| Project Title | Global Vision, Standardisation & Stakeholder Engagement in 5G |
|---|---|
| **Project Acronym** | Global5G.org |
| **Grant Agreement No** | 761816 |
| **Instrument** | Coordination and Support Action |
| **Topic** | Shaping the global 5G PPP vision by strengthening the link between vertical industry, standardisation, and research, focusing on potential future investments in 5G and rollout to market, as well as policy, regulatory, spectrum, and legal discussions |
| **Start Date of Project** | 01.07.2017 |
| **Duration of Project** | 30 Months |
| **Project Website** | www.global5g.org |

# D3.2 – Market overview and comparative analysis

| | |
|---|---|
| **Work Package** | WP3 – Global 5G ecosystem: standards and support of consensus building |
| **Lead Author (Org)** | IDC |
| **Contributing Author(s) (Org)** | Daniela Rao, John Delaney (IDC), Lis Pourcher, Fabrice Clari (Inno) |
| **Due Date** | 30.06.2019, M24 |
| **Date** | 18.07.2019 (Final Delivery) |
| **Version** | 1.0 |

## Dissemination Level

| | |
|---|---|
| x | PU: Public |
| | PP: Restricted to other programme participants (including the Commission) |
| | RE: Restricted to a group specified by the consortium (including the Commission) |
| | CO: Confidential – only for members of the consortium (including the Commission) |

## Versioning and contribution history

| Version | Date | Authors | Notes |
|---|---|---|---|
| 0.1 | 08.02.2019 | Daniela Rao (IDC) | ToC |
| 0.2 | 06.06.2019 | Daniela Rao, John Delaney (IDC) | First draft version |
| 0.3 | 12.06.2019 | Lisa Purcher, Fabrice Clari (Inno) | Contribution with Mapping Tool maps |
| 0.4 | 28.06.2019 | Daniela Rao (IDC), Lisa Purcher, Fabrice Clari (Inno) | Revision of the document |
| 0.5 | 12.07.2019 | Daniela Rao (IDC) | Final revision of the document |
| 1.0 | 18.07.2019 | Daniela Rao (IDC) | Delivered version after final quality check by Trust-IT (J. Favaro) |

## Disclaimer

Global5G.org has received funding from the European Commission's Horizon 2020 research and innovation programme under the Grant Agreement no 761816. The content of this document does not represent the opinion of the European Commission, and the European Commission is not responsible for any use that might be made of such content.

## Table of contents

## List of Figures



## List of Tables

# List of common definitions in Global5G.org

| *Acronym/ Abbreviation* | *Description* |
|---|---|
| **5G PPP** | 5G Infrastructure Public Private Partnership |
| **5G AP** | 5G for Europe Action Plan |
| **5G IA** | 5G Infrastructure Association, representing the private side of the 5G PPP |
| **3GPP** | 3rd Generation Partnership Project, providing complete system specifications for cellular telecommunications network technologies, leading 5G standardisation, currently in Phase 1 of the 3GPP 5G effort for Release 15. Full compliance with the ITU's IMT-2020 requirements is anticipated with the completion of 3GPP Release 16 at the end of 2019 – In Phase 2 of the 3GPP 5G effort |
| **ASIL** | Automotive safety integrity level |
| **BEREC** | Body of European Regulators for Electronic Communications |
| **BSS** | Business support systems |
| **CAM** | Connected and automated mobility |
| **CAN** | Controller area network |
| **Capex** | Capital expenditure |
| **CPS** | Cyber physical system |
| **CSP** | Communication service provider |
| **CTO** | Chief technical officer |
| **DA** | Distributed automation |
| **DER** | Distributed/Decentralised energy resources |
| **DMS** | Distributed management system |
| **eMBB** | Enhanced mobile broadband (use cases mostly associated with rollout Phase 1 of 5G) |
| **EMS** | Energy management system |
| **FCC** | Federal Communications Commission |
| **FoF** | Factories of the Future |
| **GDPR** | General Data Protection Regulation |
| **IOT** | Internet of Things |
| **ITU** | International Telecommunication Union, the standards setting body within the United Nations |
| **mIoT** | Massive Internet of Things (use cases mostly associated with rollout phase 2 of 5G) |
| **IS** | International standard |
| **KPI** | Key performance indicator |
| **MCS** | Mission critical services (use cases mostly associated with rollout phase 2 of 5G) |
| **MEC** | Mobile edge computing |
| **MNO** | Mobile network operator |

| *Acronym/ Abbreviation* | *Description* |
|---|---|
| **MS** | Member state |
| **MTC** | Machine-type communications |
| **MVNO** | Mobile virtual network operator |
| **NFV** | Network function virtualisation |
| **OpEx** | Operating expenditure |
| **OSS** | Operational support systems (or sometimes open source software) |
| **PPDR** | Public protection and disaster recovery |
| **SDA** | Strategic deployment agenda |
| **SDN** | Software-defined networks |
| **URLLC** | Ultra-reliable low-latency communications |

## Essential Glossary

| Acronym/ Abbreviation | Description |
|---|---|
| **Digital transformation** | For IDC, the term digital transformation means applying new technologies to radically change processes, customer experience, and value. Digital transformation allows organisations to become digital-native enterprises that support innovation and digital disruption rather than enhancing existing technologies and models. |
| **Artificial Intelligence (AI)** | IDC defines artificial intelligence (AI) systems as a set of technologies that use deep natural language processing and understanding to answer questions and provide recommendations and direction. |
| **Internet of Things (IoT)** | IDC defines the Internet of Things (IoT) as a network of uniquely identifiable end points (or things) that communicate bidirectionally without human interaction using IP connectivity. |
| **Big Data & Data Analytics** | IDC describes big data and data analytics as a new generation of technologies and architectures designed to economically extract value from very large volumes of a wide variety of data by enabling high-velocity capture, discovery, and/or analysis. |
| **ARVR** | IDC defines augmented reality (AR) as purpose-built devices, worn on the head and over the eyes, that enable the wearer to see their surroundings while being served data or feedback. The device may overlay digital objects in the real world or simply generate actionable feedback in the form of a heads-up display. IDC defines virtual reality (VR) as purpose-built devices, worn on the head and over the eyes, which completely obscure the wearer's vision of the outside world, creating an all-inclusive virtual reality. |

## Executive Summary

The European telecommunications industry will enter the decade of the 2020s in the middle of the last of three major growth phases in its traditional connectivity business: first mobile telephony, then fixed-line broadband, and now mobile broadband.

In their core business of mobile data connectivity, mobile operators in Europe can expect only modest growth over the next few years. This leads to several strategic objectives, in the pursuit of which 5G can play a key role. But even modest growth cannot be taken for granted: It requires operators to invest in additional network capacity so they can continue to meet the demand that will generate additional revenue. 5G has a key role to play here.

In the next two years, the 5G-services proposition of European operators will consist of enhanced mobile broadband (eMBB) for consumers and enterprises in support of operators' existing business.

From 2021 onwards, ultra-reliable/low-latency communications (URLLC) and massive machine-type communications (MMTC) will emerge, which will enable mobile networks to be used for things they cannot support today, opening opportunities for new revenue streams, especially in the enterprise market.

5G will further expand the scale of mobile networks for IoT applications. In the nearer term, 5G can expand the scope of mobile networks for IoT applications, as the current generation of mobile networks still falls short of the requirements of some IoT application types in terms of data rates, responsiveness, and reliability – particularly in manufacturing, healthcare, and in the energy sector.

5G scenarios in Europe differ widely and are influenced by many local factors related to regulations, public investments, and market environments.

The Global5G.org team developed comparative analysis with the goal of offering fact-based guidance to fully realize 5G capabilities and drive appropriate EU, telecom-operator, and ICT-supply-chain-player investments. The comparative analysis is based on the 5G market maturity level indicator, which relates to the following key aspects:

- The market launch of pre-commercial 5G services – 5G trials in 5G enabled cities
- Government strategies and initiatives, such as funding and national 5G roadmaps
- Market demand structure in terms of internet-user and mobile-phone penetration rates

The comparative analysis of these indicators shows three levels of 5G readiness in Europe:

- **Countries with the highest level of market maturity, such as Estonia, the UK, Finland, Italy, Germany, Spain, the Netherlands, Luxembourg, Lithuania, and France:** As the most advanced telecom markets, these countries will have commercial 5G available by the end of 2019. In these countries, 5G is being hyped as “game changing” for the IoT enterprise market. Big data analytics demand has been unserved to date in these markets.
- **Countries with a medium level of market maturity, such as Sweden, Poland, Austria, Slovakia, Malta, Latvia, the Czech Republic, and Croatia:** These markets can expect changes and opportunities to emerge after 2022. Public organizations, telecom operators, and ICT supply chain players will be involved in trials of 5G-related services.
- **Countries with a low level of market maturity, such as Hungary, Denmark, Cyprus, Slovenia, Romania, Portugal, Ireland, Greece, Belgium, and Bulgaria:** These countries face 5G-deployment-related challenges due to regulations and national plans. Telecom operators here will focus on network virtualization. Initial 5G investments in these countries will support enhanced mobile broadband use cases, the expansion of public cloud services for enterprises, and the provision of digital content services for consumers, all of which will drive demand for the mass market availability of 5G.

Even though the 5G scenario in Europe – being diverse and influenced by many local factors related to regulations, public investments, and macroeconomic environments – requires a differentiated approach, institutions and industry stakeholders should consider the following general recommendations:

- **Consider European diversity an advantage and a stimulus to deploy innovative pre-commercial 5G services** tailored to address the needs of specific niches of sophisticated customers. The European telecommunications services market has a high level of maturity in terms of mobile connections and device penetration. To attract and retain customers, telecom operators and all ICT supply-chain players (including OEMs) will have to compete in the 5G market with broad set of innovative services. In several areas, willingness among customers (both consumers and enterprises) to experiment with new and advanced 5G services will be high, but funds to support initiatives, trials, and pilots and, eventually, commercialisation will be limited, despite such initiatives' essential role in the evolution of the European 5G market.
- **Monitor 5G evolution in the most advanced countries – those with the highest 5G readiness levels, where competition is the highest.** In these countries, the 5G and IoT markets are evolving faster than we had previously expected, with new players entering from other industries, such as OT players in the manufacturing sector and digital content distribution from broadcasters. Mergers and acquisitions, partnerships, and alliances are likely to accelerate in the 5G arena, so it is essential to maintain a fair competitive environment, as this will be crucial for the growth of European 5G market.
- **Foster the development of the 5G market in countries with low and medium levels of readiness to deploy commercial 5G services.** In these countries, incentives, funding, and government-backed initiatives to support greater 5G integration with 4G networks and to foster the creation of new 5G capabilities and IoT services for specific sectors (i.e. healthcare, logistics, and transportation) will help telcos and other ICT supply-chain players tap into the new market opportunities generated, and possibly to implement new business models around those opportunities.

# Introduction

## Scope and Purpose

This report aims to gauge Europe's market maturity for the successful deployment of 5G and provides fact-based guidance to fully realize 5G capabilities by driving appropriate and timely investments.

The report provides a comprehensive market overview and a comparison across 10 EU member states covering pre-commercial and commercial 5G services deployment and focusing on the main accelerators and constrains impacting on 5G market development in Europe.

The analysis conducted for this study breaks down into three broad areas of research:

- **Research area 1:** European wireless and mobile market forecasts
- **Research area 2:** A forecast of the European IoT market and the role of 5G networks
- **Research area 3:** Comparative analysis of the main European 5G country markets

Research activities includes:

- Extensive desk research on EU 5G regulatory and market environments through in-depth literature reviews and ad-hoc material collection and systematization
- Comparative analysis of pre-commercial and commercial 5G services markets in the main EU countries, identifying in each country's main differences regarding regulation, spectrum access, 5G connectivity deployment, pre-commercial trials, competitive dynamics, and funding, with the goal of providing information about the issues that may slow down 5G rollouts in specific countries/areas

## Terms of Reference and Methodology

The results presented in this document are based on IDC's continuous research, mapping tool software developed by inno-tsd, and inputs from collaborative activities with 5G PPP, meetings, webinars, calls, and third-party events. The results reflect the context within which 5G innovations are being created, covering multi-faceted perspectives, sector-specific needs and approaches, and major issues that cut across country markets.

## Structure of the Document

The document is divided into the following chapters, each corresponding to a major item, as specified below:

- **Section 1** offers a summary of market demand trends and macroeconomic dynamics in Europe, focusing on the emerging digitalization demand that 5G will address.
- **Section 2** provides an overview of the Internet of Things market and the main roles and opportunities generated by 5G networks.
- **Section 3** is dedicated to longitudinal comparative analysis and provides 5G market maturity maps that identify market maturity levels by country.

# 1 5G European market overview

This section provides a market overview of the European mobile network services market over the next four years, focusing on:

- Demand evolution, with trends in mobile network usage and Telecom operators' revenues
- 5G network infrastructure development
- European telecom operators' strategies and challenges in the transition to 5G

## 1.1 Mobile Network Services Demand Evolution in Europe

European telecom operators will enter the 2020s in the middle of the third major growth phase in their traditional connectivity business; the first was mobile telephony; the second was fixed-line broadband; now we have mobile broadband.

When mobile broadband began is a matter of some debate. 3G started commercially in Europe around 2002/2003, but 3G phones did not support the Worldwide Web during the first few years. Something that looked more like broadband on the mobile network began around 2007/2008, enabled by two emerging technologies:

- A High-Speed Packet Access (HSPA) upgrade for 3G networks
- Mobile phones supporting the protocols needed to access the web directly, such as HTTP and HTML

The advent of 4G (LTE) in 2010–2012 made mobile broadband a more attractive proposition for the mass market because it enabled customers to download, upload, and stream video, which had become the predominant internet content type by then. This pushed mobile broadband revenues to a higher level of growth. IDC's Telecoms Services Database shows that, at the end of 2011, broadband data access accounted for 17.5% of mobile operators' service revenues in Western Europe.

A good deal of growth is still left in mobile broadband in Europe. As presented in the below figure, IDC forecasts mobile data revenues (excluding SMS) to grow at a compound annual growth rate (CAGR) of 5.5% per annum during the four-year period between the end of 2018 and the end of 2022. Fixed-line data revenues will also expand during that period, but at the lower CAGR of 2.0%, owing to the more mature state of that market. Revenues from the traditional communications services of telephony and SMS will shrink, continuing the decline that has been in progress for several years. Fixed-line telephony revenues will decline at a CAGR of 3.5% over the same period, while mobile telephony and SMS revenues will decline at negative CAGRs of 5.0% and 5.4%, respectively, reflecting mobile usage migration from telecom-operator-provided services to voice and messaging provided by over-the-top services such as Skype, WhatsApp, and FaceTime.

The overall effect of these shifts during the next five years will be as follows:

- Fixed-line service revenues decline at a CAGR of 0.3%.
- Mobile service revenues will expand at a CAGR of 1.1%.

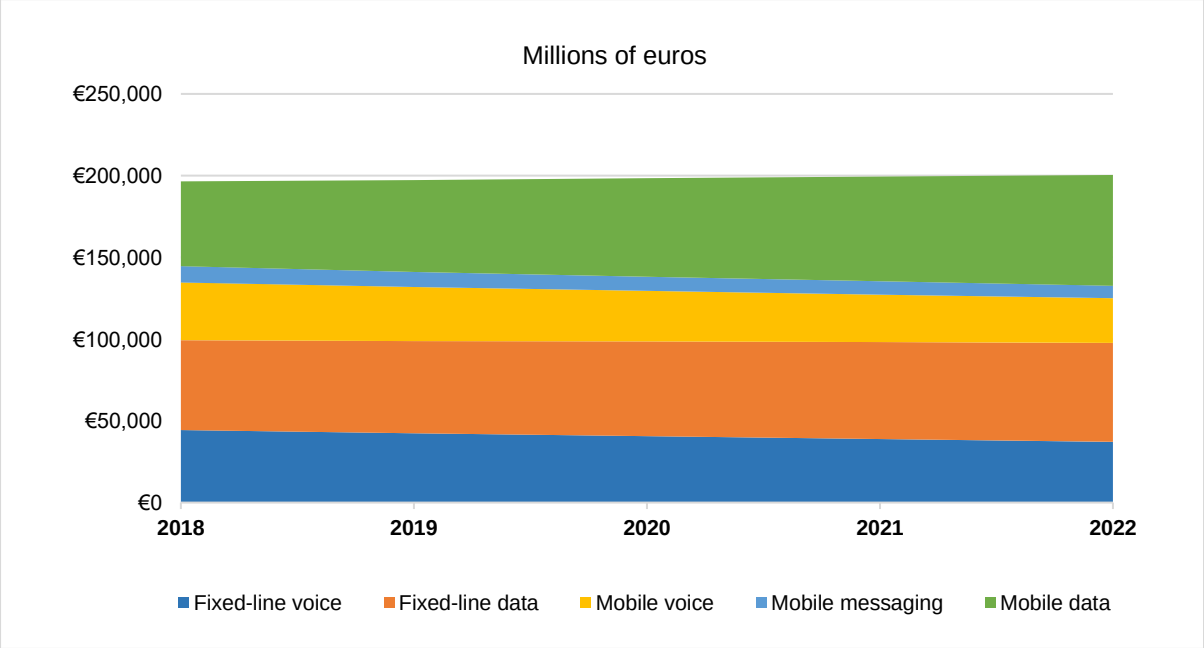
We will also see a gradual shift in total telecom services revenues from fixed to mobile. At the end of 2018, mobile revenues accounted for slightly under half (49.5%) of total telecom services revenues in Western Europe. IDC forecasts that they will cross the 50% threshold during 2020 to account for 51.3% of total telecom services revenues by the end of 2022.

Fixed and mobile connections will grow from about 970 million in 2018 to 1,047 million in 2022, driven by mobile connections, which will represent more than 65% of growth, expanding at a CAGR of approximately 3% through to 2022.

Mobile connection growth through to 2022 breaks down as follows:

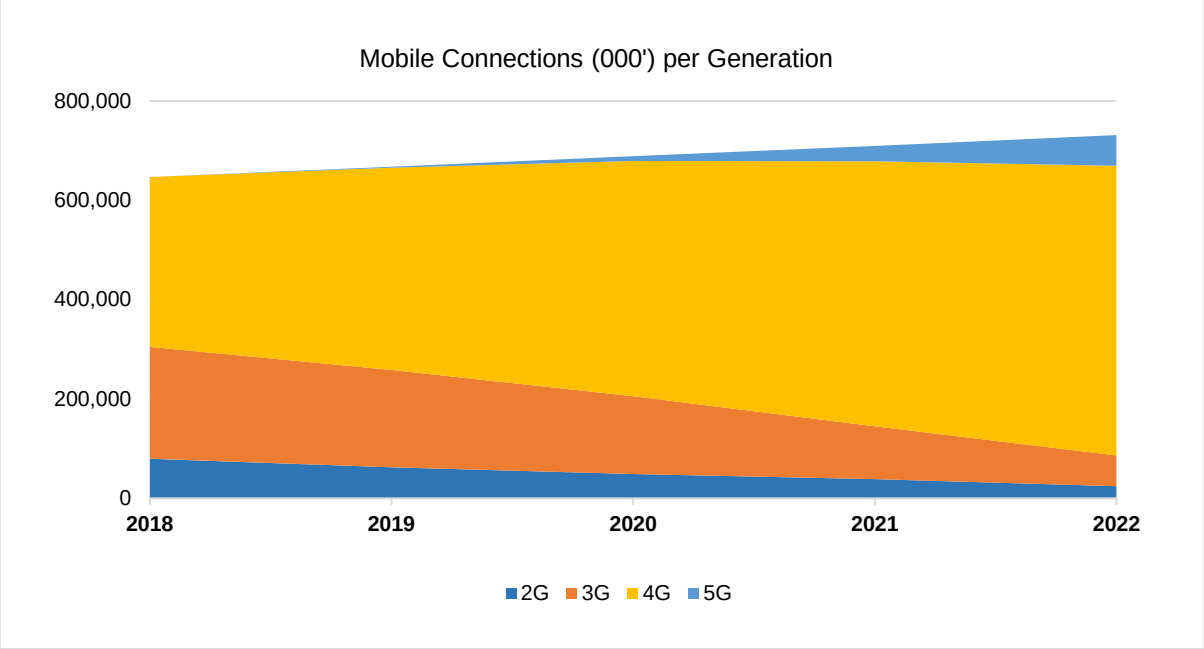
- 4G connections (more than 50% of the total number) will expand at a CAGR of approximately 14%, while 5G connections will arrive on the market from 2019.
- Mobile phone voice & data connections will expand at a CAGR of approximately 5%, while M2M connections will record a CAGR of 15%.
- Mobile phone voice-only connections will decrease strongly, while the number of connections via dongle, Mi-Fi, and embedded in tablets and notebooks will remain almost flat.

*Figure 1: Telecom operators' fixed and mobile services revenues in Europe, 2018–2022*



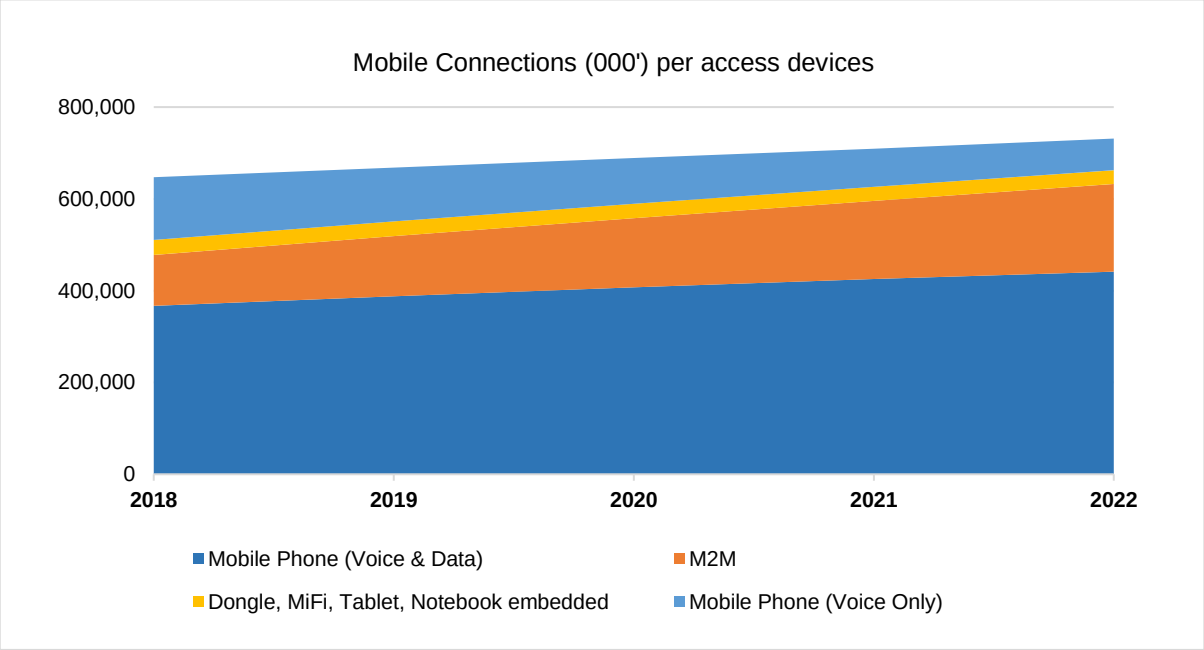

*Source: IDC, Telecommunications Services Database, Q4 2018 update*

*Figure 2: Mobile connections by mobile generation, 2018–2022*



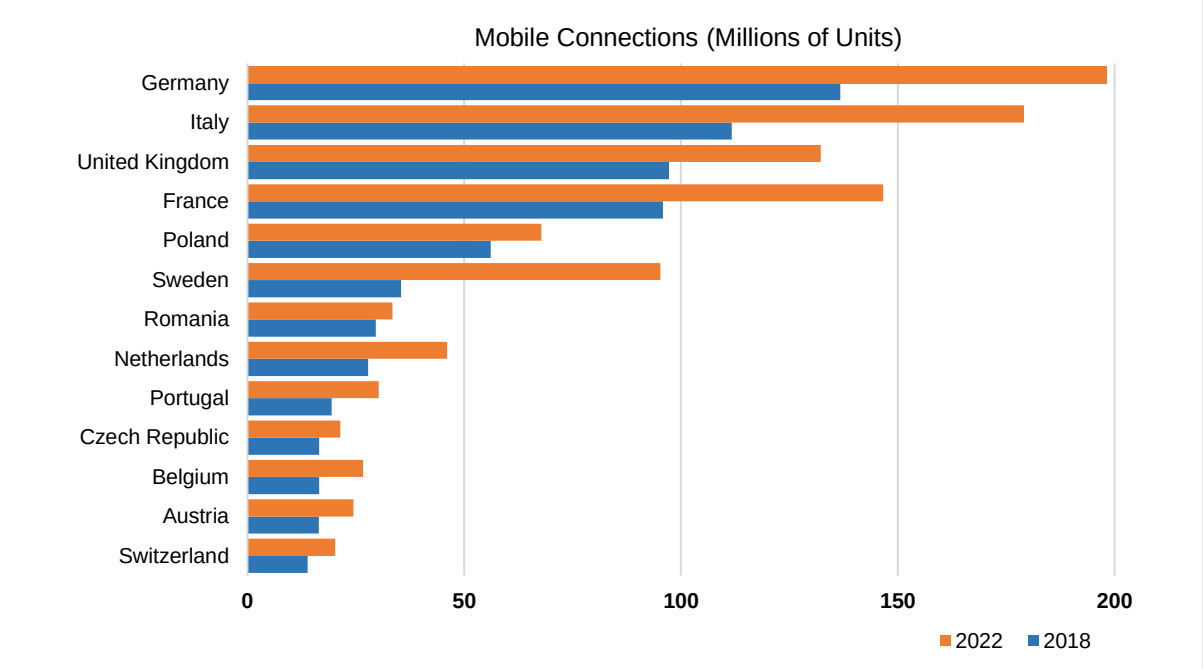

*Source: IDC, Telecommunications Services Database, Q4 2018 update*

*Figure 3: Number of mobile connections by access type, 2018–2022*




*Source: IDC, Telecommunications Services Database, Q4 2018 Update*

*Figure 4: Mobile connections (in millions) in Europe by country, 2018–2022*




*Source: IDC, Telecommunications Services Database, Q4 2018 update*

## 1.2 5G network infrastructure development: European operators' investments and challenges

Mobile data revenues have good growth potential over the coming few years. To sustain the 5.5% CAGR in mobile data revenues forecast for the 2018–2022 period, mobile operators will need more data-carrying capacity in their networks.

Network traffic generated by data customers is typically growing at 40–60% per year. If that growth is sustained, by the early-to-mid 2020s, operators will be struggling to cope with demand using only their current resources. They need new spectrum; and they need a way to get more data into their existing spectrum. It is mainly this need for more capacity that is driving the early rollout of 5G in Europe.

The major 5G network investment areas are as follows:

1) **Spectrum:** Most fundamentally, operators must invest in new spectrum licences. The cost of doing so has proven to be highly unpredictable in Europe, with a wide variation in spectrum prices both between successive mobile generations and between different countries for the same mobile generation. 5G is certainly no exception, as shown in the below table, which lists the licence prices paid for spectrum in the 3.4–3.8 GHz band in the European countries that have awarded licences so far (as of June 2019). The table includes a price per megahertz per head of population for each country – a somewhat crude measure of comparison, since other factors also vary by country, such as licence duration. Nevertheless, even on this approximate basis, we can see how widely the investment involved in 5G spectrum licensing has varied so far, ranging from a low of 3.6 cents per head of population in Finland to a high of 35.9 cents per head of population in Italy.

*Table 1: Price per megahertz per head of population by country*

| Country | Date of award | Price raised (€m)* | Amount (MHz)* | Population (m) | € cent per MHz per head* |
|---|---|---|---|---|---|
| **Austria** | 8 March 2019 | 188 | 350 | 8.773 | *6.12* |
| **Finland** | 1 October 2018 | 78 | 390 | 5.503 | 3.62 |
| **Germany** | 12 June 2019 | 4,175 | 300 | 82.790 | **16.81** |
| **Ireland** | 22 May 2017 | 78 | 350 | 4.784 | 4.66 |
| **Italy** | 3 October 2018 | 4,350 | 200 | 60.590 | **35.90** |
| **Spain** | 26 July 2018 | 438 | 200 | 46.720 | 4.69 |
| **Switzerland** | 8 February 2019 | 341 | 300 | 8.420 | 13.50 |
| **UK** | 5 April 2018 | 1,287 | 150 | 66.040 | 12.99 |

*Source: IDC research, June 2019*

*Note: The amounts shown are for the 3,4-3,8 GHz*

2) **Cell-site upgrades:** To deploy the 5G New Radio (NR) air interface, mobile operators may need to upgrade or replace some existing base stations at their cell sites with new ones.

   In some cases, operators may not need to install new base stations to deploy 5G NR because many of the 4G base stations shipped in recent years have the capability to provide 5G NR through an upgrade. Nokia and Ericsson, for example, both launched a range of 5G-ready base stations in 2016. One of the first European operators to launch 5G commercially, Swisscom, announced in April 2019 that it expects to achieve 90% population coverage of 5G by the end of the end of the year by using technology in its existing Ericsson base stations that shares spectrum dynamically between 4G and 5G, according to traffic demand. But, even for operators that do not need a rip and replace base stations, the cost of upgrading to 5G is still significant. And, if existing base stations do not already have high-order MIMO (better than 8 x 8), operators will still eventually need to upgrade to that to realise their plans for 5G capacity and coverage.

   In addition to the base stations themselves, other infrastructure at cell sites, such as masts and electrical power supplies, might need to be upgraded. 5G massive MIMO equipment is typically larger, heavier, and more power-hungry than the older base stations.

3) **New cell sites:** The main radio band that will be used to launch 5G in Europe is 3.4–3.8GHz. This is considerably higher frequency spectrum than has been used for earlier mobile generations. The highest frequency used for 4G in Europe is 2.6GHz, and a large amount of 4G coverage in Europe uses 1.8GHz (1800MHz) spectrum re-farmed from its previous use in 2G networks. Does this mean that, in addition to upgrading their existing cell sites, operators will need to build additional cell sites to roll out 5G coverage on a national level? The answer is, "Perhaps, eventually."

   European operators have been testing the usable range of 3.4–3.8GHz signals using massive MIMO as part of their 5G trials, and several of them, including multinational operators such as Orange and Vodafone, have reported good results. Orange, for example, has concluded that, by using massive MIMO in the order of 16 x 16 (or higher, in some dense areas such as Paris La Defense), it can deploy 5G in 3.4–3.8GHz on the same cell-site grid that it has been using for 4G coverage, without needing to build additional sites. In the early phases of 5G therefore, it seems likely that operators will avoid the need to invest in a large number of new cell sites for coverage reasons.

Eventually, however, it is likely that operators will need to boost the capacity of their 5G networks in denser usage areas by adding some cell sites – conventional macro cells, small cells, or a combination of the two. Another driver of investment in additional cell sites will be the future use of still higher frequency spectrum, including the much higher frequencies in the millimetre wave range (26GHz+), which are likely to be licensed for mobile network use in Europe during the early 2020s.

4) **Transport network upgrades:** In addition to upgrades of the radio access network (RAN), 5G will require upgrades in the capacity of the mobile transport network, i.e. the transmission links between base stations and the core network.

   European operators consider their current transport network generally to be sufficient to cope with the demands of 5G – at least for the first 12–18 months of commercial operation. They see this first phase of 5G largely as a continuation of the trend for capacity growth in the mobile network that they are already dealing with.

   However, although the short-term impact of 5G will be modest, mobile operators expect 5G to have a more extensive impact on their transport network during the next five years. The need for more capacity will be accelerated by several factors:

   - The uptake of 5G across the general customer base will start earlier than it did with 4G because there will be no lag between the availability of 5G service plans and the availability of 5G smartphones
   - As with 4G, it is likely that the faster data rates delivered by 5G will stimulate an increase in mobile data consumption per head by operators' customers
   - The introduction of higher orders of MIMO, and the availability of additional spectrum will boost the data rates delivered by 5G. This will add further stimulus to growth in consumption per head.

   As a result, operators will need a steep increase in the data capacities of their transport networks. At present, 1Gbps is the "benchmark" capacity of a cell site backhaul link. By 2023, when 5G uptake will be moving into the mainstream customer base, the benchmark is likely be 10Gbps.

5) **Core network upgrades:** The mobile core network comprises systems that aggregate data traffic from user devices, authenticate subscribers and devices, apply policies, and manage device mobility. The network then routes traffic to operator services or to the internet.

   To realise the full potential of 5G, mobile operators will need to replace the current evolved packet core (EPC) network with a new 5G core (5GC) network. Like transport upgrades, however, investment in the new 5GC will not be incurred by operators during the early phase of 5G rollout. This is because, in early 2017, the standardisation of 5G by 3GPP was split into two phases. In the first phase, called non-stand-alone (NSA), 5G networks are deployed by connecting 5G NR base stations to the existing 4G EPC.

   The second phase of 5G deployment is called stand-alone (SA) and comprises 5G NR base stations connected to the new 5GC. This mode of deployment will be standardised in 3GPP Release 16, currently scheduled to be finalised by March 2020.

   Therefore, all deployments of 5G in the first 12–18 months of commercialisation will be in NSA mode – that is, they will use the existing core network rather than a new 5G core network.

**Mobile operator investment plans indicate a conservative approach to capex.** Operators have been at pains to reassure investors about the levels of investment that will be required to build 5G networks. For example, at the Orange Capital Markets Day in December 2017, CTO Mari-Noëlle Jégo-

Laveissière declared to the audience of investment analysts that "our 5G-specific investments will be marginal from 2017 to 2020; and, thereafter, our capex as a percentage of revenues will be stable."

It is possible, however, that even in the NSA-driven phase of 5G during the early 2020s, more investment will be required than operators are hoping. Although operators believe they can avoid significant densification of the cell-site grid, as noted earlier, this is mostly based on trials rather than "live" commercial networks. In practice, operators may find that at least some extra cell sites are needed as 5G coverage is rolled out. A significant exception has already emerged, Germany's Deutsche Telekom having announced in October 2018 that it is building new base stations at a substantial rate and plans to increase the number in its German network from the 27,000 it had in 2017 to 36,000 by the end of 2021. The increase is focused on 5G, and Deutsche Telekom aims to provide 5G coverage to 99% of the German population by the end of 2025.

Beyond the 2023 horizon, still more investments may be needed to go beyond the 1% level of revenue growth and generate new revenue streams from distinctive new 5G services that 4G networks cannot support. Innovative services such as remote command-and-control and enterprise SLAs rely on potentially costly changes to the network architecture. Ultra-low latency (sub-10ms) depends on moving compute power, applications, and content closer to the point at which they are being used to minimise the length of the network path that signals need to travel. This will require investment in edge-computing server centres and links to connect them to the rest of the network. Network slicing, upon which service-level guarantees rely, needs investment in virtualisation of the RAN, as well as the core network, so that end-to-end virtual network instances can be set up and torn down as required.

## 1.3 European Telecom Operators' Strategies in the Transition to 5G

**5G will contribute to mobile operators' strategic objectives.** As described in previous pages, mobile operators face the prospect of low single-digit growth at best in their existing connectivity services businesses. This points to the need for mobile operators' strategies in Europe to include measures for:

- Protecting profit margins
- Protecting their existing businesses
- Expanding their existing businesses
- Extending into additional businesses.

Mobile operators can achieve the above measures by including the following objectives in their strategies:

**1)** To operate networks more efficiently

**2)** To seek new revenue streams from mobile connectivity: Current and potential future examples include Internet of Things (IoT) connectivity, factory/campus connectivity, enterprise service-level agreements (SLAs), connected-vehicle applications, and broadcast media carriage.

**3)** To seek new revenue streams from packages combining connectivity with additional content and services: Examples include bundling content with data plans, and vertically targeted packages such as tele-healthcare.

**4)** To seek new revenue streams by entering businesses outside connectivity. Examples include pay TV/video, banking, IT services.

**5)** To improve customer retention

**6)** To structure service pricing so that increases in service uptake and usage lead to increases in customer spending

**7)** To engage in mergers, acquisitions, and joint ventures – especially in-country combinations of two mobile operators and in-country combinations of a mobile operator and a fixed-line operator

**8)** 5G has the potential to contribute – to some extent at least – towards achieving most of these strategic objectives.

**Objective 1 – to operate networks more efficiently:** One of the most important features of each new successive mobile generation has been a new waveform schema for handling multiple access in the radio access network. In each case, one primary objective of the new waveform has been to increase the amount of information that a given amount of radio spectrum is able to carry – referred to as "spectral efficiency" or, more colloquially, as "bits per Hertz". 5G will thus enable more efficient network operation by increasing the effective data capacity of mobile operators' licensed spectrum holdings – or, putting it conversely, by requiring a smaller amount of spectrum to carry a given amount of data. The extent to which 5G's spectral efficiency is higher than 4G's is a complicated calculation, depending on several variable factors such as the order of MIMO and QAM used, and the division of traffic between downlink and uplink. However, as an indication of possible improvement, one group of researchers concluded, in a paper entitled Selected Areas in Communications (June 2017, page 99, chapter 1.1), that efficiencies of over 100% could be achieved with 5G compared with the 4G baseline.

Not only will operators be able to make more efficient use of the spectrum they are newly licensing for 5G; they will also, over time, be able to make more efficient use of their existing licensed spectrum by reducing the amount of it that they use for earlier generations of mobile access and – subject to regulatory approval – deploying 5G (and 4G) in that spectrum instead, a process referred to as "spectrum re-farming".

In addition to making more efficient use of spectrum, network vendors are also claiming that their 5G solutions will enable operators to achieve lower network power consumption for a given amount of data capacity. For example, Ericsson, in a paper called "Breaking the Energy Curve"[1], declares its commitment to make its 5G equipment in 2022 ten times more energy efficient (per transferred data) than its current (2017) 4G equipment and to drive a 35% energy saving in its Ericsson Radio System (ERS) compared with its legacy system.

Manpower cost savings are also promised in 5G network operation – through the use of artificial intelligence (AI) to automate the network monitoring, management, and maintenance processes that are currently carried out by human personnel. Huawei, for example, has been promoting integrated AI as a key theme of its 5G portfolio marketing during 2018 and 2019; and, at the 2018 Mobile World Congress, Nokia launched its Reefshark range of base-station chipsets, featuring embedded AI for optimising radio resources and, in the future, to support network slicing.

**Objective 2 – to seek new revenue streams from mobile connectivity:** Since the introduction of 2G (GSM) in the early 1990s, European mobile networks have been developed primarily to support the connectivity of consumers' mobile phones. That remains the case today, albeit that the capabilities of those phones have expanded massively during the intervening decades.

5G will expand the market for mobile connectivity by enabling the mobile network to support a wider range of devices, applications, and customer types. For example:

- The higher capacity of 5G will enable the mobile network to be a video-delivery medium for applications such as premises security surveillance and broadcast entertainment.
- The lower latency of 5G will enable the mobile network to mediate applications that require a very fast response time, such as remote control of mining & construction equipment, autonomous & semi-autonomous vehicle operation, and cloud-based VR & gaming.
- The higher connection density of 5G will accommodate many more connected devices per cell site than current networks can support and will enable the mobile network to provide for multiple co-resident IoT applications, especially in the smart-city context. Examples include smart lighting, waste management, traffic & parking management, and infrastructure monitoring.
- The use of network slicing in 5G will enable specific applications and/or specific customers to

[1] Ericsson, *Breaking the Energy Curve: Why Service Providers Should Care About 5G Energy Efficiency*, Feb.2019

receive a predetermined quality of service (QoS) – in terms of parameters such as data rate, latency, jitter, and uptime – that is not affected by what other customers connected to the same cell site are doing. This will allow the mobile network to support mission-critical applications for enterprise and public-sector customers, and it will enable mobile operators to offer such customers related service-level agreements (SLAs).

**Objective 3 – to seek new revenue streams from packages combining connectivity with additional content and services:** The higher performance of 5G – in terms of capacity, latency, connection density, and QoS guarantees – opens up new opportunities for operators to develop service packages for particular customer segments that combine connectivity with additional elements, such as content, application software. and services. In the consumer market, for example, one especially promising segment is that of gamers, whose willingness to pay for appealing new experiences is already well established. The high capacity and low latency of 5G will enable mobile networks to support real-time online gaming and VR experiences, giving operators the opportunity to bundle a high-performance connectivity plan (perhaps delivered as a network slice) with game titles, premium content, and devices such as VR headsets.

But the biggest potential in this area lies not in the consumer market, but in enterprises, especially in certain vertical sectors that have been identified as early targets. The new capabilities of 5G for supporting high-performance and mission-critical enterprise applications will increase the value and the role of mobile connectivity as a component of enterprise IT solutions.

**Objective 4 – to seek new revenue streams by entering businesses outside connectivity:** "Businesses outside connectivity" is such a large and diverse set that it is impossible to make any generic statements about the potential of 5G here. Mobile operators are entering into some new businesses in which, although the mobile network plays a significant role, 5G specifically does not offer any obvious opportunity for enhancement. For example, Orange Bank, the smartphone-only banking service launched by the French incumbent operator towards the end of 2017, functions perfectly well on 4G.

On the other hand, mobile operators have entered some other businesses that could offer more scope for using 5G to boost their prospects. For example, several European operators, such as the UK's BT, have been running trials of 5G as a medium for TV broadcasting. Another example might be usage-based motor insurance (UBI), already supported by some operators, including Vodafone and Telefonica, in which customers agree to have a device in their vehicles that monitors their driving behaviour, and their insurance premium is set according to how safely they drive. At present, the driving data generated is stored on the device (i.e. locally) for analysis later; but, with 5G connectivity, it could be possible to stream the data continuously for central analysis, opening up possibilities for real-time functionality.

We describe 5G's potential to support the strategic objective of entering new businesses as "moderate" because of the objective's diffuse nature. However, there are some specific new businesses in which 5G's potential to support successful entry could be quite strong.

**Objective 5 – to improve customer retention:** In a saturated market such as mobile telecommunications, in which there are few new customers to be won, competitors must rely mainly on taking customers from each other in order to grow their bases organically. It is therefore important for operators to make their existing customers less likely to move to competitors. 5G has some potential for contributing to this objective because it is something new; it has strong potential to appeal to customers interested in keeping up with the latest developments in mobile technology. A 4G customer coming to the end of a contract, for example, might be offered a discounted upgrade to a 5G device and service plan as a means of persuading that customer to renew instead of moving to a competitor.

Conversely, an operator bringing 5G to market before its competitors can attract customers who are interested in the new technology away from the operator's competitors. A striking example of this effect was seen in the UK during the early phases of 4G, when regulatory permission for spectrum re-farming

enabled operator EE to bring 4G plans and smartphones to market in October 2012, almost a whole year before the other UK operators were able to do so. By October 2013, EE had 1.2 million 4G customers, about one-third of whom had been acquired from competing operators.

Unlike previous generations, 5G can feasibly offer operators several waves of opportunity for customer retention and competitive acquisition because of the multiplicity of new capabilities that are in the pipeline. Being early to market with 5G mobile broadband can enhance an operator's appeal to the general mobile customer base. Later, for example, that same operator might also be ahead of its competitors in bringing ultra-low latency 5G to market, appealing to customers such as gamers in the consumer segment and to enterprise in verticals such as construction, manufacturing, and energy.

**Objective 6 – to couple usage growth with revenue growth:** This is where the potential impact of 5G on operators' strategies becomes more ambivalent. 5G could work both for and against operators' need to ensure that their customers pay more as they use more.

On the one hand, 5G can enable operators to offer larger data allowances and/or faster data rates, providing higher-priced tiers in their range of service plans. We are already seeing some European operators move in this direction. Finland's Elisa, for example, introduced two new high-speed tiers for its router-based mobile broadband packages in April 2019, both powered by 5G: a 600Mbps plan, at €40 per month, and a 1Gbps plan, at €45 per month. Some operators, such as EE, have also signalled their intention to charge a premium for 5G smartphone connectivity packages.

But heavy users' willingness to pay extra will increasingly be tested as operators continue raising the prices of their monthly packages. The early experience of US operator Verizon bodes ill in that regard. In March 2019, Verizon introduced 5G smartphone plans at a $10 premium over 4G. Only a month later, however, Verizon announced that it would "waive that charge for an undetermined period."

In the more general customer base, as 5G makes mobile behave more like fixed-line home broadband, people who have become accustomed to unlimited broadband usage over fixed line will come to expect the same thing from mobile. 5G will thus increase pressure on operators to move towards unlimited usage plans. Such plans are popular with customers because they provide certainty about monthly spending levels, and so they are powerfully attractive as a competitive tool. But their power comes at a price: Unlimited usage removes the coupling between usage growth and revenue growth, making it more difficult for operators to increase revenues in the future as their customers use their service more.

**Objective 7 – to engage in mergers, acquisitions, and joint ventures:** For over a decade, European operators have been attempting to increase economies of scale, widen their addressable customer bases, and reduce competitive intensity by combining with each other in various ways – a phenomenon that has come to be generally referred to as consolidation. The two most common forms of such intranational transactions are:

- Two mobile operators combining in a takeover (e.g. Telefonica's acquisition of E-Plus in Germany in 2014) or as a joint venture (e.g. the combination of Wind and Three in Italy in 2016)
- A mobile operator and a fixed-line operator combing to form a "converged" services provider, either in a takeover (e.g. the merger of Tele2 and Com Hem in Sweden in 2018) or a joint venture (e.g. the combination of Vodafone and Ziggo in the Netherlands in 2016)

This is another area of operator strategy in which the impact of 5G could work either way (or both ways).

In the early stages 5G could work against operators' desire to consolidate the industry because national regulatory authorities often see a new spectrum auction as an opportunity to introduce a new competitor into their markets. With the auction of 3G spectrum in the early 2000s, for example, new-entrant licences were awarded to Hutchison (under the Three brand) in several European markets, including the UK, Italy, and Austria. In France, the 4G spectrum auction in 2012 was used to introduce Iliad (under the Free Mobile brand) as a fourth mobile operator in that country. Likewise, 5G spectrum licensing is being used by regulators in some countries to try to introduce new-entrant operators. For example, in the

German 5G auction, 1&1 Drillisch acquired a licence enabling it to become Germany's fourth national mobile operator. In the Austrian 5G licensing round, completed in March 2019, licences were awarded to four new entrants, each of which will operate in different regions of the country.

However, market forces in the mobile industry – fundamentally, market saturation combined with low-to-flat revenue growth – work against an expansion in the sustainable number of industry players. These conditions point in the long term to fewer, not more, competing mobile operators. An indication of the difficulty in sustaining an increased number of mobile operators was apparent in the UK 5G spectrum auction of 2018, in which two prospective new entrants entered the bidding for licences, but both dropped out before the auction was complete or the licences awarded.

It is also possible that, over the medium-to-long term, 5G will foster, rather than impede, the progress of consolidation in the second category listed above, i.e. combinations of mobile and fixed-line operators. The high capacity and data rate of 5G support a user experience that is more akin to fixed-line broadband than previous generations of mobile, enabling service experiences with more seamless transitions between the home environment and the wide area. On the architectural level, too, 5G will support fixed/mobile convergence, with several operators (e.g. Spain's Telefonica) already implementing a common core network and service platform for both the mobile and the fixed-line access network.

### *European operators will deploy 5G in two main phases*

The first phase of the 5G standard has been available since 3GPP Release 15 was published in December 2017. This release specifies 5G in non-stand-alone (NSA) mode, in which 5G New Radio (NR) is deployed in the access network and is connected to the existing 4G core network (also known as the evolved packet core, or EPC). In NSA mode, 5G will support the enhanced mobile broadband (eMBB) use case defined by the International Telecommunications Union (ITU).

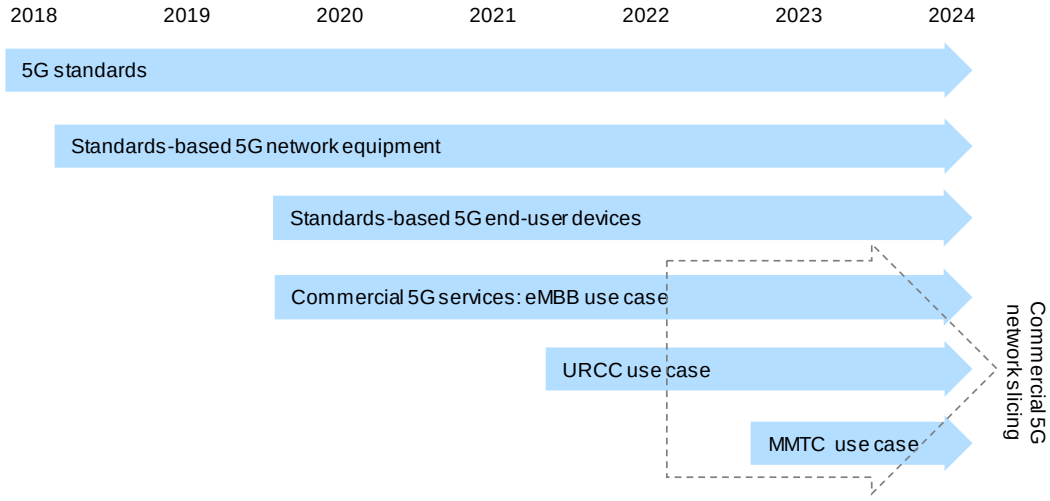
Chipsets in the first 5G end-user devices use the Release 15 standard, and they are thus compatible only with 5G NSA. Therefore, commercial 5G services launched during 2019 will all comprise NSA-based enhanced mobile broadband. Another important caveat with regard to early 5G timing is that Apple is not expected to produce a 5G version of its iPhone device before 2020. The iPhone has a large and loyal base of users, who will be required to switch to Android devices if they want to be among the first customers of 5G services. It seems unlikely that many of them will make that switch.

3GPP Release 16, due for completion in 2020, will specify the stand-alone (SA) mode of 5G, in which 5G NR in the access network is connected to the 5G Core network. In addition to eMBB, 5G SA will support the ITU's use cases of ultra-reliable/low-latency connectivity (URLLC) and massive machine-type connectivity (MMTC). This phase of 5G will continue increasing the data rate of the access network, and it will also reduce the latency and increase the connection density of the mobile network.

The availability of 5G SA devices is currently a matter of some uncertainty. However, given the expected standardisation timeline, it seems unlikely that they will become widely available before the end of 2020. That being the case, commercial 5G SA services, and hence the URLLC and MMTC use cases, will not appear widely in Europe (or elsewhere) before 2021. That, coupled with the architectural reconfiguration required for low latency and network slicing, means that commercial 5G networks will not widely support advanced vertically targeted enterprise services before the 2022–2025 timeframe.

The expected timeline for the deployment of 5G by operators in Europe is summarised in the following figure.

*Figure 5: General timeline for 5G deployment in Europe: a phased approach*




*Source: IDC, 2019*

### *Services and Marketing strategies*

Several European operators are planning to bring 5G to market with a premium charge. It remains to be seen whether this will prove to be sustainable, but, either way, it raises the question in customers' minds: "What would we want to pay a premium for?" As noted in the previous chapter, in the first phase of commercial 5G, the customer proposition will essentially be a faster smartphone data connection. This will be appealing in a few customer segments, such as tech enthusiasts and gamers. The more general customer base, though, is already reasonably satisfied with mobile data speeds (although not with coverage or price), and it will be trickier to market 5G successfully to them, especially as a premium-priced product.

The main benefit of early 5G will be extra network capacity, and, if the network has more capacity, that means customers are more likely to get a connection with good performance and will be more likely to keep it as other users join the network. In other words, 5G eMBB can offer customers a more reliable mobile data connection. Thus, “reliability” could be a successful marketing angle for the early phase of commercial 5G. It is important to note, however, that the connection is only reliable if it is available, and limited 5G coverage in the early years means that it often will not be. A more subtle issue is that promoting 5G as "more reliable" implies what customers have now (i.e. 4G) is "less reliable," which is a dangerous thing to suggest. IDC estimates over half of Western European mobile subscribers are currently 4G customers, and operators will not want them to view the service as inferior.

In addition to faster smartphone connectivity, some European operators are planning to market 5G eMBB as a home broadband service. With data rates potentially in the hundreds of megabits per second, the performance of 5G can compare favourably with existing fixed-line home broadband technologies. For operators who already have a substantial fixed-line broadband business, 5G home broadband is also a tricky proposition. It would need careful positioning to avoid the cannibalisation of existing business. It could also call into question commitments that have been made to national regulators about rolling out fibre to the premises (FTTP). However, operators without a fixed-line business are concerned about neither of these issues. For them, home broadband is a largely unproblematic target market for 5G eMBB. Examples of European operators that intend to position their early 5G as a home broadband service include Sunrise in Switzerland and Three in the UK.

Some larger operators are also trialling 5G as a fixed-wireless access (FWA) broadband connection for homes. This is a somewhat different implementation of 5G, using millimetre wave spectrum and providing point-to-point connection without support for mobility between antennae. Orange, for example, has been trialling 5G FWA service in Romania, and it has been successful from the technical standpoint. From the commercial standpoint, though, IDC research indicates that, so far, most operators see FWA as a niche 5G opportunity at best in Western Europe, although some more extensive 5G FWA opportunities may exists in Eastern European markets.

In the enterprise market, as distinct from the mass market, 5G eMBB for smartphones (and other devices, such as tablets) will also hold some appeal, as increasing amounts of enterprises' IT systems and resources are being enabled for access from and over mobile devices. These enterprises' enthusiasm is likely to be tempered to some extent, though, by the knowledge that an increase in data speeds tends to lead to a corresponding increase in data usage, and larger data allowances still generally attract extra charges in mobile operators' enterprise tariffs.

The 5G enterprise opportunity that is exciting mobile operators more than eMBB is the potential for the second phase of 5G, with URLLC and MMTC use cases and network slicing to support new vertically targeted services that cannot be supported by today's mobile networks. Verticals that have been identified by operators as promising in this regard include automotive, energy & utilities, manufacturing & heavy industry, and healthcare.

5G URLLC may hold some niche consumer opportunities, such as real-time VR and online gaming, but the deployment of these more advanced 5G capabilities will mainly be driven by the enterprise opportunity. Some operators are already seeing enterprises as the most important segment for 5G services in the long run. The head of technology research at Norway's Telenor, for example, stated that, "For Telenor, the most exciting thing about 5G is the extent to which the more flexible infrastructure will enable operators to work more closely with their business customers and other partners to develop vertically targeted innovative services." In a similar vein, Orange CEO Stephane Richard stated at the Orange Business Summit in April 2019 that, "We will prioritise industrial sites with the launch of 5G. To harness this technology shift, we need to work out what your future opportunities are, as we need to be able to enable these."

### *Timing of commercial 5G: Europe is among the leading regions*

Received wisdom in the mobile industry holds that the US and Asia are leading the way with commercial 5G deployments, while Europe lags far behind. But the facts indicate otherwise. April 2019 saw the launch of Europe's first commercial nationwide 5G mobile services, mere weeks behind the 5G services launched earlier in 2019 by operators in the US and in South Korea. Two of Switzerland's three mobile operators, Swisscom and Sunrise, started offering their customers 5G service plans in April 2019, with home routers as the access device. At the start of May 2019, Swisscom added to its device roster Europe's first commercially available 5G Smartphone, Oppo's Reno 5G. Sunrise plans to offer 5G services in 60 Swiss towns and cities by the end of 2019, and Swisscom's plans for rapid coverage rollout are still more ambitious. Enabled by dynamic spectrum allocation between 4G and 5G in its Ericsson base stations, Swisscom has promised that its 5G footprint will cover 90% of the Swiss population by the end of 2019.

From the commercial standpoint, the key difference between the early markets for 4G and those for 5G is smartphone availability. Commercial 4G services started appearing in Europe in 2010, but 4G smartphones that were compatible with the radio frequencies used in European networks did not become commercially available until mid-2012. Operators launching 4G before 2012 found that customer uptake remained at very low levels until they were able to offer 4G smartphones. The lesson was not lost on the industry. With 5G, emphasis has been greater on spectrum harmonisation at the global level, extensive work on developing software-based frequency adaptation, and a standardisation timeline to ensure the early availability of a usable specification for chipset and device makers. The result has been that, with 5G, commercial smartphones are appearing concurrently with commercial network services in Europe.

Given concurrently available 5G equipment, spectrum, and smartphones, the Swiss operators have shown that they are as keen as those in other parts of the world to bring the next generation of mobile to their networks. And they are far from being alone in Europe. In the UK, for example, Vodafone announced in May 2019 that it would start offering 5G service plans from the following July, and BT (EE) has also announced that it intends to launch 5G commercially during 2019. 5G also looks likely to go commercial in some Nordic countries during 2019. Telia, for example, launched a "pre-commercial" 5G network in Helsinki in September 2018, and, in March 2019, it announced that it had commenced pilots of 5G-powered home broadband using Nokia's FastMile 5G gateway device.

Some European operators, in contrast, look likely to wait at least until 2020 before launching 5G commercially. In some cases, this is because the regulatory authorities in the respective countries will not have awarded licences for spectrum in the primary 5G band (3.4–3.6GHz) in time for a 2019 launch. Examples of such countries include France and the Netherlands. In other cases, operators have chosen a cautious approach to 5G timing. Spain's Telefonica, for example, has stated that, although it will deploy some 5G nodes early to gain experience and market positioning, a massive rollout will come only when the operator considers that the uses cases derived from 5G promise a sustainable return on investment.

**KEY MESSAGES**

In their core business of mobile data connectivity, mobile operators in Western Europe can expect only modest growth over the next few years. This leads to several strategic objectives, in the pursuit of which 5G can play a key role. But even modest growth cannot be taken for granted: It requires operators to invest in additional network capacity so that they can continue to meet demand and generate additional revenue. 5G has a key role to play here, too.

European mobile operators are deploying 5G in two phases. In the first phase (2019–2021), the 5G service proposition will be enhanced mobile broadband (eMBB), aimed at both consumers and enterprise customers. The role of 5G in this phase will mainly be to support continued growth in operators' existing business. The second phase (2021 onwards) will see the emergence of ultra-reliable/low-latency communications (URLLC) and massive machine-type communications (MMTC). These new 5G capabilities will enable mobile networks to be used for things they cannot support today, opening up opportunities for new revenue streams – especially in the enterprise segment.

5G commercial smartphones are appearing concurrently with commercial network services in Europe. Swiss operators have shown that they are as keen as those in other parts of the world to bring the next generation of mobile to their networks. And they are far from being alone in Europe. In the UK, for example, Vodafone announced in May 2019 that it would start offering 5G service plans, and BT (EE) has announced that it intends to launch 5G commercially during 2019. 5G also looks likely to go commercial in some Nordic countries during 2019. Telia, for example, launched a "pre-commercial" 5G network in Helsinki in September 2018, and, in March 2019, it announced that it had commenced pilots of 5G-powered home broadband using Nokia's FastMile 5G gateway device.

Some European operators, by contrast, look likely to wait at least until 2020 before launching 5G commercially. In some cases, this is because the regulatory authorities in the respective countries will not have awarded licences for spectrum in the primary 5G band (3.4–3.6GHz) in time for a 2019 launch. Examples of such countries include France and the Netherlands. In other cases, operators have chosen a cautious approach to 5G timing. Spain's Telefonica, for example, has stated that, although it will deploy some 5G nodes early to gain experience and market positioning, a massive rollout will come only when the operator considers that the uses cases derived from 5G promise a sustainable return on investment.

# 2 IoT market overview: what 5G means for the future of IoT in Europe

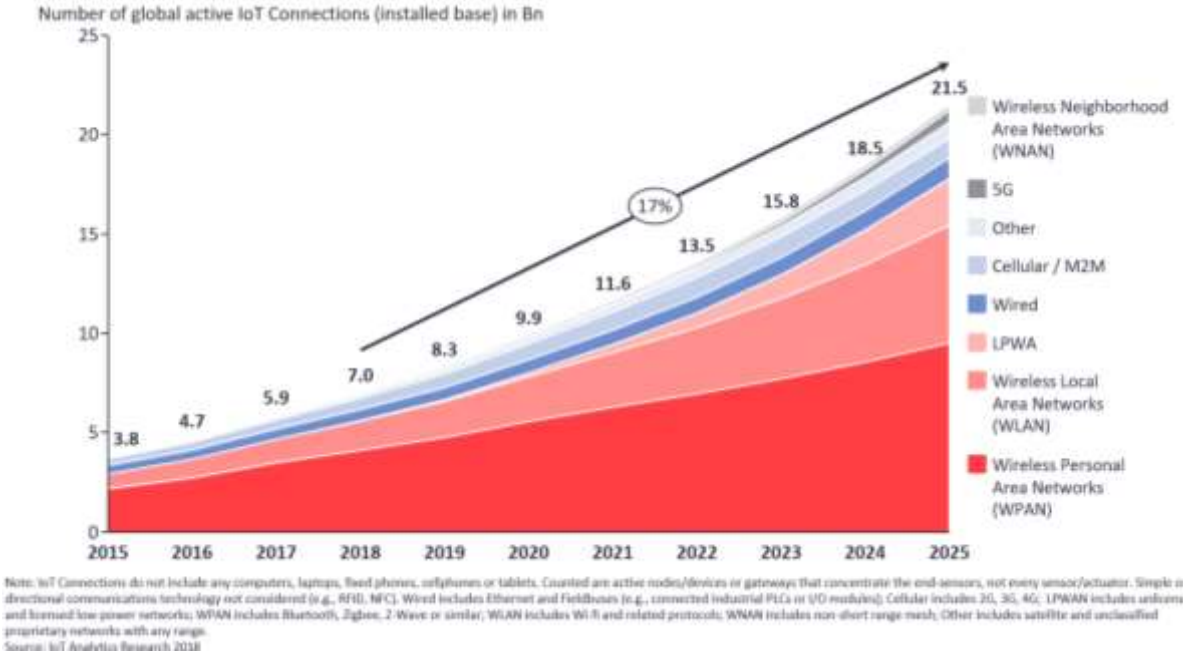
As a strategy-development anchor point, obtaining a complete overview of the IoT market in Europe by main vertical would enable ICT players and institutions to identify the industries in which 5G can be applied to generate real benefits, cost savings, and new revenues. It would help to identify which use cases to prioritize first. And it could also be used as input into digital transformation roadmaps for such entities.

**Over next four years, 5G technology is expected to become a catalyst for innovation across various industries. In particular, 5G will support the further development of IoT-based capabilities, thus helping to unleash IoT's full potential.** According with IOT analytics research, worldwide, more than 21 billion IoT devices will be connected by 2025, and this number will continue to rise. (See the below figure for details.)

Given that IoT is a network of uniquely identifiable endpoints (or "things") that autonomously communicate bidirectionally using IP connectivity, bringing together people, processes, data, and things through an integrated ecosystem, the relevance of network connections will accelerate.

5G promises a vast improvement over the current capabilities of the 4G and other wireless network technologies, with faster data speeds, latency reduced to 1 millisecond, and up to 100 times more connected devices per unit area.

*Figure 6: Number of connected devices, globally*




5G will be an enabler of Internet of Things deployment, with not just mobile phones, computers, and tablets linked to the Internet, but also a whole array of everyday objects, sensors, systems, and assets. This presents new opportunities for organizations that provide services and apps to manage complex IoT ecosystems. It also provides opportunities to convert data into "smart insights" and to monetise that data, as well as to improve quality of life and environmental safeguards.

5G will play a significant role in transforming not just how we communicate, but also how businesses and society as a whole function; it will contribute to the digitization, automation, and optimization of many business processes via IoT solutions.

The main reason IoT devices are connected is to generate data that can be analysed and acted upon by other devices, applications, machines, and/or people. Across Europe, organizations are increasingly allocating funds to ensure they have the necessary ICT tools to make the most of their investments from the data generated.

The ecosystem that makes up the IoT market is both vast and complex. It includes connectivity, modules/devices, platforms, storage, servers, analytics software, security, and IT services ranging from consulting to ongoing solutions management.

This analysis will be oriented towards market sizing for the 2018–2022 period in revenues generated by ICT players across the market, from telecom operators to consumer electronics OEMs, for the provision of ICT systems & services and the development & deployment of IoT solutions based on hardware infrastructure[2], software platforms and applications[3], IT services,[4] and connectivity[5].

## 2.1 Europe Internet of Things Evolution Trends

IoT adoption levels and growth rates vary widely across the spectrum of industries in Europe. Although some industries are ahead of others, all verticals represent strong and expanding market opportunities.

The adoption rate of IoT solutions has continued to accelerate. Organizations and Consumers are increasingly acknowledging the significant potential of IoT solutions and services. Organizations and Enterprises are pursuing IoT-enabled strategies to drive efficiencies, gain insights into business processes, and make real-time decisions.

Driven by industry-specific use cases, IoT market spending in Europe is projected to grow from €106 billion in 2018 to €190 billion in 2022. This represents a CAGR of approximately 16% over the 2017–2022 period. (See the below figure for details.)

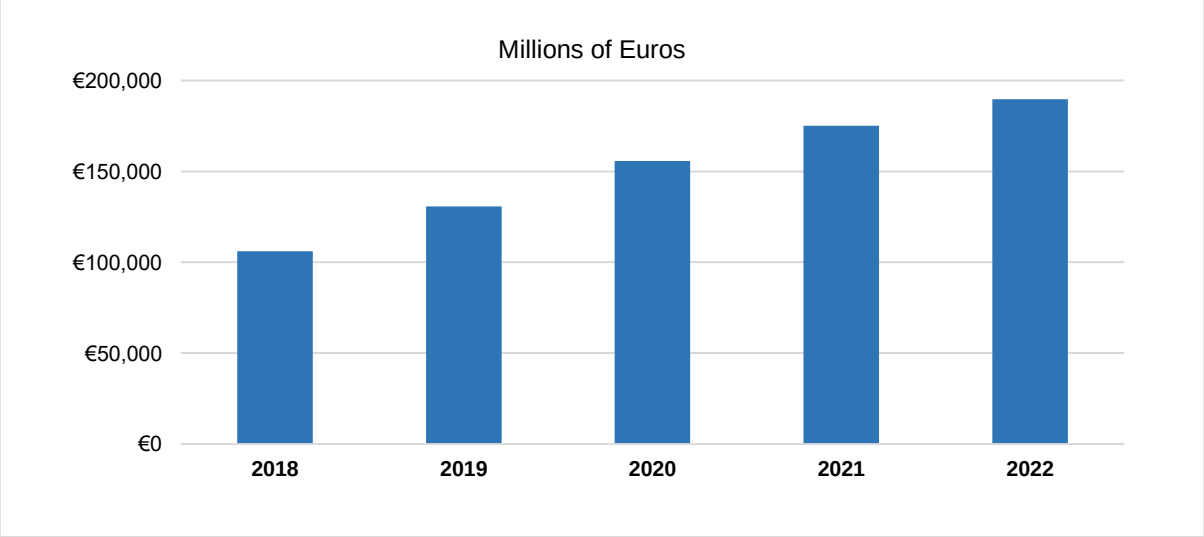
[2] Hardware Infrastructure. Hardware and IaaS Infrastructure: includes servers, storage, enterprise networks, telecom equipment, and infrastructure as a service (both basic storage and server capacity); Specialty Hardware: includes hardware related to modules and sensors, IoT hardware, AR and VR viewers, surveillance cameras, wearables, kiosks, commercial host devices, 3D printers, effectors, industrial robots, kiosks, LED luminaires, and video walls; Other Hardware: includes personal computers, tablets, smartphones, PC monitors, and security appliances.

[3] Software. Platforms and Analytics Platform Software: includes middleware, device management, connectivity management, data management, visualization, and applications enablement; Analytics Software: turns data into actionable insights that business decision makers can use to effect change in business processes; Applications: include enterprise applications and collaborative & content applications; Other Software: includes spending on system infrastructure software (e.g. security and storage software), some application development and deployment software not included in platform and analytics, software related to IoT, robotics, AR/VR, artificial intelligence, and 3D printing, and specialized operational software

[4] Services: include spending on project-based, outsourcing, and support services within traditional IT services, business consulting, business process outsourcing, other services related to innovation accelerators (e.g. specialized IT installation services), IoT services, and content as a service

[5] Connectivity Services: include both fixed and mobile voice and data services (on several network technologies) used to support specific use cases

*Figure 7: Internet of Things Market in Europe, 2018–2022*




*Source: IDC's Worldwide Semiannual Internet of Things Spending Guide, updated in May 2019*

Both public and private organizations are embracing IoT to become more efficient and enhance their business models. By now, nearly all organizations understand the need for process automation and optimization. It is becoming a competitive requirement and is driving a massive wave of new investment around business operations, communications, and services.

Most organizations recognize that IoT can help optimize their businesses, and growing numbers also understand that IoT can also be incorporated into their growth strategies. Analytics and deep integration solutions will rise to the fore as the transformational potential of IoT becomes more widely known. Connectivity, device management, and other features will become commodities, while IoT spending, of course, will be impacted by the general economic environment and business sentiment. The following factors will be the most significant in shaping the IoT market through to the end of 2022:

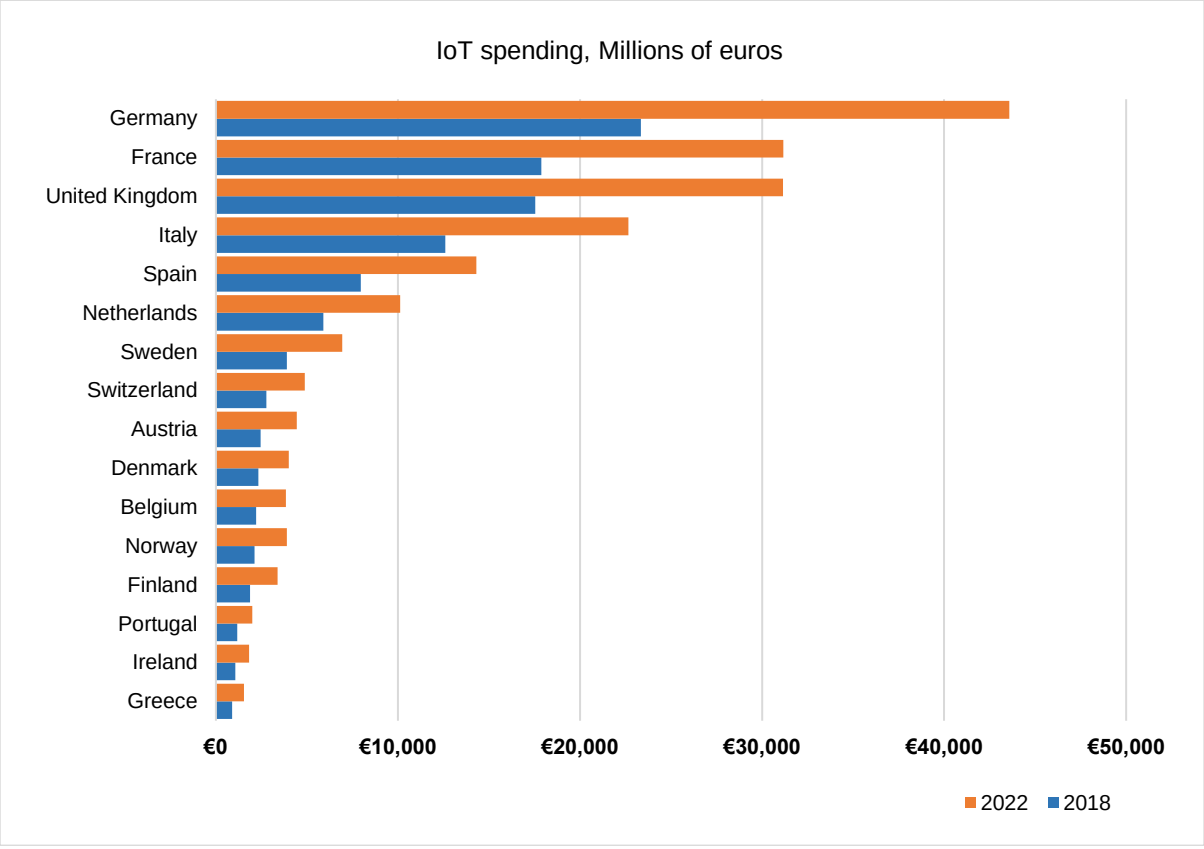
- **The proliferation of interconnected devices and "things" at the edge of the network** (e.g., smartphones, entertainment devices, building automation systems, smart meters, medical electronics, connected automobiles, industrial controllers, and RFID tags): This will drive IoT spending growth, enabling organizations to collect data and gain actionable insights into their business operations. New approaches and architectures will be required to make sense of, promptly react to, store, archive, and analyse the influx of connected data. For many organizations, the initial value of IoT will be realized in operational improvements that can be made using IoT-generated data. However, organizations will also look to monetize this data by developing new products and services. This is where the potential ROI of IoT gains a new dimension.
- **IoT Ecosystem Complexity**: The IoT ecosystem features a dizzying array of technology providers across the hardware, software, services, and connectivity landscapes. Typical enterprise computing devices network over TCP/IP and run on a limited set of operating systems. IoT devices, on the other hand, may be run over a diverse set of operating systems and communicate over a diverse set of protocols. The inherent diversity of the IoT technology stack drives the need for several layers of software to abstract the complexity of connecting to endpoints, scaling endpoint/device coverage, and managing data. Using a well-defined architecture, organizations can create applications that provide business value. Faced with shortages of staff skilled in IoT and demands to innovate quickly, companies will seek providers that can reliably deliver IoT solutions that benefit their operations.

- **Security, Privacy, and Compliance Concerns**: New types of cyberattack that target connected devices and machine generated data are continually emerging. Governments are considering new regulations to deal with the security, privacy, and compliance ramifications of IoT solutions. Security, privacy, and compliance are essential to organizations, and security concerns remain the greatest inhibitor to IoT projects getting off the ground. These concerns continue to put downward pressure on some IoT initiatives. As vast quantities of data (and content) are collected from connected "things," enterprises (and, to a lesser extent, consumers) will be increasingly concerned with compliance, governance, and privacy issues. To mitigate this inhibitor, IoT vendors should emphasize their use of specific technologies that support security and privacy compliance and industry standards.

The fastest-growing IoT markets in Europe are Germany, Italy and Spain, which have the highest spending and are expected to achieve CAGRs of above 16% between 2018 and 2022. France and United Kingdom are the other most important markets, with CAGRs of around 15% over the same period[6].

These five countries, which generate 75% of total value, are showing a growing appetite for cutting-edge technologies, while the other countries record more moderate and spending and lower annual spending growth.

*Figure 8: Internet of Things market in Europe, by Country, 2018 and 2022*




*Source: IDC's Worldwide Semiannual Internet of Things Spending Guide, updated in May 2019*

[6] IDC European Internet-of-Things Forecast, 2018–2022

**Germany** is the largest European market in terms of IoT spending. The German IoT market is strongly driven by improvements in business productivity and efficiency, as well as reductions in operational and maintenance costs. The manufacturing sector (i.e., discrete and process manufacturing) and the consumer market are contributing the largest shares to IoT spending in Germany.

Manufacturing operations, product asset management, and smart homes are the most relevant use cases. German manufacturers are the forerunners when it comes to the implementation of IoT use cases, and many of them relate to predictive maintenance.

A large share of the German manufacturing market is dedicated to the automotive industry. In this context, connected vehicles are the most important IoT use cases. However, OEMs are not only investing in technologies around connected vehicles, but also in supply chain and adjacent services suppliers, which are beginning to shift their business models from being product suppliers to become service/technology providers.

**France** is the second largest European country in terms of IoT spending. IoT adoption is fuelled by optimization and automation initiatives aimed at improving efficiency in sectors such as manufacturing, utilities, retail, and transport. Examples include various maintenance and field services, production asset management, and manufacturing operations IoT projects in the French manufacturing sector. In the utilities sector, the French IoT market is fuelled by smart grid (electricity, gas, and water) IoT projects by companies such as Engie, Enedis, GRDF, SUEZ, Sagemcom, and Birdz. The retail sector is third in the French IoT market, with relevant IoT projects regarding omnichannel operations, digital signage, and in-store contextualized marketing. The French transportation IoT market is fuelled by freight monitoring and fleet management.

**The U.K.** IoT market is attracting significant investments. In June 2108, IoTUK was created as a national program intended to increase the country's IoT capabilities and the adoption of high-quality IoT technologies and services throughout the business sector (all businesses) and the public sector. This program was launched as part of the U.K. government's £32 million investment into IoT.

In October 2018, the U.K. government launched a new voluntary code of practice to help manufacturers boost the security of internet-connected devices. This code of practice has been developed in conjunction with the National Computer Security Centre (NCSC). Many tech companies, including HP Inc. and Centrica Hive, have already signed up to commit to the code.

Companies in the U.K. are getting ready to take on IoT, which is becoming a strategic directive for many organizations as they look for ways to competitively differentiate and drive efficiencies. Investments in these services are increasing due to accelerating demand. U.K. companies are keen to use IoT to help them improve customer relationships — clearly one of the top use cases. Improving customer experience (CX) will lead to improved efficiency and, eventually, to new revenue opportunities. Subsectors with expanding IoT footprints include smart metering, fleet management, and healthcare.

**Italy** is the fourth largest European country in terms of IoT spending. Manufacturing operations and production asset management comprise the main markets, fuelled by optimization and process automation initiatives aimed at improving efficiency to overcome traditional competitive barriers, gain new customers in new markets, and maintain leadership in their well-established areas.

Smart grids for gas and electricity are the second two largest IoT use cases, with 2.4 million home gas meters already installed before 2017 and 1.8 million electricity meters, installation of which was launched in early 2017. Omnichannel operations and smart homes will be the emerging markets over the next two years, with many applications arising from the integration of the Internet of Things and artificial intelligence aimed at generating new business for companies and providing concrete and personalized help to simplify every aspect of everyday life at home.

The market's acceleration is expected to continue, especially regarding smart grid, connected vehicles, smart homes, and manufacturing IoT. In the manufacturing sector, IoT will probably benefit from the

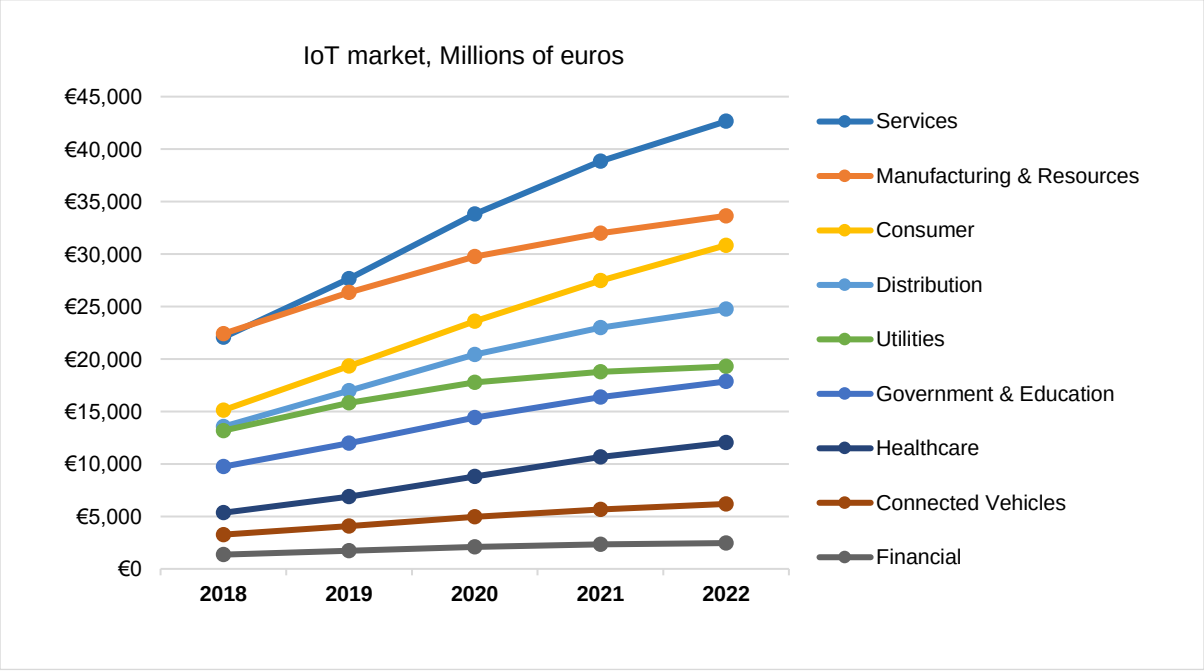
extension of incentives linked to the super amortization and hyper-depreciation provided by the National Industry 4.0 plan.

**Spain's** IoT deployments centre around improvements in customer experience and revenue generation – the key priorities behind IoT investments in the country. A good example in the country of a successful IoT implementation is one from Volvo Trucks. The company developed a post-sale paid service, which is being used in approximately 70% of the new trucks sold on the Spanish market. On the cost-reduction side, Spanish utility Aguas de Valencia offers a good example of the successful use of narrowband IoT (NB-IoT) technology. The company implemented a leak detection system in its water distribution network, which has resulted in cost savings over €5 million per year.

**Across Europe**, IoT will have an enormous impact on many industry-specific business processes. The IoT value chain is complex, involving industry-specific needs and domain expertise in individual sectors. This means that industries will invest in vertical-specific applications and solutions that will require many functional components that must interact in precise ways to make IoT a compelling value proposition for buyers.

Organizations in the services and manufacturing verticals are the biggest spenders on IoT solutions, followed by consumers. Together, these three markets currently generate about 56% of IoT spending in Europe, and they will continue to expand healthily. The utilities, distribution, and government & education verticals will also record robust IoT spending growth over the coming years, although their annual growth rates will be more moderate than those the previously mentioned frontrunners.

*Figure 9: Internet of Things market in Europe by Vertical, 2018-2022*




*Source: IDC's Worldwide Semiannual Internet of Things Spending Guide, updated in May 2019.*

*Note: The "services" category includes media, communications, professional services, transportation, and personal and consumer services. The "consumers" category includes solutions and devices for personal wellness, remote health monitoring, and smart homes.*

**The services sector** (composed of media, communications, professional services, transportation, and personal & consumer services organizations) **will generate the most spending on IoT in Europe, driven by the transportation and communications industries.**

IoT solutions help transportation and logistics companies maximize capacity, meet regulations and compliance demands, and monitor their workforces and assets in real time. The three key use cases are air traffic monitoring, fleet management, and freight monitoring. Machine-to-machine communications enable the capture of location, speed, and other performance data. GPS enables route suggestions that can be linked to weather and traffic information. This data can be used to monitor (and reward) driver performance.

Companies in the telecommunications industry have positioned themselves as connectivity and platform providers in the IoT solutions ecosystem. They also utilize IoT to optimize and improve their own businesses internally. The primary use cases for telecommunications companies relate to operating infrastructure (i.e., networks, base stations, and data centres). These include temperature and data-throughput monitoring, predictive maintenance facilitation, and field-service optimization and automation. The business value lies in cost reductions and increased uptime and stability, which ultimately improve quality of service for customers.

**The manufacturing industry will remain one of the biggest users of IoT solutions** for at least the next few years. IoT solutions have already been deployed by many organizations in the discrete and process manufacturing sectors. Sensor networks have been in place for years for asset management and manufacturing operations. Companies have started to migrate to internet-based networks to integrate islands of automation on the factory floor. This trend will accelerate as companies seek to reduce inefficiencies by increasing automation and uptime.

The main application of IoT for manufacturing companies concerns production floor operations. Through internal connections and sensors, factory machines track all production phases and communicate with each other.

IoT solutions to enable the realization of Industry 4.0, or "the smart factory" – connecting machines, work pieces, and systems to create intelligent networks along the entire production chain – will **need 5G connectivity and capacity in order to handle data loads from the ever-increasing number of sensors and connected devices involved in production**.

**The consumer market, driven by entertainment, home security monitoring and automation, and connected health, is one of the largest and fastest-growing sectors in terms of IoT spending**. Access to data generated by connected devices is changing how consumers are informed about the statuses of their households, vehicles, and family members. The driving force behind the consumer market is the smart home paradigm, a broad concept that includes solutions for environmental monitoring (e.g., temperature and humidity), consumption tracking (e.g., energy and water), security, and home system remote enablement (e.g., lighting, heating, air conditioning, window shutters, and door locks). The IoT home security and monitoring market includes connected high-definition cameras, carbon dioxide and smoke alarms, camera enabled door locks, and other devices.

**In the Government sector, IoT development is closely related to smart cities.** While smart city initiatives have long been pursued by big municipalities, many smaller cities are now launching pilots and projects. Intelligent transportation systems (e.g., parking, road, and transit infrastructure and toll collection), public infrastructure asset management, and public safety and surveillance (e.g., digital video surveillance, body-worn and in-car digital cameras, and noise detection solutions) are some of the smart city use cases being deployed to address local and central government challenges.

IoT applications can help boost strained government revenues, address citizen expectations, and support a range of government services and roles, including regulation.

**IoT in healthcare is following two separate paths: better patient experience and in-hospital experience automation.** Remote health monitoring solutions are improving quality of life through

always-on digital biometric parameter monitoring. Hospital asset–tracking solutions (for high-value medical assets), telehealth systems (the automatic exchange of medical information from one site to another), and clinical care solutions (IoT-driven monitoring for hospitalized patients) are improving hospitals and enhancing patient stays and treatments. The IoT solutions being adopted in the healthcare industry are generally aimed at improving operational efficiency, creating safer patient environments, optimizing research, and enabling the extended use of expert knowledge.

**Distribution organizations (retailers and wholesalers) are investing in IoT for both back-end systems and to refresh customer-facing processes.** Store, warehouse, and logistics teams need more tools to enhance the efficiency of inventory management. In-shop items are constantly tracked, enabling the real-time checking of item availability and sizes. Connecting stores with the respective company's online business and inventory helps retain customers and improve efficiency. IoT solutions can also provide automatic updates on maintenance needs and handle payment services. IDC expects improvements in strategic asset management and customer, product, and service experiences. Merchants are also seeking in-store marketing operations and promotion analytics, in which IoT provides a contextualized and personalized experience based on information collected about the customer.

**The utility sector is a relatively mature IoT market**. Smart electricity metering has received attention in recent years, but the real value in utility sector IoT deployments will come from use cases that support the better utilization of mission-critical assets. One aspect of this is the general move in the utility sector to smarter networks. IoT plays pivotal roles in automating transmission, transport, and distribution networks, optimizing the flow of commodities, and ensuring efficient and reliable service.

Use cases in this category span substation and gas pressure reduction automation, distributed energy resources management, quality control, and leakage reduction. The evolving role of the electricity distribution system will be a demand driver. IoT solutions are being deployed to aggregate and manage end-user demand and self-sufficient portions of the grid (e.g., demand response, virtual power plants, and microgrids). Utilities usually have a very mobile distributed workforce with numerous subcontractors, and IDC expects IoT to be increasingly visible in the management of these resources (e.g., fleet and workforce management and sensor-based health and safety applications).

**Connected vehicles, in terms of aftermarket and embedded cellular connectivity, represent the most visible IoT applications**. Adoption is being driven by a multitude of factors, such as consumer demand for more immersive vehicle experiences, automotive manufacturer's desire to better utilize connected vehicles for cost avoidance and revenue generation and their need to comply with government regulations, and mobile network operators' desire to improve aftermarket sales and services.

IDC predicts that, by 2023, nearly 70% of new light-duty vehicles and trucks, worldwide, will be shipped with embedded connectivity.

The automotive ecosystem is positioning the vehicle as the next emerging digital platform. Increasing connected vehicle penetration, in conjunction with deep software and sensor integration, is the key to unlocking this IoT platform's potential.

## 2.2 The Future of 5G Networks for IoT Connectivity

Mobile networks have clearly evolved over the decades to support ever-faster data transmission rates and ever-improving performance to all devices connected to the network. But the Internet of Things is giving rise to a growing set of applications and devices that require something different from the network:[7]

- Many IoT applications use devices that generate only relatively small amounts of data and need to operate on much lower levels of power than today's mobile cellular networks can support.
- Increasingly, IoT is being used in situations in which constant availability is critical, meaning that the best-efforts/shared-access paradigm of mobile network connectivity is insufficient.

Most future growth in the number of devices connected to mobile networks will come not from phones, but from devices associated with IoT applications.

A large and growing percentage of IoT devices will be used in situations in which external power is unavailable – where it would be too costly or impractical to connect them to external power. In such cases, devices need to draw on internal batteries for power. Those batteries are much smaller than those in smartphones, of course, and they do not have individual users to charge them every day. Indeed, the business case for deploying such devices will depend, in many cases, on leaving them unattended for years.

In addition to their requirement for low power consumption, there are some other important differences between "human" connections and the emerging class of IoT devices:

- IoT devices typically transmit and receive less data than phones and do so less frequently. Smart meters, for example, only generate a few kilobytes every month in the form of transmitted meter readings.
- There are a lot more IoT devices than phones in a given area. Even individually, some applications involve denser connections than phones. As the deployment of IoT progresses, several different applications will coexist in the same locality, which will further increase the density of connections in that area.
- Each individual connection to an IoT device generates a lot less revenue than one for a mobile phone. Therefore, the business case for some IoT applications is only viable if the per-device cost is very low.
- Very simple IoT devices are designed around the assumed availability of connectivity – indoor network coverage and/or outdoor coverage.

To cater to these IoT-centric requirements, two low-power/wide-area (LPWA) upgrades have been developed for 4G networks: NB-IoT and LTE-M. These technologies are likely to suffice for the growth in the number of IoT device connections projected for the next 3–4 years. Thereafter, 5G will further expand the scale of mobile-for-IoT applications. In the nearer term, 5G can also expand the scope of mobile-for-IoT applications, as the current generation of mobile networks still falls short of the requirements of some IoT application types in terms of data rates, responsiveness, and reliability. (See the below figure for details.).

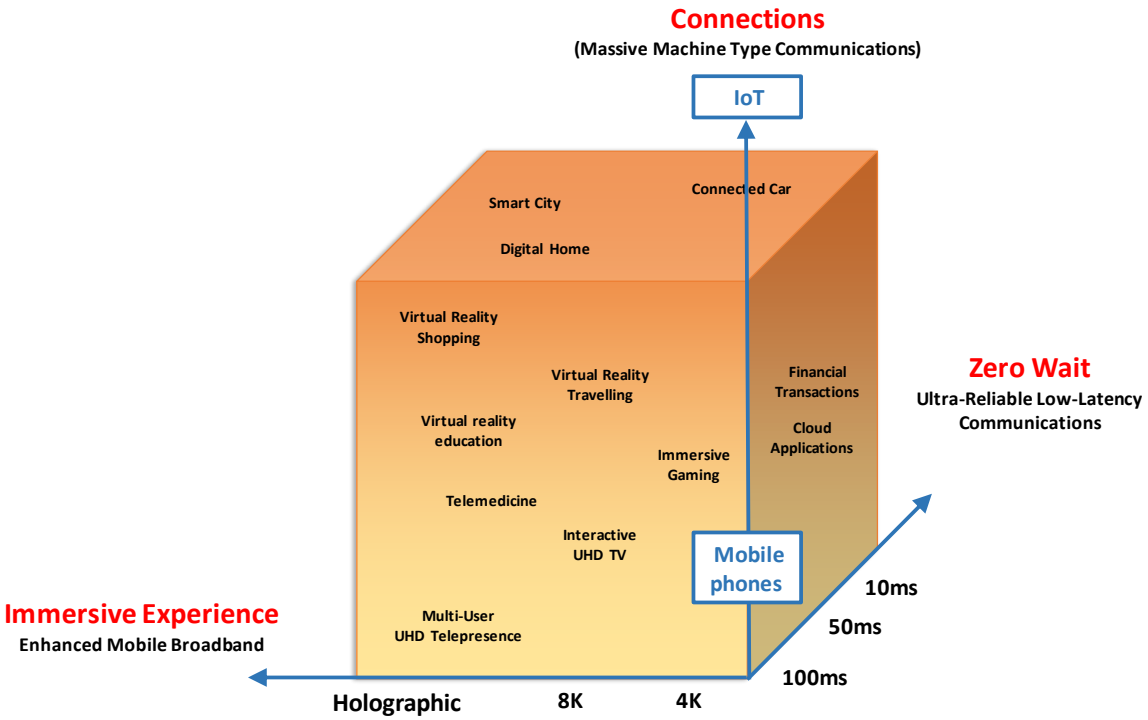
For example:

- In manufacturing, 5G could be a viable connectivity fabric for entire factories, combining the performance of wired connectivity with the flexibility of local-area wireless connectivity, and enabling new applications such as mobile robots, as well as supporting existing applications such as workforce connectivity.

[7] IDC: *The Future of Mobile Networks for IoT Connectivity: LPWA and 5G, 2018*

- In healthcare, 5G in combination with high-definition video and medical diagnostic equipment can be used to enable expert-led treatment of emergency patients to begin in the ambulances taking them to hospital, rather than having to wait until they arrive.
- In the energy sector, 5G can form the foundation of a wide variety of solutions, ranging from smart metering and smart grids, enabled by high-density connectivity, to heavy operational applications such as using robots instead of human workers in dangerous exploration and extraction sites.

*Figure 10: 5G capability and IoT applications*




*Source: IDC, 2018*

With leaner new approaches to signalling and device management, the 5G core network will further expand the connectivity density of mobile cell sites – ultimately, to the order of 1 million devices per square kilometre.

As noted previously, virtualization of the radio access network (RAN) in 5G will enable network slicing. This will enable mobile operators to provide a particular customer or application with their own "virtual" network, which delivers a guaranteed minimum level of performance regardless of what other customers and applications are doing. In this way, 5G networks will be able to support the kind of service-level agreements (SLA) that mobile operators have so far been unable to provide – for example, relating to mission-critical IoT applications such as smart grid and smart road infrastructure.

**KEY MESSAGES**

5G will be an enabler of Internet of Things deployment, with not just mobile phones, computers, and tablets linked to the Internet, but also a whole array of everyday objects, sensors, systems, and assets. This presents new opportunities for organizations that provide services and apps to manage complex IoT ecosystems. It also provides opportunities to convert data into "smart insights" and to monetise that data, as well as to improve quality of life and environmental safeguards.

The main reason IoT devices are connected is to generate data that can be analysed and acted upon by other devices, applications, machines, and/or people. Across Europe, organizations are increasingly allocating funds to ensure they have the necessary ICT tools to make the most of their investments from the data generated.

IoT adoption levels and growth rates vary widely across the spectrum of industries in Europe. Although some industries are ahead of others, all verticals represent strong and expanding market opportunities.

Driven by industry-specific use cases, IoT market spending in Europe is projected to grow from €106 billion in 2018 to €190 billion in 2022. This represents a CAGR of approximately 16% over the 2017–2022 period.

The fastest-growing IoT markets in Europe are Germany, Italy and Spain, which have the highest spending and are expected to achieve CAGRs of above 16% between 2018 and 2022. France and United Kingdom are the other most important markets, with CAGRs of around 15% over the same period.

5G will further expand the scale of mobile-for-IoT applications. In the nearer term, 5G can also expand the scope of mobile-for-IoT applications, as the current generation of mobile networks still falls short of the requirements of some IoT application types in terms of data rates, responsiveness, and reliability, as is evident in several sectors:

- In manufacturing, 5G could be a viable connectivity fabric for entire factories, combining the performance of wired connectivity with the flexibility of local-area wireless connectivity, and enabling new applications such as mobile robots, as well as supporting existing applications such as workforce connectivity.
- In healthcare, 5G in combination with high-definition video and medical diagnostic equipment can be used to enable expert-led treatment of emergency patients to begin in the ambulances taking them to hospital, rather than having to wait until they arrive.
- In the energy sector, 5G can form the foundation of a wide variety of solutions, ranging from smart metering and smart grids, enabled by high-density connectivity, to heavy operational applications such as using robots instead of human workers in dangerous exploration and extraction sites.

# 3 Longitudinal Comparative Analysis

This section provides comparative analysis of the European 5G market to better understand the maturity levels and differences across the relevant EU countries, to offer fact-based guidance around realizing 5G capabilities, and to drive EU, telecom-operator, and ICT-supply-chain-player investment in 5G.

## 3.1 Methodology and approach

The following comparative analysis draws on the information gathered using the Global5G Mapping tool. This tool acts as a central repository for 5G deployment indicators. This first version mainly focuses on EU countries (although some indicators cover non-EU countries). Data sources include the Global5G.org EC project, the 5G Observatory,[8] and other Institutional sources.[9]

Different indicators are available, some enabling the creation of color-coded heat maps (different colours representing different degrees) and maps of different locations (e.g., of 5G trials) and others being used to complete fact sheets for the various countries involved.

For this comparative analysis of the European 5G scenario, the Global5G.org project team considered the following indicators for each country:

- The number of 5G trials
- The number of 5G enabled cities
- Public national budget allocated to 5G
- The national 5G roadmap
- The internet user penetration rate (as a percentage)
- The mobile phone subscription penetration rate (as a percentage)

Based on the analysis of each of the above indicators, the Global5G project team created a **composite indicator to determine the level of 5G maturity and readiness to deploy 5G commercial services. This indicator indicates the level of 5G market maturity by country**, enabling the identification of the similarities and differences between the countries and of local factors likely to impact the mass-market deployment of 5G.

A scale was created for each included indicator, as shown in the following table. The scales were established using a collaborative approach and through the calculation of average numbers for each European country. The units used for these included indicators are “low”, “medium”, and “high”.

[8] 5G Observatory Quarterly Report, Up to March 2019
[9] World Population Review, IDC researches

*Table 2: The structure of 5G maturity market indicator*

| Indicator | Scale |
|---|---|
| **Number of trials** | >10 trials = high<br>6–10 trials = medium<br>0–5 trials = low |
| **Number of 5G-enabled cities** | >5 cities = high<br>1–5 cities = medium<br>No cities = low |
| **Public national budget dedicated for 5G per inhabitant (in euros in 2019)** | >€600 = high<br>€300–600 = medium<br><€300 = low |
| **National 5G roadmap** | Yes = high<br>No = low |
| **Internet user penetration rate (as a percentage of the population)** | >90% = high<br>90–70% = medium<br><70% = low |
| **Mobile-phone-subscribe penetration rate (per 100 inhabitants)** | >170 = high<br>170–145 = medium<br><145 = low |

To evaluate the **5G maturity market level**, the scales have been given points and an average has been calculated based on the following:

- High = 3 points
- Medium = 2 points
- Low = 1 point

**The 5G market maturity level indicator is an average of these results on a scale of 1 to 3, with 1 being low and 3 being high. See Annex 1 for a calculation of the composite indicator of 5G market maturity for each country.**

## 3.2 The European scenario and 5G market maturity

European 5G scenarios differ widely and are influenced by many local factors related to regulations, public investments, and market environments.

The 5G market maturity levels of the European countries included, based on the indicators described in previous paragraph, summarize the key aspects of 5G market developments, ranking items about:

- The launch of 5G pre-commercial services on the market (5G trials, enabled cities, and spectrum auction timing)
- Government strategies and initiatives (funding and national 5G roadmaps)
- Market demand structure in terms of internet users and mobile phone penetration

### *Number of 5G trials*

The number of 5G trials is the first indicator analysed. It is the most important in terms of understanding the ways in which operators and institutions are investing in and deploying 5G networks.

In terms of the number of trials, the following five European countries are the most active: **Spain, France, Italy, Germany, and the UK**.

Spain is the country with the highest number of trials (22 in March 2019), followed by the other four countries, each with a little fewer trials. In these countries, the main operators and manufacturers have been working on 5G trials since 2016. Since then, they have run many 5G functionality and technicality experiments regarding access, programmability, and streaming functions. Starting at the end of 2017 operators and manufacturers shifted their attentions towards vertical-specific pilots with the intention of experimenting with 5G networks as enablers of Internet-of-Things applications.

In Spain, the most active operator is Telefónica, which has run many trials – mainly involving the automotive industry and transportation, with experimentation relating to distributed multimedia content in moving vehicles. While media and entertainment represent one of the most important areas of technical trials in recent years, in recent months, Industry 4.0, agriculture, and e-health have become new fields of experimentation.

In France, the most active operator is Orange, followed by Bouygues Telecom. Both operators are working in collaboration with manufacturers like Nokia, Huawei, Ericsson, and Qualcomm on trials focused on automotive and road transport, e-health, Industry 4.0, smart cities, and media and entertainment.

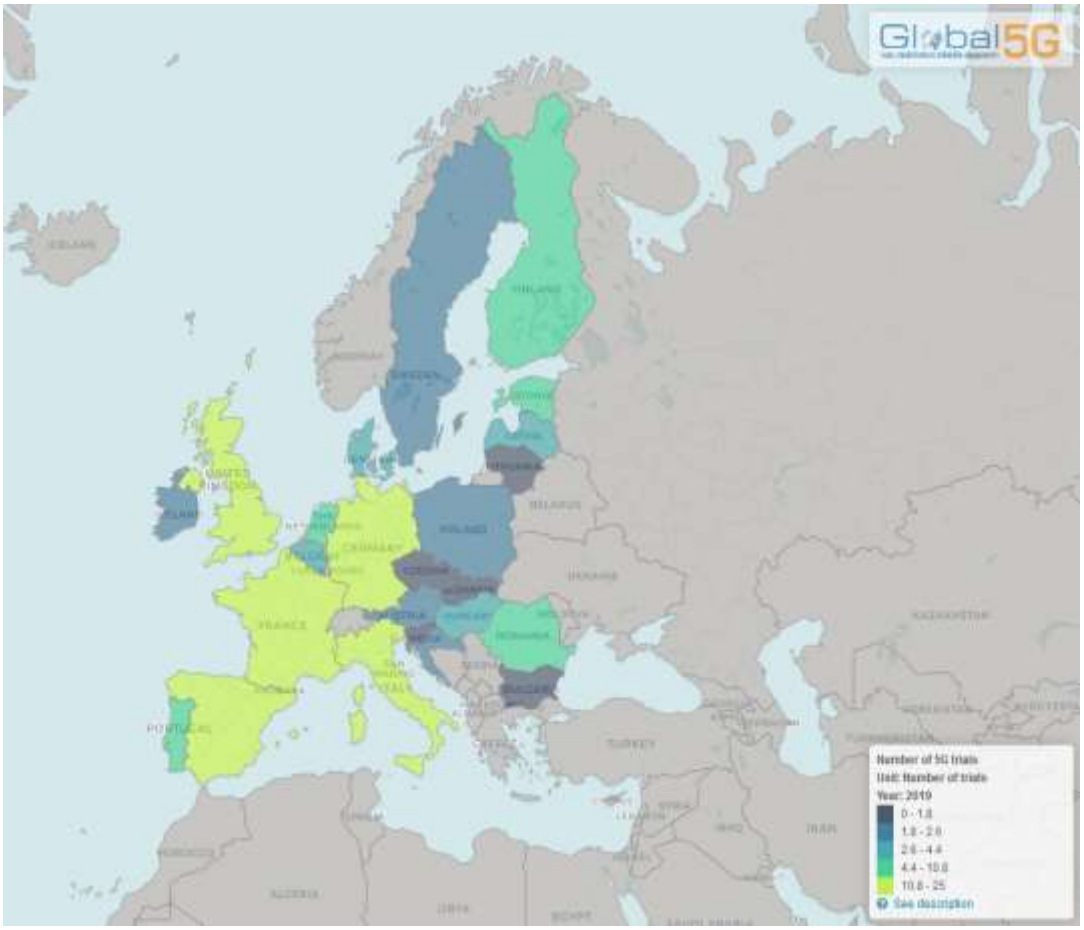
In Italy, 17 trials have been carried out since 2017. the main operator is TIM, which has collaborated with manufacturers Ericsson, Huawei, Nokia, and Qualcomm. The first trials, in 2016 and in 2017, were focused on smart cities and media and entertainment, but the most recent ones have involved new verticals, such as e-health, Industry 4.0, public safety, smart utilities, and transportation, with demonstrations based on an ultra-fast mobile network for remotely driven cars, remote-controlled industrial robots, and remote virtual visits to museums and artworks.

In Germany, the most active operators are Deutsche Telekom and Telefónica, both working on trials focused on verticals such as media and entertainment, Industry 4.0, and, most recently, energy – smart energy grid management, supporting the decentralized distribution of energy with a real-time and secure 5G communications system.

In the UK, the main operators are Vodafone and EE, which are focusing their trials on verticals such as automotive and road transport, e-health, and media and entertainment.

Countries with fewer than 10 trials each, such as the Netherlands, Switzerland, and Portugal, are experimenting in verticals such as media and entertainment, Industry 4.0, and (only in the Netherlands) Agriculture.

*Figure 11: Number of 5G trials per country*



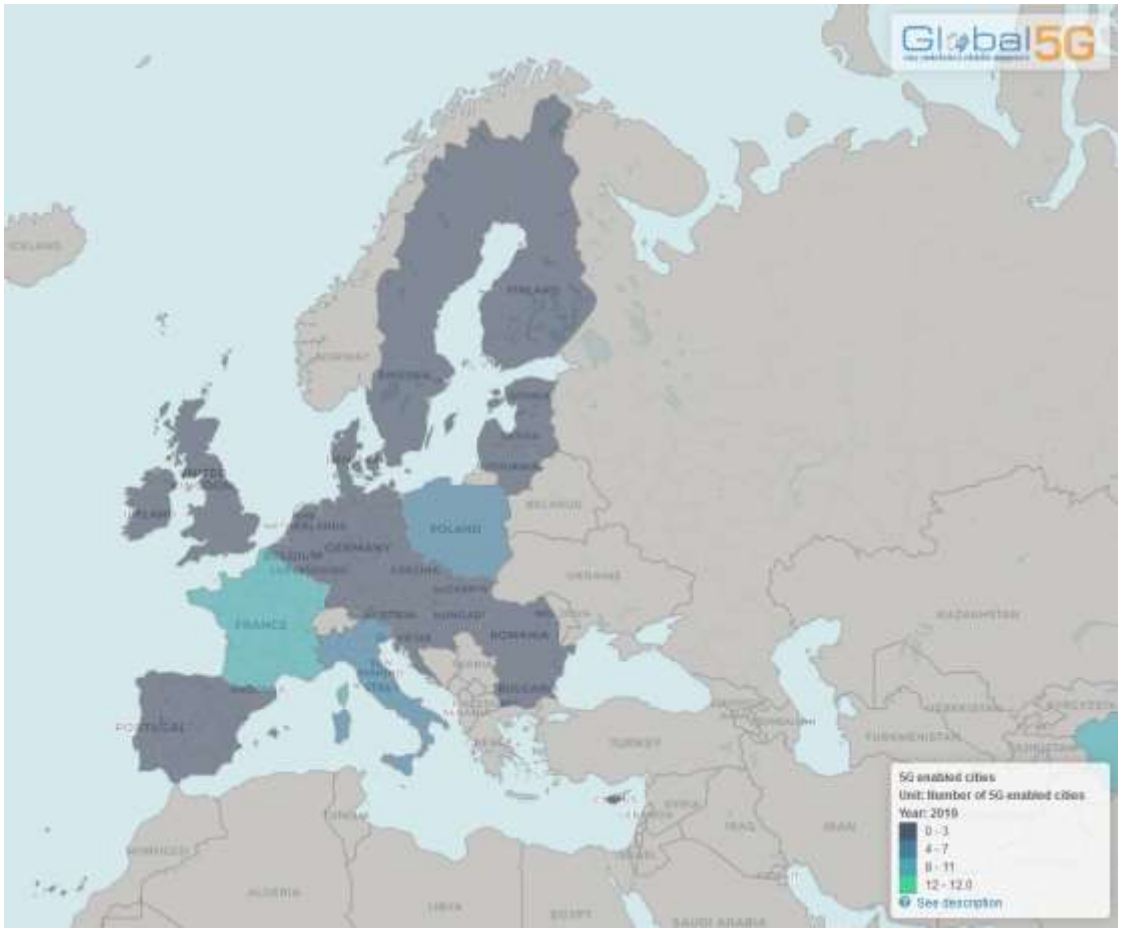

*Source: An INNO elaboration of information from the European 5G Observatory, 2019*

### *5G enabled cities*

The second indicator analysed, trial cities, helps us understand which European countries are at the forefront of 5G trials and pilots, enabling us to validate the real user environment and identify valuable vertical-specific use cases.

According to the 5G Observatory's third quarterly report, these trial cities aim to provide support for a variety of 5G technology and service trials and for valuable vertical-specific use cases, especially concerning the smart city concept, and to enable the validation of those trials in real user environments. When compared with private sector organizations, public entities such as cities usually have different interests, even for similar use cases. Examples include e-health, energy, transport, smart buildings, and digital service portals. In all these areas, shared technology platforms, free access, and open data and interfaces, as well as the full involvement of local ecosystem players and residents, are common priorities.

*Figure 12: Number of 5G enabled cities per country*




*Source: An INNO elaboration of information from the European 5G Observatory, 2019*

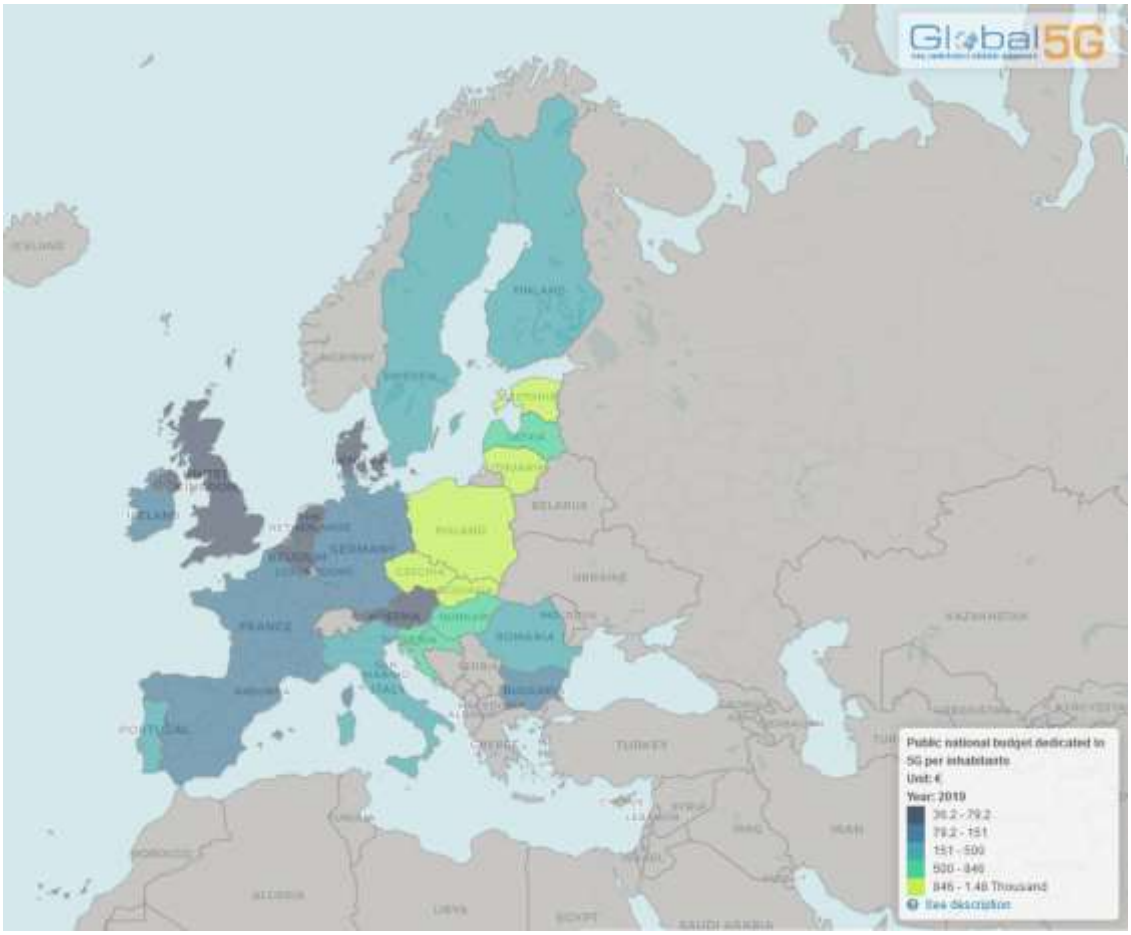
### *Public national budget dedicated to 5G per inhabitant*

The national budget dedicated to 5G trials and development represents another important gauge – one that indicates the strategic importance each country places to the implementation and launch of 5G. The National budget includes the following governmental budgets:

- National budget (ICT) – EAFRD
- National budget (ICT) – ERDF
- National budget (research and innovation) – ERFDR
- National budget (research and innovation) – ERDF
- National budget (transport and energy network infrastructure) – CF
- National budget (transport and energy network infrastructure) – ERDF
- The "Connecting Europe" facility – telecom grants (2014–2017).

In terms of national budget dedicated to 5G per inhabitant, Poland, the Czech Republic, Slovakia, Lithuania, and Estonia are the countries with the highest levels.

*Figure 13: Public national budget dedicated to 5G per inhabitant*

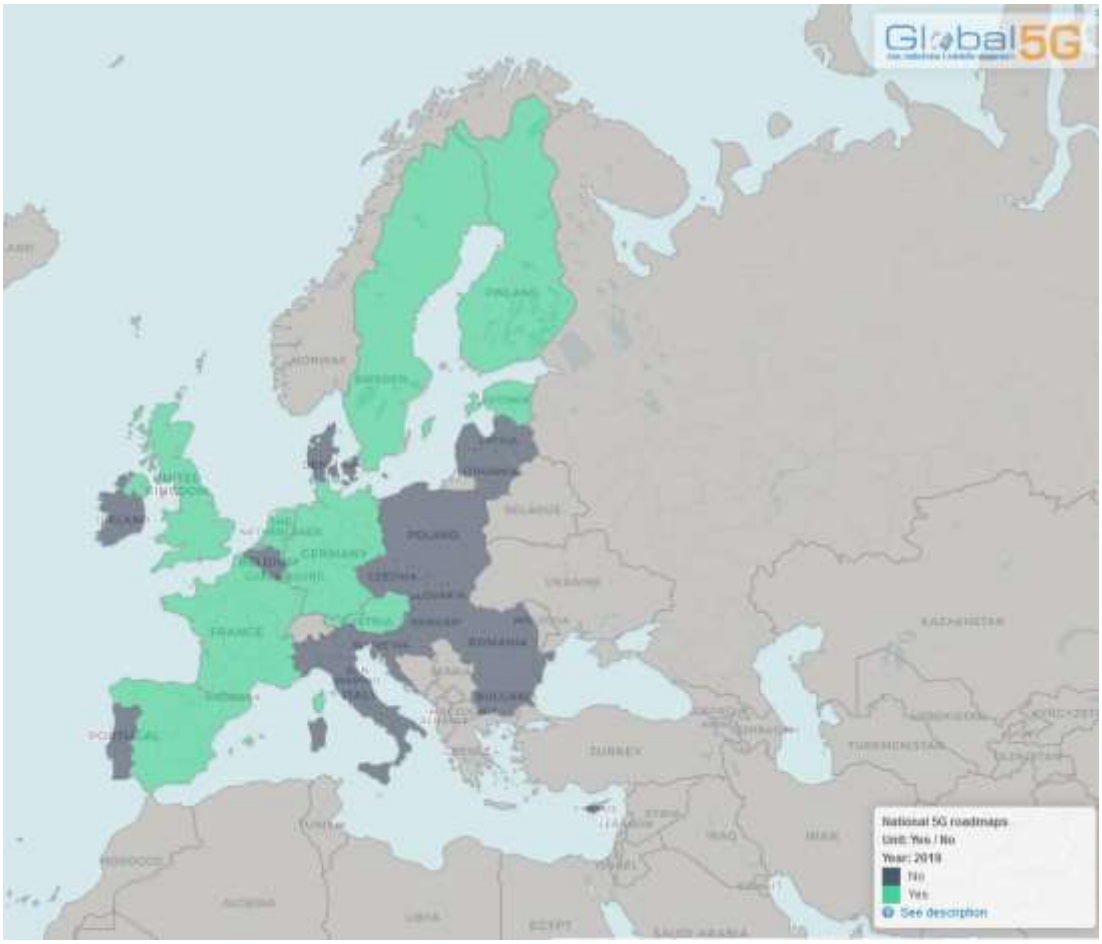



*Source: An INNO elaboration of information from the European 5G Observatory and from other sources, 2019*

### *National 5G roadmaps*

The review of progress made towards 5G development shows various stages. Ten countries published precise national 5G roadmaps that set concrete targets and define priority areas and milestones. The countries that have defined specific national 5G roadmaps are Austria, Estonia, Finland, France, Germany, Luxemburg, the Netherlands, Spain, Sweden, and the United Kingdom.

*Figure 14: National 5G roadmaps*

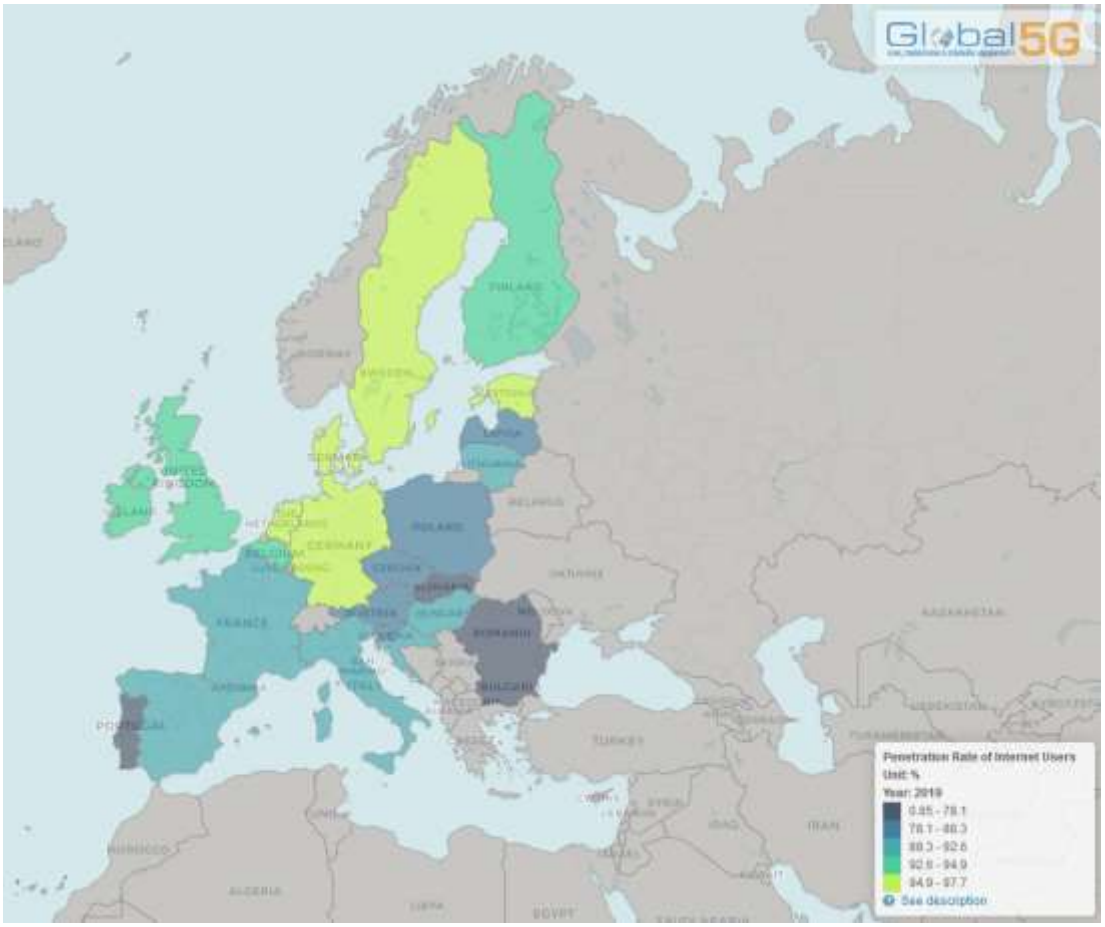



*Source: An INNO elaboration of information from the European 5G Observatory, 2019*

### *Internet user penetration rate*

The internet penetration rate is the number of internet users active in each country as a part of the total population. Six Countries had penetration rates of more than 95% in 2018. These Countries are Denmark, Estonia, Germany, Luxembourg, the Netherlands, and Sweden.

*Figure 15: Internet user penetration rate (as a percentage)*

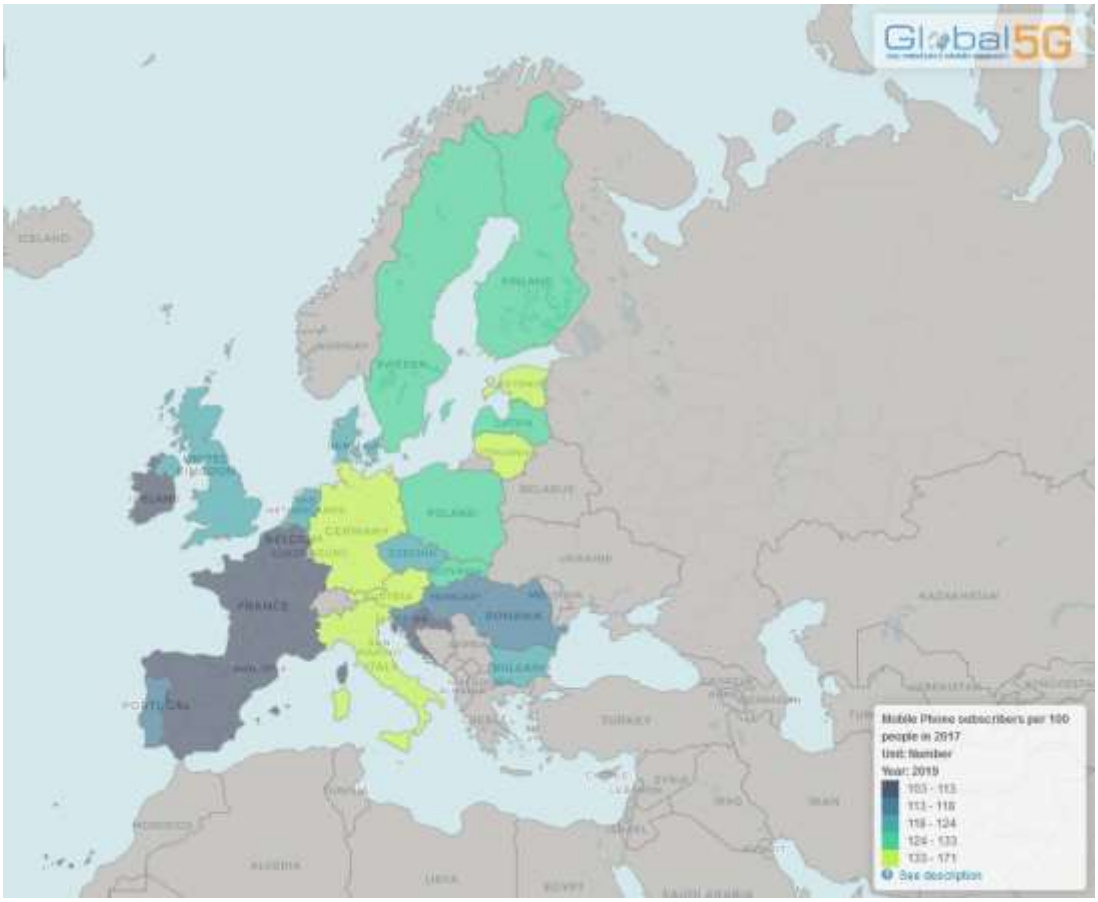



*Source: An INNO elaboration of Internet World State statistics, 2019*

### *Mobile phone subscription penetration rate*

The mobile connection penetration rate reflects how many mobile connections are active in each country as a proportion of the total population. In 2017, all countries had a penetration rate of more than 133%, and these rates show a strong use of mobile devices by European population.

*Figure 16: Mobile phone subscriptions per 100 inhabitants in 2017*




*Source: An INNO elaboration of information from the European 5G Observatory and from other sources, 2019*

## 3.3 5G market maturity level: a picture of Europe

The Global5G.org team developed comparative analysis with the goal of offering fact-based guidance to fully realize 5G capabilities and drive appropriate EU, telecom-operator, and ICT-supply-chain-player investments. The comparative analysis is based on the 5G market maturity level indicator, which relates to the following key aspects:

- The market launch of pre-commercial 5G services – 5G trials in 5G enabled cities
- Government strategies and initiatives, such as funding and national 5G roadmaps
- Market demand structure in terms of internet-user and mobile-phone penetration rates

The 5G maturity level map, as presented in the "Methodology" paragraph (see Figure 19, below, and find details in Annex 1), shows three levels of 5G market maturity in Europe:

- **The countries with the highest level of market maturity** (more than 1.83 points) are Estonia, the UK, Finland, Italy, Germany, Spain, the Netherlands, Luxembourg, Lithuania, and France.
- **The countries with a medium level of market maturity** (between 1.83 and 1.67 points) are Sweden, Poland, Austria, Slovakia, Malta, Latvia, the Czech Republic, and Croatia.
- **The countries with a low level of market maturity** (fewer than 1.67 points) are Hungary, Denmark, Cyprus, Slovenia, Romania, Portugal, Ireland, Greece, Belgium, and Bulgaria.

The countries showing the **highest level of maturity** represent the most advanced markets, where public organizations, telecom operators, and ICT supply-chain players will see:

- **Commercial 5G available by the end of 2019:** European mobile operators are starting to offer commercial 5G services, but coverage and device range will be very limited, and initial service propositions will simply cater to faster data rates. The availability of coverage and devices will broaden in 2020, but ultra-reliable low-latency communications (URLLC) and massive machine-type communications (MMTC) will not appear until 2022–2024, which will limit scope for developing distinctive service propositions that 4G cannot deliver.
- **5G being hyped as "game-changing" and "far more than another new radio access technology (just another G)":** The first 5G services will not live up to that hype, mainly due to a lack of coverage. To minimize the risk of a backlash, operators will focus 5G services marketing on mass market "bundles", similar to 4G offerings, while the service improvements of 5G networks will be rolled out incrementally, in a series of phases, with the goal of becoming the foundation infrastructure of many Internet-of-Things applications.
- **Uninhibited demand for IoT and 5G in the enterprise:** The predicted enterprise spending growth will be driven by continued investment in networks and network upgrades (particularly, but not exclusively, 5G networks), Industry 4.0 initiatives (Industrial IoT), and demand for data (accessed through connectivity).
- **Emerging big data analytics demand (created by 5G availability):** Such demand has been unserved to date. This demand will be driven by greater automation (and integration into existing telecom networks) and many new services and capabilities in the healthcare, logistics, and transportation sectors.

The countries with a **medium level of maturity** could be considered markets in which to expect changes and opportunities after 2022. The following points relate to public organizations, telecom operators, and ICT supply-chain players in these markets:

- **Telecom operators will accelerate their drive into 5G trials and complementary services.** In particular, such services will relate to entertainment, energy, healthcare, insurance, and home/business security. Telecom operators will adopt different strategies in this regard, including acquisitions, partnerships, white-labelling, and the development of their own business

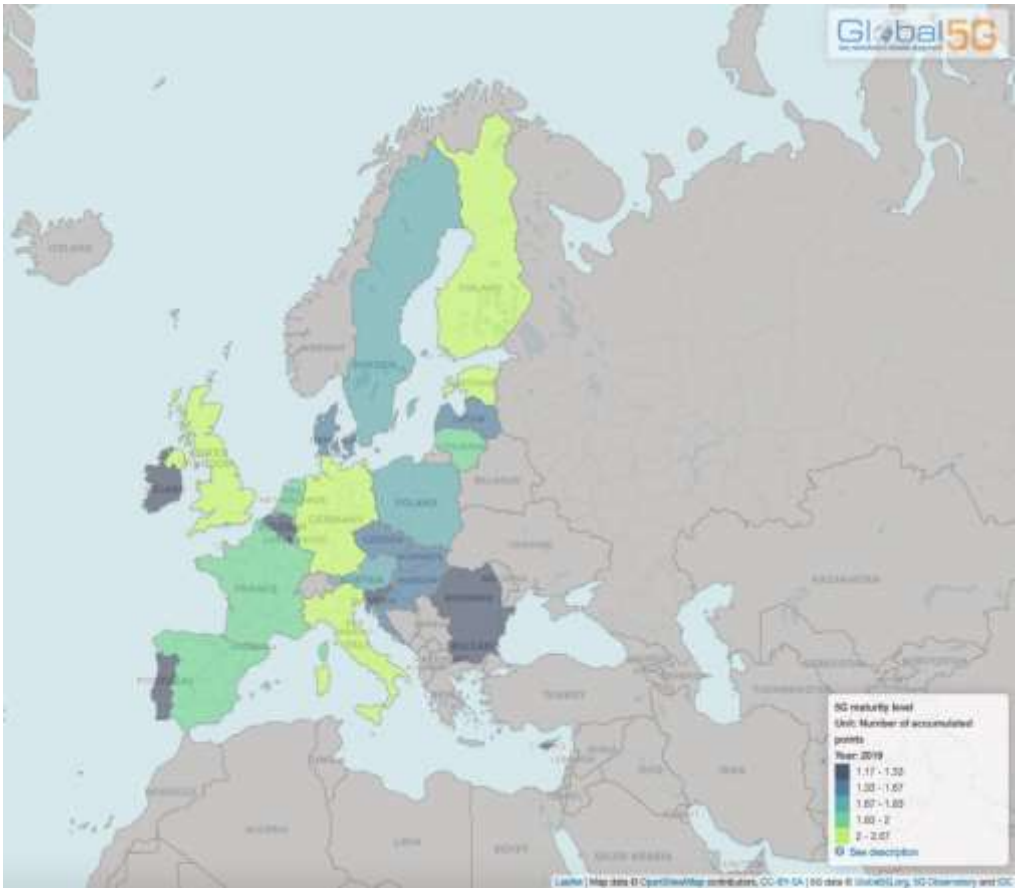
units. But telcos will need to articulate their diversification strategies to demonstrate consistency and alignment with their main assets – namely, mobile services on smartphones, smart home services, omnichannel management, and IoT platforms. Such moves will ultimately prelude new business models in a 5G world.

- **Consumers will adapt and their usage patterns, and their service expectations will change**. Most consumers will expect to be able to use their devices and have access to the same high-quality experiences when they travel as they do when they are at home. Consumers are demanding multiscreen viewing options, greater flexibility in their content packages, and personalized experiences. For telecom operators, this creates a number of operational and service challenges. These include enabling authentication and access from multiple devices, formatting content to fit the access device of choice, and ensuring the operations support systems (OSS) and business support systems (BSS) deployed are capable of supporting multiscreen delivery.
- **Early 5G markets will be driven by the presence of large enterprises**. Successful enterprise 5G mobility deployments that are innovative and demonstrate tangible financial viability will help drive the scale necessary to achieve ROI for wireless operators on their 5G network buildouts. 5G use cases in enterprise mobility will relate to augmented reality, UHD video streaming, mobile cloud computing, and desktop virtualization on traditional mobile devices, such as smartphones, tablets, and even some laptops. Other use cases involving cellular-enabled wearables and new form factors will also factor into enterprise 5G device adoption.

The countries demonstrating a **low level of maturity** are markets in which challenges related to regulations and national plans can slow the deployment of 5G. The following points relate to public organizations, telecom operators, and ICT supply-chain players in these markets:

- **Network virtualization and cloudification:** Telecom operators need to accelerate network function virtualization deployments to improve time-to-market, agility, and capital efficiency. Infrastructure cloudification will be key in 5G networks, but today's virtualization rate is low, and telecom operators have to adopt a consistent strategy across network and IT domains.
- **Investments in 5G:** In the first phase, investments will support enhanced mobile broadband use cases, while the second phase (from 2021 onward) will support new use cases with significant impacts on core, edge, transport, and orchestration. Partnerships between telecom operators and IT vendors will be oriented to identifying the most promising use cases to justify 5G investment.
- **The growing use of public cloud services:** This will drive enterprise demand for communication services. Enterprises will increasingly look for predictable performance, security, and connectivity privacy from their key providers, as opposed to best-effort Internet connectivity. Network service providers' primary role in cloud will be to connect customers to the cloud services they want to consume in a private, secure, performant, and compliant way. Telecom operators will need to build ecosystems of partners, including public cloud providers and datacentre operators, to be successful in this regard.
- **Rapid acceleration in consumer market growth related to paid content services and subscription business models:** The current growth in consumer engagement with paid content services is being driven by the value proposition of paid online experiences and outcomes. Consumers' willingness to pay indicates that online services need not rely entirely on advertising and that vendors can target recurring revenue streams to support business. The subscription business model is in use across a variety of consumer market segments, ranging from digital content to shaving supplies. However, the degree to which consumers may feel some subscription fatigue is worth paying attention to going forward, although the growth of the subscription model does not preclude the continued value of advertising-based services.

*Figure 17: 5G market maturity level by Country*



*Source: An INNO elaboration of information from the European 5G Observatory and from other sources, 2019*

**KEY MESSAGES**

This comparative analysis of European 5G market provides an overview of the maturity levels and differences across the relevant EU countries and offers fact-based guidance to fully realize 5G capabilities and drive appropriate EU, telecom-operator, and ICT-supply-chain-player investments.

5G scenarios in Europe differ widely and are influenced by many local factors related to regulations, public investments, and market environments.

The 5G readiness of European countries is based on key aspects of 5G market developments, with evaluations being based on the following:

- The launch of 5G pre-commercial services on the market (5G trials, enabled cities, and spectrum auction timing)
- Government strategies and initiatives (funding and national 5G roadmaps)
- Market demand structure in terms of internet users and mobile phone penetration

Comparative analysis (based on "Methodology" developed by the Global5G project team) shows three levels of 5G market maturity:

- The countries with the highest level of market maturity (more than 1.83 points) are Estonia, the UK, Finland, Italy, Germany, Spain, the Netherlands, Luxembourg, Lithuania, and France.
- The countries with a medium level of market maturity (between 1.83 and 1.67 points) are Sweden, Poland, Austria, Slovakia, Malta, Latvia, the Czech Republic, and Croatia.
- The countries with a low level of market maturity (fewer than 1.67 points) are Hungary, Denmark, Cyprus, Slovenia, Romania, Portugal, Ireland, Greece, Belgium, and Bulgaria.

The countries showing the highest levels of maturity represent the most advanced markets, where commercial 5G will be available by the end of 2019. In these markets, 5G will be hyped as “game changing” for the IoT enterprise market, markets in which demand for big data analytics has been unserved to date.

The countries with a medium level of maturity are markets in which to expect broad changes and opportunities only after 2022. Telecom operators will accelerate their drive into 5G trials and complementary services. Consumer demand for multiscreen viewing options will accelerate, but early 5G markets in these countries will be driven by large enterprises.

The countries demonstrating low levels of maturity are markets in which challenges related to regulations and national plans will slow 5G deployment. Telecom operators will accelerate network function virtualization. 5G investments will initially support enhanced mobile broadband use cases. The growth of enterprise public cloud services and consumer demand for digital content services will eventually drive the emerging 5G mass market.

# 4 Conclusions

Over the next four years, 5G will further expand the scale of mobile networks for IoT applications. In the nearer term, 5G can also expand the scope of IoT applications over mobile networks, as the current generation of mobile networks still falls short regarding the requirements of some IoT application types in terms of data rates, responsiveness, and reliability – particularly in sectors such as manufacturing, healthcare, and energy.

As is evident from the comparative analysis of the team at Global5G.org (which covered the most relevant similarities and differences in the levels of 5G readiness, or market maturity, of the respective European countries), the 5G scenario in Europe is diverse and influenced by many local factors related to regulation, public investment, and macroeconomic environment; it thus requires a differentiated approach. Government institutions and industry stakeholders should therefore consider the following general recommendations:

- **Consider European diversity an advantage and a stimulus to deploy innovative pre-commercial 5G services** tailored to address the needs of specific niches of sophisticated customers. The European telecommunications services market has a high level of maturity in terms of mobile connections and device penetration. To attract and retain customers, telecom operators and all ICT supply-chain players (including OEMs) will have to compete in the 5G market with broad set of innovative services. In several areas, willingness among customers (both consumers and enterprises) to experiment with new and advanced 5G services will be high, but funds to support initiatives, trials, and pilots and, eventually, commercialisation will be limited, despite such initiatives' essential role in the evolution of the European 5G market.
- **Monitor 5G evolution in the most advanced countries – those with the highest 5G readiness levels, where competition is the highest.** In these countries, the 5G and IoT markets are evolving faster than we had previously expected, with new players entering from other industries, such as OT players in the manufacturing sector and digital content distribution from broadcasters. Mergers and acquisitions, partnerships, and alliances are likely to accelerate in the 5G arena, so it is essential to maintain a fair competitive environment, as this will be crucial for the growth of European 5G market.
- **Foster the development of the 5G market in countries with low and medium levels of readiness to deploy commercial 5G services.** In these countries, incentives, funding, and government-backed initiatives to support greater 5G integration with 4G networks and to foster the creation of new 5G capabilities and IoT services for specific sectors (i.e. healthcare, logistics, and transportation) will help telcos and other ICT supply-chain players tap into the new market opportunities generated, and possibly to implement new business models around those opportunities.

## ANNEX 1: Composite-indicator calculation: 5G market maturity by country

| COUNTRY | Austria | Belgium | Bulgaria | Croatia | Cyprus | Czech Rep | Denmark | Estonia | Finland | France | Germany | Greece | Hungary | Ireland | Italy | Latvia | Lithuania | Luxembou | Malta | Netherlan | Poland | Portugal | Romania | Slovak Re | Slovenia | Spain | Sweden | UK |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| N. of 5G Trials | 2 | 4 | 1 | 2 | 0 | 0 | 3 | 5 | 10 | 19 | 16 | 3 | 3 | 2 | 17 | 3 | 1 | 0 | 0 | 7 | 2 | 5 | 5 | 0 | 0 | 25 | 2 | 14 |
| Level | Low | Low | Low | Low | Low | Low | Low | Medium | High | High | High | Low | Low | Low | High | Low | Low | Low | Low | Medium | Low | Medium | Medium | Low | Low | High | Low | High |
| Point | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 3 | 3 | 3 | 1 | 1 | 1 | 3 | 1 | 1 | 1 | 1 | 2 | 3 | 2 | 2 | 1 | 1 | 3 | 1 | 3 |
| 5G National Roadmap | Yes | No | No | No | No | No | No | Yes | Yes | Yes | Yes | No | No | No | No | No | No | Yes | No | Yes | No | No | No | No | No | Yes | Yes | Yes |
| Level | High | Low | Low | Low | Low | Low | Low | High | High | High | High | Low | Low | Low | Low | Low | Low | High | Low | High | Low | Low | Low | Low | Low | High | High | High |
| Point | 3 | 1 | 1 | 1 | 1 | 1 | 1 | 3 | 3 | 3 | 3 | 1 | 1 | 1 | 1 | 1 | 1 | 3 | 1 | 3 | 1 | 1 | 1 | 1 | 1 | 3 | 3 | 3 |
| Public National budget/population (euro) | 65 | 63 | 95 | 639 | 164 | 1.247 | 36 | 1.367 | 153 | 106 | 83 | 503 | 757 | 106 | 230 | 846 | 850 | 44 | 597 | 58 | 1.096 | 479 | 498 | 1.482 | 525 | 149 | 160 | 52 |
| Level | Low | Low | Low | High | Low | High | Low | High | Low | Low | Low | Medium | High | Low | Low | High | High | Low | Medium | Low | High | Medium | Medium | High | Medium | Low | Low | Low |
| Point | 1 | 1 | 1 | 3 | 1 | 3 | 1 | 3 | 1 | 1 | 1 | 2 | 3 | 1 | 1 | 3 | 3 | 1 | 2 | 1 | 3 | 2 | 2 | 3 | 2 | 1 | 1 | 1 |
| Mobile Phone subscribers per 100 people | 171 | 105 | 120 | 103 | 138 | 119 | 122 | 145 | 132 | 106 | 134 | 116 | 113 | 103 | 141 | 126 | 151 | 136 | 140 | 121 | 132 | 114 | 114 | 131 | 117 | 113 | 126 | 120 |
| Level | High | Low | Medium | Low | High | Medium | Medium | High | Medium | Low | Medium | Medium | Low | Low | High | Medium | High | High | High | Medium | Medium | Low | Low | Medium | Medium | Low | Medium | Medium |
| Point | 3 | 1 | 2 | 1 | 3 | 2 | 2 | 3 | 2 | 1 | 2 | 2 | 1 | 1 | 3 | 2 | 3 | 3 | 3 | 2 | 2 | 1 | 1 | 2 | 2 | 1 | 2 | 2 |
| 5G enabled cities | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 6 |
| Level | Low | Low | Low | Low | Low | Low | Low | Medium | Medium | Low | Low | Low | Low | Low | Medium | Low | Low | Low | Low | Low | Low | Low | Low | Low | Low | Low | Low | High |
| Point | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 2 | 1 | 1 | 1 | 1 | 1 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 3 |
| Penetration Rate of Internet Users/population | 88% | 94% | 66% | 91% | 82% | 88% | 97% | 98% | 94% | 93% | 96% | 70% | 89% | 93% | 92% | 86% | 90% | 97% | 83% | 96% | 78% | 78% | 74% | 85% | 80% | 93% | 97% | 95% |
| Level | Medium | High | Low | High | Medium | Medium | High | High | High | High | High | Low | Medium | High | High | Medium | High | High | Medium | High | Low | Low | Low | Medium | Low | High | High | High |
| Point | 2 | 3 | 1 | 3 | 2 | 2 | 3 | 3 | 3 | 3 | 3 | 1 | 2 | 3 | 3 | 2 | 3 | 3 | 2 | 3 | 1 | 1 | 1 | 2 | 1 | 3 | 3 | 3 |
| **5G Market maturity level** | **1,83** | **1,33** | **1,17** | **1,67** | **1,50** | **1,67** | **1,50** | **2,67** | **2,33** | **2,00** | **2,17** | **1,33** | **1,50** | **1,33** | **2,17** | **1,67** | **2,00** | **2,00** | **1,67** | **2,00** | **1,83** | **1,33** | **1,33** | **1,67** | **1,33** | **2,00** | **1,83** | **2,50** |