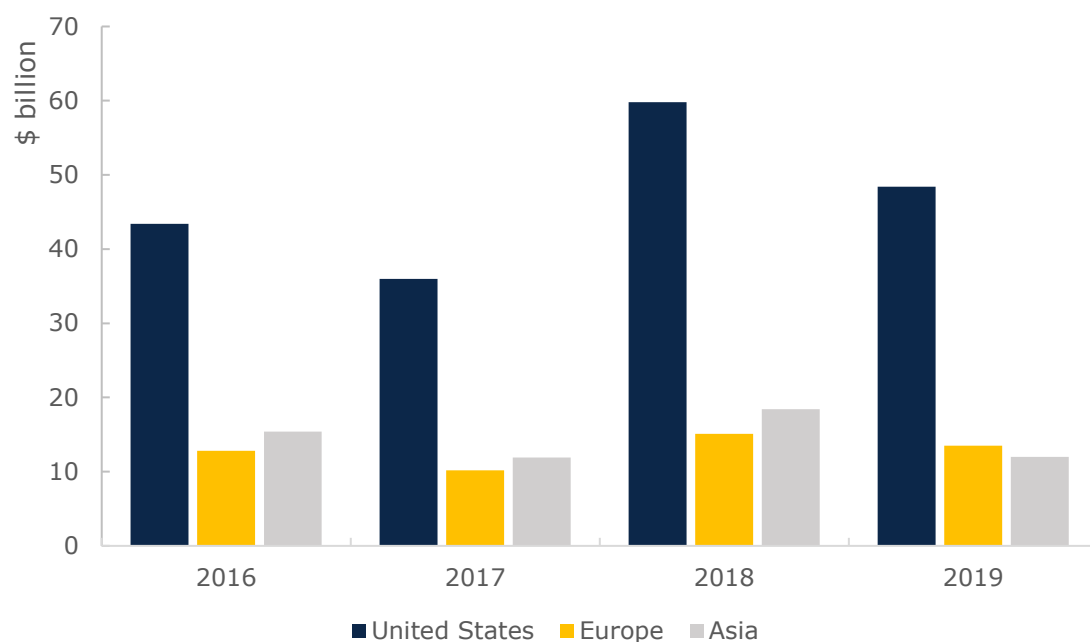


Exhibit C.31. Fundraising activity by VC funds per region
[Source: Axon Consulting, based on KPMG report]

This gap becomes even more pronounced when we consider the real levels of investment by VC firms into companies in their respective regions (Exhibit C.31). In 2019, deal value topped \$100 billion for the second consecutive year in the United States, and the region's deal count exceeded 10 000 for the third consecutive year.^{161,162} Asian deal values also exceeded those of Europe, with massive growth between 2017 and 2018 bolstered by several mega deals taking place in the region (e.g. Grab, Bitmain, OYO Rooms).

¹⁶¹ PitchBook, NVCA Venture Monitor, Q4 2019: <https://pitchbook.com/news/reports/q4-2019-pitchbook-nvca-venture-monitor>

¹⁶² PitchBook, Annual European Venture Report 2019: <https://pitchbook.com/news/reports/2019-annual-european-venture-report>

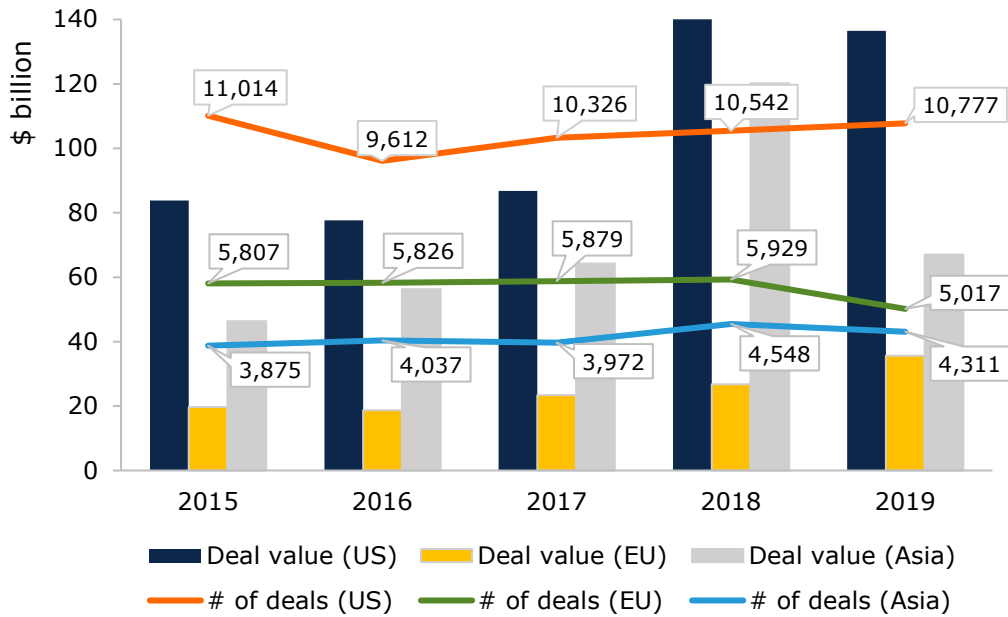


Exhibit C.32. VC amount invested and number of deals: comparison between the European Union, United States and Asia [Source: Axon Consulting, based on PitchBook reports]

Following the arguments presented throughout Annex C, the presence of such a large financing gap is not justified, given that European tech has proven itself of equal value to that of the United States and Asia in recent years.

Similar to Europe, VC activity in the United States also experienced profound diversification across various sectors and industries during 2019, led by enterprise software, fintech, logistics, pharma & biotech, consumer goods, automotive and aerospace. At the technology level, AI and machine learning have continued to be a hotbed area for VC investors, which have matured alongside these technologies.

VC funding gap in Europe

When assessing levels of VC investment in 5G and advanced-connectivity technologies, we found that the level of detail in existing databases is insufficient to properly identify such investments. Databases provide information about the industries in which VCs invest and the technology categories of the invested companies. However, the databases have not yet tailored tags for 5G or advanced connectivity. For instance, it is possible to identify investments in VR but not to extract the proportion of VR requiring 5G or other advanced-connectivity technologies.

Therefore, it is not possible to accurately calculate any funding gap on 5G and advanced connectivity between Europe and other jurisdictions. Instead, we assessed the potential range of such a gap.

For this purpose, we identified two sets of relevant technology categories within ten high 5G-impact verticals¹⁶³:

- ▶ a “conservative” set that includes categories most likely to be associated with 5G or advanced connectivity;¹⁶⁴ and
- ▶ an “aggressive” set also including categories that may be associated with 5G or advanced connectivity.¹⁶⁵

When looking at the three-year averages¹⁶⁶ of private investment from Europe and United States–Canada inside the identified verticals and technology categories, and estimating the number of 5G companies falling within these categories,¹⁶⁷ we observe a difference in funding (both per financial round and per company/year) between the two regions. When extrapolated to the estimated number of advanced-connectivity-based companies in Europe, this difference translates to an estimated funding gap of between €4.6 billion and €6.6 billion annually, benchmarked against US-Canada funding levels.

Inter-continental private investment

2019 was set to be the year with the strongest interest in Europe from US and Asian investors in European companies. According to Atomico’s 2019 report, approximately one of every five funding rounds in Europe currently includes the participation of at least one US or Asian investor.¹²⁹ This figure jumps sharply for large funding rounds of over \$100 million, about 90% of which involve at least one US or Asian investor.¹²⁹ The growth of US and Asian VC activity in Europe is reflected in the total capital invested into the European Union by investors based in those regions. In 2019, investments into Europe from Asia-based and US-based investors approached \$4 billion and \$9.8 billion, respectively, representing fourfold increases since 2016¹²⁹ and exceeding 40% of total investment.¹⁶⁸ The pattern is similar in the PE landscape, with a total of €4.5 billion invested in portfolio companies in Europe by non-European PE firms during 2018. These findings indicate the significant roles played by overseas investors in the current European landscape.

¹⁶³ Telecoms; Media and Gaming; Robotics; Transport; Security; Health; Event Tech; Education; Sports; Energy.

¹⁶⁴ Connected Devices, AR; Autonomous and Sensor Tech.

¹⁶⁵ Connected Devices; AR; Autonomous Sensor Tech; VR; IoT; 3D.

¹⁶⁶ Source: Dealroom. The highest three funded companies from each vertical per year were removed to avoid outliers in the calculation.

¹⁶⁷ Source: Dealroom. Calculated using the “conservative” and “aggressive” SME categorisation sets.

¹⁶⁸ Dealroom, “Quarterly European Venture Capital Report,” Q3 2019 (<https://blog.dealroom.co/wp-content/uploads/2019/10/Dealroom-Q3-2019-Report-vFINAL.pdf>)

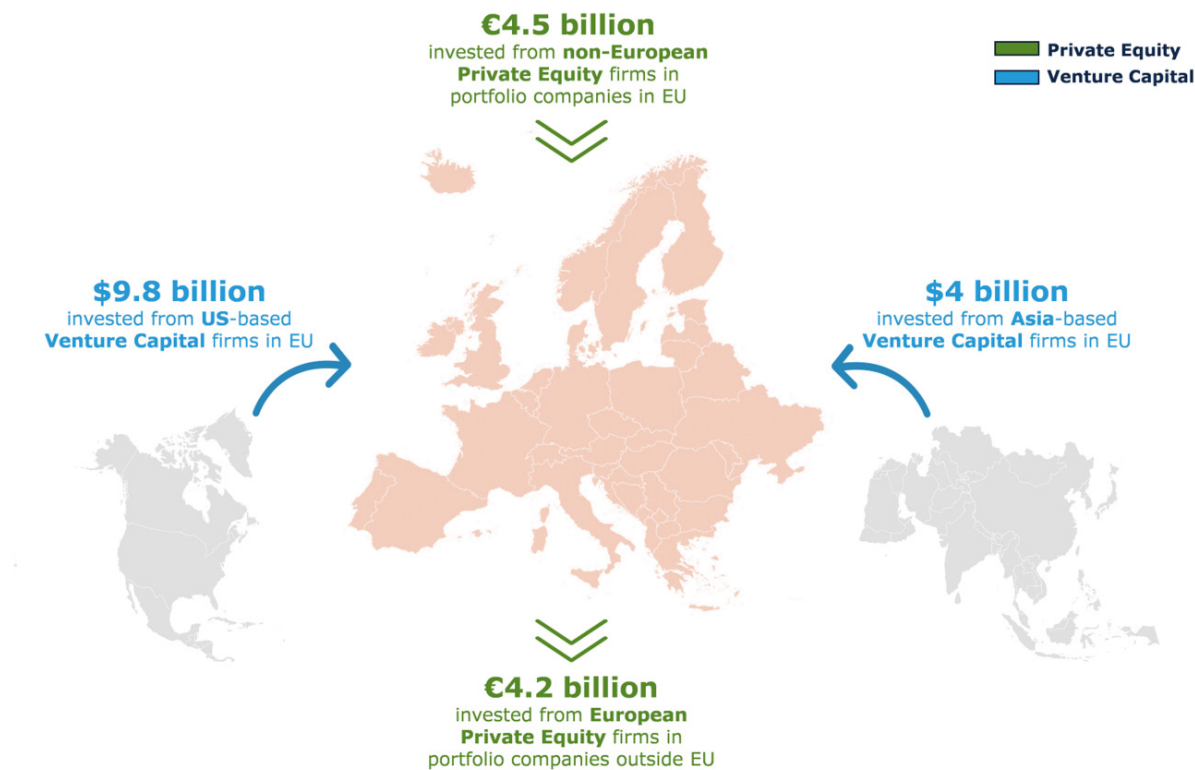


Exhibit C.33. Venture capital and private equity investment from non-European actors in 2019

[Source: Axon Consulting, based on Atomico and Invest Europe report]

External private investment into Europe is higher than ever, which is possibly related to the large gap between the funding needs of burgeoning SMEs and the low investment activity of their VC counterparts. With demand exceeding supply in Europe, the entry of foreign investment is a natural economic phenomenon and reinforces the previously expressed view on European tech and talent. It is inferable from our research that increasing the accessible options for late-stage funding would leave less room for foreign investment, and European VCs would be led to offer better investment conditions to SMEs.

CVC activity

The situation for **CVCs** is essentially identical to that for VC. The three focal regions have not evolved equally during recent years, resulting in the comparatively uneven distribution of investment amount and number of deals among them. In addition, the investment themes of CVC have recently differed between regions: for instance, US CVCs have been especially active in the field of cybersecurity, whereas Asian CVCs have been focused on boosting digital health using AI. The performance of CVCs in each region can be summarised as follows:

- **United States:** CVC funding of US start-ups reached new highs during 2019, with a total of \$31.2 billion invested and 1 191 deals closed. Despite the slight decline in the

participation rate of corporates over 2016 and 2017 in the main innovation hubs (California, New York, Massachusetts), CVC investment activity has since rebounded.

- ▶ **European Union:** European CVC activity increased substantially from 2018 to 2019, with investments rising from \$5.4 billion to \$7.5 billion (39% increase) and a total of 608 deals year-round. The United Kingdom, Germany and France attracted the most CVC investment in Europe in 2019, at 24%, 20% and 12%, respectively, followed by Sweden (7%), Spain (6%) and Switzerland (5%).
- ▶ **Asia:** The participation of corporate players in the Asia-Pacific investment ecosystem is essential, given its unique evolution. Asia attracted 40% of all CVC deals worldwide in 2019, representing the fifth consecutive annual increase on this measure. Activity was particularly intense among Chinese start-ups, both in number of deals and amount invested (286, \$6.3 billion), followed by India (110, \$2.4 billion) and Japan (429, \$2.1 billion).

One illustrative initiative of an international CVC during 2019 was the launch of the Qualcomm Ventures 5G Ecosystem Fund to invest up to an aggregate of \$200 million.¹⁶⁹ The fund focuses on investing in start-ups developing new and innovative 5G use cases. In Japan, the telecommunications company KDDI partnered with a local VC firm to set up KDDI Open Innovation Fund 3, with \$186 million to invest in innovative technologies and 5G-based businesses over a five-year period.¹⁷⁰ As pointed out above, European CVCs are also showing explicit interest in 5G investments.

Overall, CVC activity in Europe has increased over recent years, with a 42% CAGR for the 2014–2019 period. Nevertheless, Europe still struggles to keep pace with the United States and Asia, as Exhibit C.34 emphasises.

¹⁶⁹ <https://www.qualcomm.com/news/releases/2019/10/24/qualcomm-launches-200m-5g-investment-fund>

¹⁷⁰ <https://www.rcrwireless.com/20180406/5g/kddi-vc-fund-invest-5g-tag23>

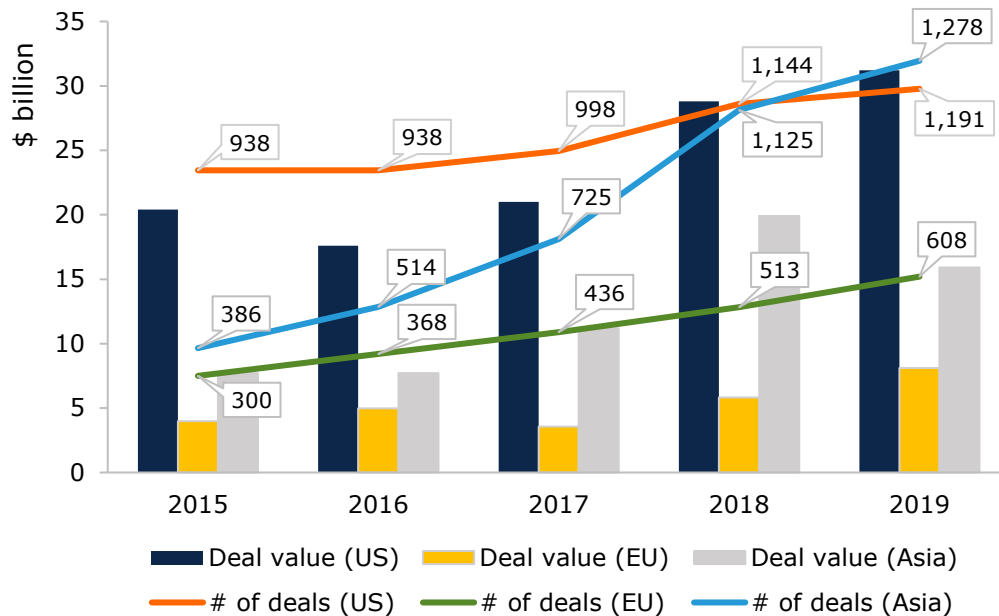


Exhibit C.34. CVC amount invested and number of deals: comparison between European Union, United States and Asia [Source: Axon Consulting, based on CB Insights report¹³³]

Several factors could explain these disparities in the number and value of deals. First, Europe has historically had a lower number of large corporations due to the large segmentation and heterogeneity of the European market. Second, consequently lower valuation levels have been observed in Europe.

Compared to the United States, Europe is similar in talent levels and economic size but still has a lower investment level, once again representing the funding gap in Europe.

Comparison with global access to finance

From an investment perspective, the United States has always been the traditional benchmark in terms of maturity. This suggests that, as regards 5G, the United States will naturally take the lead in market maturity due to the support of a strong financial market. Conversely, the superior 5G-readiness of Asia confers an advantage in terms of market development and use-case offerings. However, technology development is still a defining factor across the globe and limits how quickly certain markets can progress. As such, there is a more level playing field in this area globally compared to Europe, which increases the importance of SMEs' role in driving innovation.

The allocation of private investment to 5G is far greater in the United States and Asia than in Europe. In 2017, private investment in tech innovation (including 5G-related areas such as industrial IoT, VR and autonomous vehicles) reached nearly \$150 billion in the United

States, whereas European private investors committed roughly one-third of this amount.¹⁷¹ Similarly, in 2018, European private investment in deep tech reached just 25% of that in the United States.¹⁷² This difference in investment culture between the United States and Europe suggests that 5G will receive significantly more investment overseas in the following years.

While 5G itself is still at an unclear development stage globally, its perceived risk profile varies internationally. US private investors are renowned for having a greater appetite for risk than their European counterparts, which will likely lessen the high-risk perception of 5G among US investors. This is illustrated by the 2019 launch of the Qualcomm Ventures 5G Ecosystem Fund to invest in start-ups developing new and innovative 5G use cases. Asia has also demonstrated a significant appetite for risk in recent years, based on the appearance of a large number of new start-ups and VC mega funds ready to fuel their growth. Two examples are the Softbank Vision Fund and KDDI Open Innovation Fund 3. Furthermore, in countries such as China, the risk of private investment in 5G is somewhat alleviated by the huge amount of state investment that is already committed to 5G infrastructure networks nationwide.¹⁷³ Finally, the most obvious difference between Europe and the United States/China is that the latter two have greater homogeneity. As single markets with a common government and language, they do not have to deal with many of the obstacles to homogeneity and scale that continue to confront Europe.

¹⁷¹ GSMA, "The 5G Era in the US"

(<https://www.gsmainelligence.com/research/?file=4cbbdb475f24b3c5f5a93a2796a4aa28&download>)

¹⁷² Axon Partners Group, "Participation of Institutional Investors in European Venture Capital."

¹⁷³ Goldman Sachs, "5G's Future in China" (https://www.goldmansachs.com/insights/pages/from_briefings_01-july-2019.html)

Annex D. Glossary

3GPP	3rd Generation Partnership Project
5G IA	5G Infrastructure Association
5G PPP	5G Infrastructure Public Private Partnership
5GAP	5G Action Plan for Europe
AI	Artificial Intelligence
AR	Augmented Reality
BEREC	Body of European Regulators for Electronic Communications
BMWi	Federal Ministry for Economic Affairs and Energy (Germany)
CAGR	Compound Annual Growth Rate
COSME	Programme for the Competitiveness of Enterprises and Small and Medium-sized Enterprises
CPE	Customer-Premises Equipment
CPS	Cyber-Physical Systems
C-V2X	Cellular Vehicle-to-Everything
CVC	Corporate Venture Capital
Early Stage	The early stage of company financing (generally seed to Series A), which represents the very early phase of start-up development
EIC	European Innovation Council
EECC	European Electronic Communications Code
eMBB	Enhanced Mobile Broadband
ERP	European Recovery Programme
FWA	Fixed Wireless Access
GDP	Gross Domestic Product
H2020	Horizon 2020
ICT	Information and Communication Technology
Late Stage	The late stage of company financing (generally Series B to D +), which generally coincides with the growth and expansion phase of start-up development
IoT	Internet of Things
LTE	Long-Term Evolution
mMTC	Massive Machine-Type Communications
MNO	Mobile Network Operator
MR	Mixed Reality
NB-IoT	Narrowband IoT
OTT	Over-the-Top
PE	Private Equity
Pre-seed	Very early stage of company financing (generally undertaken by angel investors, friends and family or micro VCs), which supports the business from idea to early proof of concept
RAN	Radio Access Network
SME	Small and Medium-Sized Enterprise
TMT	Technology, Media & Telecom
URLLC	Ultrareliable Low-Latency Communication
V2V	Vehicle-to-Vehicle
VC	Venture Capital
VR	Virtual Reality

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