TELECOM ADVISORY SERVICES

ASSESSING THE ECONOMIC POTENTIAL OF 10G NETWORKS IN EUROPE

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Telecom Advisory Services LLC (TAS) is an international consulting firm specialized in the development of business strategies and public policies for digital and telecommunications companies, governments, and international organizations. Its clients include leading companies in the digital and telecommunications sectors, as well as international organizations such as the International Telecommunication Union, the World Bank, the Inter-American Development Bank, the World Economic Forum, the UN Economic Commission for Latin America and the Caribbean, the GSMA Association, the CTIA, the NCTA, GIGAEurope, the Wi-Fi Alliance, the Dynamic Spectrum Alliance and the FTTH Council (Europe).

This study was funded by GIGAEurope. The authors are solely responsible for the views expressed in this study.

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EXECUTIVE SUMMARY

The cable internet industry has invested significantly — and continues to invest — in upgrading networks to the DOCSIS 3.1 standard, amongst other capacity enhancements. Because of these investments, a large portion of the cable networks in Europe is already meeting the objectives of the European Commission's strategy on Connectivity for a European Gigabit Society. In fact, today's networks have proven to be extremely reliable for the delivery of e-health services, on-line education, and teleworking platforms when facing the COVID 19 pandemic.[1]

Leveraging the expansive cable infrastructure already deployed, the cable industry – led by NCTA – The Internet & Television Association, CableLabs and GIGAEurope – announced in 2019 that it had begun the next phase of the evolution of its broadband platforms, called '10G'. The new technology is capable of delivering download and upload speeds of up to ten times that of the fastest networks today. While many broadband providers have used recent investments to enable services offering Gigabit connectivity on a widespread basis[2] today, the cable industry's evolution to a future 10G platform promises even greater strides in performance.

> The evolution to 10G will allow the emergence of more secure, lower latency broadband connections that will eventually be capable of delivering close to symmetrical download and upload speeds of up to 10 Gbps.

Future benefits of 10G are not only derived from faster speed, lower latency, and symmetric performance but also from new uses of the technology. With the 10G technology, operators will be able to improve the performance of existing applications, and seamlessly support a wide variety of innovative services for consumers as well as support forward-looking use cases for businesses and government.

In particular, this new technology will be a critical infrastructure for delivering e-health services, on-line education, and telework platforms. The impact of 10G platform technologies on quality health care delivery cannot be underestimated. For example, e-health use cases built around accessing ultra-fast broadband will result in productivity improvements in image data download. **A 2 Gigabyte CT scan requires 11 minutes to be transferred over a standard broadband connection, but only 1.7 seconds over a 10 Gbps link.** This will enable doctors in a central location to read diagnostic images uploaded from multiple locations. 10G will also contribute to the ability of doctors to conduct procedures by means of a remotely controlled robot. High speed – high quality connectivity will also reduce transaction costs in the health care sector.[3] Other applications include the use of Augmented Reality/Virtual Reality platforms to support the population living under conditions of lockdown.

1 Liberty Global networks were capable of handling a 32% increase in downstream traffic driven by video-streaming and downloading files and 61% increase in upstream load resulting from higher usage of collaborative tools (see Liberty Global (2020). Operational Performance). Likewise, Vodafone's fixed broadband usage increased more than 50% in Italy and Spain alone, with downstream traffic increasing by 44% (see Wibergh, J. (2020). An update on Vodafone's networks).

2 Gbps speeds have been made available by cable operators in Belgium, Switzerland, Germany and Ireland; roll-out in the Netherlands and the United Kingdom is taking place on a rolling basis.

3 See https://2zn23x1nwzzj494slw48aylw-wpengine.netdna-ssl.com/wp-content/uploads/2019/11/Gigacities-report-FINAL1.pdf.

This study focuses on an assessment of the broader social and economic benefits associated with this next evolution of cable broadband platforms in four European Union countries - Belgium, Germany, Ireland, the Netherlands -, as well as Switzerland and the United Kingdom. That said, the conclusions could be extended to other geographies. The analysis addresses four key areas of economic value creation: (i) capital investment as a contributor to GDP and jobs linked to network deployment; (ii) the spillovers of the 10G network resulting from new use cases and an enhancement of business efficiencies; (iii) the creation of new jobs triggered by economic spillovers; and (iv) the benefits to consumers resulting from new applications and higher broadband service quality.

> This report has used cable infrastructure as the basis to estimate the benefits of 10G connectivity. However, the benefits related to the services and applications stems from the availability of 10G capability and not the technology being used to deliver it.

Therefore, the benefits related to the building of the 10G cable infrastructure could be extrapolated to any 10G-capable technology.

- **Network investment for deploying 10G will lead to a contribution to Gross Domestic Product (GDP) of approximately €25.1 billion[4] and 115,500 job years.**

The investment required for operators to add 10G capabilities to their networks in the six countries under study will equal € 16.0 billion.[5] In addition to the direct economic impact yielded by this investment in technology and construction of networks, there will be indirect and induced output of € 9.1 billion due to the need of intermediate goods and services to support this evolution of cable broadband platforms. This will result in total GDP impact associated with the migration to 10G of € 25.1 billion. In addition, spending on 10G development will be associated with the creation of 115,500 job years over a four-year span. Of these, 69,700 job years will be in the construction sector, 10,300 in electronic equipment, 6,700 in other manufacturing and 28,800 in other sectors.

- **Once the networks are deployed, they will generate spillovers in the amount of €106.8 billion in cumulative GDP in all six countries**

Spillovers from the increase in network speed enabled by 10G will lead to additional benefits to GDP. **Aggregate GDP contribution from the return to speed benefits of 10G services across all six European countries under study will generate spillovers in the amount of € 106.8 billion in cumulative GDP. This will result from the impact of these networks on the overall economies of the six countries by increasing efficiencies associated with the deployment of smart manufacturing, advanced logistics, and even precision agriculture.** This is equivalent to an average of € 26.7 billion per year (or 0.26% of the aggregate GDP of all six countries).[6]

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4 Foreign exchange conversion rates used throughout the study: US$ 1 = € 0.85; US$ 1 = CHF 0.91; US$ 1 = GBP 0.76.

5 The investment numbers are based on the calculations and methodologies set out in Section 4.1 and are based on applying the rear view mirror principle where possible. This principle is a relevant indicator for future investment predictions. However, reality may differ from these estimates due to economic, social, technological or regulatory changes.

6 These estimates were developed with econometric models linking the increase in broadband speed to economic growth and job creation. Details are included in chapters 2 and 4, as well as in appendix C

- **The efficiencies that will result from providers' evolution to 10G networks will generate 347,600 new jobs, which equals an average of 86,900 new jobs per year, or 0.10% of the aggregate labour force across the six countries.**

In addition to the GDP growth driven by these spillovers, the migration to 10G in all six countries will create 347,600 new jobs. These effects will vary by sector, with 10G making a particularly significant contribution to the creation of service sector jobs. This next evolution of broadband platforms will generate 1,766,000 service sector jobs, equivalent to 441,500 average per year. The difference between the total employment growth (347,600) and service sector job creation (1,766,000) highlights the role of 10G as an enabler of labour shifts between the manufacturing and services sector. A sizeable portion of jobs lost in the future to automation in the primary and secondary sectors could be gradually replaced by jobs in the services sector, an effect that can be enabled by 10G acting as a general-purpose technology.

- **The evolution of networks to 10G will generate € 19.0 billion in consumer surplus.**

Past research indicates that **consumers have an increased willingness to pay for faster speeds and lower latency broadband,** as these factors increase the value of connectivity by providing access to a whole new range of e-health, teleworking, entertainment and information applications.[7] By providing faster service, the migration to 10G will yield an increase in consumer surplus reaching € 19.0 billion between 2021 and 2027 across the six countries under study, with an average annual value of € 4.8 billion.[8]

- **In total, the aggregate economic contribution of 10G in the six European countries under study will be nearly € 150.9 billion.**

The aggregate GDP contribution from this migration to 10G services across all six European countries under study will generate economic benefits in the amount of € 150.9 billion in cumulative GDP, which is equivalent to an average of € 37.7 billion per year.

- **Additional economic value may be realised by regulatory and policy changes that will speed up and increase the incentive for private network investment.**

The economic value associated with 10G networks reviewed so far represents a baseline scenario that assumes no specific policy or regulatory intervention aimed at incentivizing the migration to 10G. However, certain policies could act as a stimulus for the move to 10G.

The objective of the 2018 European Electronic Communications Code is to promote investment and the roll-out of Very High Capacity Networks – a good example of which are today's cable networks and **future 10G technology.** A prudent, investment-oriented implementation of the 2018 European Electronic Communications Code, scale-promoting competition policy and realistic market analysis – deregulation where justified, avoiding overregulation – could bring significant gains. A major step towards build out and

7 See AT Kearney study "Viewed through the Lens of the Consumer", Liberty Global Policy series 2018. https://2zn23x1nwzzj494slw48aylw-wpengine.netdna-ssl.com/wp-content/uploads/2019/02/Viewed-Through-the-Lens-of-the-Consumer.pdf; Nevo, A., Turner, J., and Williams, J. (2016) "Usage-based pricing and demand for residential broadband", Econometrica, vol. 84, No.2 (March), 441-443, and Liu, Y-H; Prince, J., and Wallsten, J. (2018). Distinguishing bandwidth and latency in households' willingness-to-pay for broadband internet speed.

8 These estimates were developed based on estimates of the impact of speed on consumer surplus generated by academic research in the United States. See chapters 6 and Appendix F.

adoption of 10G networks will be achieved by bringing fibre much closer to the customer. Unrestricted access to ducts and poles owned by utilities, municipalities and other telecommunications operators would be an important regulatory support. The proposal to enable license-exempt use of the lower part of the 6 GHz band (5925-6425 MHz), to allow more effective and efficient use of spectrum and significantly improve the user experience of Wi-Fi will also represent a significant contribution. Finally, Europe also needs more policy measures which streamline and harmonize bureaucratic permission processes and allow the use of modern and cost reducing digging methods like micro- or nanotechnologies.

> In summary, the evolution of cable networks to 10G technology represents a critical infrastructure required to build future economies capable of delivering enhanced consumer welfare, bringing substantial societal benefits and additional competitiveness in Europe.

In addition, 10G networks represent a way to meet the need for ever increasing speed, lower latency and greater security required by broadband users, consumers and businesses alike. Our analysis shows that there are substantial economic benefits from this technological evolution: GDP growth, job creation, support for emerging applications and consumer surplus.

This study is structured around eight chapters, complemented with technical appendices:

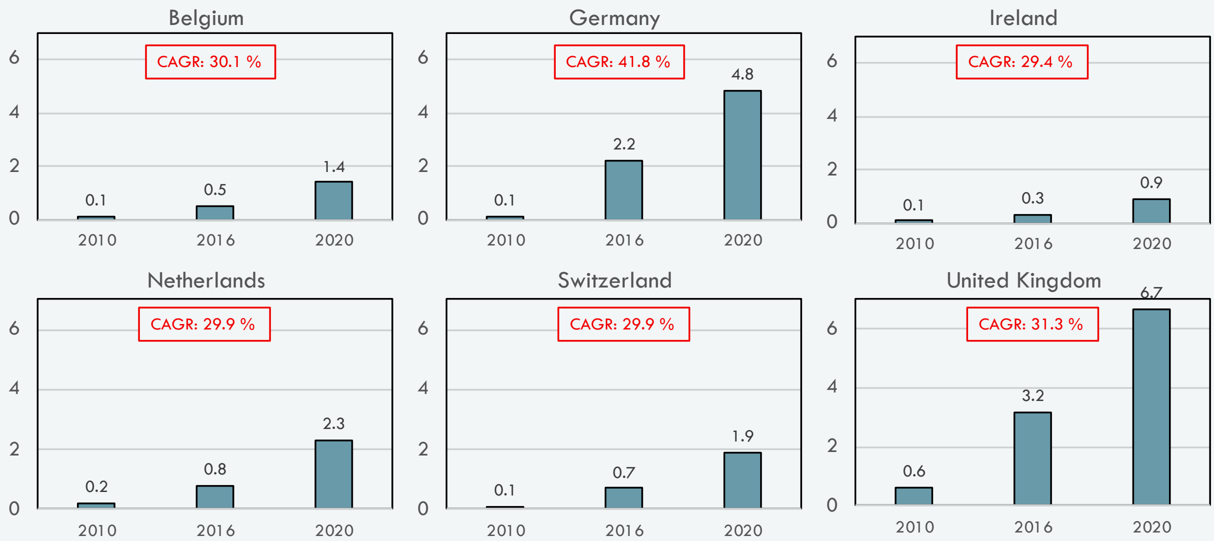
- Chapter 1 explains how 10G networks differ in terms of technology, features, and performance from current cable technology, while representing a gradual migration path from DOCSIS 3.1.
- Chapter 2 reviews the theoretical frameworks and methodologies relied upon for conducting the assessment of economic benefits of 10G networks.
- Chapter 3 tackles the impact of the new services that will be enabled by 10G networks, focusing on the delivery of a selected list of enterprise use cases (for example, smart manufacturing and precision agriculture), public services (such as e-health and smart cities), and consumer applications (such as massive multiplayer gaming and immersive video).
- Chapter 4 presents an estimate, based on input-output analysis, of the impact that the investment in 10G will have on GDP and job creation, primarily in the electronics equipment and construction industries.
- Chapter 5 assesses the economic benefit (or spillovers) of 10G once these networks can support such advanced capability. Our estimates in this case are based on econometric modelling of historical data on the so-called “return to speed”.[9]
- Chapter 6 presents our estimation of the increase in consumer surplus as a result of faster service speeds, assuming the applications presented in Chapter 3 are enabled by 10G.
- Chapter 7 combines the results of our different assessments of economic benefit by country.
- Chapter 8 outlines some public policy and regulatory stimuli for European countries that could accelerate the development of 10G networks and the implications of these stimuli on the estimation of economic benefits.
- All analyses and models in support to the calculations included in this study are compiled in the corresponding appendices.

9 Research, reviewed in Appendix B, has provided significant evidence on the impact broadband speed has on GDP growth, job creation and consumer surplus.

1. TECHNOLOGY, FEATURES AND PERFORMANCE OF 10G NETWORKS

There has been tremendous growth in Internet traffic over the last decade. Internet traffic in the six European countries under study has been growing at an average annual growth rate of 32.7 % (See Graphic 1-1).

GRAPHIC 1-1. INTERNET MONTHLY TRAFFIC (IN EXABYTES[10])



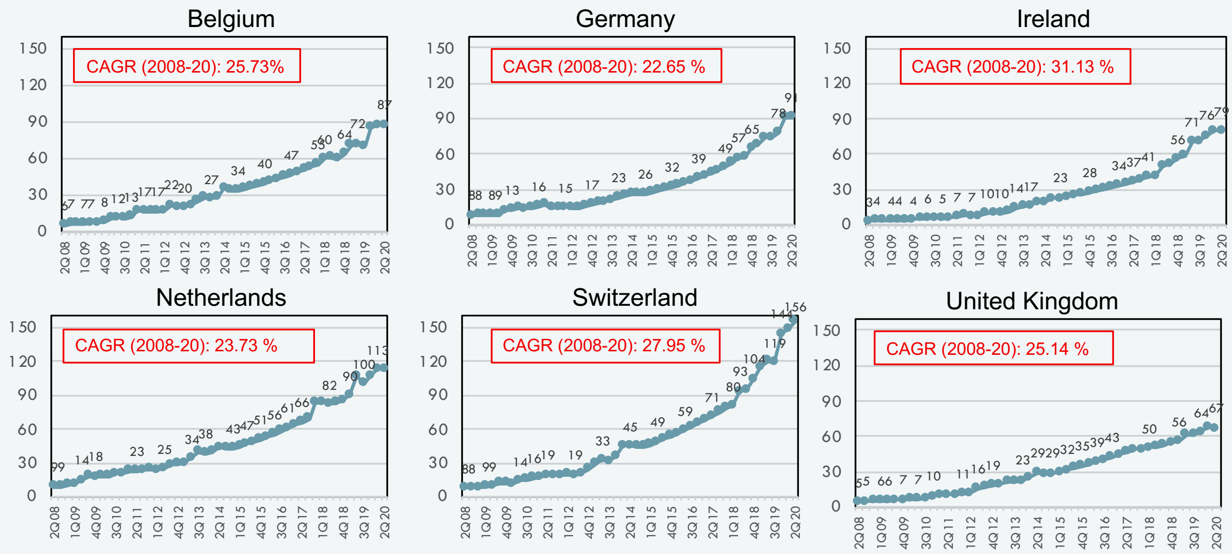
Source: Cisco Visual Networking Index; Telecom Advisory Services analysis

The increase in the number of devices that rely on the internet (PCs, smartphones, tablets, smart TVs) is one factor driving the growth in traffic. In parallel, the usage per device has increased dramatically. In 2020, each smartphone in Europe generated on average 5.49 GB per month (up from 2.30 GB in 2017).[11] This will continue to grow: a 4K TV set in the United Kingdom generates 6.3 GB per month of traffic through video-streaming in 2017 and is expected to reach 26.8 GB by 2022.

As expected, the growth in Internet traffic has been paralleled by an increase in fixed broadband speed. In fact, the average fixed broadband download speed across the six European countries under study has been growing by 26.1% annually (see Graphic 1-2 and Appendix A)[12]

10 An Exabyte is equivalent to 1,073,741,824 gigabytes.
11 Source: CISCO Visual Networking Index.
12 The analysis here and in Appendix A is based on Ookla/Speedtest daily Internet traffic compiled between 2008 and 2020, as reported in the site. The service measures the bandwidth (speed) and latency of a visitor's Internet connection against one of 4,759 geographically dispersed servers located around the world. Each test measures the data rate for the download direction, i.e. from the server to the user computer, and the upload data rate, i.e. from the user's computer to the server.

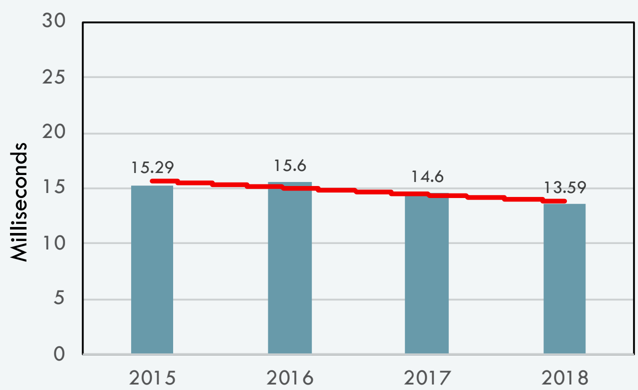
GRAPHIC 1-2. FIXED BROADBAND AVERAGE DOWNLOAD SPEED (IN GBPS)



Source: Ookla/Speedtest; Telecom Advisory Services analysis

Network speed and latency[13] are related since transmission technology is one of the factors that reduce the time it takes for packets to travel from the source to the user.[14] This is why network latency has also been decreasing. For example, in the United Kingdom latency has decreased from 15.29 Ms. in 2015 to 13.59 Ms in 2018 (see Graphic 1-3).

GRAPHIC 1-3. UNITED KINGDOM: FIXED BROADBAND (CABLE AND FTTX) PEAK AVERAGE LATENCY



Note: The source of the raw data used by Ofcom is the site SamKnows. The values are derived from measurement of six specific carriers. Each year value is an arithmetic average of all cable and fibre observations within the country.
Sources: OFCOM. UK Home Broadband Performance (2015-18); Telecom Advisory Services analysis.

13 Latency measures the time it takes for a data packet from one point in the network to another. High latency has a negative impact on the service quality of interactive applications. It is affected by several factors such as the physical distance data must travel (for example geostationary satellites require data to travel 22,000 miles each way), the number of nodes the data must traverse (which pushes service providers to cache content closer to their end users), and how the network equipment (routers, switches, etc.) buffers and forwards the data.
14 The other two factors driving latency is the network architecture and the capability of the technology to schedule buffers..

The network communications industry, including both the incumbent telecommunications operators and cable broadband providers, has been increasing the capabilities of its networks to accommodate the growing demand for faster broadband speed and lower latency (See Appendix A on speed coverage by country).

> While speed, latency and quality of service have been improving significantly, the ever-growing user needs fuelled by new applications is pushing for additional network enhancements.

TECHNOLOGY AND FEATURES

Since the end of the twentieth century, the cable industry has been deploying successive generations of the international telecommunications standard that allow for the addition of high-bandwidth data transfer over an existing coaxial cable network. Developed in March 1997, DOCSIS (Data Over Cable Service Interface Specification) allows operators to offer higher performance broadband service without having to replace completely their coaxial cable networks.[15]

Cable operators in Europe have been actively migrating to DOCSIS 3.0 and DOCSIS 3.1 over the past years. As of mid-2019, 65.5% of cable broadband households were supported by DOCSIS 3.1 in Belgium[16], while coverage of the technology reached 71.7% in Switzerland.[17] Ireland deployment began in the second half of the year.[18] As of the end of 2019, Germany has deployed DOCSIS 3.1 standard to 70% (24 million) of households.[19] 54% of Netherlands cable networks is DOCSIS 3.1 enabled, expecting to reach 100% in 2021. Belgian operators are also deploying DOCSIS 3.1 networks. As a result, cable speed coverage has reached significant levels. For example, **1 Gbps speeds have been made available by cable operators footprint in Belgium, Switzerland, Germany and Ireland. Roll-out in the United Kingdom and the Netherlands is proceeding on a rolling basis.**

In January 2019, the cable industry announced an industry initiative, labelled “10G”, that would build on the work the industry has done implementing DOCSIS 3.1 and lead to the deployment of enhanced network performance via a new iteration of its DOCSIS standard along with other improvements. Not only will 10G deliver ten times the current most prevalent maximum speeds offered to consumers; it is combined with latency of 1 millisecond which is critical for applications where timeliness is important as is the case in industrial IOT and e-Health applications (we address this further in the use cases reviewed in chapter 3). In addition, the technology is fully compatible with prior generations of DOCSIS 3.0 and 3.1, which reduces migration costs and minimizes consumer disruption.

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15 DOCSIS comprises two main components: the physical layer (called PHY) and the media access control layer (MAC). The physical layer pertains to the wiring and routing equipment used, as well as the frequency at which data is transmitted through the physical systems. The MAC layer handles the information being processed over the network components.
16 Source: European Commission (2020). Broadband coverage in Europe 2019. Luxembourg: European Union.
17 Source: SUISSE DIGITAL, Switzerland’s cable TV association.
18 Source: Virgin Ireland interview.
19 Source: ANGA, The Broadband Association (Germany); however, KDG has 75.5% of homes passed ready for DOCSIS 3.1.

The implementation of the new standard will require cable operators to drive fibre deeper into their networks. Since the early 1990s, cable operators have relied on network technology that is comprised of a fibre portion connecting a cable head end to an optical node (which converts the optical signal to a radio frequency), and a coaxial cable equipped with amplifiers to enhance the radio frequency signal quality. The deeper fibre is deployed in the cable network, the lower the number of households supported by the node. This increases the cable broadband capacity available to each user. More fibre in the cable network requires more nodes, which means that a lower number of users share the coaxial cable. This increases the capacity available to each user.

Cable operators will use different approaches to tackle their upcoming evolution to 10G network capabilities.[20] The economics for deploying 10G varies depending on the approach to be followed by the cable operator. To implement 10G, operators also will have to install additional electronic equipment to gain more capacity in the fibre link. As more service groups are created, equivalent Cable Modem Termination System (CMTS) capacity must be added. Moreover, upgrades to Digital Optics (10G Ethernet) are required for deploying Distributed Access Architectures, such as Remote PHY. **Additionally, operators will need to install new or upgraded set-top boxes or Digital Terminal Adapters in the customer premise to offer digital video while freeing valuable spectrum and upgrading the modem in the home to be able to receive the new speeds.**

20 See, for example, https://www.lightreading.com/cable/docsis/cablelabs-kicks-off-pursuit-of-docsis- 40/d/d-id/752355..1.

2 THEORETICAL FRAMEWORK FOR ESTIMATING THE ECONOMIC CONTRIBUTION OF 10G NETWORKS

In this report, we assess the economic impact of 10G in terms of both the investment needed to facilitate the migration to this new platform as well as in the context of measuring the "return to speed." Return to speed is defined as the impact an increase of broadband speed has in enabling new applications which would, in turn, generate improvements in economic growth, enterprise productivity, job creation and consumer surplus.

This chapter is structured in four sections. First, we discuss the economic impact of investment in broadband infrastructure deployment (detailed review of research literature is presented in Appendix B). Second, we summarize the different effects of broadband speed (economic growth, employment, enterprise productivity, and consumer surplus). Third, the methodologies upon which we rely to estimate each of the economic effects are presented. Finally, we discuss how these methodologies are integrated within a single theoretical framework.

Before describing this methodology in more detail, it is important to note that our economic analysis focuses on the impact anticipated from the industry's expected use of next generation technology in future 10G platforms. As such, we make no effort in this analysis to quantify benefits that may flow today from cable's use of current generation technology (DOCSIS 3.1), even though the performance improvements in networks achieved over the past few years in achieving Gigabit connectivity have been substantial and can be viewed as part of the industry's roadmap to full realization of 10G network technology.

2.1. ECONOMIC IMPACT OF NETWORK EVOLUTION

> As outlined in chapter 1, the evolution of cable broadband platforms to next generation 10G platforms will entail capital spending that will be funded from ongoing capital expenditures which, in turn, will translate into GDP growth and jobs. The migration to 10G will affect the economy and employment in three ways:

- 10G will require **investment to upgrade cable's current infrastructure.** This translates directly into additional GDP and jobs (technicians, construction workers, manufacturers of telecommunications equipment).
- In addition, these expenditures create **indirect spending** triggered by upstream buying and selling between cable operators and their suppliers (electric supplies, metal products, etc.).
- Finally, the household spending resulting from the **income generated from the direct and indirect jobs creates additional "induced" economic effects.**

Several studies, discussed in Appendix B, have examined these effects. All this research calculated multipliers, which measure the total output and employment change throughout the economy resulting from a given amount of investment made in broadband networks[21]. The impact of broadband investment is often measured with input-output tables[22]. While input-output tables are a reliable tool for predicting investment impact, they are static models reflecting the interrelationship between economic sectors at a certain point in time. Since those interactions may change, the matrices from one period may overestimate or underestimate the impact of broadband investment in a different period. For example, if the electronic equipment industry is outsourcing jobs overseas at a fast pace, the employment impact of broadband investment will diminish over time, since part of the investment will "leak" overseas. Multipliers based on an earlier time period may not pick up these effects. However, all these effects are well understood, and therefore, with the caveat of the static nature of input-output tables, the results are quite reliable.

2.2. BROADBAND SPEED EFFECTS ON ECONOMIC GROWTH AND OTHER MEASURES OF WELL-BEING

We discuss the research on the **impact of increasing fixed broadband speed on various measures of economic well-being** in Appendix B. This research covers economic growth, household income, enterprise activity, job creation and consumer surplus.

- **Economic growth:** First and foremost, research generally concludes that **faster internet access has a positive impact on GDP growth.** Among the main findings in the literature is that there appears to be a required minimum threshold of broadband speed needed to generate economic benefits. Furthermore, the relationship linking broadband speed to GDP growth is non-linear and stepwise. In other words, a jump in speed does not yield a continuous proportional impact in GDP growth.

- **Household income:** Some research indicates that **households in advanced economies gain more from faster broadband speed than in emerging countries,** although the impact of speed on income may not be as strong due to reverse causality; that is, higher speeds can increase income, but higher income also can increase speeds and this is not always considered when estimating these effects.

- **Enterprise activity:** Several studies indicate that **faster broadband speeds result in more extensive use of the Internet, which leads, in turn, to more enterprise sales and overall productivity.**

- **Job creation:** The impact of broadband on job creation has been found to be channelled through intermediate variables. For example, **faster broadband increases regional attractiveness, which in turn attracts new firms to the area and incubates new firms in need of workers.**

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21 Multipliers are of two types. Type I multipliers measure the direct and indirect effects (direct plus indirect divided by the direct effect), while Type II multipliers measure Type I effects plus induced effects (direct plus indirect plus induced divided by the direct effect).

22 Input-output tables measure the interdependence of an economy's productive sectors by considering the product of each industry both as a commodity demanded for final consumption and as a factor in the production of itself and other goods.
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That said, it should be noted that, since this effect enables firm relocation, it could result in a zero-sum game as more workers in one region imply less workers in another. Another set of research findings indicates that **higher broadband speed leads to an acceleration of innovation** and, therefore, the growth of companies primarily in the services sector with little effect in agriculture and manufacturing.[23]

- **Consumer surplus:** The availability of high-speed broadband increases consumers' willingness to pay for Internet use since it allows access to new applications like 4K video streaming and massive parallel gaming. However, as in the case of impact on GDP growth, the effect is non-linear. In other words, faster speed does not proportionally yield more consumer surplus.

2.3 METHODOLOGIES USED FOR ASSESSING THE ECONOMIC IMPACT OF 10G

Based on the review of the research literature regarding the economic impact of broadband speed we decided to focus the study on the three areas where significant and consistent research evidence has been generated so far:

- **The impact of investment needed to migrate to 10G:** **as with any infrastructure project,** the migration to 10G will require investment with the consequent direct, indirect, and induced contribution to GDP and job creation. Our approach here will be based on I/O analysis.

- **Spillover of existing and future applications[24]:** consistent with past literature on the impact of communications technology, **the increasing speeds from 10G will have an impact on cost efficiencies, market expansion, and new product development.** These effects translate into growth of GDP as well as new jobs resulting from the development of new business models and firms. Our methodological approach in this case is based on econometric models.

- **Consumer surplus:** this is **the value that consumers would be willing to pay for a service or a good compared to what they actually pay.** Our assessment of consumer surplus will be based on the results of primary consumer research.[25]

The methodologies used for assessing the contribution of 10G in each of these areas are discussed in more detail in Appendix C.

23 For example, Hasbi (2017) analysed panel data on 36,000 municipalities in France between 2010 and 2015 and found that deployment of high-speed broadband (> 30 Mbps) increases company relocation and start-up development in the non-agricultural sector.

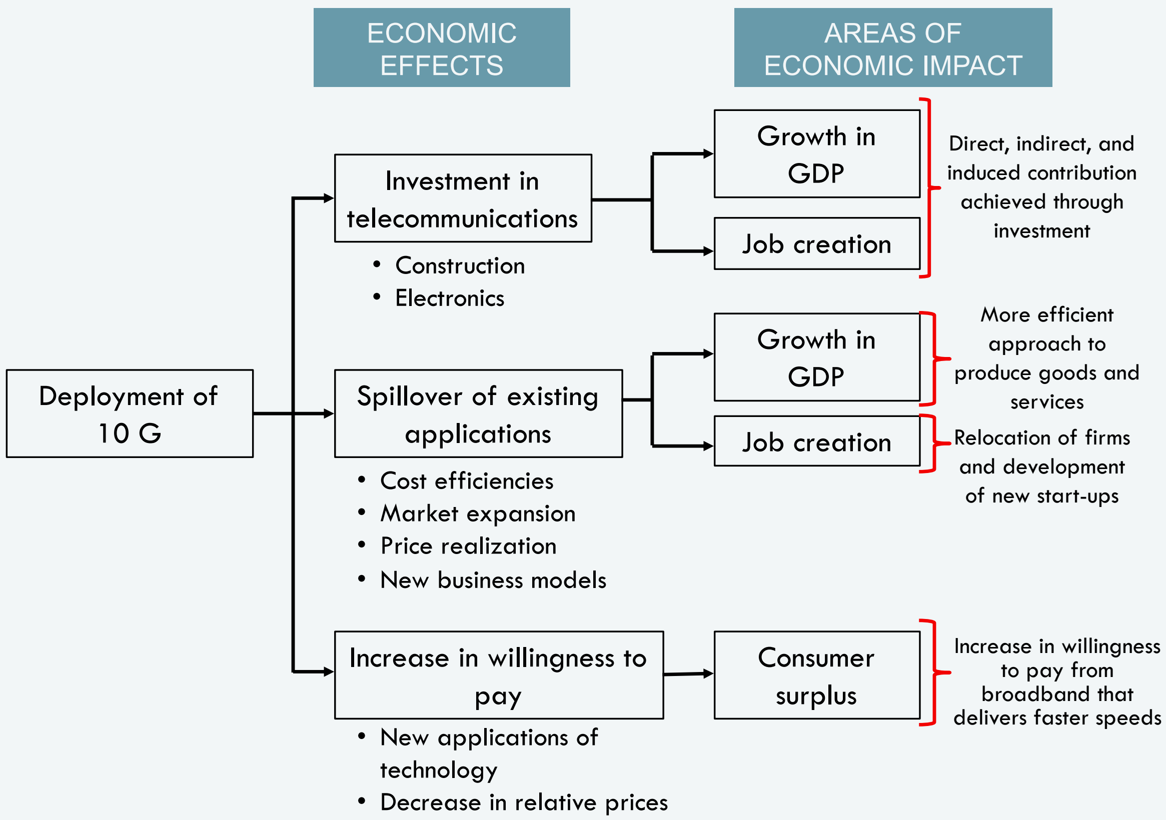
24 Spillover of new applications and business models not only derive from the "return to speed" (driven by low latency and improved performance) but from new uses of the technology. This last domain comprises not only technologies that are currently under implementation, but also applications that are at an early stage of the development life cycle. For these cases, our analysis will be primarily qualitative although attempts are made to estimate benefits at the sector level.

25 The estimation of consumer surplus will be based on data generated by previous research conducted in the United States, primarily that of Nevo, A., Turner, J., and Williams, J. (2016) "Usage-based pricing and demand for residential broadband", Econometrica, vol. 84, No.2 (March), 441-443., although we also consulted Liu, Y-H; Prince, J., and Wallsten, J. (2018). Distinguishing bandwidth and latency in households' willingness-to-pay for broadband internet speed.

2.4 COMPILING ECONOMIC EFFECTS WITHIN A SINGLE ECONOMIC VALUE ESTIMATING FRAMEWORK

We combine all three analyses that measure the economic benefit of 10G - the one-time impact of 10G investment, the spillover effects of 10G as the migration to 10G occurs, including the enablement of new applications, and the calculation of consumer surplus - within a single framework (see figure 2-1).

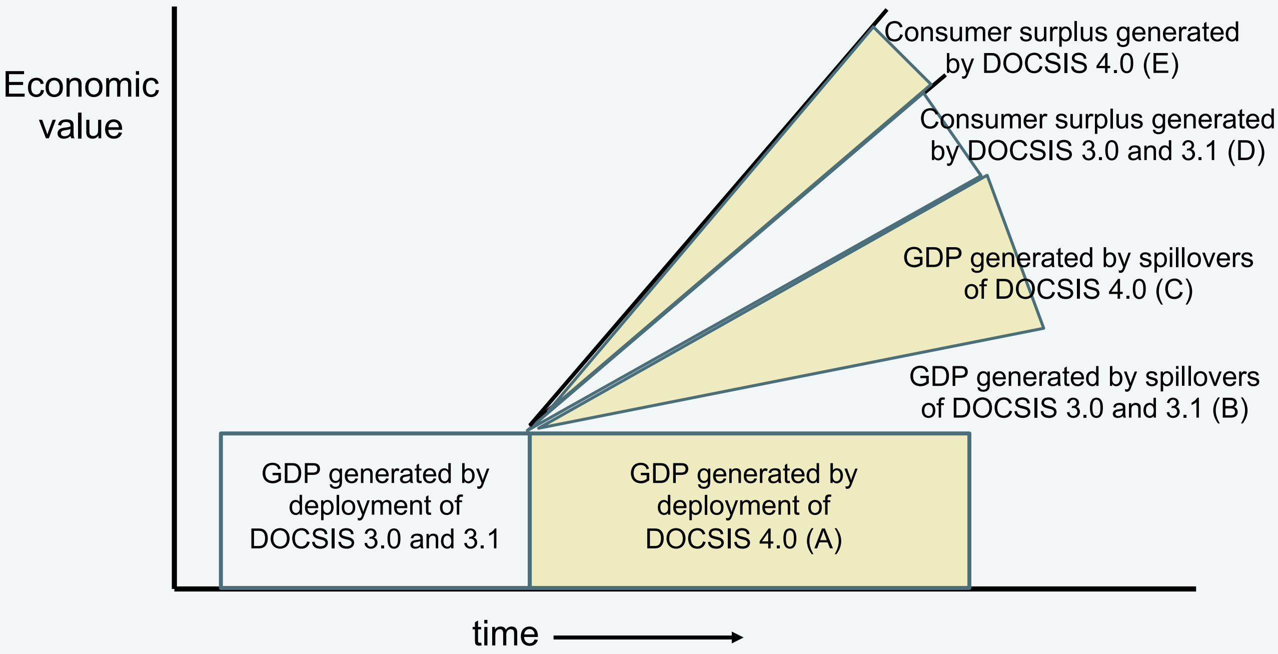
FIGURE 2-1. ECONOMIC CONTRIBUTION OF 10G



Source: Telecom Advisory Services

These three effects do not appear simultaneously and need to be assessed in terms of their impact over time. In addition, spillovers are estimated once the migration to 10G infrastructure begins. Therefore, their impact on GDP growth and job creation will be added to the construction and equipment purchase effect on output and employment (Katz et al., 2009; Katz, 2012). However, since spillovers materialize as a result of the ongoing increase in broadband speed, it is important to differentiate the portion of the growth in speed that can be attributed to a natural inertia-driven increase versus the part that takes place when the migration to 10G infrastructure begins. Finally, since GDP measures output at market prices, it does not capture the utility attached to consumer surplus. Thus, for purposes of measuring total economic value derived from 10G, we add the surplus attributable to 10G (that is, exclusive of any increase that would happen in the absence of 10G) to GDP spillovers.

FIGURE 2-2. FRAMEWORK FOR ASSESSING ECONOMIC VALUE OF 10G



Source: Telecom Advisory Services

According to the framework of figure 2-2, the economic value of 10G attributable to DOCSIS 4.0 will be estimated by adding the effects depicted in areas A, C, and E. The GDP generated as the network evolves to the DOCSIS 4.0 standard (area A) represents an extension of the construction effect triggered by current capital spending in network modernization. Once the migration to DOCSIS 4.0 begins, spillovers and consumer surplus attributed to the increase in speed and quality, like reduced latency attached to the technology, will begin to emerge (areas C and E). However, to estimate the incremental effects from 10G attributable to DOCSIS 4.0, we need to subtract the economic effects yielded by the average increase in speed resulting from the natural progress of DOCSIS 3.1 that would occur in the absence of 10G (areas B and D) from the amount that will occur as a result of 10G (E and C).

3. ENABLEMENT OF EMERGING APPLICATIONS AND USE CASES BY 10G NETWORKS

A fundamental driver of the economic value of 10G resides in its capability to enable innovative applications and use cases. These applications will be deployed within the consumer, enterprise and public services markets, and have significant impact on enterprise productivity, health care delivery and consumer wellbeing. It is not possible to know with full certainty what applications such speeds will enable - much like the developers of 3G technologies did not envision the full impact of the iPhone. However, only by making the capability available will many new applications be developed. **Notwithstanding all the future applications that this sort of capability will enable and that are impossible to predict at this stage, these are some that we know are in the pipeline and will take advantage of these speeds.**

Our analysis of the value of emerging applications is complicated by the fact that the value of 10G functionality cannot be easily disaggregated from the contribution of other technologies (such as augmented reality). As explained below,

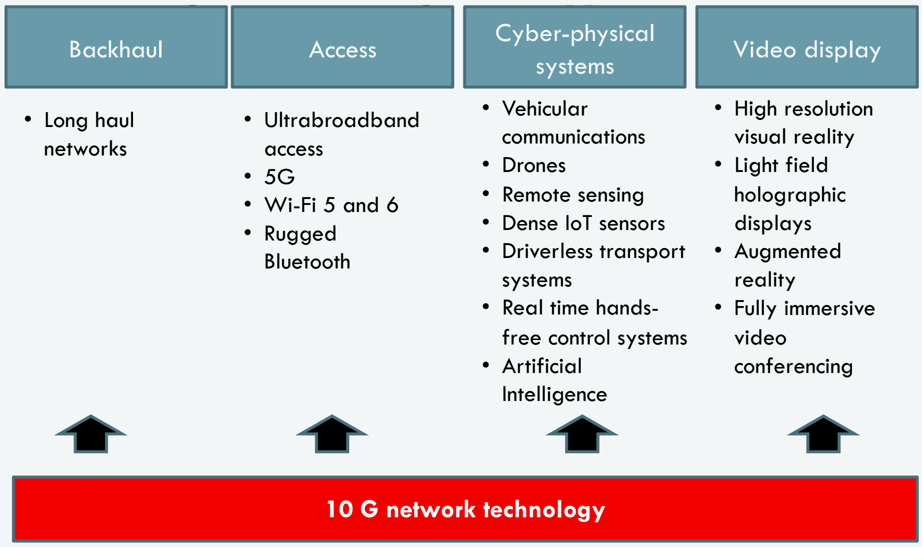
> the emerging applications and use cases that will improve enterprise performance will be implemented and developed within an environment that combines multiple technologies, including 10G.

This universe of relevant technologies can be grouped into four areas:

- Access: technologies that provide the connectivity to end-user devices.
- Backhaul: technologies that provide high performance transport capacity from nodes and points of signal distribution, such as wireless base stations and Wi-Fi hotspots.
- Cyber-physical systems: systems built around the integration of computing power, networking, and physical process. Computers and networks monitoring and controlling physical processes, which in turn, generate feedback loops into computers.
- Video displays: devices capable of displaying video signals and integrating them into the delivery of new information.

Within this typology, 10G technology will play a critical role facilitating the flow of information among devices and display components (see figure 3-1).

FIGURE 3-1. TECHNOLOGIES CONTRIBUTING TO NEW APPLICATIONS AND BUSINESS MODELS



Source: Telecom Advisory Services

3.1. PUBLIC SERVICES

E-HEALTH

e-Health use cases built around accessing ultra-fast broadband are predicated on productivity improvement in data download, and support in conducting remote medical procedures. The ongoing pandemic has prompted changes in health care delivery aimed at reducing staff exposure to infected patients, which in turn have raised the importance of digital infrastructure to deliver remote services.

> While e-health technology is not new, COVID-19 is highlighting the need to adopt platforms relying on high capacity broadband networks such as 10G.

Four types of use cases appear to be particularly relevant to enhance the capacity of the health care system to face the pandemic: (i) connectivity for early COVID-19 detection, (ii) remote diagnostic, (iii) tele-surgery, and (iv) remote health care training.

While the first type of use case is still embryonic, its potential is significant. Developed by King's College in the University of London with support of Great Britain's National Institute of Health, **the COVID-Collab platform aims at combining the input of multiple wearable devices to detect early symptoms of COVID-19** such as cardiac frequency during resting hours and sleeping patterns.[26] The combination of multiple sensors and transmission of data to processing platforms could be efficiently transmitted through 10G to provide early warning and potentially traceability information.

26 Valdovinos, C. (2020). COVID Symptom Tracker. DPL News (August 19).

High capacity broadband is also critical in delivering imaging medical data that requires extremely large bandwidth to be transmitted. As an example, **a 2 Gigabyte CT scan requires 11 minutes to be transferred over a 100 Mbps connection.**[27] **As an alternative, 1 GB link reduces the transmission time to 17 seconds.** This will enable doctors in a central location to read diagnostic images uploaded from multiples locations.

The third application area in e-Health is the ability to conduct remote procedures via the use of ultrafast broadband such as 10G. Originally approved by the Food and Drug Administration in the United States in 2000, the da Vinci Surgical system is a robot that performs operations while being remotely controlled by a surgeon from a console[28]. This system also delivers highly magnified, 3D high-definition views of the surgical area and requires stringent synchronization and low latency requirements, both on the display and on the sensors capturing the motion and position of the instruments[29]. While some research indicates that surgeons can adapt up to 200 Ms.[30],

> some tele-surgical operations require latencies between 3 and 10 Ms.[31] This 3D high definition imaging, combined with the delivery of extremely precise remote commands, require very high bandwidth.

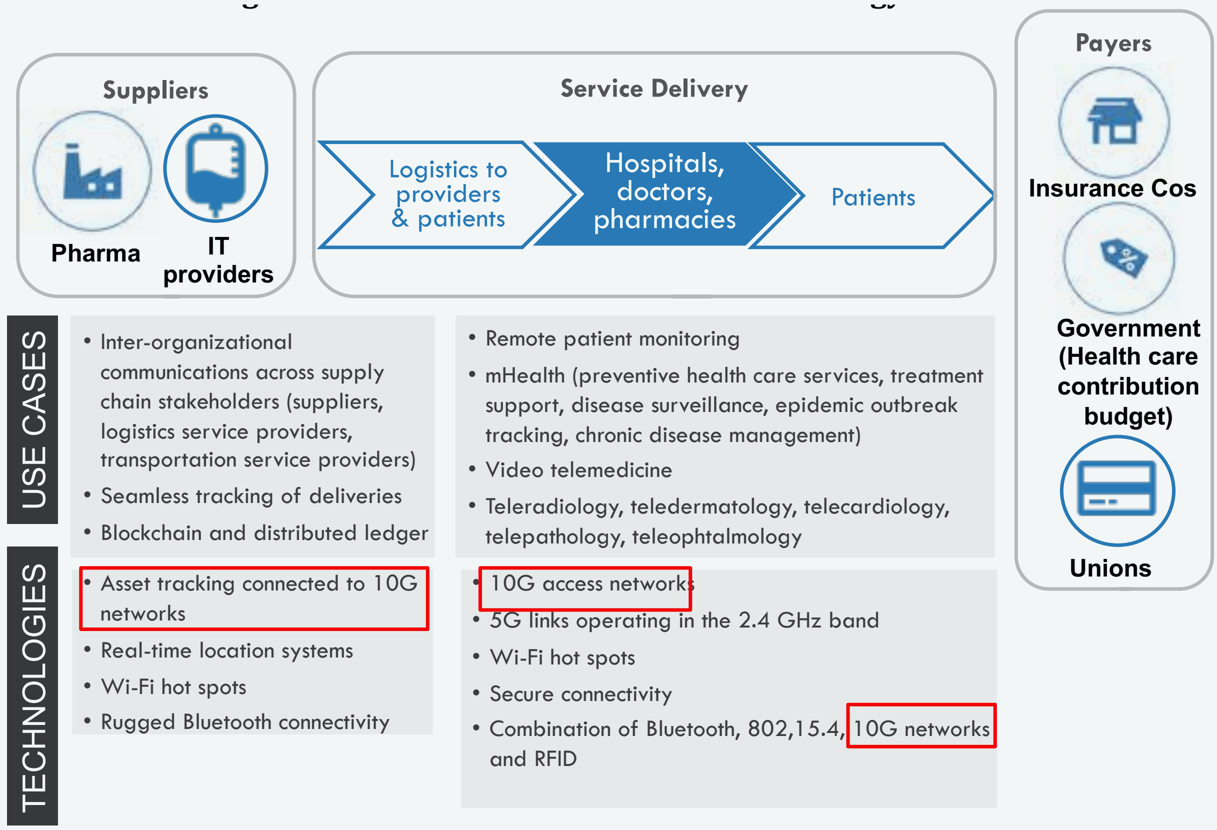
More recently, the Medivis platform integrates augmented reality and holographic visualization to guide surgical navigation[32]. The integration of imaging and virtual reality is also being researched for enhancing certain types of interventions. A study conducted in the Nanjing Medical University of China reports of a platform that relies on computed tomography and MRI images to create a computer-aided design model of the patient to undergo spinal surgery. This CAD image is imported into a computer and relayed to a virtual headset worn by the surgeon. The surgeon sees these 3D virtual images of the patient's spine in combination with the patient's real body in a mixed reality environment. This **virtual projection is used to guide accurately needles into the patient's injured vertebra, significantly improving the outcome of the surgery.**[33]

Finally, **virtual reality based medical training supported by 10G is a cost-efficient option to prepare health care staff for medical emergencies**[34]. This type of platforms can be adapted to provide training for doctors, nurses, and even non-first responders.[35]

In addition to all the applications reviewed above, 10G will provide an efficient connectivity framework between patients, care providers, and monitoring equipment. It will also support the delivery of HD image quality in specialties such as dermatology and wound care. Applications in this area include ubiquitous access to imaging and medical records, advanced telemedicine (including treatment using robotics and AR/VR), and remote clinical care. In this context, 10G will be a critical enabler (see figure 3-2).

27 Similarly, an echocardiogram study would require 10.1 minutes over a 50 Mbps line (see Saunders, J. et al. "Broadband applications: categories, requirements and future networks", First Monday, Volume 17, Number 11).
28 Source: Jason Buckweitz, Columbia Institute for Tele-Information.
29 Source: Cedric Westphal, Huawei.
30 Perez, M. at el. (2016). "Impact of delay on telesurgical performance: study on the robotic simulator dV-Trainer", International Journal of Computer Assisted Radiology and Surgery, April, Volume 11, Issue 4, pp. 581-587.
31 Zhang, Q. et al. (2018). Towards 5G Enabled tactile robotic telesurgery (Mar 9).
32 Shieber, J. (2019). Medivis gets FDA approval for its augmented reality surgical toolkit. TechCrunch.
33 Carfagno, J. (2019). Spinal surgeons perform better when using virtual reality. Docwirenews (August 9).
34 Immersive education: CHLA and Oculus expand VR Medical training programs to new institutions.
35 Jenkins, A. (2019). Walmart CEO: VR Training Helped Save Lives in El Paso Shooting. Fortune (August 20).

FIGURE 3-2. E-HEALTH: USE CASES AND TECHNOLOGY ENABLERS



Source: Telecom Advisory Services

The use of e-Health platforms will be stimulated by government support originated within the telecommunications sector and even from the health care eco-system aimed at improving the system performance in the context of the pandemic.[36] **The necessity of increased use of e-Health solutions was recognised by the Commission in its 2018 Communication on the Transformation of Digital Health and Care[37]; this has only been sharpened as a result of the pandemic.**

36 On March 30, 2020, the International Nursing Association of Clinical Simulation and Learning (INACSL) and the Society for Simulation in Healthcare (SSH) supported the use of virtual simulation as a replacement for clinical hours for students currently enrolled in health sciences professions (i.e. nursing students, medical students) during the current public health crisis caused by COVID-19.

37 See European Commission (2018). Communication From The Commission To The European Parliament, The Council, The European Economic And Social Committee And The Committee Of The Regions, Brussels (April 25). on enabling the digital transformation of health and care in the Digital Single Market; empowering citizens and building a healthier society

SMART CITIES

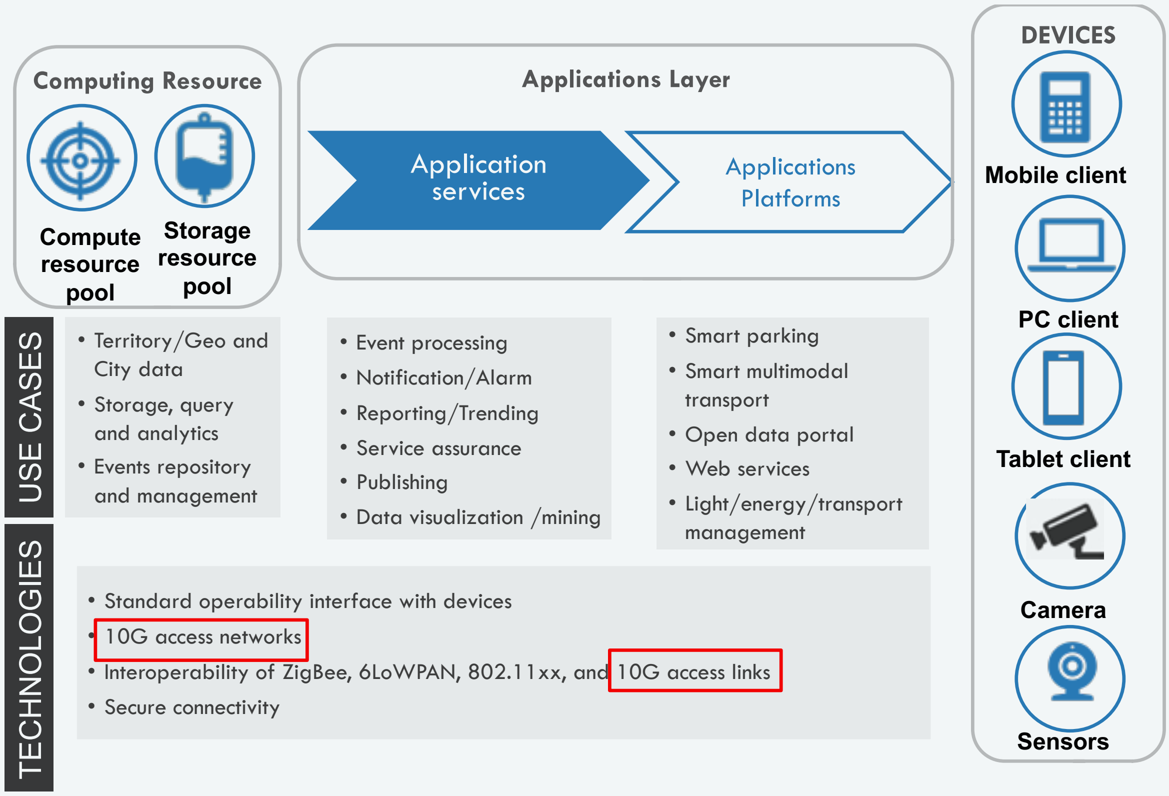
Many different types of applications and potential new business models coexist under the umbrella concept of "smart cities". Some of the key technology applications include lighting, security, energy/utilities, physical infrastructure environmental monitoring, and transportation/mobility. 10G networks will play a key role in these applications through interconnection and backhauling of the myriad of wireless devices used to deliver these services.

Smart city applications require real time, voice and video communications that rely on the use of conventional network protocols such as Bluetooth, Zigbee, and Personal Area Network (PAN) for access.[38] In general, these applications have low bandwidth and low latency requirements. The continued increase of devices will likely require the high capacity backhauling of 10G networks. Additionally,

> some applications, such as intelligent transportation systems (which require the data to arrive within milliseconds in order to allow the control systems to react accordingly) require high bandwidth and low latency that 10G can supply.

10G networks will become a critical component of the smart city infrastructure (see figure 3-3).

FIGURE 3-3. SMART CITY: USE CASES AND TECHNOLOGY ENABLERS



Source: Telecom Advisory Services

38 Jawhar, I. et al. (2018). "Networking architectures and protocols for smart city systems" Journal of Internet services and applications, 9-26

Smart City applications using wireless sensor networks linked through a 10G backhauling infrastructure include the following:

- Citizens can monitor the pollution concentration in each street, or they can get automatic alarms when the radiation rises to a certain level;
- Municipal authorities can optimize the irrigation of parks or the lighting of the city;
- Water leaks can be easily detected, or noise maps can be generated;
- Vehicle traffic can be monitored in order to modify the city's traffic lights in a dynamic way;
- Motorists can get timely information to locate a parking space, saving time and fuel. This information can reduce traffic jams and pollution, while improving the quality of life.

For researchers to provide some estimates of the economic value derived from the deployment of Smart City infrastructure, it is necessary for them to break down its multiple benefits:

- Improved mobility: Strong ICT infrastructure and sustainable transport systems;
- Economic growth: High productivity, entrepreneurship and ability to transform;
- Sustainable environment: Sustainable resource management, pollution prevention, and environmental protection;
- Quality of life: Cultural facilities, housing quality, health and safety issues; and
- Better administration: Political strategies and perspectives, transparency and community participation in decision-making.

Within the first category, a study by the Harvard Centre for Risk Analysi[39] estimates a monetized value of public health losses of approximately $31 billion from traffic congestion and the resulting motor vehicle emissions in 83 U.S. cities. On top of this is a $60 billion cost of wasted time and fuel due to congestion in the same cities.[40] While these costs can be addressed through multiple policy initiatives, traffic light synchronization and more efficient response to traffic incidents (both enabled by wireless sensors operating in unlicensed spectrum bands) can also be positive contributors. **Analysts[41] estimate that, under certain conditions, traffic light synchronization reduces congestion by up to 10% and air pollution up to 20%. This would result in an added economic benefit of $15.1 billion only from the mobility bonus.**

In addition to environmental gains, smart cities contribute to economic growth. Efficient transportation and improvements in quality of life can attract economic activity to cities and boost productivity. Making a city more attractive helps provide business with the labour force to create its products and buyers to consume them. For example, researchers[42] found that 40% of employment growth in U.S. metropolitan areas is due to improvements in the quality of life. While the research only isolates the effect of consumer related factors (e.g. restaurants) affecting quality of life, it would be reasonable to assert that the latter is driven as well by innovations pertaining to the deployment of Smart City infrastructure.

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39 Levy, J., Buonocore, J. and Von Stackelberg, K. (2010). Evaluation of the public health impacts of traffic congestion: a health risk assessment, Environmental Health, 9:65

40 Schrank, D., Lomax, T. (2007). The 2007 Urban Mobility Report, Texas Transportation Institute.

41 Pantak, M. (2013) Do synchronized traffic lights really solve congestion woes? retrieved from: http://blog.esurance.com/do-synchronized-traffic-lights-really-solve-congestion-woes/#.U6MtvhZy-hN.

42 Shapiro, J. (2005). Smart Cities: Quality of Life, Productivity, and the Growth Effects of Human Capital. NBER Working Paper 11615, September.

3.2. CONSUMER

For many forward-looking consumer applications, technical capabilities that can generate a visual experience close to reality as well as the ability to handle extremely high synchronization and "round-trip" speeds will be needed. In the words of an expert,

> ".... the eye can receive 720 million pixels for each of 2 eyes, at 36 bits per pixel for full colour and at 60 frames per second: that's 3.1 trillion (tera) bits! Today's compression standards can reduce that by a factor of 300 and even if future compression could reach a factor of 600 (which is the goal of future video standards), that still means we need 5.2 gigabits per second of network throughput; maybe more." [43]

10G, with its extremely high throughput and low latency, is ideally suited to facilitate these technologies. More specifically, under these constraints, the use cases reviewed below will require a combination of 5G for high speed mobile connectivity, high speed throughput Wi-Fi routers, and 10G networks for backhaul and, in some cases, fixed connectivity. **Beyond the bandwidth requirement, forward-looking consumer applications are very demanding in terms of low latency.** For example, while immersive videoconferencing can function with latency of a 100 milliseconds latency, some of the applications described below require 10 millisecond or less.

This technology has become more critical for consumers in the context of the COVID-19 pandemic. At the more basic level, under complete or partial lockdown conditions, residential consumers have to rely on ultra-fast broadband to carry out many daily tasks that previously required physical contact. For starters, a four or more-member family relies on multiple broadband devices simultaneously downloading and uploading high volumes of data. In certain families, both parents are operating PCs for conducting cloud computing processing and videoconferencing for teleworking, while the children are engaged in learning simulations and videoconferencing for distance learning. Beyond the increase in traffic driven by existing applications, the new "normal" is putting more pressure on the development of platforms that are better adapted to the current conditions, with the consequent increase in high capacity networks. In the case of distant learning, conventional videoconferencing platforms need to add more functionality for the teaching instructors to sense whether the students are absorbing the concepts or for students to detect whether they are asking too many questions and, therefore, delaying the whole class[44]. **Finally, some consumer applications will become even more important to address the social isolation resulting from the pandemic. One of them is the delivery of remote virtual reality platforms aimed at mitigating the isolation of the elderly living under lockdown conditions.** Some nursing homes have already adopted virtual reality platforms providing 360-degree travel experience[45], while some providers are delivering a blend of entertainment and therapy VR programming for senior residences. Research has shown that virtual reality can capture memory-care patients' attention longer than traditional senior-living programming.[46]

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43 Westphal, C. (2017). Challenges in networking to support augmented reality and virtual reality, Presentation to IETF98 – ICNRG Meeting – 3/30/17.

44 Govindarajan, V. and Srivastava, A. (2020). "What the shift to virtual learning could mean for the future of higher ed". Harvard Business Review (March 31).

45 Lumpkin, L. (2019). A recent college graduate helps nursing-home residents see the world — without leaving home. Washington Post. (October 14).

46 Read, K. (2019). Virtual Reality lets seniors travel without leaving home. Star Tribune (July 123).

TELEWORKING SUPPORT

The gradual deployment of prophylactic measures taken to confront COVID-19, such as the closure of workplaces and home quarantine, has led to a spike in telecommunications network usage. Overall, Internet traffic increased approximately 30%. One of the key changes in traffic patterns has been an increase in broadband uplink driven by the natural increase in the number of devices using video conferencing platforms and cloud computing now connected at home. Data collected from 125 million Wi-Fi routers around the world show an 80% increase in PC uploads to cloud computing with additional peaks from video conference calls observed since the end of March 2020.[47]

Even after the COVID crisis passes, researchers do not expect a full return to the prior working and studying patterns. Flannery et al. (2020) estimate that,

> once the pandemic subsides, we will end up with some hybrid version of today (54% working full/part time from home) and where we were prior to the crisis (27%).

Many more may continue to work from home several days a week, thus still needing the telecommuting infrastructure even if they do return to the office on a semi-regular basis.[48] In this context, 10G technology will be particularly adept at supporting the new teleworking pattern, and capable of handling spikes in traffic triggered by telecommuting, a fact that will become prevalent in the "new normal".

VIRTUAL REALITY/AUGMENTED REALITY

Virtual reality (VR) is a computer-generated simulation which makes the user, through sensory stimulation, feel as if he or she is experiencing a real-world scenario. A virtual reality modelling language creates an interactive sequence of audio, animations, and video content that can be downloaded from the cloud to simulate a virtual environment.

Augmented reality (AR) is defined as the "augmentation" or overlays of a live, direct or indirect view of a physical environment by computer-generated input. It can be delivered on smart phones, tablets or a PC. The technology relies on "markers" that trigger AR animation, after which the software delivers animation or digital information to the user device. Its primary applications, so far, are for business and educational purposes.[49] Beyond these, **augmented reality technology will trigger the development of a whole new set of consumer services and apps (especially in marketing), which will, in turn, require a large amount of bandwidth for an acceptable user experience.**

There are multiple consumer use cases of VR/AR technologies. At the more basic level, there is the personal movie theatre with a head mounted display. From there, it moves into the educational use recreating the experience of a classroom, or a room in a cultural institution, like a museum. A more complex use entails the close to real time delivery of a sports or live event to many users, where each one perceives the experience from a specific field of view. Gaming applications which replicate a virtual environment with interactions between different users in a synchronized manner represent an extension of the MMOG applications reviewed above.

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47 Gil, T. et al. (2020). The new normal: holiday level Wi-Fi upload

48 Flannery, S., Park, L., Lam, L. Roper, A., and Barajas, D. (2020). Mapping the new normal for telecom services & communications infrastructure. Morgan Stanley (June 11).

49 A simple use case is one where a user captures the image of a real-world object, and the underlying platform detects a marker, which triggers it to add a virtual object on top of the real-world image displaying it on the camera screen (see Pokémon Go).

These two technologies - virtual reality and augmented reality - can become very bandwidth intensive and therefore, suited to operate in a broadband environment enabled by 10G. This is especially true if the use case is not mobile, although even in mobility applications, 10G would fulfil a backhauling function linking the 5G base station or the Wi-Fi hot spot to the cloud. For example, a low resolution of 360o virtual reality platform would require 25 Mbps bandwidth for streaming. However, **if the device is providing image quality comparable to high definition TV, 80-100 Mbps bandwidth is required. Finally, a "retinal" 360o video delivery would require at least 600 Mbps.**[50] As in the case of Massively multiplayer online gaming, while this technology could be supported by networks with lower speeds than that provided by 10G if connected on a standalone basis, it would be significantly hampered when being part of a network of devices connected to a single hub (see below).

In the case of augmented reality, the 360o low-resolution videos also require approximately 25 Mbps of throughput for streaming.[51] However, **most applications require at least 100 Mbps throughput and latencies of as low as 1 Ms.** However, if there is a requirement to extend the dynamic range and resolution that cameras are capable of capturing, the bitrate should increase by orders of magnitude. As an example, a retina level AR display without compression will require several Gbps of throughput to generate a fully immersive experience.[52] Likewise, low latency is a key quality feature of AR technology. For example, 20 Ms. latency produces a perceivable video delay, while even 10 Ms. yields jitter.[53] This issue becomes a concern in enterprise-based applications of augmented reality.

IMMERSIVE VIDEO/8K ENTERTAINMENT

As video quality continues to improve with higher resolution and more dynamic colour and brightness, video streaming is likely to require higher speeds. More intensive usage will likely arise from other applications and services as well. More immersive video technologies, such as higher-resolution virtual reality or light field holographic displays (discussed below), also will require greater bandwidth.

Ultra-high definition 8K has twice the horizontal and vertical resolution of 4UHD with four times as many pixels overall (and sixteen times more than the 1080 HDTV format). While it is difficult to predict overall consumer adoption of this technology, given the lack of available content, if widespread adoption occurs, it will create the need for additional bandwidth. In this case, however, future bandwidth need will have to be assessed in the context of adoption of enhanced video compression standards. It is estimated that, **absent better compression, 8K bit rate requirement could reach between 80 Mbps and 100 Mbps for each channel stream.**[54] **While a single 8K set could be handled by networks with lower speeds than that enabled by 10G, its adoption within a multi-device multi-family household could result in the need to transition to such networks.**

50 Mastrangelo, T. (2016). "Virtual Reality check: are our networks ready for VR?", Technically speaking
51 Source: Cedric Westphal, Huawei.
52 Source: Mushroom Networks.
53 Source: Mike Wittie, Montana State University.
54 Kishore, A. (2017, Oct.). Worried about bandwidth for 4K? Here comes 8K! Light Reading, Retrieved from http://www.lightreading.com/video/4k-8k-video/worried-about-bandwidth-for-4k-here-comes-8k!/d/d-id/737330.

MASSIVELY MULTIPLAYER ONLINE GAMING

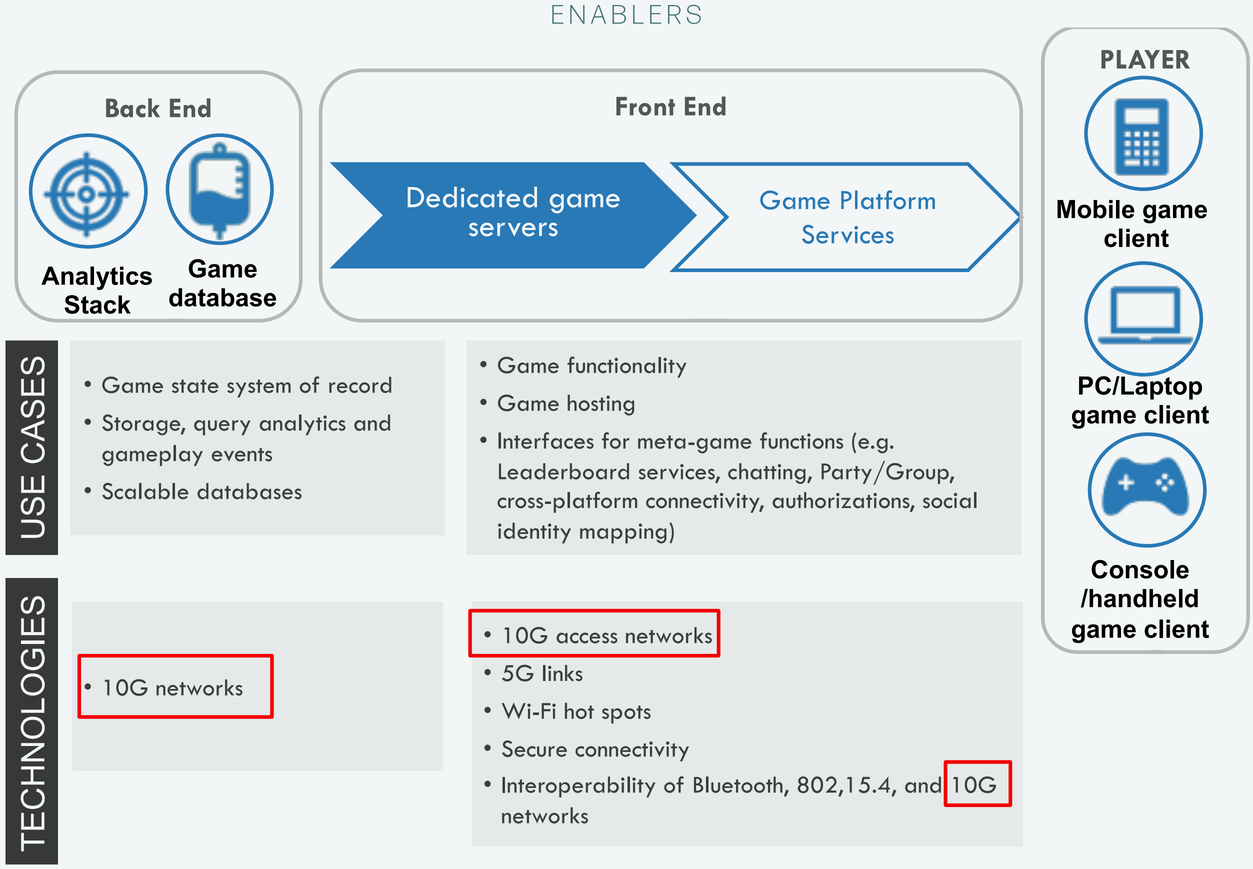
A massively multiplayer online game (MMOG) involves a large number of players, interacting with the same server. From a technology standpoint, an online multiplayer game is a virtual environment generated by computers, in which users that are geographically distributed perceive a graphical representation of a virtual world and control their virtual character known as avatar. This functionality drives high volumes of data transfers from information exchange, moving characters, and conducting other actions. MMOG platforms typically face a scalability challenge because they must handle a large number of connected players, while presenting them with a consistent view of the virtual world.

Under a centralized server configuration, MMOG systems require high bandwidth combined with low latency to be delivered in a consistent manner to all users.[55] The more dynamically rich a game environment is, the higher the requirement for bandwidth. For example, research in future development highlight the need for several technical features[56] that could be better delivered by 10G networks:

- Development of a more immersive "world" to lower a player's suspension of disbelief
- Upgrade of the game engine to include collision detection and game physics
- Latency reduction
- More developed graphics and effects

In this context, 10G could become a key enabler of future gaming networking architectures (see figure 3-4).

FIGURE 3-4. MASSIVE MULTIPLAYER GAMING: USE CASES AND TECHNOLOGY ENABLERS



Source: Telecom Advisory Services

55 Ali, A. F. et al. "An overview of networking infrastructure for Massively Multiplayer Online Games", Conference Proceedings, pp. 619-628.

56 Achterbosch, L. (2008). "Massively multiplayer online role-playing games: the past, present and future", ACM Computers in Entertainment, Vol. 5, No. 4, article 9.

High throughput enabled by 10G networks can facilitate links between the devices in use and games servers. Alternatively, 10G networks can also serve as the back-haul transport facility operating in the background for remote mobile devices.

As lockdowns and quarantine at home have been dictated around the world to face the coronavirus pandemic, **online gaming has emerged as a popular means of addressing social isolation.** With the practice of social distancing reducing consumer and business activity to a minimum, gaming offers an engaging distraction for people at home looking for social interaction. In Italy, Telecom Italia reported that large contributor to the

> 70% increase in fixed network traffic is online games such as Fortnite[57] since March 2020.

New platforms are under development to face this growing need but aiming to rely on high throughput broadband networks and cloud computing.[58]

3.3. ENTERPRISE

An enterprise use case is an application based on a combination of multiple technologies aimed at restructuring production processes, driving business value by solving specific operational problems or addressing bottlenecks. Such an application can reduce the time to market for product development, improve responsiveness to changes in demand, increase efficiency in resource management, and/or facilitate the development of new products. As stated above, 10G networks will play a key role as enablers in the delivery of use cases that will make a significant contribution to enterprise productivity.

PRECISION AGRICULTURE AND FOOD PROCESSING

Precision agriculture represents a systems-based approach for site-specific management of crop production systems. The efficiency of agricultural machinery can be increased through the deployment of sensors (grain yield, optical sensors for weed detection, and control systems for fertilizer spreading) which are linked to standardized bus systems to transmit data streams. In fact, most of the benefit of precision farming systems will come from whole farm management uses, which would include the use of sensors, remote sensing and telemetry.[59] Sensor networks are dependent on deploying point-to-point and point-to-multipoint network technologies. Point-to-point communications rely on wireless meteorological stations and RFID tags for field information collection. On the other hand, point-to-multipoint communication for data collection relies on 802.15.4 and 61oWPAN, as well as Wi-Fi and ZigBee, which both operate in the 2.4 GHz band.

57 Lepido, D. and Rolander, N. (2020). “Housebound Italian kids strain network with Fortnite marathon”, Bloomberg, April 22.

58 Business Research Company (2020). “Video gaming reaches an all-time high since COVID-19 lockdown initiation”. Cision (May 5).

59 Lowenberg-DBoer, J. (2000). Economic analysis of precision farming. Federal University of Vicosa, Retrieved from: http://www.ufrrj.br/institutos/it/deng/varella/Downloads/IT190_principios_em_agricultura_de_precisao/livros/Capitulo_7.pdf.

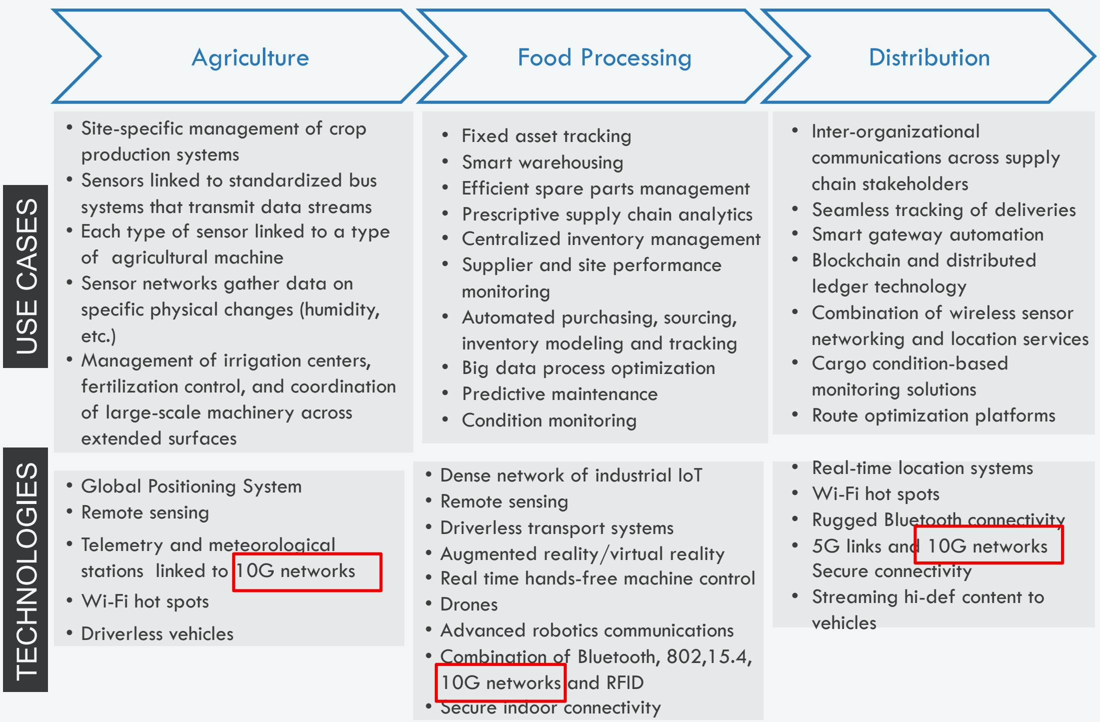
This combination of wireless technologies is extremely dependent on deep fibre connectivity, such as the one provided by 10G[60] . Satellites are not suited to precision agriculture due to their high latency, capacity limitations, and economics.

> As technology advances and the volumes of data to manage agriculture production grow, higher speeds will likely be necessary, requiring more symmetrical data flows, with a better balance of download and upload speeds and reliability.[61]

The European Commission has recognised the necessity of increased use of precision agriculture to improve the sustainability, resilience and competitiveness of the sector, in addition to the improvements that such technologies can make in the lives of farmers. In April 2019, twenty-five European countries signed a Declaration of cooperation on ‘A smart and sustainable digital future for European agriculture and rural areas’ to take a number of actions to support a successful digitisation of agriculture and rural areas in Europe. It recognises the potential of digital technologies to help tackle important and urgent economic, social, climate and environmental challenges facing the EU’s agricultural sector and rural areas.[62]

Figure 3-5 presents the multiplicity of use cases that can have an impact on the agricultural and food processing value chain as well as the role 10G networks can fulfil in facilitating their implementation.

FIGURE 3-5. AGRICULTURE AND FOOD PROCESSING: USE CASES AND TECHNOLOGY ENABLERS



Source: Telecom Advisory Services

60 See United States Department of Agriculture (2019). A case for rural broadband: Insights on rural broadband and next generation precision agriculture technologies. Washington, DC, April.

61 Ibid., p. 3.

62 European Commission (2019). “EU Member States join forces on digitalisation for European agriculture and rural areas”. Digibyte, April 9.

The impact of precision agriculture, and therefore the economic value of the technologies that will enable it, can be estimated based on its contribution to the increase in total factor productivity through more efficient use of labour and other inputs (water, seeds, fertilizers) along with improved timeliness of operations (optimization of agronomic windows, reduction of spoilage and harvest losses).

SMART LOGISTICS

The logistics of supply chains is a complex sequence of coordinated activities, comprising the following components: merchandise transport, warehousing, customs operations, payments operations, as well as the operations outsourced to third parties by producers and sellers. The efficient performance of logistics depends on factors ranging from agreements facilitating cross-border commerce to the infrastructure of gateways, roads, and last mile transportation links. Telecommunications is a critical enabler of the efficient functioning of logistics at multiple levels:

- Inter-organizational communications across supply chain stakeholders (suppliers, OEMs, logistics service providers, transportation service providers, supply chain nodes, customs agencies)
- Seamless tracking of deliveries
- Smart gateway automation (cargo handling, paperless processing, customs interfaces)
- Blockchain and distributed ledger technology
- Warehousing robotics
- Combination of wireless sensor networking and location services
- Cargo condition-based monitoring solutions
- Route optimization platforms

10G networks will enable a portfolio of networking platforms that will facilitate the deployment of smart logistics use cases:

- Interconnect remote sensing devices
- Real-time location systems
- Provide backhaul for Wi-Fi hot spots
- Rugged Bluetooth connectivity
- 5G links operating in the 2.4 GHz band
- Secure connectivity
- Streaming high definition content to vehicles

> The deployment of smart logistics use cases has been proven to drive significant economic benefits such as a 5% reduction in supply coordination costs, 5% improvement in on-time delivery of merchandise, and 3% to 25% reduction in raw materials purchasing costs.[63]

63 World Economic Forum (2017). The impact of the Fourth Industrial Revolution on supply chains.

SMART MANUFACTURING

Smart manufacturing is defined as the use of advanced technology to resolve production challenges. It should be noted, however, that smart manufacturing contributes not only to increasing productivity but can also have a positive impact on product quality, worker safety, and improved customer experience downstream.

High-speed broadband is a critical enabler of smart manufacturing at two levels. First, 10G will enable intra-firm manufacturing use cases such as 3D printing/additive manufacturing, 3D digital modelling, modelling simulation and analysis, and cloud-based distributed enterprise resource planning.[64]

The second level where broadband plays a critical role is in the facilitation of inter-organizational communication with suppliers of parts and raw materials. In general, manufacturing value chains are comprised of many actors, both upstream and downstream of the producer.

Like the use cases related to smart logistics, given the multiplicity of actors participating in the manufacturing chain, proper orchestration among them requires the ability to share correct and timely information about the status of the different processes. Among the benefits of greater coordination are better inventory control, more efficient use of resources and equipment, cost and time reduction in the different processes, better monitoring of and faster reaction to changes in demand, greater logistical flexibility and better financial results.[65]

The increasing complexity of manufacturing chains makes it even more necessary to improve coordination between processes and actors. The greatest complexity is evidenced at the following different levels: (i) network complexity, due to an increase in the number of actors within the chain and the links between them; (ii) complexity of processes, due to an increased amount of them; (iii) product complexity, due to the higher number of components; (iv) demand complexity, due to an increase in demand volatility and fragmentation; and (v) organizational complexity, due to the greater number of levels involved and their tendency to work in silos (Christopher and Holweg, 2011).

High-speed broadband can enable a rich list of both intra-firm and inter-organizational use cases (see table 3-2).

64 Source: Irene Petrick, INTEL.
65 Source: Agustina Calatayud, Inter-American Development Bank.

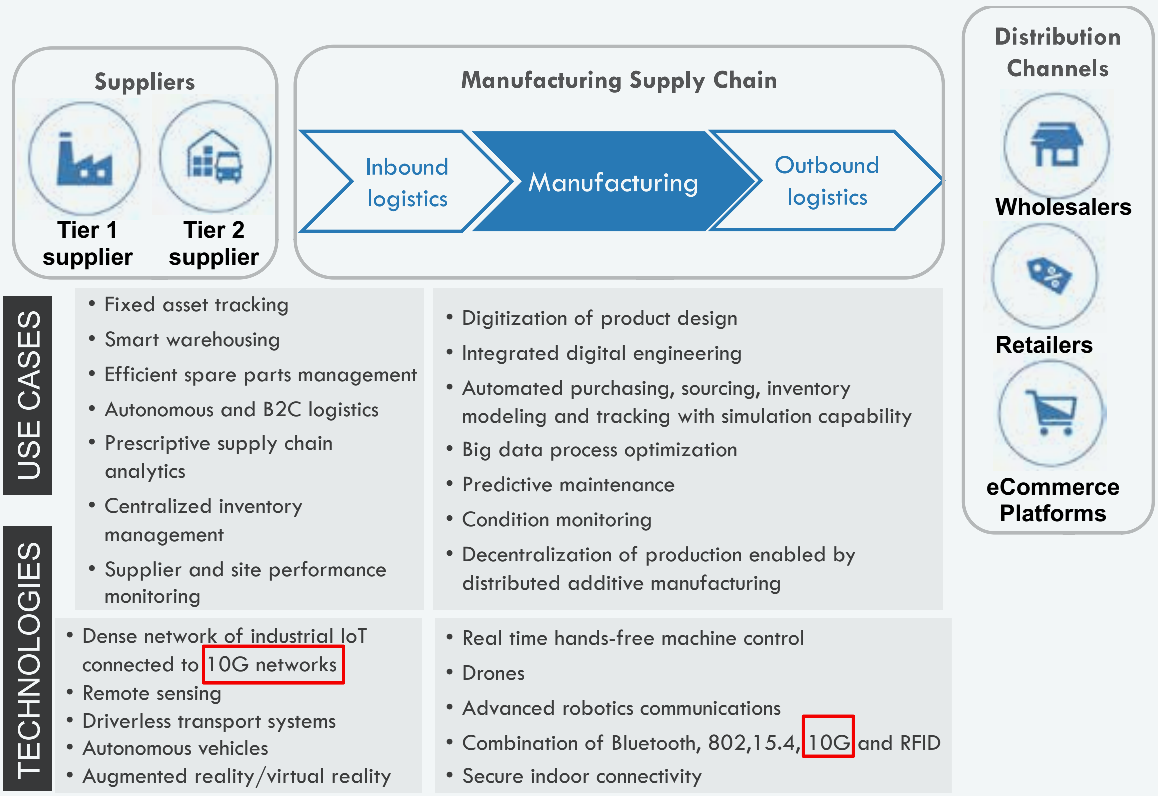
TABLE 3-2. IMPORTANCE OF BROADBAND IN SMART MANUFACTURING USE CASES

Use case	Importance of broadband as an enabler
Predictive maintenance (detection through temperature, audio signal and/or machine vibrations monitoring, using historical data)	High
Remote assistance using augmented reality	High
Real time asset performance monitoring and visualization	Medium
Digitized standard procedures for line operations with integrated workflow and multimedia sharing	Low
Expanded high-performance computing to reduce product design simulation life cycles	High
Rapid design prototyping through 3-D additive manufacturing	High
Single platform for real time supply chain decisions	Medium
Cost optimization of operations through sensor analysis	High
Enterprise manufacturing intelligence system to upgrade operations management	Medium
Automation and optimization of manual material selection and inventory management	Low
Part traceability from unique digital tag based on surface scanning	High

Source: World Economic Forum (2018). The next economic growth engine: Scaling Fourth Industrial Revolution Technologies in production

Use cases, enabled by high speed broadband, are deployed along all stages of the manufacturing value chain (see figure 3-6).

FIGURE 3-6. SMART MANUFACTURING: USE CASES AND TECHNOLOGY ENABLERS



Source: Telecom Advisory Services

4. IMPACT OF INVESTMENT IN THE MIGRATION TO 10G

The estimation of the one-time effect of the migration to 10G is based on the total capital investment expected to support the commercialization of this technology, broken down into the sectors that will receive the corresponding spending (electronic equipment, construction, etc.). We first estimate the investment per sector, and input this into the corresponding "rows" of the input/output table. This allows us to estimate the impact on output, value added, and employment. These estimates include direct effects (triggered by investment in network infrastructure), indirect effects (generated in the supply of goods and services in support of direct spending), and induced effects (produced by household spending based on the income earned from the direct and indirect effects).

4.1. CALCULATION OF CAPITAL SPENDING RELATED TO THE MIGRATION TO 10G[66]

The amount of capital required to advance the evolution of cable's 10G platform is dependent on how deep the fibre is extended in the network, and consequently how many homes are passed per node (this is referred to as a service group). The depth of fibre deployment also determines the amount of electronic equipment (e.g. amplifiers) needed

Beyond fibre deployment, 10G requires additional electronic equipment. For example, Cable Modem Termination System (CMTS) capacity must be added to each new service group created. Moreover, upgrades to Digital Optics (10G Ethernet) are required for deploying Distributed Access Architectures, such as installing Remote PHY, MAC/PHY of the emerging Flexible MAC architecture (FMA) standard. Finally, full 10G capabilities will require installing new set-top boxes or Digital Terminal Adapters in the customer premise to free valuable spectrum while also upgrading the modem in the home to be able to receive the new speeds.

The economics for migrating to 10G varies depending on the network starting point and the approach to be followed by the cable operator:

- **Total homes passed:** For three European countries (Belgium, Netherlands and Switzerland), estimates of homes passed were determined based on the triangulation of three sources: a calculated estimate based on IHS Market data for 2017, a reported estimate by IDATE for September 2018, and a forecast value by Kagan for 2019 (see table 4-1).

66 The following investment numbers are based on the calculations and methodologies set out in this Section 4.1 and are based on applying the rear view mirror principle where possible. This principle is a relevant indicator for future investment predictions. However, reality may differ from these estimates due to economic, social, technological or regulatory changes.

TABLE 4-1. EUROPEAN COUNTRIES: TOTAL BROADBAND HOMES PASSED

Country	Cable Internet Subscribers	Percent of cable homes taking Internet	Cable broadband homes passed
Belgium	1,983,820	0.4379	4,530,300 (*)
Netherlands	3,371,300	0.4736	7,339,700 (*)
Switzerland	1,245,000	0.4293	2,900,000 (*)

(*) Estimated

Sources: IHS Markit (2018). European Broadband Cable 2018.IDATE DigiWorld for FTTH Council Europe; S&P. Global Forecast Tables; Telecom Advisory Services analysis.

For the remaining countries, we compiled the German data from ANGA, The Broadband Association (2020) that reports that 28,300,000 homes are Cable Broadband Passed. For Ireland and United Kingdom, data was sourced from Liberty Global PLC Form 10-K (2019), that reports that for Ireland 939,900 homes are Cable Broadband Passed and for United Kingdom the value is 14,894,400 homes.

We estimate the size of cable's investment for the migration to 10G using the historical data of Liberty Property and Equipment additions reported in Liberty Global PLC Form 10-K (2019) between 2017 and 2019 and in Liberty Global Fixed Income Release Q42019 (see Table 4-2).

TABLE 4-2. 10G INVESTMENT

		Belgium	Germany	Ireland	Netherlands	Switzerland	United Kingdom
Cable broadband homes passed ('000)		4,530	28,300	940	7,340	2,900	14,894
Annual investment (€'000'000) (*)		€ 341	€ 2,253	€ 43	€ 494	€ 189	€ 674
Annual Cost per Home Passed		€ 75.31	€ 73.26	€ 45.23	€ 67.35	€ 65.30	€ 45.23
Number of years		4	4	4	4	4	4
Total investment (€'000'000)	Construction (**)	€ 798	€ 5,269	€ 99	€ 1,156	€ 443	€ 1,575
	Electronics (***)	€ 567	€ 3,742	€ 71	€ 821	€ 315	€ 1,119
	Total	€ 1,365	€ 9,011	€ 170	€ 1,977	€ 758	€ 2,694
Annual investment (€'000'000)	Construction	€ 199	€ 1,317	€ 25	€ 289	€ 111	€ 394
	Electronics	€ 142	€ 936	€ 18	€ 205	€ 79	€ 280
	Total	€ 341	€ 2,253	€ 43	€ 494	€ 189	€ 674
	Total (in loc. curr.)	€341	€ 2,253	€ 43	€ 494	CHF 203	£ 602

(*) Property and Equipment Additions + Proportional of Central and Corporate Spending - Customer Premises Equipment Share Spending (using Liberty Global Fixed Income Release Q42019 and Kagan shares) - Upgrade and Rebuild Spending (using Liberty Global Fixed Income Release Q42019 and Kagan shares). For Belgium and Switzerland, we adjusted the number to represent the full market. Germany's value was estimated using UK/Ireland Cost per Homes Passed

(**) 58.47% of total investment using Kagan estimates for the United States

(***) 41.53% of total investment using Kagan estimates for the United States

Source: ANGA The Broadband Association; Liberty Global PLC Form 10-K (2019); Liberty Global Fixed Income Release Q42019; Kagan. Update S&P Global Investment Numbers (2020); Telecom Advisory Services analysis

The total **investment for 10G deployment over four years (time estimated to require 10G roll-out)** was split between the amount to be assigned to construction vs. the purchasing of electronic equipment. This generates the values to be inputted in the input/output matrices of each country to estimate the economic impact of investment.

4.2. ESTIMATING THE ECONOMIC IMPACT OF THE MIGRATION TO 10G

Our calculation of the impact of the migration to 10G on GDP and jobs is achieved by entering the sector investment (in electronics and construction) in the input-output tables for each country. This analysis will provide an estimate of direct, indirect, and induced GDP and employment for the total investment and on an annual basis, with the corresponding multipliers. In addition, we quantify the sectors that will benefit the most from the investment, as well as estimate the portion of the total investment that will be used to the purchase foreign goods and services (the "leaked" investment). Additional detail of these calculations is presented in Appendix D.

We estimate that the cable industry in the six countries under study will invest € 15.975 billion over four years (2024-2027) as it migrates to 10G, of which € 6.634 billion will be dedicated to the purchase of electronic equipment (Remote MAC/PHY, Digital optics, node amplifiers, TAP replacements and CMTs), while € 9.340 billion will be spent on construction. This investment will generate € 9.080 billion in additional (indirect and induced) output, resulting in a total GDP impact of € 25.055 billion (see table 4-3).

TABLE 4-3. COUNTRIES STUDIED: TOTAL ONE-TIME GDP IMPACT FROM 10G INVESTMENT (IN € BILLIONS)

Country	Investment			Indirect + Induced	Total Output	Multiplier
	Construction	Electronics	Total			
Belgium	€ 0.798	€ 0.567	€ 1.365	€ 0.855	€ 2.219	1.626
Germany	€ 5.269	€ 3.742	€ 9.011	€ 4.796	€ 13.807	1.532
Ireland	€ 0.099	€ 0.071	€ 0.170	€ 0.059	€ 0.229	1.350
Netherlands	€ 1.156	€ 0.821	€ 1.977	€ 1.317	€ 3.294	1.666
Switzerland	€ 0.443	€ 0.315	€ 0.758	€ 0.405	€ 1.162	1.534
United Kingdom	€ 1.575	€ 1.119	€ 2.694	€ 1.648	€ 4.343	1.612
Total	€ 9.340	€ 6.634	€ 15.975	€ 9.080	€ 25.055	1.568

Source: Telecom Advisory Services analysis

While the GDP multiplier across all countries is 1.568, it ranges between 1.350 for Ireland and 1.666 for Netherlands.

Close to 17.01% of the total output of € 25.055 billion, or € 4.262 billion, corresponds to goods imported to each of the six countries (see table 4-4).

TABLE 4-4. COUNTRIES STUDIED: DOMESTIC VS. IMPORTED GOODS OF TOTAL ONE-TIME GDP IMPACT FROM 10G INVESTMENT (IN € BILLIONS)

Country	Total Output	Domestic additional production	Imported goods	Percent of imported goods
Belgium	€ 2.219	€ 1.778	€ 0.442	19.90%
Germany	€ 13.807	€ 11.428	€ 2.379	17.23%
Ireland	€ 0.229	€ 0.190	€ 0.039	17.06%
Netherlands	€ 3.294	€ 2.757	€ 0.537	16.30%
Switzerland	€ 1.162	€ 1.034	€ 0.128	11.02%
United Kingdom	€ 4.343	€ 3.605	€ 0.738	16.98%
Total	€ 25.055	€ 20.792	€ 4.262	17.01%

Source: Telecom Advisory Services analysis

Finally, spending on 10G will result in the creation of 115,520 job years over a four-year span. Of the total jobs, 69,732 job years will be in the construction sector, 10,254 in electronic equipment, and 6,748 in other manufacturing sectors, plus 28,785 in other, non-manufacturing industries (table 4-5).

TABLE 4-5. COUNTRIES STUDIED: TOTAL ONE-TIME EMPLOYMENT IMPACT FROM 10G INVESTMENT (IN JOB YEARS)

Country	Direct jobs			Indirect + induced			Total jobs	Multiplier
	Construction	Electronics	Total	Manufacturing	Other	Total		
Belgium	4,494	348	4,842	325	1,717	2,042	6,884	1.422
Germany	45,948	7,331	53,279	4,460	18,359	22,820	76,099	1.428
Ireland	588	87	675	33	121	154	829	1.229
Netherlands	5,282	331	5,612	680	3,005	3,684	9,297	1.656
Switzerland	1,883	390	2,273	276	698	975	3,247	1.429
UK	11,538	1,767	13,305	974	4,885	5,859	19,164	1.440
Total	69,732	10,254	79,986	6,748	28,785	35,533	115,520	1.444

Source: Telecom Advisory Services analysis

The average employment multiplier is 1.444, meaning that for every direct job associated with investment related to the evolution of the platform to 10G, 0.444 jobs will be created among the suppliers to the cable industry, and as a result of induced consumption.

Finally, of the 115,520 jobs created, 93,307 will be skilled jobs and the remaining 22,213 will be unskilled jobs.

5. SPILLOVER IMPACT OF 10G NETWORKS ON GDP AND JOB CREATION

As reviewed in chapter 2 and Appendix B, broadband speed has been proven to have an economic impact beyond the GDP and job contribution resulting from the deployment of networks. Denominated "spillovers", this impact reflects the contribution of broadband, especially high-speed offerings, to the whole economy by rendering enterprise operations more efficient, facilitating the reach of new markets, and stimulating the development of new business models. To measure this contribution, we developed two econometric models based on extensive speed data sets for 156 countries between 2008 and 2019 (see Appendix E). The model results indicate that a 1% increase in broadband speed yields a 0.0073 increase in GDP, 0.00232 increase in total new jobs, and 0.01530 increase in service sector jobs.

Spillovers have already materialized as a result of the ongoing increase in average broadband speed yielded by DOCSIS 3.0 and DOCSIS 3.1. However, since we do not quantify those effects in this analysis, we instead focus on estimates that can be exclusively attributed to the DOCSIS specifications that will follow 3.1. To estimate what the increase in average download speeds will be under DOCSIS 4.0 and beyond, we first assume that the natural growth in speeds that has occurred so far within the DOCSIS 3.0 and 3.1 contexts will extend in the future.[67] Then, we develop a projection of average download speed after the migration to 10G begins. For this purpose, it is assumed that by 2027 average speed will be equivalent to approximately 13% of the weighted average download speed of 10Gbps after seven years[68]. Once we complete this forecast, we subtract the evolution of the growth in speed driven by DOCSIS 3.0 and 3.1 (a natural extrapolation of the current trend) from the average download speed under 10G to calculate the increase in speed that is exclusively attributed to this technology. We then use this value as the independent variable in economic impact models (that estimate the contribution of speed to GDP growth and employment).

> The 10G evolution of broadband networks in all six European countries under study will generate spillovers amounting to € 106.825 billion in cumulative GDP, equivalent to an average of € 26.706 billion per year (see table 5-1).

67 Using Ookla/Speedtest data we consider the quarterly growth rate of fixed broadband speed of the last two years (2Q20/2Q18) for Belgium (4.60%), Ireland (5.86%) and Netherlands (4.02%). For Germany we use the quarterly growth rate 4Q18/4Q19 (4.44%) to avoid considering the COVID-19 impact in speed. Similarly, we consider the period 3Q19/4Q18 for Switzerland (4.62%) and the period 2Q19/2Q18 for the United Kingdom (4.78%).

68 According to the FCC Report the ratio of average to peak speed in the US in June 2018 is 12.75% (94 Mbps/713.5 Mbps).

TABLE 5-1. COUNTRIES STUDIED: 10G TOTAL SPILLOVER IMPACT ON GDP (2024-27)

Country	Cumulative GDP Impact (€ B)	Average annual GDP impact over four years (€ B)	GDP (2027) (€ B)	Annual GDP impact in 2027 as percent of total GDP
Belgium	€ 5.981	€ 1.495	€ 562	0.27%
Germany	€ 46.863	€ 11.716	€ 4,448	0.26%
Ireland	€ 3.342	€ 0.836	€ 423	0.20%
Netherlands	€ 9.902	€ 2.476	€ 976	0.25%
Switzerland	€ 4.843	€ 1.211	€ 805	0.15%
United Kingdom	€ 35.893	€ 8.973	€ 2,879	0.31%
TOTAL	€ 106.825	€ 26.706	€ 10,093	0.26%

Sources: International Monetary Fund; Telecom Advisory Services analysis

A key factor driving the divergent levels of impact across countries is the improvement in average fixed broadband download speed resulting from the migration to 10G (see table 5-2).

TABLE 5-2. AVERAGE FIXED BROADBAND DOWNLOAD SPEED AS ENABLED BY 10G (2024-27) (IN MBPS)

Country	2024	2025	2026	2027	CAGR
Belgium	261	417	665	1,062	59.58%
Germany	267	424	674	1,071	58.97%
Ireland	274	428	668	1,043	56.10%
Netherlands	304	472	734	1,139	55.27%
Switzerland	419	599	855	1,220	42.79%
United Kingdom	216	362	606	1,015	67.46%

Source: Telecom Advisory Services analysis

As depicted in table 5-2, the highest improvements in average download speeds[69] as a result of 10G deployment are realized in the United Kingdom, Belgium and Germany.

In addition to GDP growth, the spillovers from the migration to 10G in all six European countries will create 347,568 new jobs, equivalent to 86.892 average per year (see table 5-3).

69 Average download speed is calculated as an average across all broadband connections..

TABLE 5-3. EUROPEAN COUNTRIES: 10G SPILLOVER IMPACT ON TOTAL NEW JOBS (2024-27)

Country	Cumulative total job creation	Average annual new job creation over four years	Country labour force 2027	Annual labour force impact in 2027 as percent of total labour force in 2027 (%)
Belgium	17,648	4,412	4,764,786	0.09%
Germany	146,593	36,648	39,047,809	0.09%
Ireland	6,371	1,593	2,261,932	0.07%
Netherlands	30,616	7,654	8,655,575	0.09%
Switzerland	9,922	2,481	4,673,754	0.05%
United Kingdom	136,417	34,104	31,443,191	0.11%
TOTAL	347,568	86,892	90,847,047	0.10%

Sources: International Labour Organization and Eurostat; Telecom Advisory Services analysis

Based on the econometric models, we also estimate that the spillovers from 10G will contribute significantly to the creation of service sector jobs. The migration to 10G networks in all six European countries under study will generate 1,766,027 service sector jobs, equivalent to 441,507 average per year (see table 5-4).

TABLE 5-4. EUROPEAN COUNTRIES: 10G SPILLOVER IMPACT ON SERVICE SECTOR JOBS (2024-27)

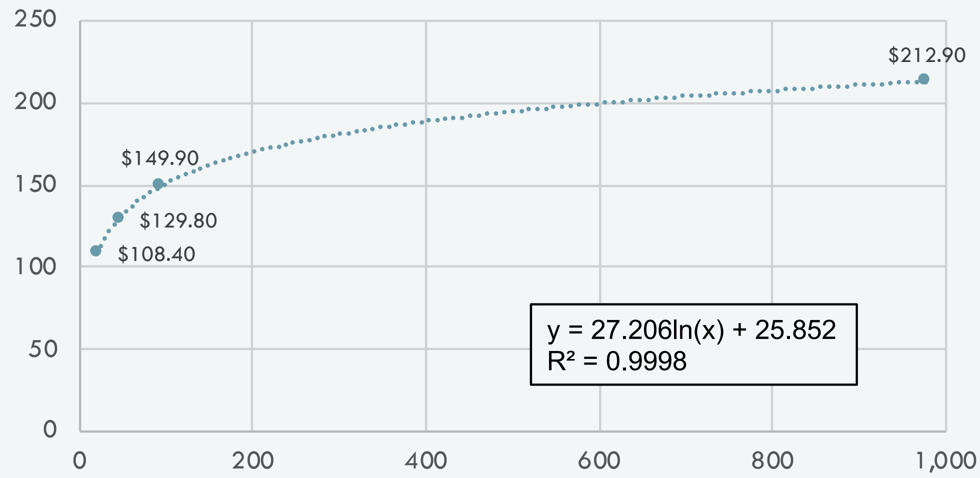
Country	Cumulative total service sector job creation	Average annual service sector job creation over four years	Country service sector Labour force 2027	Annual service sector labour impact in 2027 as percent of total service sector labour in 2027 (%)
Belgium	91,457	22,864	3,742,219	0.61%
Germany	695,232	173,808	27,860,685	0.62%
Ireland	32,352	8,088	1,748,298	0.46%
Netherlands	168,515	42,129	7,231,873	0.58%
Switzerland	50,604	12,651	3,624,637	0.35%
United Kingdom	727,867	181,967	25,500,627	0.71%
TOTAL	1,766,027	441,507	69,708,337	0.63%

Sources: International Labour Organization; Telecom Advisory Services analysis

6. ESTIMATION OF CONSUMER SURPLUS

The analysis we conducted for the estimation of consumer surplus relies, in part, on data from research on the relationship between speed and willingness to pay.[70] The coefficient linking speed to consumer surplus was then used to estimate the value to be derived by faster download speeds enabled by 10G. (see Graphic 6-1).

GRAPHIC 6-1. LOG CURVE OF RELATIONSHIP BETWEEN BROADBAND SPEED AND CONSUMER SURPLUS (BASED ON NEVO ET AL., 2016)



Note: Based on data points of table VII and table VI of Nevo et al., 2016.
Source: Nevo et al. (2016); Telecom Advisory Services analysis

It should be noted that, due to the lack of European research on consumer surplus and broadband speed, we used the data on consumer surplus from the United States to assess this effect in Europe, although that was calibrated with European consumer research.[71] The details of these calculations are presented in Appendix F.

> The migration to 10G across the six European countries under study will enable a substantial increase in fixed broadband average download speed which, based on research of willingness to pay for additional speed, will yield an increase in consumer surplus (see table 6-1).

70 Nevo, A., Turner, J., and Williams, J. (2016) "Usage-based pricing and demand for residential broadband", Econometrica, vol. 84, No.2 (March), 441-443, and Liu, Y-H; Prince, J., and Wallsten, J. (2018). Distinguishing bandwidth and latency in households' willingness-to-pay for broadband internet speed.

71 See AT Kearney study "Viewed Through the Lens of the Consumer", Liberty Global Policy series 2018, and Oxera (2019). Gigabit broadband: what does it mean for consumers and society, Study prepared for Liberty Global, October 28, 2019.

TABLE 6-1. EUROPEAN COUNTRIES: TOTAL CONSUMER SURPLUS RESULTING FROM 10G MIGRATION (IN € BILLIONS) (2024-2027)

	2024	2025	2026	2027	Total
Belgium	€ 0.207	€ 0.420	€ 0.637	€ 0.861	€ 2.125
Germany	€ 0.696	€ 1.435	€ 2.217	€ 3.044	€ 7.392
Ireland	€ 0.023	€ 0.047	€ 0.071	€ 0.096	€ 0.237
Netherlands	€ 0.288	€ 0.581	€ 0.880	€ 1.185	€ 2.934
Switzerland	€ 0.060	€ 0.120	€ 0.182	€ 0.245	€ 0.607
United Kingdom	€ 0.554	€ 1.128	€ 1.725	€ 2.343	€ 5.749
TOTAL	€ 1.828	€ 3.731	€ 5.712	€ 7.774	€ 19.045

Source: Telecom Advisory Services analysis

As indicated in table 6-1, the total consumer surplus resulting from the migration to 10G in the six European countries under study will grow from € 1.828 billion to € 7.774 billion between 2024 and 2027.

7. CONSOLIDATION OF THE ECONOMIC CONTRIBUTION OF 10G NETWORKS

The aggregate economic contribution of 10G in each of the six countries under study is summarized in local currencies below in Table 7.1. More detail about these consolidated results, as well as the rest of the results discussed in this chapter, can be found in Appendix G.

TABLE 7-1. EUROPEAN COUNTRIES: TOTAL ECONOMIC CONTRIBUTION OF 10G (IN BILLIONS)

		BE	DE	IE	NL	CH	UK
Network investment	Direct	€ 1.365	€ 9.011	€ 0.170	€ 1.977	CHF 0.811	£2.409
	Indirect and induced	€ 0.855	€ 4.796	€ 0.059	€ 1.317	CHF 0.433	£1.474
	Total	€ 2.219	€ 13.807	€ 0.229	€ 3.294	CHF 1.244	£3.883
Spillovers		€ 5.981	€ 46.863	€ 3.342	€ 9.902	CHF 5.185	£32.093
Consumer surplus		€ 2.125	€ 7.392	€ 0.237	€ 2.934	CHF 0.650	£5.141
Total (in local currency)		€ 10.325	€ 68.062	€ 3.809	€ 16.130	CHF 7.079	£41.116

Source: Telecom Advisory Services analysis

In addition, 10G will contribute to the creation of new jobs across all six countries (see table 7-2).

TABLE 7-2. EUROPEAN COUNTRIES: TOTAL CONTRIBUTION OF 10G TO JOB CREATION

		BE	DE	IE	NL	CH	UK
Network investment	Direct	4,842	53,279	675	5,612	2,273	13,305
	Indirect and induced	2,042	22,819	154	3,684	975	5,859
	Total	6,884	76,099	829	9,297	3,247	19,164
Spillovers		17,648	146,593	6,371	30,616	9,922	136,417
Total		24,532	222,692	7,200	39,913	13,170	155,581

Source: Telecom Advisory Services analysis

The network investment and spillovers of 10G will generate an estimated average of 116,000 jobs per year. Of these jobs, 29,000 will be employed either directly or indirectly in the migration of the networks every year, while spillovers will create an average of 87,000 jobs every year. The relationship between each dollar invested and the jobs generated varies by country, depending on the amount of investment that is assigned to the purchase of foreign inputs and the amount of labour intensity by sector (see table 7-3).

TABLE 7-3. EUROPEAN COUNTRIES: COST PER JOB GENERATED (€)

	BE	DE	IE	NL	CH	UK
Cost per direct employment (*)	€281,833	€169,123	€251,993	€352,298	€333,281	€202,514
Cost per Employment (**)	€ 55,628	€ 40,463	€ 23,615	€ 49,539	€ 57,518	€ 17,319

(*) Direct Network Investment Spending/Direct Network Investment Job creation
(**) (*) Direct Network Investment Spending/Total Job creation
Source: Telecom Advisory Services analysis

Finally, 10G will be an important factor in ensuring that jobs lost in the primary and secondary economies are compensated through new employment in the service sector (see table 7-4).

TABLE 7-4. EUROPEAN COUNTRIES: SERVICE SECTOR JOBS

	2024	2025	2026	2027	Total
Belgium	22,882	22,870	22,858	22,846	91,457
Germany	175,865	174,486	173,119	171,762	695,232
Ireland	8,041	8,072	8,103	8,135	32,352
Netherlands	42,060	42,106	42,152	42,198	168,515
Switzerland	12,597	12,633	12,669	12,705	50,604
United Kingdom	181,311	181,747	182,185	182,624	727,867
Total	442,757	441,915	441,086	440,269	1,766,027

Source: Telecom Advisory Services analysis

10G networks will contribute a total of 1,766,000 service sector jobs over a four-year period (or 441,000 per year). As mentioned before, by creating jobs in the service sector to offset some of the jobs in the primary and secondary sectors of the economy that will be lost to automation (estimated at 14 % of the labour force in advanced economies over the next two decades by Nedelkoska and Quintini, 2018), 10G will enable a compensating effect for this potential job loss.

8. PUBLIC POLICY IMPLICATIONS AND ALTERNATIVE SCENARIO

Our estimation of economic value associated with the migration of cable platforms to 10G networks presented above represents a baseline scenario with no policy or regulatory intervention; that is, the private sector cable operators are left to their own devices to upgrade their networks, offer service, and manage new or upgraded subscriptions. As an alternative, **we develop a scenario which assumes certain policy interventions that would help serve as an incentive for the migration to 10G.** Of course, policy interventions, such as the implementation of price regulation on cable systems, could have the effect of slowing down the implementation of 10G and reducing the potential benefits from this migration.

For the European countries under study, freeing up space for capital expenditure would shorten the time necessary for the migration to 10G. Even more decisive would be to use policy instruments, including competition policy, in a way that allows further development of scale to promote innovation and the roll-out of 10G technology. In particular within the cable sector, further consolidation can bring the benefits of high-speed, high-quality connectivity closer to a larger group of consumers and businesses.

The European Union has set ambitious goals for Europe's digital future in its Digital Strategy, building on the goals of the Gigabit Society strategy. It envisages a society rooted in digitalization, where technology works for people and all can benefit from a competitive digital economy.

> The migration to 10G supports the goals outlined in the Digital Strategy, including enabling innovative technologies, creating jobs in the digital sector and supporting sustainable solutions to aid in the reduction of carbon emissions.

Supporting the migration to 10G will enable the Digital Strategy and ensure that technology works for all.

While the economic and societal benefits of 1 Gbps connectivity for Europe in 2015 were estimated to amount more than €200 Billion, moving to 10G will create a considerable increase. To reap these benefits, policies are needed to:

- **Stimulate investments.** EU legislation strives to balance consumer interests, in particular in terms of prices, and the promotion of investments in VHC networks. It is essential that in implementing this framework, national authorities keep this balance and their eyes on the horizon. In the long term, the interests of the consumer are aligned with those of 10G network investors, as they will benefit from higher speeds and better quality of service as a result of innovation.

- **Allow for a careful use of subsidies.** In May 2017, the European Commission estimated that the investment gap to reach the digital targets in 2025 was € 155 billion, on a total need of € 500 billion. In order to close this gap, public money must not get in the way of private investment. Subsidies should only be used where the market fails, to avoid market distortion. In this framework, the proceeds from spectrum auctions should not be used to subsidize the roll out of networks where VHC networks are present or a business-case exists.

- **Consider prudent use of market regulation.** A predefined set of markets have to be assessed at regular intervals – regulation may be imposed on these markets only under restricted conditions and only based on the principles of appropriateness and proportionality. With the ever-increasing competition in Europe it's time to continue the trend of deregulation as foreseen by the Commission in its draft revised Recommendation relevant markets. Regulatory authorities must exercise restraint in the use of ex-ante instruments to address market failure.

- **Determine unrestricted duct and pole access.** Regulators should focus more on providing unrestricted access to underground ducts and poles both by streamlining the access regime to third party ducts (telecom operators, utilities and municipalities) under the umbrella of the Cost Reduction Directive and where appropriate and proportionate introduce Significant Market Power (SMP) based measures to ease access to telecoms incumbents' passive infrastructure.

- **Reduce and harmonise administrative hurdles and use of modern trenching technologies.** There are a number of policy measures which could simplify and support necessary new build of fibre in HFC networks. For example, streamlining of bureaucratic permission processes (digging permits and requirements for restoring build out areas and street surfaces) for fibre build out and faster decision making could speed up deployment. Similarly, using of already existing municipal or county broadband / fibre managers as one stop shopping point for fibre/10G projects, and allowing general permission for use of modern and cost reducing low depth digging methods like micro- or nano-trenching.

- **Endorse technology neutrality.** As 10G technology shows, the HFC networks are able to provide a substantial answer to the demand for VHC connectivity. Only a policy that is based on a mix of technologies will lead to the achievement of the EU's digital objectives within the set timeframe.

- **Support unlicensed spectrum allocation.** As mentioned above, the demand by consumers and businesses for data over the internet has been increasing substantially and is expected to continue to grow. Most of this traffic today is being carried by Wi-Fi and Wi-Fi's share of this traffic is expected to continue to grow.[72] This increase in data traffic on Wi-Fi will be driven by factors such as the large increase in Wi-Fi connected devices, including smartphones and 4K televisions. Policymakers and regulators should do more to ensure that consumers benefit from 10G and multi-gigabit Wi-Fi by making spectrum available to unlicensed use. Following the recommendation from the CEPT (Conférence Européenne des Administrations des Postes et des Télécommunications) the lower part of the 6 GHz band should be made available as unlicensed and in a harmonised way across Europe. The proposal to enable license-exempt use of the lower part of the 6 GHz band (5925-6425 MHz) will allow more effective and efficient use of spectrum and significantly improve the user experience of Wi-Fi[73].

72 According to Cisco, Wi-Fi's share of Internet traffic in 2017 was 50.4% and this is expected to grow to 56.6% of all traffic in 2022. Comments of Cisco Systems, Inc. at 4, ET Docket No. 18-295, GN Docket No. 17-183 (filed Feb. 15, 2019)

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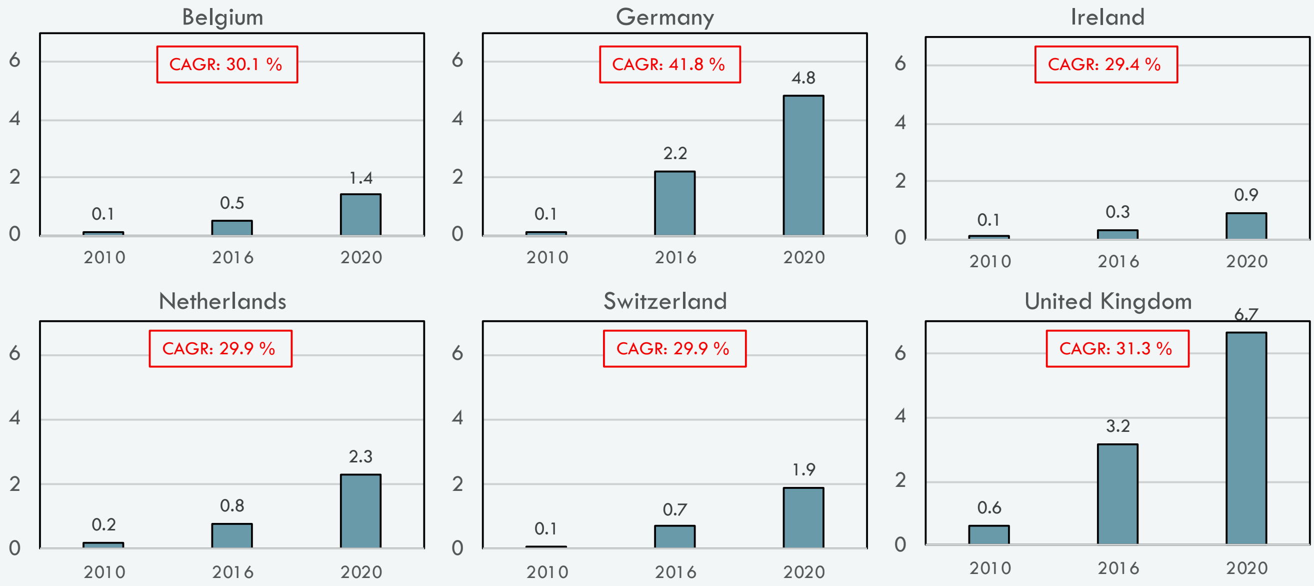
APPENDICES

APPENDIX A: TRENDS IN INTERNET SPEED, USAGE AND LATENCY

There has been tremendous growth in Internet traffic over the last decade. As documented by the Cisco Visual Networking Index, Internet traffic in the six countries under study has been growing at an average annual rate of 31.3%, albeit with differences across countries (see Graphic A-1).

GRAPHIC A-1. INTERNET MONTHLY TRAFFIC (IN EXABYTES[74])



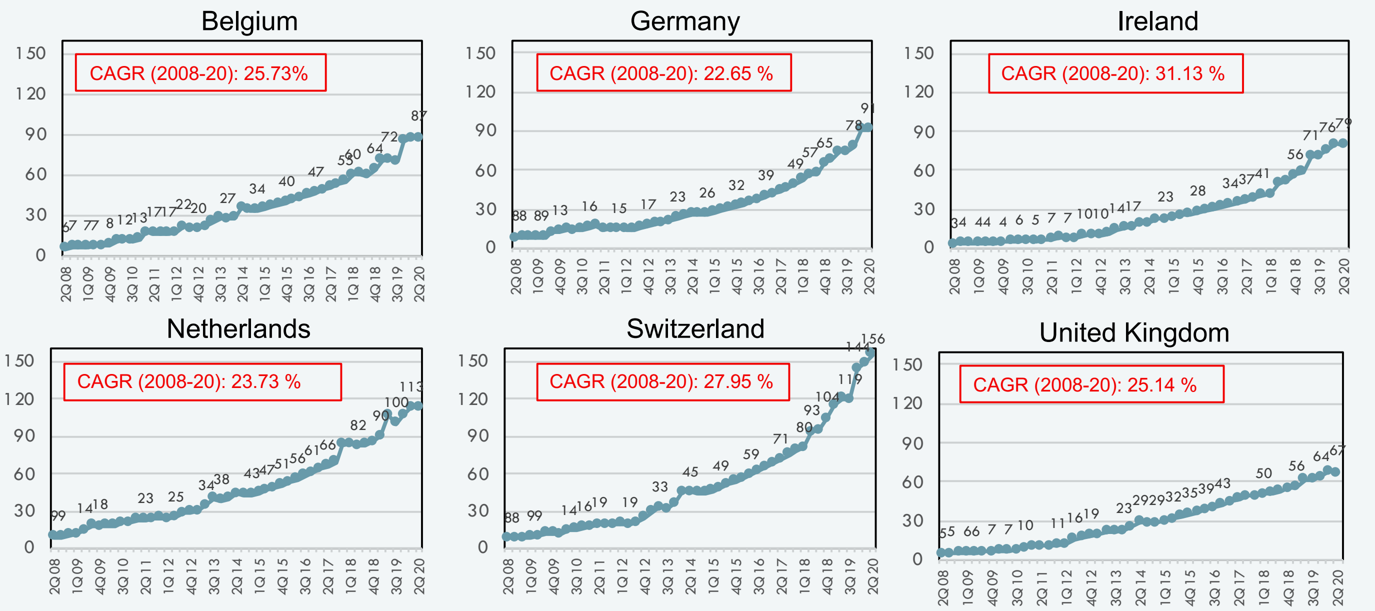
Source: Cisco Visual Networking Index; Telecom Advisory Services analysis

As expected, the growth in Internet traffic has been paralleled by an increase in fixed broadband speed. In fact, we estimate that the average broadband download speed across the six countries under study has been growing by 26.06% annually[75] (see graphic A-2).

74 An Exabyte is equivalent to 1,073,741,824 gigabytes.

75 The following analysis is based on Ookla/Speedtest daily Internet traffic compiled between 2008 and 2014, and monthly data between 2017 and 2020, as reported in the site. The service measures the bandwidth (speed) and latency of a visitor's Internet connection against one of 4,759 geographically dispersed servers (as of August 2016) located around the world. Each test measures the data rate for the download direction, i.e. from the server to the user computer, and the upload data rate, i.e. from the user's computer to the server.

GRAPHIC A-2. FIXED BROADBAND AVERAGE DOWNLOAD SPEED (IN GBPS)



Source: Ookla/Speedtest; Telecom Advisory Services analysis

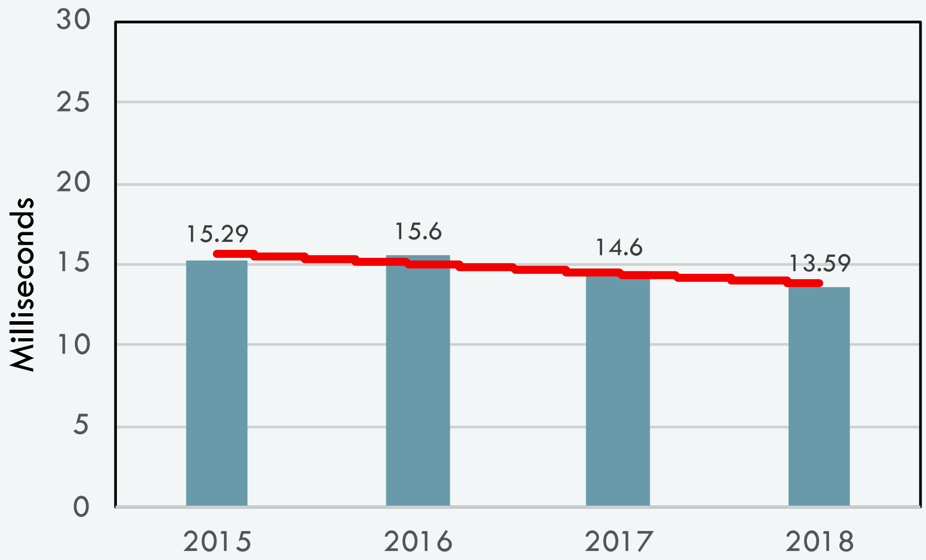
As indicated in Graphic A-2, since the beginning of 2015, the average fixed broadband download speed has increased 2.5 times in the Belgium, 3.3 in Germany, 3.3 in Ireland, 2.5 in the Netherlands, 3.4 in Switzerland and 2.2 in the United Kingdom.

Simultaneously, network latency[76] has also been decreasing. Network speed and latency are related since transmission technology is one of the factors that reduces the time it takes for packets to travel from the source to the user[77]. In the United Kingdom latency has decreased from 15.29 Ms. in 2015 to 13.59 in 2018 (see Graphic A-3).

76 Latency measures the time it takes for a data packet from one point in the network to another. High latency has a negative impact on the service quality of interactive applications. It is affected by several factors such as the physical distance data must travel (for example geostationary satellites require data to travel 22,000 miles each way), the number of nodes the data must traverse (which pushes service providers to cache content closer to their end users), and how the network equipment (routers, switches, etc.) buffers and forwards the data.

77 The other two factors driving latency is the network architecture and the capability of the technology to schedule buffers.

GRAPHIC A-3. FIXED BROADBAND (CABLE AND FTTX) PEAK AVERAGE LATENCY



Note: The source of the raw data is SamKnows. The values are derived from measurement of specific carriers in each country (six in the UK, fifteen in the US); while reliable in measuring year-to-year change within each country, cross country comparisons are not possible. Each year value is an arithmetic average of all cable and fibre observations within the country.
Sources: OFCOM. UK Home Broadband Performance (2015-18); Telecom Advisory Services analysis.

The communications industry, comprising both telecommunications operators and cable broadband providers, has been increasing the capabilities of its networks to accommodate the growing demand for faster broadband speed and lower latency. The deployment of DOCSIS 3.0 and 3.1 cable networks combined with FTTx have provided an adequate response to the need for additional fixed broadband. As of 2018, the broadband communication networks (telco or cable) in the European countries under study had the capability of delivering service of 1 Gbps to over 50% of the population (see table A-1)[78].

78 This did not mean that 1 Gbps service was being offered in all markets. As of August 2019, the fastest service by country was Telenet Boost (500 Mbps) in Belgium, Vodafone (1Gbps) in Germany, Eircom (1Gbps) in Ireland, Ziggo (500 Mbps) and KPN (500 Mbps) in the Netherlands, Swisscom (1Gbps) in Switzerland), and Virgin Media (362 Mbps) in the United Kingdom. s.

TABLE A-1. EUROPE: FIXED BROADBAND DOWNLOAD SPEED COVERAGE (PERCENT HOUSEHOLDS THAT CAN ACCESS BROADBAND WITH AT LEAST INDICATED SPEED) (2013-2018)

	2013						2018					
	Belgium	Germany	Ireland	Netherlands	Switzerland	United Kingdom	Belgium	Germany	Ireland	Netherlands	Switzerland	United Kingdom
>2 Mbps	99.9%	99.4%	95.9%	100.0%	100.0%	98.4%	99.9%	99.4%	99.7%	100.0%	100.0%	99.2%
>30 Mbps	97.9%	65.2%	48.4%	99.0%	99.2%	79.1%	98.4%	87.9%	97.5%	99.8%	99.2%	93.9%
>100 Mbps	96.1%	56.4%	41.2%	97.6%	79.6%	47.7%	96.9%	66.3%	78.6%	99.8%	98.9%	52.1%
1 Gbps	0.4%	10.5%	1.7%	23.3%	38.5%	0.9%	69.7%	43.2%	50.6%	91.9%	71.1%	48.8%

Sources: EU. Broadband Coverage in Europe (2013-2019); ANGA; Bundesnetzagentur; IDATE DigiWorld for FTTH Council Europe; Telecom Advisory Services analysis.

European subscribers also have increasingly acquired faster speed plans (see table A-2).

TABLE A-2. EUROPE: SUBSCRIBERS BY DOWNLOAD SPEED TIER (PER 100 POPULATION) (2019

	Belgium	Germany	Ireland	Netherlands	Switzerland	United Kingdom
<30 Mbps	1.7%	15.0%	5.3%	3.6%	4.5%	10.4%
30 – 100 Mbps	13.1%	16.0%	13.6%	19.5%	34.7%	22.5%
100-200 Mbps	25.2%	11.0%	10.8%	22.6%	- - -	7.2%
1 Gbps	0.0%	0.2%		- - -	7.0%	- - -

Sources: OECD. Broadband statistics; EU. Broadband in the member states; ANGA; Bundesnetzagentur; IDATE DigiWorld for FTTH Council Europe; Telecom Advisory Services analysis.

Since the end of the twentieth century, the cable industry has been deploying successive generations of an international telecommunications standard that allows for the addition of high-bandwidth data transfer over an existing coaxial cable TV system. Originally developed in March 1997, DOCSIS (Data Over Cable Service Interface Specification) allows operators to offer higher performance broadband without having to replace completely their coaxial cable networks[79].

79 DOCSIS comprises two main components: the physical layer (called PHY) and the media access control layer (MAC). The physical layer pertains to the wiring and routing equipment used, as well as the frequency at which data is transmitted through the physical systems. The MAC layer handles the information being processed over the network components.

There have been three different major iterations of DOCSIS over the years: 1.x, 2.x, and 3.x. The original specs, 1.0 and 1.1, had a working limit of 40 Mbps for the downstream speed and 10 Mbps for the upstream speed. DOCSIS 2.0 introduced no new capacity for the downstream speed, but it did triple the upstream speed that could be offered. The most significant changes, however, came in 2006 with the introduction of DOCSIS 3.0, which significantly increased hypothetical upstream and downstream speeds to 1 Gbps and 100 Mbps, respectively.[80] Six years later, Cable Labs introduced DOCSIS 3.1, an enhancement to DOCSIS 3.0. This generation provided an additional speed enhancement, potentially supporting up to 10 Gbps in maximum downstream speed and 2 Gbps in upstream speed. Table A-3 presents the key features and dates of deployment of the different generations of DOCSIS.

TABLE A-3. DOCSIS: SPEED FEATURES AND DEPLOYMENT DATES

	DOCSIS 1.0	**DOCSIS 1.1**	**DOCSIS 2.0**	**DOCSIS 3.0**	**DOCSIS 3.1**
Maximum downstream speed	40 Mbps	40 Mbps	40 Mbps	1 Gbps	10Gbps
Maximum upstream speed	10 Mbps	10 Mbps	30 Mbps	100 Mbps	1-2 Gbps
Specification date	1997	1999	2001	2006	2013
Commercial Equipment availability	1999 (*)	2001 (*)	2003 (*)	2008	Early 2016
Start of deployment	2000 (**)	2002 (**)	2004 (**)	2007	Ongoing

Notes:
(*) Based on dates when Cable Labs certified the first few modems
(**) Date when majority of modems were certified
Source: Cable Labs

Cable operators in Europe have been actively deploying DOCSIS 3.0 and DOCSIS 3.1 over the past few years. As of 2019, 100% of cable broadband households were supported by DOCSIS 3.0 in Belgium[81], Ireland[82] and Switzerland[83]. With regards to DOCSIS 3.1 deployment, Germany is the most advanced nation, having deployed the standard to 26% (8.8 million) of households[84] (the remaining having DOCSIS 3.0), while Belgian and Irish operators are undergoing field trials, expecting to complete full deployment by 2020.

80 DOCSIS 3.0 was enabled by the introduction of channel bonding. Channel bonding allows for the aggregation or combination of several downstream and upstream channels to deliver these much-improved speeds. With this technique, the more channels that are present, the better, so for instance, while a 16 downstream by 4 upstream set-up is fast, a 24 x 8 system can be even faster.
81 Source: Telenet interview
82 Source: Virgin Ireland interview
83 Source: Digital Suisse, Switzerland's cable TV association.
84 Source: ANGA, The Broadband Association (Germany); however, KDG has 75.5% of homes passed ready for DOCSIS 3.1..

APPENDIX B: PREVIOUS RESEARCH ON THE ECONOMIC BENEFITS OF BROADBAND

ECONOMIC IMPACT OF NETWORK INVESTMENT

As outlined in chapter 3, the migration to 10G will entail capital spending which will translate into GDP growth and jobs through three effects. In the first place, the investment related to 10G will translate directly into additional GDP and jobs (such as telecommunications technicians, construction workers, and manufacturers of the required telecommunications equipment). In addition, this investment creates indirect spending triggered by upstream buying and selling between suppliers and cable operators (electric supplies, metal products, etc.). Finally, the household spending resulting from the income generated from the direct and indirect jobs creates additional "induced" economic effects.

Six national studies have estimated the impact of broadband network construction mostly on job creation, although one study estimates the impact on GDP: Crandall et al. (2003), Atkinson et al. (2009), Liebenau et al. (2009), and in prior research carried out by the author (Katz et al., 2008, Katz et al, 2009, Katz et al., 2010). All these studies relied on input-output analysis and assumed a given amount of capital investment: for example, US$ 63.6 billion needed to reach ubiquitous broadband service, defined as DSL and cable modem service available at the time in the United States (Crandall et al. 2003) (see Table B-1).

TABLE B-1: ECONOMIC IMPACT OF NETWORK DEPLOYMENT

Country	Authors – Institution (*)	Objective	Results
United States	Crandall et al. (2003) – Criterion Economics	Estimate the employment impact of broadband deployment aimed at increasing household adoption from 60% to 95%, requiring an investment of US$ 63.6 billion	• Creation of 60,656 jobs per year over nineteen years • Total jobs: 1.159 million (including 546,000 for construction and 665,000 indirect)
	Atkinson *et al.* (2009) – ITIF	Estimate the impact of a US$ 10 billion investment in broadband deployment	• Total jobs: 498,000 jobs if investment achieved in one year (including 64,000 direct, 166,000 indirect and induced, and 268,000 in network effects)
Switzerland	Katz et al. (2008) – Telecom Advisory Services /Polynomics	Estimate the impact of deploying a national broadband network requiring an investment of CHF 13 billion	• Total jobs: 114,000 over four years (including 83,000 direct and 31,000 indirect)
United Kingdom	Liebenau et al. (2009) – London School of Economics	Estimate the impact of investing US$ 6.4 billion to achieve the target of the *"Digital Britain"* Plan	• Total jobs: 280,000 jobs if investment achieved in one year (including 76,500 direct, 134,500 indirect and induced, and 69,500 in network effects)

Country	Authors – Institution (*)	Objective	Results
Germany	Katz et al. (2010)	Estimate the impact of investing EUR 20.243 billion for implementing the 2014 Broadband Strategy	• Total GDP: EUR 20.2 billion in investment and EUR 52.32 billion in additional output • Total jobs: 304,000 jobs (including 158,000 direct, 71,000 indirect and 75,000 induced
United States	Katz and Suter (2009)	Estimate the impact of investing US$ 6.39 billion for broadband deployment, of which 2.5 billion would be in wireless technology	• Total jobs: 127,800 direct and indirect jobs

Source: Compiled by Telecom Advisory Services

BROADBAND SPEED AND ECONOMIC SPILLOVERS

The research on the impact of increasing fixed broadband speed, first and foremost, has focused on GDP growth. This research generally concludes that faster internet access has a positive impact on GDP growth.

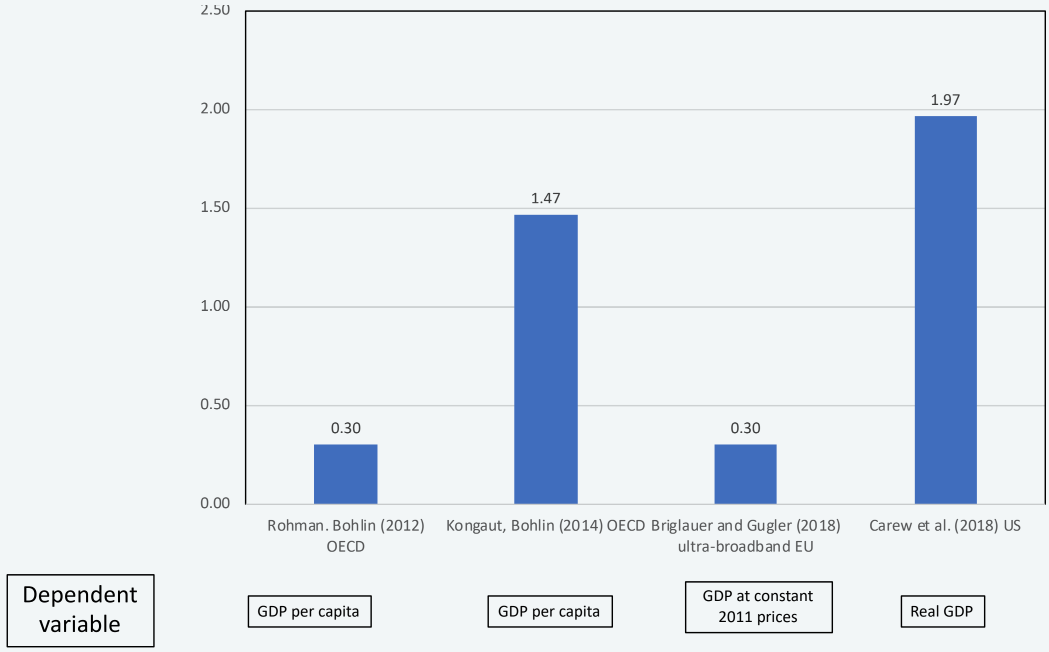
Two types of effects explain this causal relationship. First, faster broadband contributes to an improvement in productivity resulting from the adoption of more efficient business processes. For example, improved marketing of excess inventories and optimization of the supply chain are two of the effects that might be generated. Second, faster connectivity yields an acceleration of the rate of introduction of new products, services, and the launch of innovative business models.

An early study that assessed the impact of broadband speed on GDP (Rohman, Bohlin, 2012) looked at 33 OECD countries and concluded that a 100% increase (or doubling) of speed yields a 0.3% increase in GDP. Following on this study, Kongaut and Bohlin (2014) used a similar approach but differentiated between high and low-income OECD countries and determined that an increase in broadband speed of 1% yields an increase in GDP per capita of 0.147% for a general sample of countries, 0.1% for low income countries and 0.06% for high income countries.

Two studies completed in 2018 provided additional evidence of broadband speed impact on GDP. Briglauer and Gugler (2018) looked at data for 27 EU member states between 2003 and 2015. In this case, 1% increase in basic broadband adoption was found to increase GDP by about 0.015%, while 1% increase in ultra-fast broadband adoption lead to an incremental increase of 0.004-0.005% of GDP. That said, these results are driven from ordinary least square models. A two-stage least square regression testing the impact of ultrafast broadband penetration found a small (0.003) but significant effect over and above the effects of basic broadband on GDP. In another iteration, Carew et al. (2018) concluded that a 1% increase in speed equates to a 0.0197% in real GDP. Therefore, a 100 percent increase yields 1.37 percent increase in real GDP.

As indicate in Graphic B-1, while all studies conclude that broadband speed has an impact on GDP, the range of contribution varies. Some of the difference is explained by the methodologies used. For example, Carew et. al (2018) did not include broadband adoption as an independent variable which means that the effect of speed subsumes broadband penetration. In other cases, part of the difference in effects can be explained by the variance in average broadband download speed at the time of the study: for example, when Rohman and Bohlin (2012) conducted their study, average broadband download speed was 8.3 Mbps.

GRAPHIC B-1. STUDIES MEASURING THE GDP IMPACT ON BROADBAND SPEEDS (IMPACT OF 100% INCREASE IN SPEED ON GDP) (%)



Source: Compiled by Telecom Advisory Services

BROADBAND SPEED AND HOUSEHOLD INCOME

While broadband speed has been consistently found to have a positive effect on economic growth, the evidence of a positive contribution of Internet speed to household income is less conclusive. Rhoman and Bohlin (2013) concluded that there are positive benefits from broadband speed on income, though those are not linear and continuous, but nonlinear and stepwise. Furthermore, the authors found that the impact for lower speed is greater in three large emerging countries (Brazil, Indica and China) and for higher speeds it is greater in OECD countries. The authors found that for the same increase in upgrade in speeds (0.5 Mbps to 4 Mbps), the income effect is bigger in OECD countries than BIC countries ($322 per month vs $46 per month). On the other hand, Ford (2018) analysed data of US and found no economic payoff from a 15 Mbps speed difference.

BROADBAND SPEED AND ENTERPRISE PRODUCTIVITY

The contribution of broadband speed to enterprise productivity has been studied in terms of its efficiency enhancement and productivity levels. In a study of Irish firms, Haller et al. (2019) found significant productivity gains from broadband availability in two services industries: Information & Communication services and Administrative & Support Service Activities. The effects measured for these two sectors were large, equivalent to about a third of the typical variation in productivity. Smaller effects were found in other sectors. These results suggest the benefits of broadband for productivity depend heavily upon sectoral and firm characteristics. Cariolle et al. (2017) studied firms in 62 countries, using World Bank data, and detected a large impact of broadband speed on a firm's average annual sales and sales per worker.

BROADBAND SPEED AND JOB CREATION

Research on the impact of broadband speed on employment, which takes place through firm relocation and start-up incubation, is fairly conclusive. Generally, research in this area has been focused on the United States, although one study relied on French data. Whitacre et al. (2014) looked at local level data of non-metropolitan United States counties between 2001 and 2010 and identified a positive impact of broadband speed on unemployment reduction. In particular, rural areas with fast broadband tend to attract more creative class workers. Bai (2016) studied United States counties between 2011 and 2014 and found that while broadband has a positive impact on employment, ultra-fast broadband has smaller incremental effects. Lobo et al. (2019) studied the counties within the US state of Tennessee and found that unemployment rates are about 0.26 percentage points lower in counties with high speed broadband compared to counties with low speed service. As with Whitacre et al. (2014), this study found that better quality broadband has a disproportionately greater effect in rural areas.

The only study conducted outside the United States was done by Hasbi (2017), analysing panel data on 36,000 municipalities in France between 2010 and 2015. The author found that deployment of high-speed broadband (> 30 Mbps) increases company relocation and start-up development in the non-agricultural sector. These two effects yield a positive contribution to the reduction of unemployment.

BROADBAND SPEED AND CONSUMER SURPLUS

Consumer surplus is defined as the amount that consumers benefit from purchasing a product for a price that is less than what they would be willing to pay. Broadband consumer surplus, typically assessed against dial up or pricing differences, indicates a high willingness to pay for speed. Most studies of consumer surplus derived from faster speed are based on surveys or focus groups where consumers stipulate what they would be willing to pay for broadband (Savage et al. (2004); Greenstein and McDewitt (2011); Liu et al. (2018)). For example, Greenstein and McDewitt (2009) analysed survey data of willingness to pay for dial up vs. broadband and concluded that in 2006 the switch from dial-up to broadband access generated between US$ 4.8 billion and US$ 6.7 billion in consumer surplus. Liu et al. (2018) administered two surveys of US consumers to measure households' willingness-to-pay for changes in price, data caps, and speed. They found that the valuation of bandwidth is highly concave. US households are willing to pay about US$ 2.34 per Mbps ($14 total) monthly to increase bandwidth from 4 Mbps to 10 Mbps, US$ 1.57 per Mbps ($24) to increase from 10 to 25 Mbps, and US$ 0.02 per Mbps ($US19) for an increase from 100 Mbps to 1000 Mbps.

Other studies that lack access to survey data tend to rely on pricing differences to estimate consumer surplus (Greenstein and McDewitt, 2011; Greenstein and McDewitt, 2012). For example, Greenstein and McDewitt (2011) compared deployment, use of broadband and pricing between 2004 and 2009 for Brazil, US, Spain, United Kingdom, Mexico, Canada, and China. They concluded that a decline in broadband real prices[85] generated consumer surplus in 2009 of $ 10.1 billion in the United States and £ 0.8 billion in the United Kingdom. In 2012, Greenstein and McDewitt (2012) replicated this analysis for thirty OECD countries and concluded that the total consumer surplus from broadband in 2010 amounted to US$ 156.7 billion. The authors also determined that the bonus was comparable to the size of the broadband market: in the countries that are the focus of this study, the authors estimated a broadband consumer surplus for Belgium (US$ 2.74 billion), Germany (US$ 11.80 billion), Ireland (US$ 431 million), Netherlands (US$ 5.11 billion), Switzerland (US$ 2.09 billion), the United Kingdom (US$ 8.04 billion), and the United States (US$ 39.79 billion).

Finally, other studies on consumer surplus focus on how consumers' data usage reacts to variations in price. For example, Nevo et al. (2015) studied hour-by-hour Internet usage for 55,000 US subscribers facing different price schedules. They concluded that consumer surplus for speed is heterogeneous. Consumers will pay between $0 to $5 per month for a 1 Mb/s increase in connection speed, with an average of $2[86]. However, and very relevant to our study of 10G, they stipulated that, with the availability of more content and applications, consumers will likely increase their usage, implying greater time savings and a greater willingness to pay for speed. This last study was relied upon for developing consumer surplus coefficients relative to 10G.

85 The authors' starting point is the unchanged nominal prices for broadband over time; however, since household income grows following inflation, broadband deflated prices and the amount of household income dedicate to its purchasing diminishes.

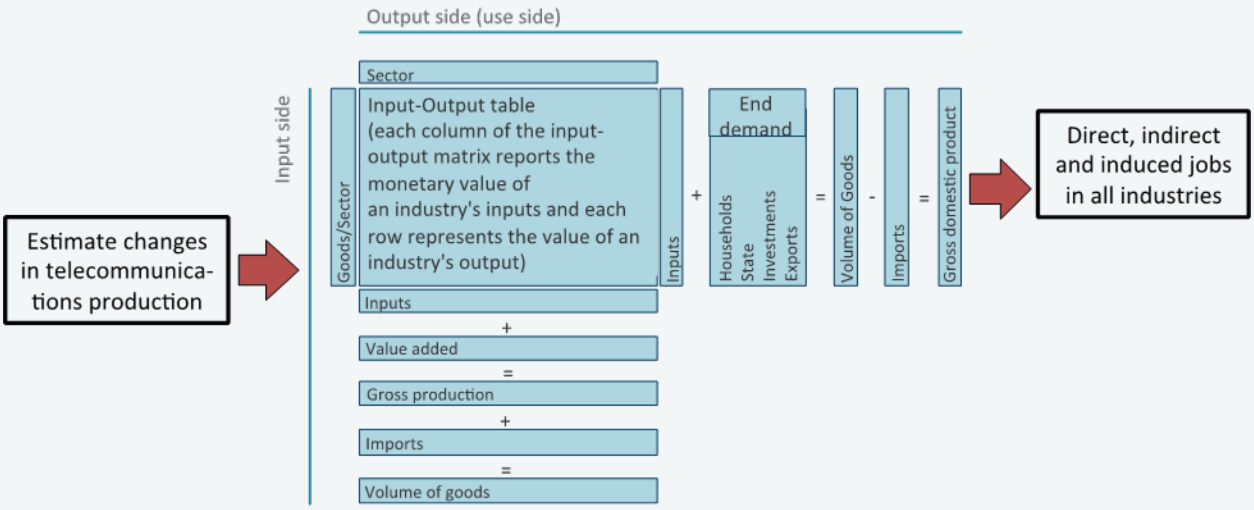
86 Heterogeneity in willingness to pay for broadband was also highlighted by Rosston et al. (2010)..

APPENDIX C: MODELS USED TO ESTIMATE THE ECONOMIC IMPACT OF 10G

ESTIMATING THE IMPACT OF INVESTMENT IN 10G DEPLOYMENT

As described in the review of the literature presented above, the core methodology for estimating the impact of investment in 10G is based on input/output matrices. The structure of an input/output (I/O) table comprises horizontal rows describing how an industry's total output is divided among various production processes and final consumption, and each column denotes the combination of productive resources used within one industry (see figure C-1).

FIGURE C-1. STRUCTURE OF AN INPUT-OUTPUT MATRIX



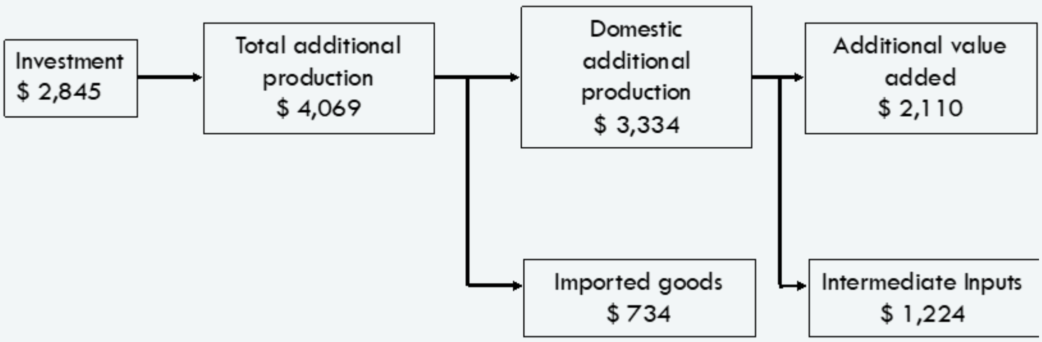
I-O tables assume that some inputs are used by sectors that produce output (intermediate output), which in turn is sold to another sector for consumption (final output); total output adds intermediate and final outputs. By using labour productivities, one can calculate job creation from output. For purposes of this analysis, I/O tables were developed for each of the six countries under study. For international consistency, each I/O matrix was constructed with a common framework relying on data extracted from the Global Trade Analysis Project (GTAP) database[87].

The output of each I/O table is structured as follows (see figure C-2):

87 This approach is commonly used for assessing of economic impact of infrastructure projects by institutions like the World Bank.

FIGURE C-2. EXAMPLE OF OUTPUT OF INPUT / OUTPUT RESULTS TABLE

Direct, indirect effects and multipliers total			
Value Added	Direct Effect	1699.069	mUSD
	Indirect Effect	369.802	mUSD
	Induced Effect	41.630	mUSD
	Total Effect	2110.501	mUSD
	Multiplier	1.242	
Employment	Direct Effect	7.295	th employees
	Indirect Effect	1.828	th employees
	Induced Effect	0.465	th employees
	Total Effect	9.587	th employees
	Multiplier	1.314	
Total Industry Output	Direct Effect	2845.000	mUSD
	Indirect Effect	1123.961	mUSD
	Induced Effect	100.068	mUSD
	Total Effect	4069.028	mUSD
	Multiplier	1.430	



As indicated in Figure C-2, input-output tables can estimate the one-time impact of investment in broadband technology on employment and GDP, differentiating between direct, indirect, and induced effects. In addition, since the tables are based on the interrelationships among sectors and quantifies the intermediate goods produced in country versus those that are imported, the portion of the network investment that is "leaked" to foreign providers can also be estimated. Finally, the tables can also estimate the breakdown of jobs to be created by sector.

The calculation of the investment effects of 10G requires entering in the I/O table the estimated spending required for this migration. Spending needs to be broken down by economic sector (for example, construction and electronic equipment).

ESTIMATING SPILLOVERS

In the assessment of 10G economic contribution, spillovers refer to the impact the technology will have beyond the investment needed once it is being deployed. Since more extensive and complete datasets were available at the time of this study, rather than relying on the prior research discussed above, we developed new econometric models to estimate the impact of speed on GDP and employment. Once the models were developed, the coefficients of broadband speed were used to calculate the economic impact from spillovers.

The econometric models were based on historical data panels constructed for 159 countries for a time series between 2008 and 2019. The data comprised 7,314 observations of quarterly data for:

- Average fixed broadband download speed[88] (source: Ookla Speedtest)
- Gross Domestic Product (at current prices US$) (source: IMF)[89]
- Gross Domestic Product (at current prices US$ adjusted for PPP) (source: IMF)
- Population (source: IMF)
- Unemployment rate (source: IMF)
- Fixed broadband adoption (percent of households with fixed broadband with a speed of at least 256 kbps) (source: International Telecommunications Union)
- Controls for country and time periods

The data panels were cut in three samples to calculate coefficients of GDP impact by speed level (download speeds between 1Mb and 10 Mb, download speeds between 10 Mb and 40 Mb, and download speeds higher than 40 Mb) and the following model was specified (see exhibit C-1).

EXHIBIT C-1. MODEL FOR ESTIMATING THE IMPACT OF FIXED BROADBAND SPEED ON GDP

$$lnGDP_{it} = \beta_0 + \beta_1 lnGDP_{it-1} + \beta_2 lnDownload\ Speed_{it-4} + \beta_3 lnEmployment_{it} + \beta_4 lnInvestment\ Rate_{it} + \beta_5 lnFixed\ Broadband\ Adoption_{it} + \delta Country_i + \vartheta Time_t + \mu_{it}$$

WHERE THE MODEL INCLUDES:

- a control for the previous quarter's GDP, to isolate the inertial effect of country growth
- download speed lagged by four quarters (1 year) to avoid reversed causality effect
- changes in employment, to isolate the effect on GDP of the evolution of the labour market
- the country's investment rate (% of GDP) to isolate the effect of investment on GDP
- the penetration rate to separate the broadband adoption effect from the speed effect

Regressions were run only for periods and countries with a fixed broadband adoption higher than 1% of households with the following results (see table C-1).

---

88 The data on Speedtest/Ookla covers 159 countries.
89 The models used GDP at current prices in USD since the objective is to measure the impact of GDP in USD, without considering PPP as a deflator.

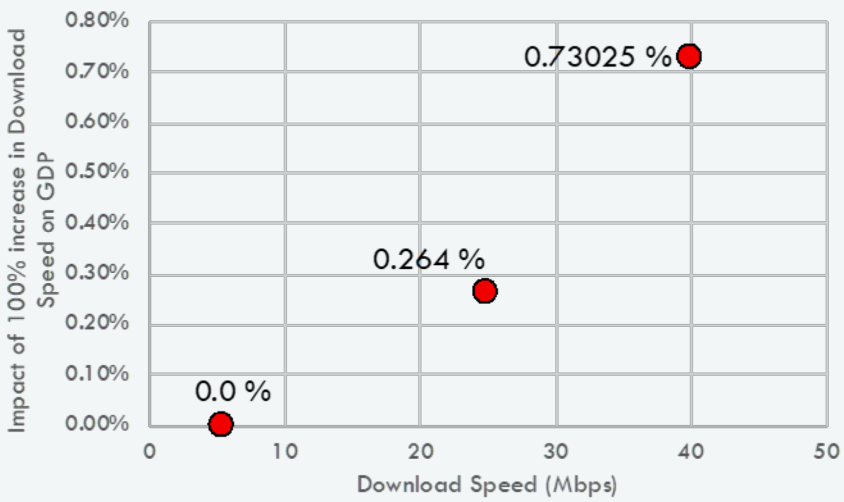
TABLE C-1. IMPACT OF FIXED BROADBAND DOWNLOAD SPEED ON GDP

Impact on ln GDP	Download Speed < 10 Mbps	Download Speed 10 Mbps - 40 Mbps	Download Speed higher than 40 Mbps
Ln Download Speed$_{t-4}$	-0.00206 (0.00136)	0.00264 (0.00138) ***	0.00730 (0.00211) ***
Ln Employment$_t$	0.00664 (0.00189) ***	0.00525 (0.00168) ***	0.00458 (0.00165) ***
Ln Investment$_{t-4}$	0.01459 (0.00216) ***	-0.00616 (0.00382)	-0.00085 (0.00481)
Country Effect	Yes	Yes	Yes
Time Effect	Yes	Yes	Yes
Control for growth of previous GDP	Yes	Yes	Yes
Control for Fixed Broadband adoption	Yes	Yes	Yes
Number of countries	116	105	49
Observations	2,113	1,792	575
R-Square	0.9516	0.9262	0.9438

***, **, * significant at 1%, 5% and 10% critical value respectively.

As indicated in the coefficients of download speed, the faster download speed, the greater GDP growth impact (see Graphic C-1).

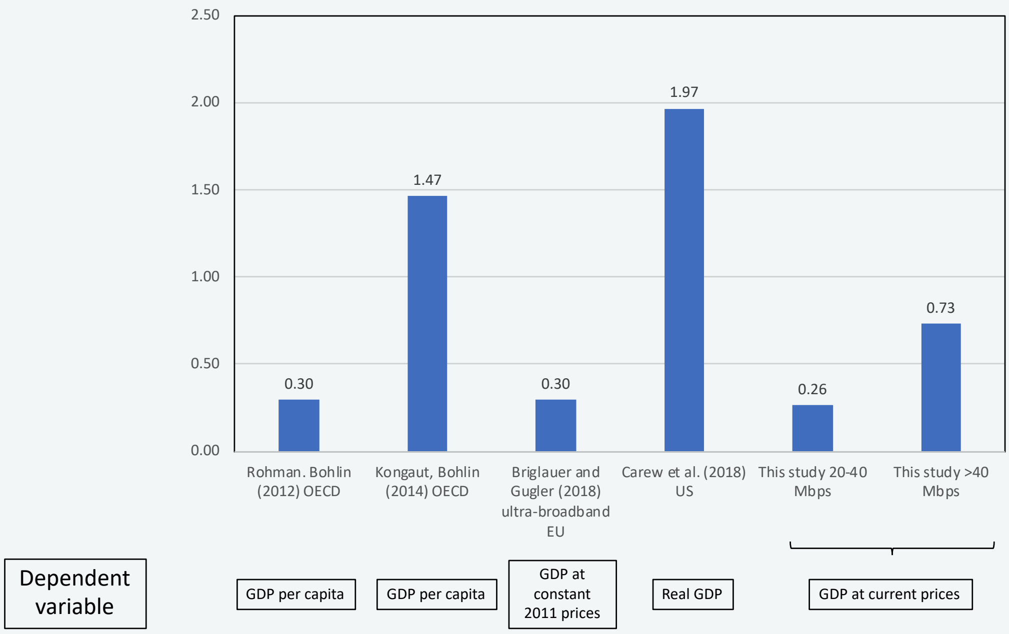
GRAPHIC C-1: SPILLOVER IMPACT OF DOWNLOAD SPEED ON GDP



Source: Telecom Advisory Services analysis

According to the results, the impact on GDP of fixed broadband download speeds under 10 Mbps is non-existent, while once the average speed is in a range between 10 and 40 Mbps, the effect on GDP is positive and statistically significant. The effect on GDP is even greater for download speeds in excess of 40 Mbps[90]. The results of this study (see Graphic C-2) are in the range of what was estimated by Briglauer and Gugler (2018) for the EU ultrabroadband impact, while the difference with Carew et. al (2018) is likely because, since broadband adoption is not included in their model as an independent variable for control purposes, the effect of speed subsumes broadband penetration. On the other hand, the Kongaut and Bohlin (2014) study is somewhat limited due to the time period over which speed data is gathered (up to 2013); furthermore, the fact that speed impact appears to be higher in low income OECD countries (see below) might run against some of the microeconomic research indicating that the contribution of fast broadband is higher when acting as an enabler of digital applications prevalent in advanced economies.

GRAPHIC C-2: STUDIES MEASURING THE GDP IMPACT ON BROADBAND SPEEDS (IMPACT OF 1% INCREASE IN SPEED ON GDP) (%)



Source: Compiled by Telecom Advisory Services

In the case of job impact estimation, additional controls, besides those included in Exhibit C-1, are included in the model.The controls are previous population growth, and an education index to isolate the effects of human capital on employment. The following model was specified (see exhibit C-2).

90 We use the coefficient of speed impact for connections greater than 40 Mbps which represents a conservative assumption given that the result of the regressions indicates an increasing relationship between speed and impact.

EXHIBIT C-2. MODEL FOR ESTIMATING THE IMPACT OF FIXED BROADBAND SPEED ON JOB CREATION

$$
\begin{aligned}
lnEmployment_{it} &= \beta_0 + \beta_1 lnPopulation_{it-1} + \beta_2 lnDownload\ Speed_{it-4} + \beta_3 lnGDP_{it-1} \\
&+ \beta_4 lnInvestment\ Rate_{it-4} + \beta_5 lnFixed\ Broadband\ Adoption_{it-1} \\
&+ \beta_6 lnEducation\ Index_{it-4} + \delta Country_i + \vartheta Time_t + \mu_{it}
\end{aligned}
$$

Regressions were run for Total Employment and for Service Sector Employment only for periods and countries with a fixed broadband adoption higher than 1% of households with the following results (see table C-2)

TABLE C-2. IMPACT OF FIXED BROADBAND DOWNLOAD SPEED ON EMPLOYMENT

Impact on ln Employment	Employment in all sectors	Employment in the services sector
Ln Download Speed$_{t-4}$	0.00232 (0.00095) **	0.01530 (0.00104) ***
Ln Education Index$_{t-4}$	0.19995 (0.02275) ***	0.32428 (0.02481) ***
Ln Investment$_{t-4}$	0.01024 (0.00218) ***	-0.00090 (0.00238)
Country Effect	Yes	Yes
Time Effect	Yes	Yes
Control for previous GDP growth	Yes	Yes
Control for previous FBB adoption growth	Yes	Yes
Control for previous growth of Population	Yes	Yes
Number of countries	120	120
Observations	4,440	4,440
R-Square	0.7006	0.7612

***, **, * significant at 1%, 5% and 10% critical value respectively.

The coefficient of speed impact on overall employment, while positive and statistically significant, is small (0.00232) compared to the impact on the service sector (0.01530), indicating a dual effect of broadband speed. These results are consistent with the findings highlighted in the research literature review. In particular, fast broadband speeds have an impact on firm development pertaining to industries in the services sector but no effect in manufacturing (Hasbi, 2017).

This leads us to conclude that 10G, as an enabler of technology platforms associated with automation and the Fourth Industrial Revolution, might have an impact on labour force restructuring (shift from manufacturing to the services sector).For example, recent research on the impact of automation indicates that 14% of jobs in OECD countries are likely to be automated, while another 32% will incur significant changes in the way they are conducted as a result of automation (Nedelkoska and Quintini, 2018). In the context of our results, a large portion of the jobs lost to automation in manufacturing will be replaced by jobs in the services sector and faster broadband speeds should be conceived as a general-purpose technology acting as an enabler of this compensating effect.

APPLYING ECONOMETRIC MODELS TO SPILLOVER EFFECTS

In order to use the econometric models to quantify the spillovers, we must first estimate what will be the average fixed broadband download speed in an environment enabled by 10G. For this purpose, the difference with supply and demand is calculated based on the historical relation between peak and average download speed, where peak is assumed to be the fastest market offering.

Since spillovers would materialize as a result of the ongoing increase in average broadband speed, we need to estimate the contribution that can be exclusively attributed to 10G networks. To estimate what the increase in average download speeds will be under 10G, we first assume that the natural growth in speeds that has occurred so far within the DOCSIS 3.0 and 3.1 contexts will extend in the future. Then, we develop a projection of average download speed after the migration to 10G begins. For this purpose, it is assumed that by 2027 average speed will be equivalent to approximately 13% of the weighted average download speed of 10Gbps after seven years. According to the FCC Report the ratio average to peak speed in the US in June 2018 is 12.75% (94 Mbps/713.5 Mbps). This ratio was extended to European countries.

ENABLEMENT OF APPLICATIONS

As alluded to in the review of the literature, the economic impact of speed is influenced by the applications enabled by the network. The econometric models used in the estimation of spillovers are not capable of estimating the value of specific applications and use cases enabled by the technology. Part of the reason of this limitation is that future benefits of 10G are not only derived from faster speed, low latency, and symmetric performance but also from new uses of the technology. This last domain comprises not only use cases that are currently being implemented (such as smart cities) but also applications that are at an early stage of the development life cycle. This analysis addresses the economic value of 10G focusing on applications in order to provide some micro-economic validation of the macro-estimates generated in the spillover econometric models. Along these lines, these values are subsets of the overall estimates calculated in the spillover section and not additional value created on top of the spillover effects.

Our analysis will focus on assessing the impact of five groups of emerging applications (see figure C-3).

FIGURE C-3. EMERGING APPLICATIONS ENABLED BY 10G

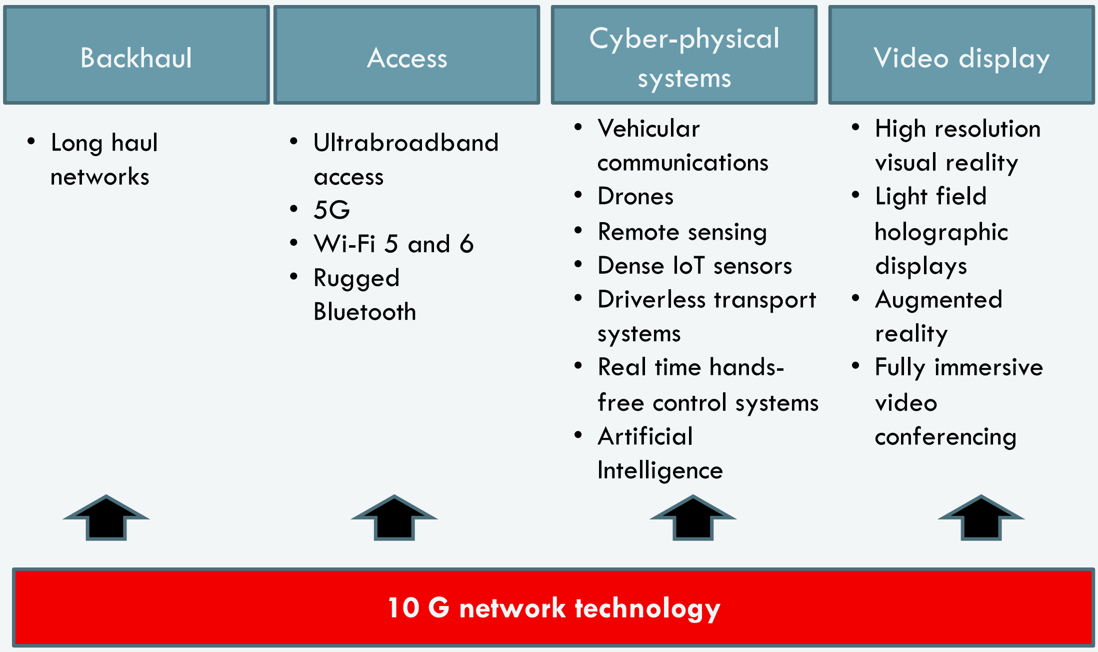
		Applications/Use cases	
		Under implementation and deployment	At an early development stage
Markets	Individual consumers	• Massive multiplayer gaming • Immersive video/8K entertainment	
	Enterprises	• Precision agriculture and food processing • Smart manufacturing • Smart logistics	• Massive Internet of Things • Algorithm-based security systems
	Public services	• eHealth • Smart cities	• Tele-surgery

An analytical challenge in assessing the economic contribution of 10G to the value of these applications is that 10G represents a critical enabler of emerging use cases and new business models, but its contribution is achieved in combination with other technologies and platforms. The analytical difficulty of disaggregating the impact of ICT from the facilitative role played by broadband has been previously identified in the research (Foley et al, 2009). This universe of relevant technologies can be grouped into four areas:

- Access: technologies that provide the connectivity to end-user devices.
- Backhaul: technologies that provide high performance transport capacity from nodes and points of signal distribution, such as wireless base stations and Wi-Fi hotspots.
- Cyber-physical systems: systems built around the integration of computing power, networking, and physical process. Computers and networks monitor and control physical processes, which in turn, generate feedback loops into computers.
- Video display: devices capable of displaying video signals and integrating it into the delivery of new information.

Within this typology, 10G technology will play a critical role facilitating the flow of information among devices and display components (see figure C-4).

FIGURE C-4. TECHNOLOGIES CONTRIBUTING TO NEW APPLICATIONS AND BUSINESS MODELS



Source: Telecom Advisory Services

Thus, we consider the economic contribution of 10G to emerging applications as an enabler and we do not assess independently from other technologies.

ESTIMATING CONSUMER SURPLUS

As explained in the review of the literature on broadband generated consumer surplus, most studies rely on changes in consumer behaviour as a result of new service availability (Nevo et al., 2016), market research (Savage et al., 2004; Greenstein and McDewitt, 2009; Liu et al, 2018) or changes in pricing in relation to product quality (Greenstein and McDewitt, 2011; Greenstein and McDewitt, 2012). The methodological challenge in this study is to estimate the expected change in consumer surplus resulting from a product not yet generally deployed[91], particularly when considering that the full value of 10G availability will materialize only once new applications are developed.

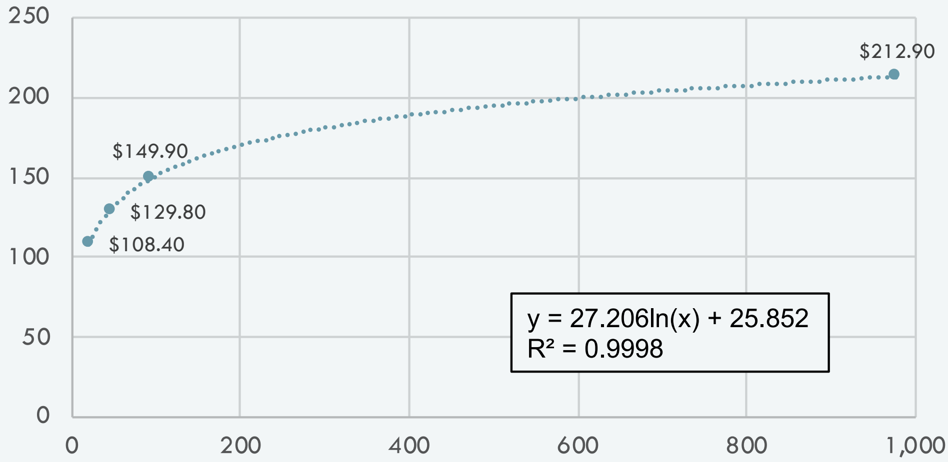
The analysis conducted for this study relies on the data specifying the relationship between speed and consumer surplus generated by Nevo et al. (2016).[92] This research provides empirical evidence for the United States stating that consumers' willingness to pay (WTP) for improved broadband speed of 1 Mbps ranges from nearly zero to just over US$ 5.00. The range is determined by heterogeneity in WTP, although the average value is US$ 2.02, and the median is US$ 2.48. Furthermore, the study indicates that higher speed does indeed generate substantial surplus. However, due to an apparent declining marginal value, speeds of more than 10 times those offered by the typical cable plans imply only 1.5 times the surplus.

91 A 10Gigabit per second product is currently being offered in some limited areas of the United States (for example, service providers offering 10Gbps service include the Electric Power Board of Chattanooga, Tennessee, Fision in Salisbury, North Carolina, and Vtel in Vermont)

92 Nevo, A., Turner, J., and Williams, J. "Usage-based pricing and demand for residential broadband", Econometrica, vol. 84, No.2 (March), 441-443.

The data provided in the Nevo et al. (2016) study allows the estimation of a log curve depicting the relationship between consumer surplus and speed (see Graphic C-3).

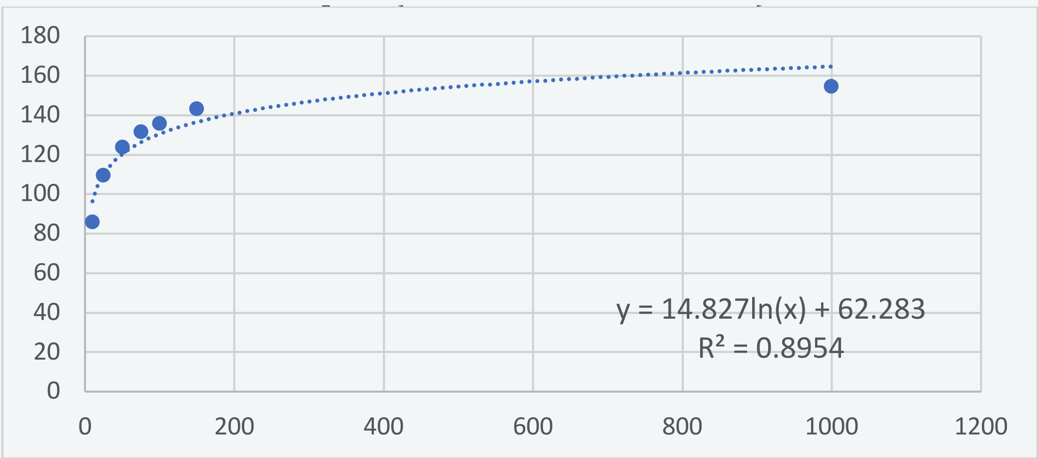
GRAPHIC C-3. LOG CURVE OF RELATIONSHIP BETWEEN BROADBAND SPEED AND CONSUMER SURPLUS (BASED ON NEVO ET AL., 2016)



Note: Based on data points of table VII and table VI of Nevo et al., 2016.
Source: Nevo et al. (2016); Telecom Advisory Services analysis

For reference, to calibrate the curve in Graphic C-3, the same analysis was conducted for the work carried out by Liu et al. (2018) (see Graphic C-4).

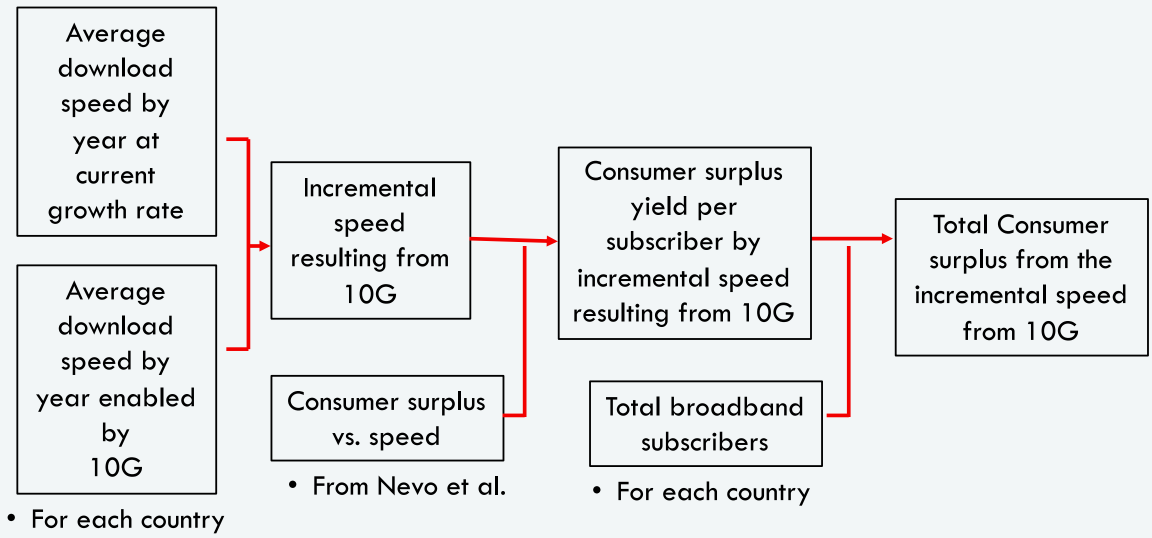
GRAPHIC C-4. LOG CURVE OF RELATIONSHIP BETWEEN BROADBAND SPEED AND CONSUMER SURPLUS (BASED ON LIU ET AL., 2018)



Source: Liu et al. (2018); Telecom Advisory Services analysis

According to the data of the Graphic C-3, an increase in speed from 92.5 Mbps to 977.9 Mbps (ten times) increases consumer surplus from $149.9 to $212.9 (close to 1.5 times). The equation linking speed to consumer surplus from Graphic C-3 was then used to estimate the value to be derived by faster download speeds enabled by 10G. For this purpose, the difference between average download speed enabled by 10G and average download speed if speed increased annually at the current growth rate was multiplied by the coefficient of the log curve as depicted in the graphic above (see figure C-5).

FIGURE C-5. ESTIMATE OF CONSUMER SURPLUS AS A FUNCTION OF SPEED



APPENDIX D: IMPACT OF INVESTMENT IN SUPPORT OF 10G MIGRATION ON GDP AND EMPLOYMENT

BELGIUM

The Belgium cable industry will spend a total of € 1.365 billion spread over four years to deploy 10G. We estimate that this spending will result in € 2.219 billion in one-time contribution to GDP (see table D-1).

TABLE D-1. BELGIUM: IMPACT OF INVESTMENT IN 10G ON GDP

	Four Years (in million)	Annual (*) (in million)
Direct	€ 1,365	€ 341
Indirect	€ 763	€ 191
Induced	€ 91	€ 23
Total	€ 2,219	€ 555
Multiplier	1.626	

(*) Over four years
Source: Based on I/O table developed with GTAP database; Telecom Advisory Services analysis

The € 341 million annual direct effect on GDP will be concentrated in the electronics (41.53%) and the construction (58.47%) sectors. On the other hand, the € 214 million annual indirect and induced impact benefits the industries supplying goods and services (trade, business services, metal products and mineral products). Of the total impact on GDP, € 442 million (that is to say 19.90 %) represent imported goods and services. The investment "leakage" is concentrated in the electronics sector.

Additionally, the migration to 10G in Belgium will translate into 1,721 annual jobs (see table D-2).

TABLE D-2. BELGIUM: IMPACT OF INVESTMENT IN 10G ON EMPLOYMENT

	Total (job years)	Annual jobs (*)
Direct	4,842	1,211
Indirect	1,479	370
Induced	563	141
Total	6,884	1,721
Multiplier	1.422	

(*) Over four years
Source: Based on I/O table developed with GTAP database; Telecom Advisory Services analysis

We estimate that 66.27% of jobs related to 10G deployment will be in construction, 12.36% will be in trade, 6.40 % will be in Business Services, while only 5.09% will be in the computer, electronic and optical products sector.

Finally, of the 6,884 jobs created, 6,030 will be skilled jobs and the remaining 854 will be unskilled jobs (see table D-3)

TABLE D-3. BELGIUM: IMPACT OF INVESTMENT IN 10G BY TYPE OF EMPLOYMENT

	Total Effect	Direct Effect	Indirect Effect	Induced Effect
Unskilled	854	555	216	82
Skilled	6,030	4,287	1,263	480
Total	6,884	4,842	1,479	563

Source: Based on I/O table developed with GTAP database; Telecom Advisory Services analysis

GERMANY

The German cable industry will spend a total of € 9.011 billion over four years as it transitions to 10G. Of this amount, € 5.269 billion will be invested in construction, and € 3.742 billion in electronic equipment. This investment will result in € 13.807 billion in one-time contribution to GDP (see table D-4).

TABLE D-4. GERMANY: IMPACT OF INVESTMENT IN 10G ON GDP

	Four Years (in billion)	Annual (*) (in billion)
Direct	€ 9.011	€ 2.253
Indirect	€ 4.261	€ 1.065
Induced	€ 0.535	€ 0.134
Total	€ 13.807	€ 3.452
Multiplier	1.532	

(*) Over four years

Source: Based on I/O table developed with GTAP database; Telecom Advisory Services analysis

The € 2.253 billion annual direct effect in GDP will be concentrated in the electronics (41.53%) and construction (58.47%) sectors. On the other hand, the € 1.199 billions of annual indirect and induced impacts are focused in the industries supplying goods and services (trade, business services, communication, metal products, mineral products and rubber & plastic products). Of the total impact on GDP, € 2.379 billion (that is to say 17.23 %) represent imported goods and services. The investment "leakage" in the German case is concentrated in the computer & electronic products, business services, mineral products and metal products sectors.

Additionally, the investment required for the migration to 10G will translate into 19,025 annual jobs (see table D-5).

TABLE D-5. GERMANY: IMPACT OF INVESTMENT IN 10G ON EMPLOYMENT

	Total (job years)	Annual jobs (*)
Direct	53,279	13,320
Indirect	17,486	4,372
Induced	5,333	1,333
Total	76,099	19,025
Multiplier	1.428	

(*) Over four years

Source: Based on I/O table developed with GTAP database; Telecom Advisory Services analysis

We estimate that 60.59% of jobs related to 10G deployment will be in construction, 9.70% in computer and electronics products, 8.84% in trade and 8.53% in business services sector.

Finally, of the 76,099 jobs created, 59,665 will be skilled jobs and the remaining 16,433 will be unskilled jobs (see table D-6)

TABLE D-6. GERMANY: IMPACT OF INVESTMENT IN 10G BY TYPE OF EMPLOYMENT

	Total Effect	Direct Effect	Indirect Effect	Induced Effect
Unskilled	16,433	11,313	3,924	1,197
Skilled	59,665	41,966	13,563	4,136
Total	76,099	53,279	17,486	5,333

Source: Based on I/O table developed with GTAP database; Telecom Advisory Services analysis

IRELAND

The Irish cable industry will spend a total of € 170 million over four years as it transitions to 10G. Of this amount, € 71 million will be invested in the electronics sector, and € 99 million in construction. This capital spending will result in a € 229 million one-time contribution to GDP (see table D-7).

TABLE D-7. IRELAND: IMPACT OF INVESTMENT IN 10G ON GDP

	Four Years (in million)	Annual (*) (in million)
Direct	€ 170	€ 43
Indirect	€ 51	€ 13
Induced	€ 9	€ 2
Total	€ 229	€ 57
Multiplier	1.350	

(*) Over four years

Source: Based on I/O table developed with GTAP database; Telecom Advisory Services analysis

The € 43 million annual direct contribution to GDP will be concentrated in the electronics (41.53 %) and construction (58.47 %) sectors. On the other hand, the € 15 million annual indirect and induced impact is focused in the industries supplying goods and services (trade, business services, financial services and mineral products sector). Of the total impact on GDP, € 39 million (that is to say 17.06 %) represent imported goods and services. This investment “leakage” is concentrated in the computer and electronic products, business services, mineral products and metal products sector.

Additionally, the GDP impact will translate into 207 annual jobs (see table D-8).

TABLE D-8. IRELAND: IMPACT OF INVESTMENT IN 10G ON EMPLOYMENT

	Total (job years)	Annual jobs (*)
Direct	675	169
Indirect	102	26
Induced	52	13
Total	829	207
Multiplier	1.229	

(*) Over four years
Source: Based on I/O table developed with GTAP database; Telecom Advisory Services analysis

We estimate that 71.23% of jobs related to 10G deployment will be in construction, 10.50% in computer and electronics products, 5.41% in trade, 2.52% in business services and 2.08% in mineral products sector.

Finally, of the 829 jobs created, 729 will be skilled jobs and the remaining 100 will be unskilled jobs (see table D-9)

TABLE D-9. IRELAND: IMPACT OF INVESTMENT IN 10G BY TYPE OF EMPLOYMENT

	Total Effect	Direct Effect	Indirect Effect	Induced Effect
Unskilled	100	79	14	7
Skilled	729	595	89	45
Total	829	675	102	52

Source: Based on I/O table developed with GTAP database; Telecom Advisory Services analysis

NETHERLANDS

The Dutch cable industry will spend a total of € 1.977 billion over four years as it transitions to 10G. Of this amount, € 1.156 billion will be invested in construction and € 821 million in the electronics sector. This network capital expenditures will result in € 3.294 billion in total one-time contribution to GDP (see table D-10).

TABLE D-10. NETHERLANDS: IMPACT OF INVESTMENT IN 10G ON GDP

	Four Years (in billion)	Annual (*) (in billion)
Direct	€ 1.977	€ 0.494
Indirect	€ 1.225	€ 0.306
Induced	€ 0.092	€ 0.023
Total	€ 3.294	€ 0.824
Multiplier	1.666	

(*) Over four years
Source: Based on I/O table developed with GTAP database; Telecom Advisory Services analysis

The € 494 million annual direct contribution to GDP will be concentrated on the electronics (41.53%) and construction (58.47%) sectors. On the other hand, the € 329 million annual indirect impact will be focused in the industries supplying goods and services (business services, trade, metal products and mineral products sector). Of the total impact on GDP, € 0.537 billion (that is to say 16.30%) represents imported goods and services. This investment "leakage" is concentrated in the computer and electronic products, business services, metal products, mineral products and chemical products sector.

Additionally, the GDP impact will translate into 2,324 annual jobs (see table D-11).

TABLE D-11. NETHERLANDS: IMPACT OF INVESTMENT IN 10G ON EMPLOYMENT

	Total (job years)	Annual jobs (*)
Direct	5,612	1,403
Indirect	2,847	712
Induced	837	209
Total	9,297	2,324
Multiplier	1.778	

(*) Over four years
Source: Based on I/O table developed with GTAP database; Telecom Advisory Services analysis

We estimate that 57.05% of jobs related to 10G deployment will be in construction, 12.85% in trade, 11.85% in business services, 3.59% in computer and electronic products and 2.90% in metal products sector.

Finally, of the 9,297 jobs created, 8,251 will be skilled jobs and the remaining 1,046 will be unskilled jobs (see table D-12)

TABLE D-12. NETHERLANDS: IMPACT OF INVESTMENT IN 10G BY TYPE OF EMPLOYMENT

	Total Effect	Direct Effect	Indirect Effect	Induced Effect
Unskilled	1,046	489	430	127
Skilled	8,251	5,123	2,417	711
Total	9,297	5,612	2,847	837

Source: Based on I/O table developed with GTAP database; Telecom Advisory Services analysis

SWITZERLAND

The Swiss cable industry's migration to 10G will require total capital spending of CHF 811 million over four years. Of this amount, CHF 474 million will be invested in construction and CHF 337 million in the electronics sector. This network capital expenditures will result in a CHF 1,244 million in one-time contribution to GDP (see table D-13).

TABLE D-13. SWITZERLAND: IMPACT OF INVESTMENT IN 10G ON GDP

	Four Years (in million)	Annual (*) (in million)
Direct	CHF 811	CHF 203
Indirect	CHF 391	CHF 98
Induced	CHF 42	CHF 10
Total	CHF 1,244	CHF 311
Multiplier	1.534	

(*) Over four years
Source: Based on I/O table developed with GTAP database; Telecom Advisory Services analysis

The CHF 203 million annual direct contribution to GDP will be concentrated in the electronics (41.53 %) and construction (58.47 %) sectors. On the other hand, the CHF 108 million) annual indirect and induced impact is focused on the industries supplying goods and services (trade, business services, wood products, mineral products and metal products sectors). Of the total impact on GDP of CHF 137 million (that is to say 11.02 %) represent imported goods and services. Investment "leakage" is concentrated on the computer and electronics products sector.

Additionally, the GDP impact will translate into 812 annual jobs (see table D-14).

TABLE D-14. SWITZERLAND: IMPACT OF INVESTMENT IN 10G ON EMPLOYMENT

	Total (job years)	Annual jobs (*)
Direct	2,273	568
Indirect	780	195
Induced	195	49
Total	3,247	812
Multiplier	1.429	

(*) Over four years

Source: Based on I/O table developed with GTAP database; Telecom Advisory Services analysis

We estimate that 58.10% of jobs related to 10G deployment will be in construction, 12.15% in computer and electronics products, 7.82% in trade, 8.20% in business services and 3.23% in wood products sector.

Finally, of the 3,247 jobs created, 2,610 will be skilled jobs and the remaining 638 will be unskilled jobs (see table D-15)

TABLE D-15. SWITZERLAND: IMPACT OF INVESTMENT IN 10G BY TYPE OF EMPLOYMENT

	Total Effect	Direct Effect	Indirect Effect	Induced Effect
Unskilled	638	436	161	40
Skilled	2,610	1,837	619	155
Total	3,247	2,273	780	195

Source: Based on I/O table developed with GTAP database; Telecom Advisory Services analysis

UNITED KINGDOM

We estimate that the cable industry in the United Kingdom will spend a total of £ 2.409 billion over four years for its migration to 10G. Of this amount, £ 1.409 billion will be invested in construction, and £ 1.000 billion in electronic equipment. This spending will result in a £ 3.883 billion in one-time contribution to GDP (see table D-16).

TABLE D-16. UNITED KINGDOM: IMPACT OF INVESTMENT IN 10G ON GDP

	Four Years (in billion)	Annual (*) (in billion)
Direct	£ 2.409	£ 0.602
Indirect	£ 1.356	£ 0.339
Induced	£ 0.118	£ 0.030
Total	£ 3.883	£ 0.971
Multiplier	1.612	

(*) Over four years

Source: Based on I/O table developed with GTAP database; Telecom Advisory Services analysis

The £ 0.602 billion annual direct effect in GDP will be concentrated in the electronics (41.53 %) and construction (58.47 %) sectors. On the other hand, the £ 369 million annual indirect and induced impact is focused on the industries supplying goods and services (business services, trade, communications, financial services, metal products and mineral products sectors). Of the total impact on GDP £ 0.659 billion (that is to say 16.98 %) represents imported goods and services. This investment "leakage" is concentrated in the computer and electronic products, business services, mineral products, wood products, ferrous metals, mineral products, metal products, wood products and chemical sectors.

Additionally, the GDP impact will translate into 4,791 annual jobs (see table D-17).

TABLE D-17. UNITED KINGDOM: IMPACT OF INVESTMENT IN 10G ON EMPLOYMENT

	Total (job years)	Annual jobs (*)
Direct	13,305	3,326
Indirect	4,617	1,154
Induced	1,242	311
Total	19,164	4,791
Multiplier	1.440	

(*) Over four years

Source: Based on I/O table developed with GTAP database; Telecom Advisory Services analysis

We estimate that 58.10% of jobs related to 10G deployment will be in construction, 12.15% in computer and electronics products, 7.82% in trade, 8.20% in business services and 3.23% in wood products sector.

Finally, of the 19,164 jobs created, 16,022 will be skilled jobs and the remaining 3,142 will be unskilled jobs (see table D-18)

TABLE D-18. UNITED KINGDOM: IMPACT OF INVESTMENT IN 10G BY TYPE OF EMPLOYMENT

Table D-18. United Kingdom: Impact of investment in 10G by type of employment

	Total Effect	Direct Effect	Indirect Effect	Induced Effect
Unskilled	3,142	2,154	779	210
Skilled	16,022	11,151	3,838	1,032
Total	19,164	13,305	4,617	1,242

Source: Based on I/O table developed with GTAP database; Telecom Advisory Services analysis

APPENDIX E: IMPACT OF SPILLOVERS FROM THE 10G MIGRATION ON GDP AND EMPLOYMENT

BELGIUM

The analysis of Ookla/Speedtest data 2020 indicates the fixed broadband average download speed in the second quarter of 2020 in Belgium had reached 87 Mbps. An extrapolation of the 2Q20/2Q18 quarterly growth rate of 4.60% indicates that by the fourth quarter of 2020, the average speed would reach 95 Mbps and by 2027, it would be 336 Mbps. In the absence of country specific data for European nations, the ratio of average to peak speed in the United States in June 2018 of 12.75% (94 Mbps/713.5 Mbps) was extended to European countries.

Considering that the Belgium cable industry is currently undergoing DOCSIS 3.1 trials we assume that the migration to 10G will start in 2024, meaning that spillovers will begin to take place in that year. Starting in 2024, average download speed would start increasing at a faster rate than the historical one, reaching 13% of peak 10G speeds by 2027 (see table E-1).

TABLE E-1. BELGIUM: FIXED BROADBAND SPEED (2020-2027)

	2020	2021	2022	2023	2024	2025	2026	2027
Average download speed (in Mbps)	95	114	137	164	196	235	281	336
Average download speed growth	12.03%	19.70%	19.70%	19.70%	19.70%	19.70%	19.70%	19.70%
Average download speed with 10G (Mbps)	95	114	137	164	261	417	665	1,062
Average download speed growth	12.03%	19.70%	19.70%	19.70%	59.58%	59.58%	59.58%	59.58%

Source: Telecom Advisory Services analysis

By applying the two average download speed scenarios (with and without 10G) to the coefficient of the speed impact of speed on GDP for average speed higher than 40 Mbps (an 0.0073 % increase in GDP for every 1% increase in broadband speed), we calculate the GDP impact of both scenarios. By subtracting the impact of historical speed growth without 10G from the impact of the faster speed growth, we can estimate the GDP impact exclusively attributed to 10G (see table E-2).

TABLE E-2. BELGIUM: 10G SPILLOVER IMPACT ON GDP (2023-2027)

	2023	2024	2025	2026	2027
Speed contribution to GDP	0.73%	0.73%	0.73%	0.73%	0.73%
Impact of historical speed growth on GDP	0.14%	0.14%	0.14%	0.14%	0.14%
Impact of speed growth with 10G on GDP	0.14%	0.43%	0.43%	0.43%	0.43%
Impact on GDP attributed only to 10G	0.00%	0.29%	0.29%	0.29%	0.29%

Source: Telecom Advisory Services analysis

We can now use the values on the last line of table E-2 to estimate the spillover impact of 10G on GDP. The starting point is Belgium's GDP, as reported by the International Monetary Fund and Eurostat projections, to which the impact of the last line in table E-2 is applied (see table E-3)

TABLE E-3. BELGIUM: 10G SPILLOVER IMPACT ON GDP (2023-2027)

	2023	2024	2025	2026	2027	Total
GDP (in billion €)	€ 486	€ 504	€ 523	€ 542	€ 562	
Impact due to 10G (in billion €)	€ 0.000	€ 1.414	€ 1.467	€ 1.522	€ 1.578	€ 5.981
Total GDP (with 10G impact) (in Billion €)	€ 486	€ 505	€ 524	€ 544	€ 564	

Source: IMF Data for 2019; European Commission annual change forecast (Summer 2020, Interim) for 2020/2021; Since 2022 IMF annual growth projection (2019); Telecom Advisory Services analysis

Overall, our analysis indicates that the cumulative spillover impact through 2027 on GDP of fixed broadband speed enabled by 10G in Belgium will reach € 5.981 billion.

We conduct a similar analysis to assess the impact of 10G on overall employment and service sector jobs, with the starting point being the difference in download speed scenarios presented in table E-1. In the case of the impact of speed on overall employment, we estimated that a 1% increase in broadband speed yields a 0.00232 increase in total employment. We use this coefficient to calculate the employment impact of both download speed scenarios in table E-1, and by subtracting the impact of historical speed growth without 10G from the impact of the faster speed growth, we can estimate, the employment growth attributed to the new technology (see table E-4)

TABLE E-4. BELGIUM: 10G SPILLOVER IMPACT ON TOTAL EMPLOYMENT (2021-2027)

	2021	2022	2023	2024	2025	2026	2027	Total
Speed contribution to total employment	0.23%	0.23%	0.23%	0.23%	0.23%	0.23%	0.23%	
Total employment ('000')	4,780	4,777	4,775	4,772	4,770	4,767	4,765	
Jobs due to historical speed growth ('000)	2.184	2.183	2.182	2.181	2.180	2.179	2.178	15.267
Jobs with 10G speed growth ('000)	2.184	2.183	2.182	6.596	6.593	6.590	6.586	32.915
Impact attributed to 10G ('000)	0.000	0.000	0.000	4.416	4.413	4.411	4.408	17.648
Total employment (with 10G impact) ('000)	4,780	4,777	4,775	4,777	4,774	4,772	4,769	

Source: Eurostat for 2019; European Commission annual change forecast (Spring 2020) for 2020/2021; Since 2022 ILO growth annual growth projection; Telecom Advisory Services analysis

The sum of the second to last line of table E-4 indicates that the cumulative impact of spillovers on overall employment of fixed broadband speed enabled by 10G between 2024 and 2027 will reach 17,648 jobs.

In the case of the service sector, the coefficient of speed impact on service employment that we estimated in the econometric model presented in table C-2 states that a 1% increase in broadband speed yields 0.0153 % increase in service jobs. We use this coefficient to calculate the employment impact of both download speed scenarios. By subtracting the impact of historical speed growth without 10G from the impact of the faster speed growth, we can estimate the service sector employment growth attributed to 10G (see table E-5).

TABLE E-5. BELGIUM: 10G SPILLOVER IMPACT ON SERVICE SECTOR EMPLOYMENT (2020-2027)

	2020	2021	2022	2023	2024	2025	2026	2027	Total
Speed contribution to service jobs	1.53%	1.53%	1.53%	1.53%	1.53%	1.53%	1.53%	1.53%	
Total service employment ('000)	3,710	3,754	3,752	3,750	3,748	3,746	3,744	3,742	
Service jobs due to historical speed growth ('000)	3.715	11.180	11.314	11.308	11.302	11.296	11.290	11.284	78.977
Service jobs with 10G speed growth ('000)	3.715	11.180	11.314	11.308	34.185	34.167	34.149	34.130	170.434
Impact attributed only to 10G ('000)	0.000	0.000	0.000	0.000	22.882	22.870	22.858	22.846	91.457
Total service employment (with 10G impact) ('000)	3,710	3,754	3,752	3,750	3,771	3,769	3,767	3,765	

Source: Eurostat for 2019; European Commission annual change forecast (Spring 2020) for 2020/2021; Since 2022 ILO growth annual growth projection; Telecom Advisory Services analysis

As indicated in table E-5, the cumulative impact of spillovers on service sector employment of fixed broadband speed enabled by 10G between 2024 and 2027 will reach 91,457 jobs.

The difference between the total employment growth (17,648) and service sector job creation (91,457) highlights the role of 10G as an enabler of labour shifts between the manufacturing and services sector. Research on the impact of automation on the labour force indicates that in Belgium 16 % of jobs (approximately 1,200,000) are likely to be automated within two to three decades, while another 26% will incur significant changes in the way they are conducted because of automation (Arntz et al., 2016; Nedelkoska and Quintini, 2018). Our results show that a large portion of the jobs lost to automation in the primary and secondary sectors could be gradually replaced by jobs in the service sector. Thus, faster fixed broadband speeds enabled by 10G should be conceived, then, as a general-purpose technology acting as an enabler of this compensating effect.

GERMANY

The analysis of Ookla/Speedtest fixed broadband data in Germany indicates that average download speed in the second quarter of 2020 had reached 91 Mbps. An extrapolation of the 4Q19/4Q18 quarterly growth rate of 4.44 % indicates that by the fourth quarter of 2020, the average download speed would reach 100 Mbps, while by 2027 it would be 336 Mbps. In the absence of country specific data for European nations, the ratio of average to peak speed in the United States in June 2018 of 12.75% (94 Mbps/713.5 Mbps) was extended to European countries.

We assume that the migration to 10G will begin in 2024 and will start to generate spillovers that same year. As a result, average fixed broadband download speed is estimated to begin increasing that year at a faster rate than the extrapolation of the historical trend (see table E-6).

TABLE E-6. GERMANY: FIXED BROADBAND SPEED (2020-2027)

	2020	2021	2022	2023	2024	2025	2026	2027
Average download speed (in Mbps)	100	118	141	168	200	237	283	336
Average download speed growth	28.33%	18.99%	18.99%	18.99%	18.99%	18.99%	18.99%	18.99%
Average download speed with 10G (Mbps)	100	118	141	168	267	424	674	1,071
Average download speed growth	28.33%	18.99%	18.99%	18.99%	58.97%	58.97%	58.97%	58.97%

Source: Telecom Advisory Services analysis

By applying the two average download speed scenarios (with and without 10G) to the coefficient of the impact of speed on GDP that we estimated for average speed higher than 40 Mbps (an 0.0073 % increase in GDP for every 1% increase in broadband speed), we estimate the GDP impact of both download speed scenarios. The GDP impact attributed to the technology is estimated by subtracting the impact of faster speed from the extrapolation of historical speed growth without 10G (see table E-7).

TABLE E-7. GERMANY: 10G SPILLOVER IMPACT ON GDP (2023-2027)

	2023	2024	2025	2026	2027
Speed contribution to GDP	0.73%	0.73%	0.73%	0.73%	0.73%
Impact of historical speed growth on GDP	0.14%	0.14%	0.14%	0.14%	0.14%
Impact of speed growth with 10G on GDP	0.14%	0.43%	0.43%	0.43%	0.43%
Impact on GDP attributed only to 10G	0.00%	0.29%	0.29%	0.29%	0.29%

Source: Telecom Advisory Services analysis

We use the values on the last line of table E-7 to estimate the spillover impact of 10G on GDP. The starting point is Germany's GDP as reported by the International Monetary Fund and Eurostat to which the impact of the last line in table E-7 is applied (see table E-8).

TABLE E-8. GERMANY: 10G SPILLOVER IMPACT ON GDP (2023-2027)

	2023	2024	2025	2026	2027	Total
GDP (in billion €)	€ 3,769	€ 3,928	€ 4,094	€ 4,267	€ 4,448	
Impact due to 10G (in billion €)	€ 0.000	€ 10.998	€ 11.463	€ 11.948	€ 12.453	€ 46.863

Source: IMF Data for 2019; European Commission annual change forecast (Summer 2020, Interim) for 2020/2021; Since 2022 IMF annual growth projection (2019); Telecom Advisory Services analysis

To sum up, the analysis indicates that the cumulative impact through 2027 on Germany's GDP of fixed broadband speed enabled by 10G will reach € 46.863 billion.

We also assess the impact of 10G on overall employment and service sector jobs, with the starting point being the difference in download speed scenarios presented in table E-6. In the case of impact of speed on overall employment, we estimated that a 1% increase in broadband speed yields a 0.00232 increase in total employment (see table C-2). We use this coefficient to calculate the employment impact of both download speed scenarios in table E-6, and by subtracting the impact of faster speed from the one resulting from extrapolating the historical speed growth without 10G, the new employment growth attributed to the technology is isolated (see table E-9).

TABLE E-9. GERMANY: 10G SPILLOVER IMPACT ON TOTAL EMPLOYMENT (2023-2027)

	2023	2024	2025	2026	2027	Total
Speed contribution to total employment	0.23%	0.23%	0.23%	0.23%	0.23%	
Total employment ('000')	40,296	39,981	39,667	39,356	39,048	
Jobs due to historical speed growth ('000')	17.754	17.615	17.477	17.340	17.204	123.319
Jobs with 10G speed growth ('000')	17.754	54.697	54.268	53.843	53.421	269.912
Impact attributed to 10G ('000')	0.000	37.082	36.791	36.503	36.217	146.593

Source: Eurostat for 2019; European Commission annual change forecast (Spring 2020) for 2020/2021; Since 2022 ILO growth annual growth projection; Telecom Advisory Services analysis

The sum of the last line of table E-9 indicates that the cumulative impact of spillovers on overall employment of fixed broadband speed enabled by 10G between 2024 and 2027 will reach 146,593 jobs.

We conduct a similar analysis to assess the impact of 10G on service sector employment. In the case of the service sector, the coefficient of speed impact on service employment, that we estimated showed that a 1% increase in broadband speed yields 0.01530 % increase in service jobs. We use this coefficient to calculate the employment impact of both download speed scenarios. By subtracting the impact of faster speed from that produced by historical speed growth without 10G, we isolate the service sector employment growth attributed to the spillovers from this new technology (see table E-10).

TABLE E-10. GERMANY: 10G SPILLOVER IMPACT ON SERVICE SECTOR EMPLOYMENT (2023-2027)

	2023	2024	2025	2026	2027	Total
Speed contribution to service jobs	1.53%	1.53%	1.53%	1.53%	1.53%	
Total service employment ('000)	28,752	28,526	28,303	28,081	27,861	
Service jobs due to historical speed growth ('000')	84.200	83.540	82.885	82.235	81.591	583.673
Service jobs with 10G speed growth ('000')	84.200	259.404	257.371	255.354	253.352	1,278.905
Impact attributed to 10G ('000')	0.000	175.865	174.486	173.119	171.762	695.232

Source: Eurostat for 2019; European Commission annual change forecast (Spring 2020) for 2020/2021; Since 2022 ILO growth annual growth projection; Telecom Advisory Services analysis

As indicated in table E-10, the cumulative impact of spillovers on service sector employment of fixed broadband speed enabled by 10G in Germany between 2024 and 2027 will reach 695,232 jobs.

The difference between the total employment growth (146,593) and service sector job creation (695,232) highlights the role of 10G as an enabler of labour shifts between the manufacturing and services sector Research on the impact of automation on the labour force indicates that in Germany, 18 % of jobs (approximately 6,800,000) are likely to be automated within two to three decades, while another 35% will incur significant changes in the way they are conducted because of automation (Arntz et al., 2016; Nedelkoska and Quintini, 2018). In this context, a large portion of the jobs lost to automation in the primary and secondary sectors could be gradually replaced by jobs in the service sector; faster fixed broadband speeds enabled by 10G should be conceived, then, as a general-purpose technology acting as an enabler of this compensating effect.

IRELAND

The analysis of Ookla/Speedtest fixed broadband speed data in Ireland indicates that average download speed in the second quarter of 2020 had reached 79 Mbps. An extrapolation of the 2Q20/2Q18 quarterly growth rate of 5.86 % indicates that the average speed would reach 89 Mbps by the fourth quarter of 2020 and 437 Mbps by 2027. In the absence of country specific data for European nations, the ratio average to peak speed in the United States in June 2018 of 12.75% (94 Mbps/713.5 Mbps) was extended to European countries.

We assume that the migration to 10G will begin deployment in 2024, starting to generate spillovers that same year. As a result, average fixed broadband download speed is estimated to begin increasing at a faster rate than the extrapolated one in 2024 (see table E-11).

TABLE E-11. IRELAND: FIXED BROADBAND SPEED (2020-2027)

	2020	2021	2022	2023	2024	2025	2026	2027
Average download speed (in Mbps)	89	111	140	176	221	277	348	437
Average download speed growth	17.05%	25.57%	25.57%	25.57%	25.57%	25.57%	25.57%	25.57%
Average download speed with 10G (Mbps)	89	111	140	176	274	428	668	1,043
Average download speed growth	17.05%	25.57%	25.57%	25.57%	56.10%	56.10%	56.10%	56.10%

Source: Telecom Advisory Services analysis

By applying the two average download speed scenarios (with and without 10G) to the coefficient of impact for average speed higher than 40 Mbps (an 0.0073 % increase in GDP for every 1% increase in broadband speed), we can estimate the GDP impact of both download speed scenarios. Based on these two series, the impact of spillovers on GDP attributed to the technology is estimated by subtracting the impact of faster speed from that triggered by the extrapolated speed growth without 10G (see table E-12).

TABLE E-12. IRELAND: 10G SPILLOVER IMPACT ON GDP (2023-2027)

	2023	2024	2025	2026	2027
Speed contribution to GDP	0.73%	0.73%	0.73%	0.73%	0.73%
Impact of historical speed growth on GDP	0.19%	0.19%	0.19%	0.19%	0.19%
Impact of speed growth with 10G on GDP	0.19%	0.41%	0.41%	0.41%	0.41%
Impact on GDP attributed to 10G	0.00%	0.22%	0.22%	0.22%	0.22%

Source: Telecom Advisory Services analysis

The values on the last line of table E-12 are used to estimate the spillover impact of 10G on GDP. The starting point is Ireland's GDP as reported by the International Monetary Fund and Eurostat to which the impact of the last line in table E-12 is applied (see table E-13).

TABLE E-13. IRELAND: 10G SPILLOVER IMPACT ON GDP (2023-2027)

	2023	2024	2025	2026	2027	Total
GDP (in billion €)	€ 348	€ 365	€ 384	€ 403	€ 423	
Impact due to 10G (in billions €)	€ 0.000	€ 0.775	€ 0.814	€ 0.855	€ 0.898	€ 3.342

Source: IMF Data for 2019; European Commission annual change forecast (Summer 2020, Interim) for 2020/2021; Since 2022 IMF annual growth projection (2019); Telecom Advisory Services analysis

To sum up, our analysis indicates that the cumulative impact of spillovers through 2027 on Ireland's GDP of fixed broadband speed enabled by 10G will reach € 3.342 billion.

We conduct a similar analysis to assess the impact of 10G spillovers on overall employment and service sector jobs in Ireland, with the starting point being the difference in download speed scenarios with and without 10G. In the case of impact of incremental speed on overall employment, the coefficient of speed impact we calculate in the econometric model presented in Appendix C estimates that 1% increase in broadband speed yields 0.00232 increase in total employment (see table C-2). This coefficient is used to calculate the employment impact of both download speed scenarios in table E-11, and then by subtracting the impact of faster speed from the one resulting from the extrapolated speed growth without 10G, the overall employment growth attributed to the spillovers from the new technology is estimated (see table E-14).

TABLE E-14. IRELAND: 10G SPILLOVER IMPACT ON TOTAL EMPLOYMENT (2023-2027)

	2023	2024	2025	2026	2027	Total
Speed contribution to total employment	0.23%	0.23%	0.23%	0.23%	0.23%	
Total employment ('000')	2,227	2,236	2,245	2,253	2,262	
Jobs due to historical speed growth ('000')	1.321	1.326	1.331	1.337	1.342	9.285
Jobs with 10G speed growth ('000')	1.321	2.910	2.921	2.932	2.944	15.656
Impact attributed to 10G ('000')	0.000	1.584	1.590	1.596	1.602	6.371

Source: Eurostat for 2019; European Commission annual change forecast (Spring 2020) for 2020/2021; Since 2022 ILO growth annual growth projection; Telecom Advisory Services analysis

The sum of the last line of table E-14 indicates that the cumulative impact on overall employment of fixed broadband speed enabled by 10G between 2024 and 2027 in Ireland will reach 6,371 jobs.

We also assess the impact of 10G on service sector employment. In the case of the service sector, the coefficient of speed impact on service employment, as estimated in the econometric model presented in table C-2, stated that 1% increase in broadband speed yields 0.01530 % increase in service jobs. This coefficient was used to calculate the employment impact of both download speed scenarios. By subtracting the impact of faster speed from that produced by the extrapolated speed growth without 10G, the service sector employment growth attributed to spillovers from the new technology was isolated (see table E-15).

TABLE E-15. IRELAND: IMPACT ON OVERALL SERVICE SECTOR EMPLOYMENT (2023-2027)

	2023	2024	2025	2026	2027	Total
Speed contribution to service jobs	1.53%	1.53%	1.53%	1.53%	1.53%	
Total service employment ('000)	1,722	1,728	1,735	1,742	1,748	
Service jobs due to historical speed growth ('000')	6.709	6.735	6.761	6.787	6.813	47.087
Service jobs with 10G speed growth ('000')	6.709	14.777	14.833	14.890	14.948	79.439
Impact attributed to 10G ('000')	0.000	8.041	8.072	8.103	8.135	32.352

Source: Eurostat for 2019; European Commission annual change forecast (Spring 2020) for 2020/2021; Since 2022 ILO growth annual growth projection; Telecom Advisory Services analysis

As indicated in table E-15, we estimate the cumulative spillover impact on service sector employment of fixed broadband speed enabled by 10G in Ireland between 2024 and 2027 will reach 32,352 jobs.

The difference between the total employment growth (6,371) and service sector job creation (32,352) highlights the role of 10G as an enabler of labour shifts between the manufacturing and services sector. Research on the impact of automation on the labour force indicates that in the Ireland 15 % of jobs (approximately 317,000) are likely to be automated within two to three decades, while another 26% will incur significant changes in the way they are conducted because of automation (Arntz et al., 2016; Nedelkoska and Quintini, 2018). In this context, a large portion of the jobs lost to automation in the primary and secondary sectors could be gradually replaced by jobs in the services sector; faster fixed broadband speeds enabled by 10G should be conceived, then, as a general-purpose technology acting as an enabler of this compensating effect.

NETHERLANDS

Our analysis of Ookla/Speedtest fixed broadband data in the Netherlands indicates that average download speed in the second quarter of 2020 had reached 113 Mbps. An extrapolation of the 2Q20/2Q18 quarterly growth rate of 4.02% indicates that the average download speed would reach 122 Mbps by the fourth quarter of 2020 and 368 Mbps by 2027. In the absence of country specific data for European nations, the ratio of average to peak speed in the United States in June 2018 of 12.75% (94 Mbps/713.5 Mbps) was extended to European countries.

We assume that 10G will commence deployment in 2024, starting to generate spillovers that same year. As a result, average fixed broadband download speed is estimated to begin increasing at a faster rate than the historical one in 2024 (see table E-16).

TABLE E-16. NETHERLANDS: FIXED BROADBAND SPEED (2020-2027)

	2020	2021	2022	2023	2024	2025	2026	2027
Average download speed (in Mbps)	122	143	167	196	229	269	315	368
Average download speed growth	14.10%	17.09%	17.09%	17.09%	17.09%	17.09%	17.09%	17.09%
Average download speed with 10G (Mbps)	122	143	167	196	304	472	734	1,139
Average download speed growth	14.10%	17.09%	17.09%	17.09%	55.27%	55.27%	55.27%	55.27%

Source: Telecom Advisory Services analysis

By applying the two average download speed scenarios (with and without 10G) to the coefficient of speed impact for average speed higher than 40 Mbps (an 0.0073 % increase in GDP for every 1% increase in broadband speed), we estimate the GDP impact of both download speed scenarios. Based on these two series, we estimate the GDP impact attributed exclusively to the spillovers from the new technology (and not to the natural speed growth) by subtracting the impact of the historical speed growth without 10G from the faster speed (see table E-17).

TABLE E-17. NETHERLANDS: 10G SPILLOVER IMPACT ON GDP (2023-2027)

	2023	2024	2025	2026	2027
Speed contribution to GDP	0.73%	0.73%	0.73%	0.73%	0.73%
Impact of historical speed growth on GDP	0.12%	0.12%	0.12%	0.12%	0.12%
Impact of speed growth with 10G on GDP	0.12%	0.40%	0.40%	0.40%	0.40%
Impact on GDP attributed to 10G	0.00%	0.28%	0.28%	0.28%	0.28%

Source: Telecom Advisory Services analysis

We use the values on the last line of table E-17 to estimate the spillover impact of 10G on GDP. The starting point is the GDP of the Netherlands as reported by the International Monetary Fund and Eurostat. Based on this amount, we apply the impact of the last line in table E-17 (see table E-18).

TABLE E-18. NETHERLANDS: 10G SPILLOVER IMPACT ON GDP (2023-2027)

	2023	2024	2025	2026	2027	Total
GDP (in billion €)	€ 838	€ 871	€ 905	€ 940	€ 976	
Impact due to 10G (in billion €)	€ 0.000	€ 2.336	€ 2.427	€ 2.521	€ 2.619	€ 9.902

Source: IMF Data for 2019; European Commission annual change forecast (Summer 2020, Interim) for 2020/2021; Since 2022 IMF annual growth projection (2019); Telecom Advisory Services analysis

To sum up, our analysis indicates that the cumulative spillover impact of fixed broadband speed enabled by 10G through 2027 on the GDP of the Netherlands will reach € 9.902 billion.

In addition, 10G will also yield a contribution to job creation both in terms of overall employment and service sector jobs in the Netherlands. In the case of impact of incremental speed on overall employment, the coefficient of speed impact calculated in the econometric model presented in table C-2 estimated that 1% increase in broadband speed yields 0.00232 % increase in total employment. We use this coefficient to calculate the employment impact of both download speed scenarios from table E-16, and by subtracting the impact of the historical speed growth without 10G from the impact of the faster speed, we isolate the overall employment growth attributed to spillovers from the 10G technology (see table E-19).

TABLE E-19. NETHERLANDS: 10G SPILLOVER IMPACT ON TOTAL EMPLOYMENT (2023-2027)

	2023	2024	2025	2026	2027	Total
Speed contribution to total employment	0.23%	0.23%	0.23%	0.23%	0.23%	
Total employment ('000')	8,618	8,627	8,637	8,646	8,656	
Jobs due to historical speed growth ('000')	3.417	3.421	3.425	3.428	3.432	23.947
Jobs with 10G speed growth ('000')	3.417	11.063	11.075	11.087	11.099	54.563
Impact attributed to 10G ('000')	0.000	7.642	7.650	7.658	7.667	30.616

Source: Eurostat for 2019; European Commission annual change forecast (Spring 2020) for 2020/2021; Since 2022 ILO growth annual growth projection; Telecom Advisory Services analysis

The sum of the last line of table E-19 indicates that the cumulative spillover impact on overall employment of fixed broadband speed enabled by 10G between 2024 and 2027 in the Netherlands will reach 30,616 jobs.

We conducted a similar analysis to assess the impact of the spillovers from 10G on service sector employment. In the case of the service sector, the coefficient of speed impact on service employment, as estimated in the econometric model presented in table C-2, stated that 1% increase in broadband speed yields 0.01530% increase in service jobs. This coefficient was used to calculate the employment impact of both download speed scenarios. By subtracting the impact of the historical speed growth without 10G from the impact of the faster speed, we isolated the service sector employment growth attributed to spillovers from the technology (see table E-20).

TABLE E-20. NETHERLANDS: 10G SPILLOVER IMPACT ON SERVICE SECTOR EMPLOYMENT (2023-2027)

	2023	2024	2025	2026	2027	Total
Speed contribution to service jobs	1.53%	1.53%	1.53%	1.53%	1.53%	
Total service employment ('000)	7,200	7,208	7,216	7,224	7,232	
Service jobs due to historical speed growth	18.809	18.830	18.850	18.871	18.891	131.568
Service jobs with 10G speed growth	18.809	60.889	60.956	61.022	61.089	300.083
Impact attributed to 10G	0.000	42.060	42.106	42.152	42.198	168.515

Source: Eurostat for 2019; European Commission annual change forecast (Spring 2020) for 2020/2021; Since 2022 ILO growth annual growth projection; Telecom Advisory Services analysis

As indicated in table E-20, the cumulative spillover impact on service sector employment of fixed broadband speed enabled by 10G between 2024 and 2027 in the Netherlands will reach 168,515 jobs.

The difference between the total employment growth (30,616) and service sector job creation (168,515) highlights the role of 10G as an enabler of labour shifts between the manufacturing and services sector. Research on the impact of automation on the labour force indicates that in the Netherlands 12 % of jobs (approximately 1,045,000) are likely to be automated within two to three decades, while another 28% will incur significant changes in the way they are conducted due to automation (Arntz et al, 2016; Nedelkoska and Quintini, 2018). In this context, a large portion of the jobs lost to automation in the primary and secondary sectors could be gradually replaced by jobs in the services sector; faster fixed broadband speeds enabled by 10G should be conceived, then, as a general-purpose technology acting as an enabler of this compensating effect.

SWITZERLAND

The average fixed broadband download speed in Switzerland in the second quarter of 2020 had reached 156 Mbps. An extrapolation of the 3Q19/4Q18 quarterly growth rate of 4.62 % indicates that the average speed would reach 171 Mbps by the fourth quarter of 2020 and 605 Mbps by 2027. In the absence of country specific data for European nations, the ratio of average to peak speed in the United States in June 2018 of 12.75% (94 Mbps/713.5 Mbps) was extended to European countries.

Cognizant that some operators in the Swiss cable industry will select FTTx rather than the DOCSIS standard as a primary 10G architecture, the following analysis is based on spillovers that would be generated either way. We assume that the migration to 10G would commence in 2024, starting to generate spillovers that same year. As a result, we estimate average fixed broadband download speed to begin increasing at a faster rate than the historical rate in 2024 (see table E-21).

TABLE E-21. SWITZERLAND: FIXED BROADBAND SPEED (2020-2027)

	2020	2021	2022	2023	2024	2025	2026	2027
Average download speed (in Mbps)	171	205	245	294	352	421	505	605
Average download speed growth	18.26%	19.81%	19.81%	19.81%	19.81%	19.81%	19.81%	19.81%
Average download speed with 10G (Mbps)	171	205	245	294	419	599	855	1,220
Average download speed growth	18.26%	19.81%	19.81%	19.81%	42.79%	42.79%	42.79%	42.79%

Source: Telecom Advisory Services analysis

By applying the two average download speed scenarios (with and without 10G) to the coefficient of speed impact for average speed higher than 40 Mbps (an 0.0073 % increase in GDP for every 1% increase in broadband speed), we estimate the GDP impact of both download speed scenarios. Based on these two series, we derive the GDP impact attributed exclusively to spillovers from the new technology (and not to the natural speed growth) by subtracting the impact of the historical speed growth without 10G from the impact from the faster speed (see table E-22).

TABLE E-22. SWITZERLAND: 10G SPILLOVER IMPACT ON GDP (2023-2027)

	2023	2024	2025	2026	2027
Speed contribution to GDP	0.73%	0.73%	0.73%	0.73%	0.73%
Impact of historical speed growth on GDP	0.14%	0.14%	0.14%	0.14%	0.14%
Impact of speed growth with 10G on GDP	0.14%	0.31%	0.31%	0.31%	0.31%
Impact on GDP attributed to 10G	0.00%	0.17%	0.17%	0.17%	0.17%

Source: Telecom Advisory Services analysis

We use the values on the last line of table E-22 to estimate the spillover impact of 10G on GDP. The starting point is the Swiss GDP as reported by the International Monetary Fund and Eurostat. Based on this amount, we apply the impact of the last line in table E-22 (see table E-23).

TABLE E-23. SWITZERLAND: 10G SPILLOVER IMPACT ON GDP (2023-2027)

	2023	2024	2025	2026	2027	Total
GDP (in billion CHF)	CHF 723	CHF 755	CHF 789	CHF 824	CHF 861	
Impact due to 10G (in billion CHF)	CHF 0.000	CHF 1.212	CHF 1.267	CHF 1.323	CHF 1.383	CHF 4.843

Source: IMF Data for 2019; European Commission annual change forecast (Summer 2020, Interim) for 2020/2021; Since 2022 IMF annual growth projection (2019); Telecom Advisory Services analysis

To sum up, our analysis indicates that the cumulative spillover impact of fixed broadband speed enabled by 10G through 2027 on the Swiss GDP will reach CHF 4.843 billion.

In addition, 10G will also yield a contribution to job creation both in terms of overall employment and service sector jobs in Switzerland. In the case of the impact of incremental speed on overall employment, the coefficient of speed impact we calculate in the econometric model presented in chapter 3 estimates that a 1% increase in broadband speed yields 0.00232 % increase in total employment (see table C-2). We use this coefficient to calculate the employment impact of both download speed scenarios from table E-21, and by subtracting the impact of the historical speed growth without 10G from the impact of the faster speed we isolate the overall employment growth attributed to spillovers from the new technology (see table E-24).

TABLE E-24. SWITZERLAND: 10G SPILLOVER IMPACT ON TOTAL EMPLOYMENT (2023-2027)

	2023	2024	2025	2026	2027	Total
Speed contribution to total employment	0.23%	0.23%	0.23%	0.23%	0.23%	
Total employment ('000')	4,621	4,634	4,647	4,660	4,674	
Jobs due to historical speed growth ('000')	2.124	2.130	2.136	2.142	2.149	14.912
Jobs with 10G speed growth ('000')	2.124	4.600	4.613	4.627	4.640	24.835
Impact attributed to 10G ('000')	0.000	2.470	2.477	2.484	2.491	9.922

Source: Eurostat for 2019; European Commission annual change forecast (Spring 2020) for 2020/2021; Since 2022 ILO growth annual growth projection; Telecom Advisory Services analysis

The sum of the last line of table E-24 indicates that the cumulative spillover impact on overall employment of fixed broadband speed enabled by 10G between 2024 and 2027 in Switzerland will reach 9,922 jobs.

We conduct a similar analysis to assess the impact of 10G on service sector employment. In the case of the service sector, the coefficient of speed impact on service employment we estimate in the econometric model presented in table C-2 states that a 1% increase in broadband speed yields 0.01530% increase in service jobs. We use this coefficient to calculate the employment impact of both download speed scenarios. By subtracting the impact that the historical speed growth produces without 10G from the impact of the faster speed we isolate the service sector employment growth attributed to spillovers from the new technology (see table E-25).

TABLE E-25. SWITZERLAND: 10G SPILLOVER IMPACT ON SERVICE SECTOR EMPLOYMENT (2023-2027)

	2023	2024	2025	2026	2027	Total
Speed contribution to service jobs	1.53%	1.53%	1.53%	1.53%	1.53%	
Total service employment ('000)	3,584	3,594	3,604	3,614	3,625	
Service jobs due to historical speed growth ('000)	10.834	10.864	10.895	10.926	10.957	75.819
Service jobs with 10G speed growth ('000)	10.834	23.462	23.528	23.595	23.662	126.423
Impact attributed to 10G ('000)	0.000	12.597	12.633	12.669	12.705	50.604

Source: Eurostat for 2019; European Commission annual change forecast (Spring 2020) for 2020/2021; Since 2022 ILO growth annual growth projection; Telecom Advisory Services analysis

As indicated in table E-25, the cumulative spillover impact on service sector employment of fixed broadband speed enabled by 10G between 2024 and 2027 in Switzerland will reach 50,604 jobs.

The difference between the total employment growth (9,922) and service sector job creation (50,604) in Switzerland highlights the role of 10G as an enabler of labour shifts between the manufacturing and services sector. Research on the impact of automation on the labour force indicates that in advanced economies 12% of jobs are likely to be automated within two to three decades, while another 20% will incur significant changes in the way they are conducted because of automation (Arntz et al., 2016; Nedelkoska and Quintini, 2018). In this context, a large portion of the jobs lost to automation in the primary and secondary sectors could be gradually replaced by jobs in the services sector; faster fixed broadband speeds enabled by 10G should be conceived, then, as a general-purpose technology acting as an enabler of this compensating effect.

UNITED KINGDOM

The average fixed broadband download speed in the United Kingdom in the second quarter of 2020 had reached 67 Mbps. An extrapolation of the 2Q19/2Q18 quarterly growth rate of 4.78 % indicates that the average speed would reach 74 Mbps by the fourth quarter of 2020 and 273 Mbps by 2027. In the absence of country specific data for European nations, the ratio of average to peak speed in the United States in June 2018 of 12.75% (94 Mbps/713.5 Mbps) was extended to European countries.

In the following analysis we assume that the migration to 10G will commence in 2024, starting to generate spillovers that same year (see table E-26).

TABLE E-26. UNITED KINGDOM: FIXED BROADBAND SPEED (2020-2027)

	2020	2021	2022	2023	2024	2025	2026	2027
Average download speed (in Mbps)	74	89	107	129	156	188	226	273
Average download speed growth	15.86%	20.53%	20.53%	20.53%	20.53%	20.53%	20.53%	20.53%
Average download speed with 10G (Mbps)	74	89	107	129	216	362	606	1,015
Average download speed growth	15.86%	20.53%	20.53%	20.53%	67.46%	67.46%	67.46%	67.46%

Source: Telecom Advisory Services analysis

By applying the two average download speed scenarios (with and without 10G) to the coefficient of speed impact for average speed higher than 40 Mbps (an 0.0073 % increase in GDP for every 1% increase in broadband speed), we can estimate the impact of spillovers on GDP of both scenarios. Based on these two series, the GDP spillover impact we attribute exclusively to the technology is estimated by subtracting the impact of the historical speed growth without 10G from the impact of the faster speed (see table E-27).

TABLE E-27. UNITED KINGDOM: 10G SPILLOVER IMPACT ON GDP (2023-2027)

	2023	2024	2025	2026	2027
Speed contribution to GDP	0.73%	0.73%	0.73%	0.73%	0.73%
Impact of historical speed growth on GDP	0.15%	0.15%	0.15%	0.15%	0.15%
Impact of speed growth with 10G on GDP	0.15%	0.49%	0.49%	0.49%	0.49%
Impact on GDP attributed to 10G	0.00%	0.34%	0.34%	0.34%	0.34%

Source: Telecom Advisory Services analysis

We use the values on the last line of table E-27 to calculate the spillover impact of 10G on GDP. For this purpose, the impact of the last line in table E-27 is applied to the GDP of the United Kingdom as reported by the International Monetary Fund and Eurostat (see table E-28).

TABLE E-28. UNITED KINGDOM: 10G SPILLOVER IMPACT ON GDP (2023-2027)

	2023	2024	2025	2026	2027	Total
GDP (in billion £)	£2,210	£2,296	£2,385	£2,478	£2,574	
Impact due to 10G (in billion £)	£0.000	£7.570	£7.864	£8.170	£8.488	£35.893

Source: IMF Data for 2019; European Commission annual change forecast (Summer 2020, Interim) for 2020/2021; Since 2022 IMF annual growth projection (2019); Telecom Advisory Services analysis

In summary, the analysis indicates that the cumulative spillover impact of fixed broadband speed enabled by 10G through 2027 on the GDP of the United Kingdom will reach £ 35.893 billion.

In addition, spillovers from 10G will also yield a contribution to job creation both in terms of overall employment and service sector jobs. In the case of impact of incremental speed on overall employment, the coefficient of speed impact we estimate shows that a 1% increase in broadband speed yields 0.00232% increase in total employment (see table C-2). We use this coefficient to calculate the employment impact of both download speed scenarios from table E-26, and by subtracting the impact of the historical speed growth without 10G from the impact of the faster speed, we isolate the overall employment growth attributed to spill-overs from the new technology (see table E-29).

TABLE E-29. UNITED KINGDOM: 10G SPILLOVER IMPACT ON TOTAL EMPLOYMENT (2023-2027)

	2023	2024	2025	2026	2027	Total
Speed contribution to total employment	0.23%	0.23%	0.23%	0.23%	0.23%	
Total employment ('000')	31,142	31,217	31,292	31,368	31,443	
Jobs due to historical speed growth ('000)	14.836	14.872	14.908	14.944	14.980	104.106
Jobs with 10G speed growth ('000)	14.836	48.853	48.971	49.089	49.207	240.523
Impact attributed to 10G ('000)	0.000	33.981	34.063	34.145	34.227	136.417

Source: Eurostat for 2019; European Commission annual change forecast (Spring 2020) for 2020/2021; Since 2022 ILO growth annual growth projection; Telecom Advisory Services analysis

The sum of the last line of table E-29 indicates that the cumulative spillover impact on overall employment of fixed broadband speed enabled by 10G between 2024 and 2027 in the United Kingdom will reach 136,417 jobs.

We conduct a similar analysis to assess the impact of 10G on service sector employment. In the case of the service sector, the coefficient of speed impact on service employment we estimate in the econometric model in table C-2 in chapter appendix C, stated that 1% increase in broadband speed yields 0.0153% increase in service jobs. We use this coefficient to calculate the employment impact of both download speed scenarios. By subtracting the extrapolated speed growth without 10G from the impact of faster speed, we isolate the service sector employment growth attributed to spillovers from the new technology (see table E-30).

TABLE E-30. UNITED KINGDOM: 10G SPILLOVER IMPACT ON SERVICE SECTOR EMPLOYMENT (2023-2027)

	2023	2024	2025	2026	2027	Total
Speed contribution to service jobs	1.53%	1.53%	1.53%	1.53%	1.53%	
Total service employment ('000)	25,256	25,317	25,378	25,439	25,501	
Service jobs due to historical speed growth	79.161	79.352	79.543	79.734	79.926	554.490
Service jobs with 10G speed growth ('000)	79.161	260.662	261.290	261.919	262.550	1,282.357
Impact attributed only to 10G ('000)	0.000	181.311	181.747	182.185	182.624	727.867

Source: Eurostat for 2019; European Commission annual change forecast (Spring 2020) for 2020/2021; Since 2022 ILO growth annual growth projection; Telecom Advisory Services analysis

As indicated in table E-30, the cumulative spillover impact on service sector employment of fixed broadband speed enabled by 10G between 2024 and 2027 in the United Kingdom will reach 727,867 jobs.

The difference between the total employment growth (136,417) and service sector job creation (727,867) in the United Kingdom highlights the role of 10G as an enabler of labour shifts between the manufacturing and services sector. Research on the impact of automation on the labour force indicates that in the United Kingdom 11% of jobs are likely to be automated (approximately 3,600,000) within two to three decades, while another 27% will incur significant changes in the way they are conducted due to automation (Deloitte, 2015; Arntz et al., 2016; Nedelkoska and Quintini, 2018). In this context, a large portion of the jobs lost to automation in the primary and secondary sectors could be gradually replaced by jobs in the services sector; faster fixed broadband speeds enabled by 10G should be conceived, then, as a general-purpose technology acting as an enabler of this compensating effect.

APPENDIX F: ESTIMATES OF CONSUMER SURPLUS GENERATED BY THE MIGRATION TO 10G NETWORKS

BELGIUM

Based on the difference between the extrapolated growth and of fixed broadband download speeds with and without 10G, we calculated the monthly consumer surplus per cable broadband subscriber in Belgium attributable to 10G (see table F-1).

TABLE F-1. BELGIUM: MONTHLY CONSUMER SURPLUS PER CABLE BROADBAND SUBSCRIBER (2024-2027)

	2024	2025	2026	2027
1. Average download speed (in Mbps)	196	235	281	336
2. Consumer surplus based on average download speed (€)	€ 144.03	€ 148.19	€ 152.35	€ 156.51
3. Average download speed with 10G (Mbps)	261	417	665	1,062
4. Consumer surplus based on average download speed (€)	€ 150.68	€ 161.49	€ 172.30	€ 183.11
5. Consumer surplus attributed to 10G per subscriber (€)	€ 6.65	€ 13.30	€ 19.95	€ 26.60

Notes:
(2/4) Consumer surplus = 27.206*LN (Average download speed) +25.852
Source: Telecom Advisory Services analysis

As indicated in table F-1, monthly consumer surplus per subscriber due to the growth in speed attributed to 10G increases from € 6.65 in 2024 (when average download speed reaches 261 Mbps) to € 26.60 in 2027 (when average download speed reaches 1,062 Mbps). This increase in surplus is driven by an improvement in service quality (speeds and latency) as well the ability to adopt new bandwidth intensive applications.

By converting the monthly consumer surplus estimate to a yearly number and then multiplying the value by the total projected number of cable broadband subscribers, we can calculate the annual aggregate incremental consumer benefit from 10G (see table F-2).

TABLE F-2. BELGIUM: TOTAL CONSUMER SURPLUS ATTRIBUTED TO 10G (2024-2027)

	2024	2025	2026	2027
1. Annual consumer surplus per subscriber (€)	€ 79.80	€ 159.60	€ 239.40	€ 319.20
2. Total cable broadband subscribers (‘000’000)	2.60	2.63	2.66	2.70
3. Total annual consumer surplus (€ ‘000’000)	€ 207	€ 420	€ 637	€ 861
TOTAL (2024-27) (€ ‘000’000)				€ 2,125

Notes:
(1) Line 5 from table F-1*12
(2) Kagan, *Global Forecast Table* through 2024, and extrapolation of 2023-24 growth
(3) Line 1*Line 2
Source: Telecom Advisory Services analysis

As a result, we estimate that the average annual consumer surplus attributed to 10G between 2024 and 2027 in Belgium will reach € 531 million.

GERMANY

Based on the difference between the natural growth and of fixed broadband download speeds with and without 10G in Germany, we calculated the monthly consumer surplus per cable broadband subscriber in this country attributable to 10G (see table F-3).

TABLE F-3. GERMANY: MONTHLY CONSUMER SURPLUS PER CABLE BROADBAND SUBSCRIBER (2024-2027)

	2024	2025	2026	2027
1. Average download speed (in Mbps)	200	237	283	336
2. Consumer surplus based on average download speed (€)	€ 144.45	€ 148.47	€ 152.49	€ 156.51
3. Average download speed with 10G (Mbps)	267	424	674	1,071
4. Consumer surplus based on average download speed with 10G (€)	€ 151.15	€ 161.87	€ 172.59	€ 183.30
5. Consumer surplus attributed to 10G per subscriber (€)	€ 6.70	€ 13.40	€ 20.10	€ 26.79

Notes:
(2/4) Consumer surplus = 27.206*LN (Average download speed) +25.852
Source: Telecom Advisory Services analysis

As indicated in table F-3, monthly consumer surplus per subscriber due to the growth in speed attributed to 10G increases from € 6.70 in 2024 (when average download speed reaches 267 Mbps) to € 26.79 in 2027 (when average download speed reaches 1,071 Mbps). This increase in surplus is driven by an improvement in service quality (speeds and latency) as well the ability to adopt new bandwidth intensive applications.

By converting the monthly consumer surplus estimate to a yearly number and then multiplying the value by the total projected number of cable broadband subscribers, we can calculate the annual aggregate incremental consumer benefit from 10G (see table F-4).

TABLE F-4. GERMANY: TOTAL CONSUMER SURPLUS ATTRIBUTED TO 10G (2024-2027)

	2024	2025	2026	2027
1. Annual consumer surplus per subscriber (€)	€ 80.38	€ 160.76	€ 241.15	€ 321.53
2. Total cable broadband subscribers (‘000’000)	8.66	8.92	9.19	9.47
3. Total annual consumer surplus (€ ‘000’000)	€ 696	€ 1,435	€ 2,217	€ 3,044
TOTAL (2024-27) (€ ‘000’000)				€ 7,392

Notes:
(1) Line 5 from table F-3*12
(2) Kagan, *Global Forecast Table* through 2024, and extrapolation of 2023-24 growth
(3) Line 1*Line 2
Source: Telecom Advisory Services analysis

As a result, the average consumer surplus per year attributed to 10G between 2024 and 2027 in Germany will reach € 1.848 billion.

IRELAND

Based on the difference between the natural growth and of fixed broadband download speed per the forecast in Ireland, we calculate the monthly consumer surplus per cable broadband subscriber in this country attributable to 10G (see table F-5).

TABLE F-5. IRELAND: MONTHLY CONSUMER SURPLUS PER CABLE BROADBAND SUBSCRIBER (2024-2027)

	2024	2025	2026	2027
1. Average download speed (in Mbps)	221	277	348	437
2. Consumer surplus based on average download speed (€)	€ 146.77	€ 152.04	€ 157.30	€ 162.57
3. Average download speed with 10G (Mbps)	274	428	668	1,043
4. Consumer surplus based on average download speed with 10G (€)	€ 151.80	€ 162.10	€ 172.40	€ 182.70
5. Consumer surplus attributed to 10G per subscriber (€)	€ 5.03	€ 10.07	€ 15.10	€ 20.13

Notes:
(2/4) Consumer surplus = 27.206*LN (Average download speed) +25.852
Source: Telecom Advisory Services analysis

As indicated in table F-5, monthly consumer surplus per subscriber due to the growth in speed attributed to 10G increases from € 5.03 in 2024 (when average download speed reaches 274 Mbps) to € 20.13 in 2027 (when average download speed reaches 1,043 Mbps). This increase in surplus is driven by an improvement in service quality (speeds and latency) as well the ability to adopt new bandwidth intensive applications.

By converting the monthly consumer surplus estimate to a yearly number and then multiplying the value by the total projected number of cable broadband subscribers, we can calculate the annual aggregate incremental consumer benefit from 10G (see table F-6).

TABLE F-6. IRELAND: TOTAL CONSUMER SURPLUS ATTRIBUTED TO 10G (2024-2027)

	2024	2025	2026	2027
1. Annual consumer surplus per subscriber (€)	€ 60.39	€ 120.78	€ 181.17	€ 241.56
2. Total cable broadband subscribers ('000'000)	0.38	0.39	0.39	0.40
3. Total annual consumer surplus (€ '000'000)	€ 23	€ 47	€ 71	€ 96
TOTAL (2024-27) (€ '000'000)				€ 237

Notes:
(1) Line 5 from table F-5*12
(2) Kagan, *Global Forecast Table* through 2024, and extrapolation of 2023-24 growth
(3) Line 1*Line 2
Source: Telecom Advisory Services analysis

As a result, we estimate that the average annual consumer surplus attributed to 10G between 2024 and 2027 in Ireland will reach € 59 million.

NETHERLANDS

Based on the difference between the natural growth and of fixed broadband download speed per the forecast in the Netherlands, we calculate the monthly consumer surplus per cable broadband subscriber in this country attributable to 10G (see table F-7).

TABLE F-7. NETHERLANDS: MONTHLY CONSUMER SURPLUS PER CABLE BROADBAND SUBSCRIBER (2024-2027)

	2024	2025	2026	2027
1. Average download speed (in Mbps)	229	269	315	368
2. Consumer surplus based on average download speed (€)	€ 147.68	€ 151.33	€ 154.97	€ 158.62
3. Average download speed with 10G (Mbps)	304	472	734	1,139
4. Consumer surplus based on average download speed with 10G (€)	€ 154.20	€ 164.38	€ 174.55	€ 184.73
5. Consumer surplus attributed to 10G per subscriber (€)	€ 6.53	€ 13.05	€ 19.58	€ 26.10

Notes:
(2/4) Consumer surplus = 27.206*LN (Average download speed) +25.852
Source: Telecom Advisory Services analysis

As indicated in table F-7, monthly consumer surplus per subscriber due to the growth in speed attributed to 10G increases from € 6.53 in 2024 (when average download speed reaches 304 Mbps) to € 26.10 in 2027 (when average download speed reaches 1,139 Mbps). This increase in surplus is driven by an improvement in service quality (speeds and latency) as well the ability to adopt new bandwidth intensive applications.

By converting the monthly consumer surplus estimate to a yearly number and then multiplying the value by the total projected number of cable broadband subscribers, we can calculate the annual aggregate incremental consumer benefit from 10G (see table F-8).

TABLE F-8. NETHERLANDS: TOTAL CONSUMER SURPLUS ATTRIBUTED TO 10G (2024-2027)

	2024	2025	2026	2027
1. Annual consumer surplus per subscriber (€)	€ 78.31	€ 156.63	€ 234.94	€ 313.25
2. Total cable broadband subscribers (‘000’000)	3.68	3.71	3.75	3.78
3. Total annual consumer surplus (€ ‘000’000)	€ 288	€ 581	€ 880	€ 1,185
TOTAL (2024-27) (€ ‘000’000)				€ 2,934

Notes:
(1) Line 5 from table F-7*12
(2) Kagan, *Global Forecast Table* through 2024, and extrapolation of 2023-24 growth
(3) Line 1*Line 2
Source: Telecom Advisory Services analysis

As a result, the annual average consumer surplus attributed to 10G by 2027 in the Netherlands will reach € 733 million.

SWITZERLAND

Based on the difference between the natural growth and of fixed broadband download speed per the forecast in Switzerland, we calculate the monthly consumer surplus per cable broadband subscriber in this country attributable to 10G (see table F-9)

TABLE F-9. SWITZERLAND: MONTHLY CONSUMER SURPLUS PER CABLE BROADBAND SUBSCRIBER (2024-2027)

	2024	2025	2026	2027
1.Average download speed (in Mbps)	352	421	505	605
2.Consumer surplus based on average download speed (CHF)	CHF 168.68	CHF 173.15	CHF 177.63	CHF 182.10
3.Average download speed with 10G (Mbps)	419	599	855	1,220
4.Consumer surplus based on average download speed with 10G (CHF)	CHF 173.02	CHF 181.84	CHF 190.66	CHF 199.48
5.Consumer surplus attributed to 10G per subscriber (CHF)	CHF 4.34	CHF 8.69	CHF 13.03	CHF 17.37

Notes:
(2/4) Consumer surplus = 27.206*LN (Average download speed) +25.852

As indicated in table F-9, monthly consumer surplus per subscriber due to the growth in speed attributed to 10G increases from CHF 4.34 in 2024 (when average download speed reaches 415 Mbps) to CHF 17.37 in 2027 (when average download speed reaches 1,220 Mbps). This increase in surplus is driven by an improvement in service quality (speeds and latency) as well the ability to adopt new bandwidth intensive applications.

By converting the monthly consumer surplus estimate to a yearly number and then multiplying the value by the total projected number of cable broadband subscribers, we can calculate the annual aggregate incremental consumer benefit from 10G (see table F-10).

TABLE F-10. SWITZERLAND: TOTAL CONSUMER SURPLUS ATTRIBUTED TO 10G (2024-2027)

	2024	2025	2026	2027
1. Annual consumer surplus per subscriber (CHF)	CHF 52.12	CHF 104.23	CHF 156.35	CHF 208.47
2. Total cable broadband subscribers ('000'000)	1.22	1.24	1.25	1.26
3. Total annual consumer surplus (CHF '000'000)	CHF 64	CHF 129	CHF 195	CHF 262
TOTAL (2024-27) (CHF '000'000)				€ 650

Notes:
(1) Line 5 from table F-9*12
(2) Kagan, *Global Forecast Table* through 2024, and extrapolation of 2023-24 growth
(3) Line 1*Line 2

Source: Telecom Advisory Services analysis

As a result, we estimate that the average annual consumer surplus attributed to 10G in 2027 in Switzerland will reach CHF 162 million.

UNITED KINGDOM

Based on the difference between the natural growth and of fixed broadband download speed per the forecast in the United Kingdom, we calculate the monthly consumer surplus per cable broadband subscriber in this country attributable to 10G (see table F-11)

TABLE F-11. UNITED KINGDOM: MONTHLY CONSUMER SURPLUS PER CABLE BROADBAND SUBSCRIBER (2024-2027)

	2024	2025	2026	2027
1. Average download speed (in Mbps)	156	188	226	273
2. Consumer surplus based on average download speed (£)	£124.02	£127.88	£131.74	£135.60
3. Average download speed with 10G (Mbps)	216	362	606	1,015
4. Consumer surplus based on average download speed with 10G (£)	£130.81	£141.47	£152.13	£162.79
5. Consumer surplus attributed to 10G (per subscriber £)	£6.80	£13.60	£20.39	£27.19

Notes:
(2/4) Consumer surplus = 27.206*LN (Average download speed) +25.852
Source: Telecom Advisory Services analysis

As indicated in table F-11, monthly consumer surplus per subscriber due to the growth in speed attributed to 10G increases from £ 6.80 in 2024 (when average download speed reaches 216 Mbps) to £ 27.19 in 2027 (when average download speed reaches 1,015 Mbps). This increase in surplus is driven by an improvement in service quality (speeds and latency) as well the ability to adopt new bandwidth intensive applications.

By converting the monthly consumer surplus estimate to a yearly number and then multiplying the value by the total projected number of cable broadband subscribers, we can calculate the annual aggregate incremental consumer benefit from 10G (see table F-12).

TABLE F-12. UNITED KINGDOM: TOTAL CONSUMER SURPLUS ATTRIBUTED TO 10G (2024-2027)

	2024	2025	2026	2027
1. Annual consumer surplus per subscriber (£)	£81.58	£163.15	£244.73	£326.30
2. Total cable broadband subscribers ('000'000)	6.07	6.18	6.30	6.42
3. Total annual consumer surplus (£ '000'000)	£495	£1,009	£1,542	£2,095
TOTAL (2024-27) (£ '000'000)				€ 5,141

Notes:
(1) Line 5 from table F-11*12
(2) Kagan, *Global Forecast Table* through 2024, and extrapolation of 2023-24 growth
(3) Line 1*Line 2
Source: Telecom Advisory Services analysis

As a result, we estimate that the average annual consumer surplus attributed to 10G between 2024 and 2027 in the United Kingdom will reach £ 1.285 billion.

APPENDIX G: SUMMARY OF ECONOMIC BENEFITS FROM 10G MIGRATION

As discussed in chapter 2 and estimated throughout the study, 10G will yield three major categories of economic effects: 1) a direct, indirect and induced impact on GDP and employment triggered by investment in 10G network migration, 2) the spillovers on GDP and employment resulting from the impact of 10G on consumer expenditures and enterprise productivity, new business model development, and overall business expansion, as evidenced by emerging applications and use cases and 3) consumer surplus.

For the purposes of our analysis, we assume that the impact of investment in 10G starts occurring at the time when the cable industry in each country begins its shift to the deployment of DOCSIS 4.0. This leads to a conservative estimate of the economic benefits, since some of the value of the implementation of DOCSIS 3.1 should be attributed to 10G. Spillovers on GDP and employment and increases in consumer surplus begin to materialize as the 10G infrastructure is deployed.

BELGIUM

Our analysis shows that the aggregate economic contribution of 10G in Belgium will evolve from € 2.176 billion (or 0.43% of GDP) in 2024 to € 2.994 billion in 2027. These estimates assume that investment to migrate to 10G will be split evenly over four years (see table G-1).

TABLE G-1. BELGIUM: TOTAL ECONOMIC CONTRIBUTION OF 10G (IN € BILLION)

		2024	2025	2026	2027
Network investment	Direct	€ 0.341	€ 0.341	€ 0.341	€ 0.341
	Indirect and induced	€ 0.214	€ 0.214	€ 0.214	€ 0.214
	Total	€ 0.555	€ 0.555	€ 0.555	€ 0.555
Spillovers		€ 1.414	€ 1.467	€ 1.522	€ 1.578
Consumer surplus		€ 0.207	€ 0.420	€ 0.637	€ 0.861
Total		€ 2.176	€ 2.441	€ 2.714	€ 2.994
Percent of GDP		0.43%	0.47%	0.50%	0.53%

Source: Telecom Advisory Services analysis

Spillovers consistently represent the largest source of economic contribution to the GDP. At the beginning of the time period (2024 when the migration to 10G is assumed to begin), spillovers represent 64.99 % of the total impact. Over time, that proportion decreases, but it remains the largest contributor. By 2027 we estimate that spillovers contribute to 52.72 % of the aggregate economic impact. By then, consumer surplus will reach 28.75% of the total contribution and network investment the remaining 18.53%.

In addition, our estimates of the overarching impact of 10G on employment is shown in table G-2.

TABLE G-2. BELGIUM: TOTAL CONTRIBUTION OF 10G TO JOB CREATION

		2024	2025	2026	2027
Network investment	Direct	1,211	1,211	1,211	1,211
	Indirect and induced	511	511	511	511
	Total	1,721	1,721	1,721	1,721
Spillovers		4,416	4,413	4,411	4,408
Total		6,136	6,134	6,132	6,129

Source: Telecom Advisory Services analysis

We estimate that the evolution of cable's platform to 10G will generate, from investment and spillovers, an average of 6,133 jobs per year. Of these jobs, 1,721 are employed either directly or indirectly to help with the migration to 10G, while spillovers will create an average of 4,412 jobs every year.

Finally, 10G will help ensure that jobs lost in the primary and secondary economies particularly from automation are offset through new employment in the service sector. We estimate that the technology will create a total of 91,457 jobs over a four-year period (or 22,846 per year).

GERMANY

We estimate that the aggregate economic contribution of 10G to Germany will evolve from € 15.146 billion (or 0.39 % of GDP) in 2024 to € 18.949 billion (0.43 % of projected GDP) in 2027. These estimates assume that investment will be split evenly over four years of migration to 10G (see table G-3).

TABLE G-3. GERMANY: TOTAL ECONOMIC CONTRIBUTION OF 10G (IN € BILLION)

		2024	2025	2026	2027
Network investment	Direct	€ 2.253	€ 2.253	€ 2.253	€ 2.253
	Indirect and induced	€ 1.199	€ 1.199	€ 1.199	€ 1.199
	Total	€ 3.452	€ 3.452	€ 3.452	€ 3.452
Spillovers		€ 10.998	€ 11.463	€ 11.948	€ 12.453
Consumer surplus		€ 0.696	€ 1.435	€ 2.217	€ 3.044
Total		€ 15.146	€ 16.350	€ 17.616	€ 18.949
Percent of GDP		0.39%	0.40%	0.41%	0.43%

Source: Telecom Advisory Services analysis

Spillovers consistently represent the largest source of economic contribution to the GDP. At the beginning of the time period (2024 when the migration to 10G is assumed to begin), spillovers represent 72.61 % of the total impact. Over time, that proportion decreases, but it remains the largest contributor. By 2027 we estimate that spillovers contribute to 65.72 % of the aggregate economic impact. By then, consumer surplus will reach 16.07% of the total contribution and network investment the remaining 18.22%.

In addition, we find a somewhat limited impact on employment (see table G-4).

TABLE G-4. GERMANY: TOTAL CONTRIBUTION OF 10G TO JOB CREATION

		2024	2025	2026	2027
Network investment	Direct	13,320	13,320	13,320	13,320
	Indirect and induced	5,705	5,705	5,705	5,705
	Total	19,025	19,025	19,025	19,025
Spillovers		37,082	36,791	36,503	36,217
Total		56,107	55,816	55,528	55,242

Source: Telecom Advisory Services analysis

The evolution of cable's platform to 10G will generate, from investment and spillovers, an average of 55,673 jobs per year. Of these jobs, 19,025 will be employed either directly or indirectly to help with the migration to 10G, while spillovers create an average of 36,648 jobs every year.

On the other hand, 10G will help ensure that jobs lost in the primary and secondary economies, as a result of the impact from automation, are offset through new employment in the service sector. The technology will create a total of 695,232 service sector jobs over a four-year period (or 171,762 per year). As mentioned before, by creating jobs in the service sector to offset some of the jobs in the primary and secondary sectors of the economy that will be lost to automation (estimated at 18 % of the labour force over the next two decades by Nedelkoska and Quintini, 2018), 10G will enable a compensating effect for this potential job loss.

IRELAND

We estimate that the aggregate contribution of 10G to the GDP of Ireland will evolve from € 0.856 billion (or 0.23 % of GDP) in 2024 to € 1.051 billion (0.25 % of forecasted GDP) in 2027. These estimates assume that the migration to 10G (and consequently investment) will be split evenly over the four years of deployment. (see table G-5).

TABLE G-5. IRELAND: TOTAL ECONOMIC CONTRIBUTION OF 10G (IN € BILLION)

		2024	2025	2026	2027
Network investment	Direct	€ 0.043	€ 0.043	€ 0.043	€ 0.043
	Indirect and induced	€ 0.015	€ 0.015	€ 0.015	€ 0.015
	Total	€ 0.057	€ 0.057	€ 0.057	€ 0.057
Spillovers		€ 0.775	€ 0.814	€ 0.855	€ 0.898
Consumer surplus		€ 0.023	€ 0.047	€ 0.071	€ 0.096
Total		€ 0.856	€ 0.918	€ 0.984	€ 1.051
Percent of GDP		0.23%	0.24%	0.24%	0.25%

Source: Telecom Advisory Services analysis

Spillovers consistently represent the largest source of economic contribution to the GDP. In 2024, when the migration to 10G is assumed to begin, spillovers will represent 90.58 % of the total impact. Over time, that proportion decreases, but it remains the largest contributor. By 2027 spillovers are responsible for 85.41 % of the aggregate economic impact. By then, consumer surplus will reach 9.13 % of the total contribution and network investment the remaining 5.46%.

On the other hand, we find a somewhat limited impact on employment (see table G-6).

TABLE G-6. IRELAND: TOTAL CONTRIBUTION OF 10G TO JOB CREATION

		2024	2025	2026	2027
Network investment	Direct	169	169	169	169
	Indirect and induced	39	39	39	39
	Total	207	207	207	207
Spillovers		1,584	1,590	1,596	1,602
Total		1,791	1,797	1,803	1,809

Source: Telecom Advisory Services analysis

The evolution of cable's platform to 10G will generate, from investment and spillovers, an average of 1,800 jobs per year. Of these, approximately 207 are employed either directly or indirectly to help with the migration of current networks to 10G. Spillovers create an average of 1,593 jobs every year.

In addition, 10G will represent an important factor in ensuring that jobs lost in the primary and secondary economies are compensated through new employment in the service sector. The technology will contribute to create a total of 32,352 service sector jobs over a four-year period (or 8,135 per year). As mentioned before, by creating jobs in the service sector to offset some of the jobs in the primary and secondary sectors of the economy that will be lost to automation (estimated at 15 % of the labour force over the next two decades by Nedelkoska and Quintini, 2018), 10G will enable a compensating effect for this potential job loss..

NETHERLANDS

We estimate that the aggregate contribution of 10G to the GDP of the Netherlands will evolve from € 3.447 billion (or 0.40 % of GDP) in 2024 to € 4.627 billion (0.47 % of projected GDP) in 2027. These estimates assume that the migration of the network to 10G (and consequently investment) will be split evenly over four years (see table G-7).

TABLE G-7. NETHERLANDS: TOTAL ECONOMIC CONTRIBUTION OF 10G (IN € BILLION)

		2024	2025	2026	2027
Network investment	Direct	€ 0.494	€ 0.494	€ 0.494	€ 0.494
	Indirect and induced	€ 0.329	€ 0.329	€ 0.329	€ 0.329
	Total	€ 0.824	€ 0.824	€ 0.824	€ 0.824
Spillovers		€ 2.336	€ 2.427	€ 2.521	€ 2.619
Consumer surplus		€ 0.288	€ 0.581	€ 0.880	€ 1.185
Total		€ 3.447	€ 3.831	€ 4.225	€ 4.627
Percent of GDP		0.40%	0.42%	0.45%	0.47%

Source: Telecom Advisory Services analysis

Spillovers consistently represent the largest source of economic contribution to the GDP. In 2024, when the migration to 10G is assumed to begin, we find that spillovers will represent 67.76 % of the total impact. Over time, that proportion decreases, but it remains the largest contributor. By 2027 spillovers are responsible for 56.60 % of the aggregate economic impact. By then, consumer surplus will reach 25.60 % of the total contribution and network investment the remaining 17.80%.

On the other hand, we find a somewhat limited impact on employment (see table G-8).

TABLE G-8. NETHERLANDS: TOTAL CONTRIBUTION OF 10G TO JOB CREATION

		2024	2025	2026	2027
Network investment	Direct	1,403	1,403	1,403	1,403
	Indirect and induced	921	921	921	921
	Total	2,324	2,324	2,324	2,324
Spillovers		7,642	7,650	7,658	7,667
Total		9,966	9,974	9,982	9,991

Source: Telecom Advisory Services analysis

The evolution of cable's platform to 10G will generate, from investment and spillovers, an average of 9,978 jobs per year. Of these, 2,324 are employed either directly or indirectly to help with the migration of current networks to 10G every year. We estimate that spillovers will create an average of 7,654 jobs every year.

However, we find that 10G will help ensure that jobs lost in the primary and secondary economies particularly due to automation are offset through new employment in the service sector. The technology will create a total of 168,515 service sector jobs over a four-year period (or 42,198 per year). As mentioned before, by creating jobs in the service sector to offset some of the jobs in the primary and secondary sectors of the economy that will be lost to automation (estimated at 12% of the labour force over the next two decades by Nedelkoska and Quintini, 2018), 10G will enable a compensating effect for this potential job loss.

SWITZERLAND

We estimate that the aggregate contribution of 10G to the GDP of Switzerland will evolve from CHF 1.587 billion (or 0.21 % of GDP) in 2024 to CHF 1.956 billion (0.23 % of GDP) in 2027. These estimates assume that the investment to migrate the network to 10G will be split evenly over the four years (see table G-9).

TABLE G-9. SWITZERLAND: TOTAL ECONOMIC CONTRIBUTION OF 10G (IN CHF BILLION)

		2024	2025	2026	2027
Network investment	Direct	CHF 0.203	CHF 0.203	CHF 0.203	CHF 0.203
	Indirect and induced	CHF 0.108	CHF 0.108	CHF 0.108	CHF 0.108
	Total	CHF 0.311	CHF 0.311	CHF 0.311	CHF 0.311
Spillovers		CHF 1.212	CHF 1.267	CHF 1.323	CHF 1.383
Consumer surplus		CHF 0.064	CHF 0.129	CHF 0.195	CHF 0.262
Total		CHF 1.587	CHF 1.706	CHF 1.829	CHF 1.956
Percent of GDP		0.21%	0.22%	0.22%	0.23%

Source: Telecom Advisory Services analysis

Spillovers consistently represent the largest source of economic contribution to the GDP. In 2024, when the migration to 10G is assumed to begin, spillovers will represent 76.38 % of the total impact. Over time, that proportion decreases, but it remains the largest contributor. By 2027 spillovers contribute to 70.69 % of the aggregate economic impact. By then, consumer surplus will reach 13.40 % of the total contribution and network investment the remaining 15.90 %.

On the other hand, we find a somewhat limited impact on employment (see table G-10).

TABLE G-10. SWITZERLAND: TOTAL CONTRIBUTION OF 10G TO JOB CREATION

		2024	2025	2026	2027
Network investment	Direct	568	568	568	568
	Indirect and induced	244	244	244	244
	Total	812	812	812	812
Spillovers		2,470	2,477	2,484	2,491
Total		3,282	3,289	3,296	3,303

Source: Telecom Advisory Services analysis

The evolution of cable's platform to 10G will generate, from investment and spillovers, an average of 3,292 jobs per year. Of these jobs, approximately 812 per year will be employed either directly or indirectly to help the migration of the current networks to 10G. Spillovers will create an average of 2,480 jobs every year.

However, we find that 10G will help ensure that jobs lost in the primary and secondary economies particularly from automation are offset through new employment in the service sector. The technology will create a total of 50,604 service sector jobs over a four-year period (or nearly 12,705 per year). As mentioned before, to offset some of the jobs in the primary and secondary sectors of the economy that will be lost to automation 10G will enable a compensating effect for this potential job loss.

UNITED KINGDOM

We estimate that the aggregate contribution of 10G to the GDP of the United Kingdom will evolve from £ 9.036 billion (or 0.39 % of GDP) in 2024 to £ 11.554 billion (0.45 % of the projected GDP) in 2027. These estimates assume that investment to migrate the network to 10G will be split evenly over four years (see table G-11).

TABLE G-11. UNITED KINGDOM: TOTAL ECONOMIC CONTRIBUTION OF 10G (IN £ BILLION)

		2024	2025	2026	2027
Network investment	Direct	£0.602	£0.602	£0.602	£0.602
	Indirect and induced	£0.368	£0.368	£0.368	£0.368
	Total	£0.971	£0.971	£0.971	£0.971
Spillovers		£7.570	£7.864	£8.170	£8.488
Consumer surplus		£0.495	£1.009	£1.542	£2.095
Total		£9.036	£9.844	£10.683	£11.554
Percent of GDP		0.39%	0.41%	0.43%	0.45%

Source: Telecom Advisory Services analysis

Spillovers consistently represent the largest source of economic contribution to the GDP. In 2024, when the migration to 10G is assumed to begin, spillovers will represent 83.78 % of the total impact. Over time, that proportion decreases, but it remains the largest economic contributor. By 2027 spillovers contribute to 73.47 % of the aggregate economic impact. By then, consumer surplus will reach 18.13 % of the total contribution and network investment the remaining 8.40 %.

On the other hand, we find a somewhat limited impact on employment (see table G-12).

TABLE G-12. UNITED KINGDOM: TOTAL CONTRIBUTION OF 10G TO JOB CREATION

		2024	2025	2026	2027
Network investment	Direct	3,326	3,326	3,326	3,326
	Indirect and induced	1,465	1,465	1,465	1,465
	Total	4,791	4,791	4,791	4,791
Spillovers		33,981	34,063	34,145	34,227
Total		38,772	38,854	38,936	39,018

Source: Telecom Advisory Services analysis

The evolution of cable's platform to 10G will generate, from investment and spillovers, an average of 38,895 jobs per year. Of these jobs, 4,791 per year will be employed either directly or indirectly to help with the migration of current networks to 10G. On the other hand, we find that spillovers create an average of 34,104 jobs every year.

Finally, 10G will help ensure that jobs lost in the primary and secondary economies particularly from automation are offset through new employment in the service sector. The technology will create a total of 727,867 service sector jobs over a four-year period (or 182,624 per year). As mentioned before, to offset some of the jobs in the primary and secondary sectors of the economy that will be lost to automation (estimated at 11 % of the labour force, or 3,600,000 over the next two decades by Nedelkoska and Quintini, 2018), 10G will enable a compensating effect for this job loss.