Digital Economy and Society Index (DESI) 2021

Thematic chapters

Table of Contents

Table of Tables

Table of Figures

1 Introduction

1.1 The Digital Economy and Society Index reports

Since 2014, the European Commission has been monitoring Member States' digital progress through the Digital Economy and Society Index (DESI) reports. Each year, DESI includes country profiles which support Member States in identifying areas requiring priority action as well as thematic chapters offering a European-level analysis across key digital areas, essential for underpinning policy decisions.

The COVID-19 pandemic has had a significant impact on the EU's economy and on EU society. It has significantly changed the role and perception of digitalisation in our economies and societies, and accelerated its pace. It has also shown the decisive role that disruptive innovation and technology can play. As stated in the 2020 DESI reports, it has intensified the use of public and private online services, putting pressure on the capacity of digital connectivity networks. The European Commission has been coordinating a common two-pronged response to COVID-19[1]. The first part of its response is a health emergency response based on an EU Health Union, a vaccination strategy and a common approach to making it safe to travel again. The second part of its response consists of addressing the immediate and the long-term economic effects of the pandemic. Alongside Member States' short-term efforts to cushion their economies, the Commission has adjusted a number of EU programmes to provide liquidity support for companies and adopted temporary State aid measures allowing Member States to give severely affected companies further support. But to build a more sustainable, resilient and fairer Europe for future generations, massive investments and structural reforms will be needed in the medium to long term. To this end, the EU adopted a European Recovery Plan in December 2020, the Next Generation EU. The package aims to support Member States in their efforts to address the fallout from the pandemic, kick-start the EU economy and put it on a greener, more digital and more resilient path. The centrepiece of the Next Generation EU is the Recovery and Resilience Facility.

In addition, through the Technical Support Instrument[2], the Commission supports Member States in designing and implementing growth-enhancing reforms and overcoming the investment gap and accelerating the twin transitions. Member States can ask for support through the Technical Support Instrument to design and implement reforms to facilitate the digital transition in areas such e-government, digital economy, digital infrastructure (broadband), e-health and digital skills.

Digital technologies have played an important role in the coordinated response to COVID-19 at EU level. A prominent example is the adoption of the EU Digital COVID Certificate to facilitate safe free movement within the EU[3], and complementing the national tracing and contact apps with strong data protection rules. Several other 2021 initiatives contribute to a more secure, trustworthy and efficient digital environment: the planned strengthening of the code of practice to combat disinformation[4], the proposal for a European E-ID to enable all Europeans to access services online

[1] Factsheet on the EU Coronavirus response, European Commission June 2021.
[2] Regulation (EU) 2021/240 of the European Parliament and of the Council of 10 February 2021 establishing a Technical Support Instrument OJ L 57, 18.2.2021, p. 1–16.
[3] This might have dragged the revival in tourism activity (Summer 2021 Economic Forecast)
[4] COM (2021) 262 final. Monitoring is performed by the Commission in the framework of the COVID-19 Disinformation Communication of June 2020 (extended to end 2021): https://digital-strategy.ec.europa.eu/en/policies/covid-19-disinformation-monitoring.

using selective disclosure of their personal data[5], the recommendation for a joint cyber unit to operationalise progressively cooperation amongst all relevant EU stakeholders[6], the 6GHz harmonisation decision to bring about improvements in network performance[7], a proposal to extend the Roaming Regulation for a genuine 'roam-like-at-home' experience[8] and a proposed AI regulatory framework so that AI systems placed on the EU market are safe and respect fundamental EU rights and values[9] (to be complemented in 2022 by an initiative on effective liability rules for AI[10]), and the update of the industrial strategy with its focus on the twin green and digital transition of Europe's industrial ecosystems[11].

The DESI 2021 reports are based on 2020 data and present the state of the digital economy and society in the first year of the pandemic. DESI 2021 has been adjusted to reflect the two major policy initiatives set to have an impact on the digital transformation in the EU in the coming years: the Recovery and Resilience Facility (RRF) and the Digital Decade Compass. Consequently DESI country reports now incorporate a summary overview of digital investments and reforms in the recovery and resilience plans (RRPs) of the Member States, as adopted by the Council. These plans also include multi-country projects where Member States join forces to develop digital capabilities. This way, the DESI 2021 reports give an overview of the state of digitalisation in Europe, starting from a 2020 baseline and reflecting the Member States' digital ambitions for the next 6 years as expressed in their RRPs. The structure of DESI has also been adjusted to reflect the four cardinal points of the Digital Compass and the related targets for 2030, as explained in Section 1.4[12]. The DESI country reports combine quantitative evidence, on the basis of indicators across the four dimensions of the index matching the four cardinal points of the Digital Compass, with qualitative information on major national policy initiatives. The thematic chapters of the DESI 2021 report contain European-level analyses of broadband connectivity, digital skills, the digitalisation of businesses, digital public services, the ICT sector, R&D spending and Member States' use of Horizon 2020 funds.

1.2 Digital aspects of the RRF

Regulation (EU) 2021/241 of the European Parliament and of the Council establishing the Recovery and Resilience Facility[13] (RRF) was adopted in February 2021. With a budget of EUR 723.8 billion to be disbursed in non-repayable financial support (EUR 385.8 billion) and loans (EUR 338 billion), the RRF is the largest programme under Next Generation EU. It will support large-scale public investments and reforms by Member States to mitigate the economic and social impact of the COVID-19 pandemic and make European economies and societies more sustainable, resilient and better prepared for the challenges and opportunities of the green and digital transition. The RRF is

[5] SEC(2021) 228 final; SWD(2021) 124 final; SWD(2021) 125 final.
[6] COM (2021) 4520 final.
[7] Commission Implementing Decision C(2021)4240.
[8] COM/2021/85 final
[9] COM/2021/206 final.
[10] Commission SWD(2021) 84 final, Impact assessment accompanying the proposal for a Regulation of the European Parliament and of the Council laying down harmonised rules on artificial intelligence (Artificial Intelligence Act), p. 88, https://eur-lex.europa.eu/legal-content/SV/TXT/?uri=CELEX:52021SC0084; COM/2021/202 final (proposal for a Machinery Products Regulation) and COM/2021/346 final (proposal for a General Product Safety Regulation).
[11] COM/2021/350 final.
[12] Nevertheless, DESI still allows a time series analysis for 6 years.
[13] https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32021R0241&from=EN

structured around six pillars: green transition; digital transformation; smart, sustainable and inclusive growth and jobs; social and territorial cohesion; health and resilience; and policies for the next generation, children and young people, including education and skills.

The twin transitions – digital and green – are central to the RRF and to Europe's approach to recovering from COVID-19. Digital technologies have been essential for maintaining economic and social life throughout the pandemic. They will be the key differentiating factor for a successful transition to a sustainable, post-pandemic economy and society.[14] Reforms of and investments in digital technologies, infrastructure and processes will make the EU more competitive globally, as well as making it more resilient, innovative and less dependent, by diversifying key supply chains.

The RRF Regulation requires that each Member State devotes *at least* 20% of the allocation received for its Recovery and Resilience Plan (RRP) to measures fostering the digital transition and/or addressing the resulting challenges.

Annex VII of the RRF Regulation sets out the related methodology for tracking digital expenditure, divided into seven digital investments areas[15], aligned with the DESI dimensions and areas of the Digital Decade. In addition to connectivity, human capital, the digitalisation of businesses and e-government, the Regulation also covers investments in digital-related R&D and the development and deployment of key digital capacities that are essential for building Europe's digital leadership, as well as initiatives aimed at 'greening' the digital sector. From this vantage point, the RRPs are expected to give an unprecedented boost to the digital transformation and make a key contribution to creating Europe's Digital Decade. The digital transformation is also at the core of a number of European flagship initiatives that have identified areas ripe for reform and investments to address issues common to all Member States and ensure the success of the EU's[16]. In particular, the flagship initiatives 'Connect', 'Scale Up', 'Modernise' and 'Reskill and Upskill' encourage and help Member States to use their RRPs to develop advanced digital capacities and an interconnected, secure and interoperable single market for a successful economic recovery.

In the RRPs of 22 Member States[17], EUR 117 billion have been earmarked for digital expenditure, representing 26% of total RRF investment in these Member States. This means that Member States have decided to go beyond the 20% target and averaged digital investments at 26% of their allocations. Measures supporting the digital transformation are the most prominent in countries such as Austria and Germany, with more than 50% of total spending being digital, or Ireland, Lithuania and Luxembourg where expenditure related to measures supporting the digital transformation exceeds 30%.

In terms of priority areas (Figure 1), Member States allocated 37% of digital investments to digital public services (e.g. to develop platforms to give access to e-government solutions, or increase interoperability between different digital solutions to reduce the administrative burden on citizens and businesses, digitalisation of health care, transport and energy systems), followed by 20% on the digitalisation of businesses (e.g. to support the development and adoption of digital solutions by businesses, with knowledge transfer centres or financial support through loan facilities or digital vouchers) and 17% on human capital (e.g. online learning possibilities through digital platforms for

[14] See also Communication from the Commission "The EU economy after COVID-19: implications for economic governance"

[15] Connectivity; digital-related investment in R&D; human capital; e-government, digital public services and local digital ecosystems; digitalisation of businesses; investments in digital capacities and deployment of advanced technologies; greening the digital sector (SWD(2021) 12 final).

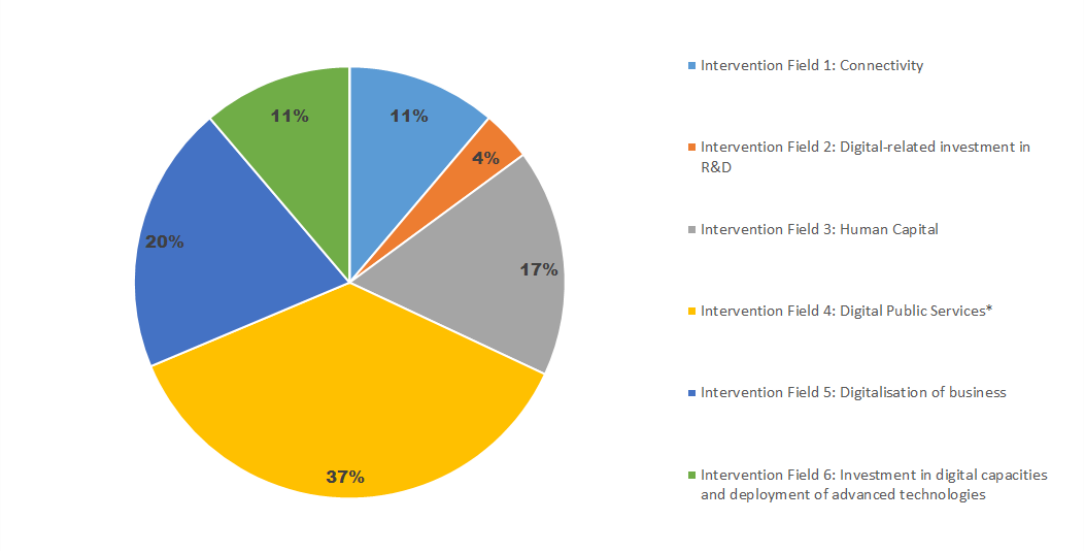
[16] Annual Sustainable Growth Strategy, COM(2020) 575 final.

[17] Entire analysis is limited to plans adopted by the Council as of 28.10.2021.

schools and individuals or including digital skills in vocational training courses). Digital reforms complement investments in national RRPs. Examples include reforms to remove barriers to the deployment of connectivity networks (e.g. permit-granting procedures, spectrum management and assignment), strategies to support digital skills development or modernise teaching methods, educational and vocational training systems, and initiatives to simplify administrative procedures and boost the use of digital public services by citizens and businesses.

The Commission identified 12 cross-border or multi-country projects[18] that are expected to strengthen Europe's resilience and act as a catalyst for the development of joint capabilities in advanced digital technologies. These projects span from the deployment of 5G along cross-border transport pathways and the creation of an EU-wide network of European Digital Innovation Hubs (EDIHs), to joining forces and pooling resources to achieve critical mass and build strong digital capabilities in areas such as cloud, microelectronics, cybersecurity or high performance computing (HPC). 18 of the RRPs adopted by the Council to date envisage participation in multi-county projects. The largest investments to be supported under the RRF are likely to be those in the second microelectronics important project of common European interest (IPCEI), the Cloud and Data IPCEI and the 5G corridors. The DESI country profiles provide further details of reforms and investments, including those related to the MCPs.

Figure 1 Digital investments in the RRF (Plans adopted by the Council as of 28.10.2021)



Source: European Commission

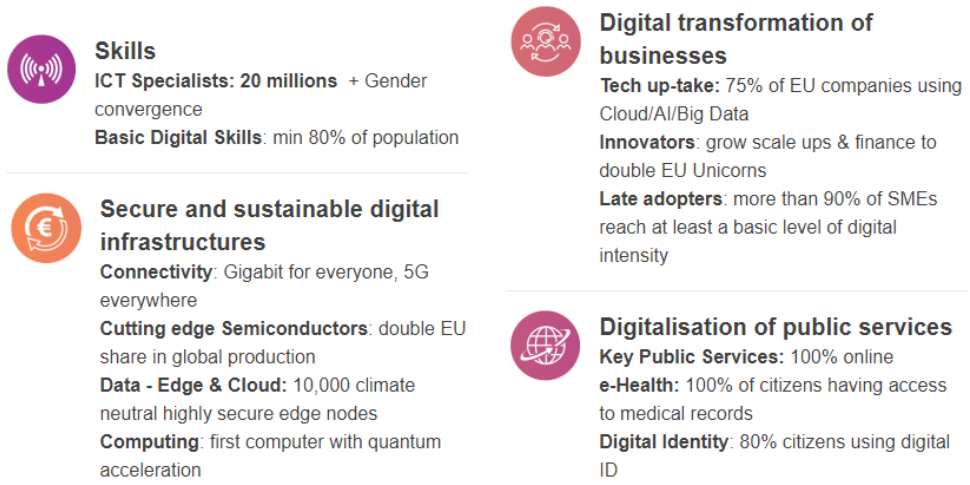
[18] The following multi-country projects have been discussed with the Member States under the RRF and/or included in the RRPs: 1. Cloud and Data, i.e. building a common, multi-purpose pan-European interconnected data processing infrastructure; 2. Microelectronics, i.e. endowing the EU with capabilities in electronics design and deployment of the next generation of low power trusted processors and other electronic components; 3. Deploying pan-European 5G corridors for advanced digital rail operations and connected and automated mobility; 4. Acquiring supercomputers and quantum computers; 5. Developing and deploying an ultra-secure quantum communication infrastructure; 6. Deploying a network of security operations centres to increase national and EU cybersecurity; 7. Connected public administration, building on the eIDAS framework; 8. European blockchain services infrastructure; 9. Completing an EU-wide network of EDIHs; 10. High-tech partnerships for digital skills through a Pact for Skills, i.e. a large-scale multi-stakeholder skills partnership to meet the growing demand for ICT specialists; 11. European reference genome, 12. Submarine cables.

1.3 The Digital Compass and the Path to the Digital Decade

Following Commission President Ursula von der Leyen's call[19] for greater digital leadership and a common vision for 2030 as well as the European Council's request that the EU develop a Digital Compass[20], the Commission adopted in March 2021 the *2030 Digital Compass: the European Way for the Digital Decade* Communication[21]. It sets out the EU's digital ambitions and lays out its vision for digital transformation by 2030. The European Council backed the Commission's approach[22].

The Communication framed the digital development in Europe around a set of four cardinal points: a digitally skilled population and highly skilled digital professions; secure and sustainable digital infrastructures; digital transformation of businesses, and the digitalisation of public services. It also proposes a set of specific targets for each cardinal point.

Figure 2 The targets of the Digital Compass



Source: European Commission

To complement the targets, a set of principles on digital citizenship reflect Europe's ambition to empower its citizens in a digital environment.

As projected in the Communication and in response to a call from the European Council[23], on 15 September 2021 the Commission adopted a proposal for a Decision on a Path to the Digital Decade, setting out the digital targets the EU as a whole is expected to reach by the end of the decade. It sets out a novel form of governance with Member States, through a mechanism of annual cooperation between EU institutions and the Member States to ensure they jointly achieve ambitions. It also proposes a mechanism to foster cooperation between Member States on multi-country projects to develop Europe's digital capacities in critical areas, as well as accelerate large-scale technological projects that are necessary for Europe's digital transition and industry transformation.

The monitoring of progress in reaching the targets at EU level, as well as of the underlying national digitalisation trends, will be part of an enhanced Digital Economy and Society Index (DESI). For each digital target, key performance indicators (KPIs) should be set out in implementing acts to be adopted by the Commission after the Decision enters into force. The KPIs will be updated when necessary for continued effective monitoring and to take account of technological developments.

[19] President von der Leyen's State of the Union address 2020
[20] European Council Conclusions 1 and 2 October 2020.
[21] COM (2021) 118 final.
[22] European Council conclusions 25 March 2021
[23] European Council Conclusions 25 March 2021.

Member States' data collection mechanisms should be strengthened to present a thorough description of the state of play of progress towards reaching the digital targets, as well as to provide information on relevant national policies, programmes and initiatives. Based on the work it is currently doing with the Member States, the Commission should prepare, in consultation with the Member States, a roadmap to set out future data collection needs.

To align DESI with the cardinal points and corresponding targets of the Digital Compass, to improve the methodology and to take account of the latest technological and policy developments, a number of changes were made to the 2021 edition of DESI.

First, as Table 1 shows, DESI indicators are now structured around the four cardinal points of the Digital Compass, replacing the previous five dimension structure.

Table 1 Structure of DESI 2021

1 Human capital[24]	Internet user skills and advanced digital skills
2 Connectivity[25]	Fixed broadband take-up, fixed broadband coverage, mobile broadband and broadband prices
3 Integration of digital technology[26]	Business digitalisation and e-commerce
4 Digital public services[27]	e-Government

Source: European Commission

11 DESI 2021 indicators serve the assessment of progress towards some of the Digital Compass targets. Going forward, DESI will be further aligned with the Digital Compass to ensure that all targets are discussed in the reports.

Table 2 Digital Compass targets in DESI 2021 in relation to the four dimensions of the index

1 Human capital	At least basic digital skills ICT specialists Female ICT specialists
2 Connectivity	Gigabit for everyone (Fixed very high capacity network coverage) 5G coverage
3 Integration of digital technology	SMEs with a basic level of digital intensity AI Cloud Big data
4 Digital public services	Digital public services for citizens Digital public services for businesses

Source: European Commission

[24] Equivalent to intervention field 3 (Human Capital) of the RRF Regulation (Regulation (EU) 2021/241 of the European Parliament and of the Council of 12 February 2021 establishing the Recovery and Resilience Facility, OJ L 57, 18.2.2021, p. 17).

[25] Equivalent to intervention field 1 (Connectivity) of the RRF Regulation.

[26] Equivalent to intervention fields 5 (Digitalisation of businesses) and 6 (Investment in digital capacities and deployment of advanced technologies) of the RRF Regulation.

[27] Equivalent to intervention field 4 (e-government, digital public services and local digital ecosystems) of the RRF Regulation.

DESI now also includes an indicator measuring the level of support that adopted ICT technologies have provided for enterprises so they can engage in more environmentally friendly actions (ICT for environmental sustainability), as well as the take-up of gigabit services, enterprises offering ICT training and e-invoices.

The index has been re-calculated for all countries for previous years to reflect the changes in the choice of indicators and corrections made to the underlying data. Country scores and rankings may thus have changed compared with previous publications. For further information, consult the DESI website.

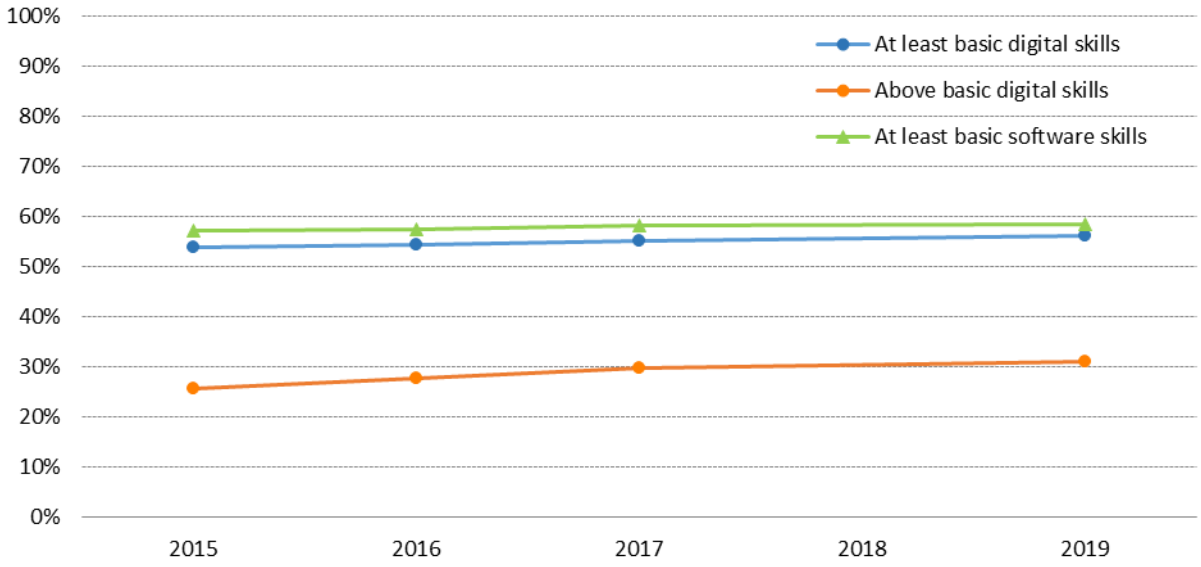
1.4 DESI 2021 results

Human capital – digital skills

The 2030 target of the Digital Compass is that at least 80% of citizens have at least basic digital skills. While 84% of people used the internet regularly in 2019, only 56% possessed at least basic digital skills. The Netherlands and Finland are the frontrunners in the EU, while Bulgaria and Romania are lagging behind. A large part of the EU population, however, still lacks basic digital skills, even though most jobs require such skills. Moreover, the 56% is only a slight increase – two percentage points – since 2015, or a yearly growth rate of only 0.9%. This growth rate needs to increase threefold to reach the 2030 target of 80%.

The growth rate is expected to accelerate in the context of an increased use of digital tools during the COVID-19 pandemic, as well as the significant investments in digital skills planned by the Member States in their RRPs.

Figure 3 Digital skills (% of individuals), 2015-2019[28]



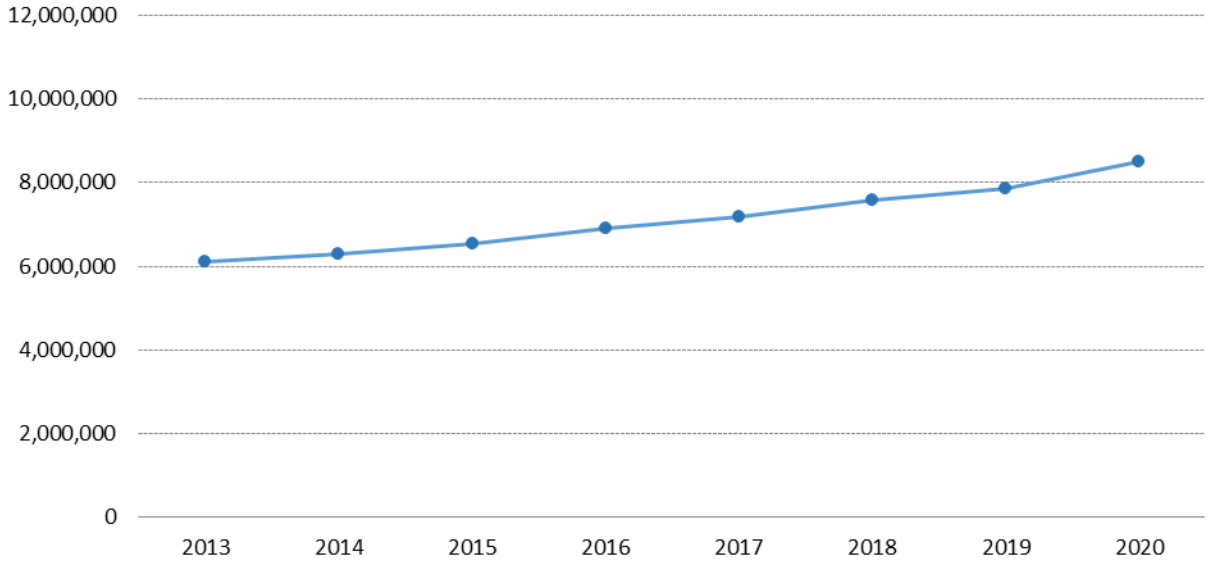
Source: Eurostat, European Union survey on the use of ICT in Households and by Individuals

According to the Digital Compass, the number of ICT specialists in the EU should reach at least 20 million by 2030, compared to 8.4 million in 2020 (corresponding to 4.3% of the labour force). Although there has been steady growth since 2013, an acceleration is needed to reach the target. As of 2020, Finland – with 7.6% – and Sweden – with 7.5% – have the highest proportion of ICT specialists in the labour force.

[28] From 2017 the digital skills indicators are collected every 2 years.

There remains a general shortage of ICT specialists on the EU labour market, and the number of vacancies keeps growing as new jobs emerge. During 2020, 55% of enterprises that recruited or tried to recruit ICT specialists reported difficulties in filling such vacancies. In key areas, such as cybersecurity or data analysis, there are constantly hundreds of thousands of vacancies. More than 70% of businesses report a lack of staff with adequate (digital) skills as an obstacle to investment. There is also a severe gender balance issue, with only 19% of ICT specialists and one in three science, technology, engineering and/or mathematics (STEM) graduates being women. Finally, this is compounded by a lack of capacity in terms of specialised education programmes in areas such as AI, quantum and cybersecurity, and by the poor integration of digital subjects into other disciplines.

Figure 4 ICT specialists, 2013-2020

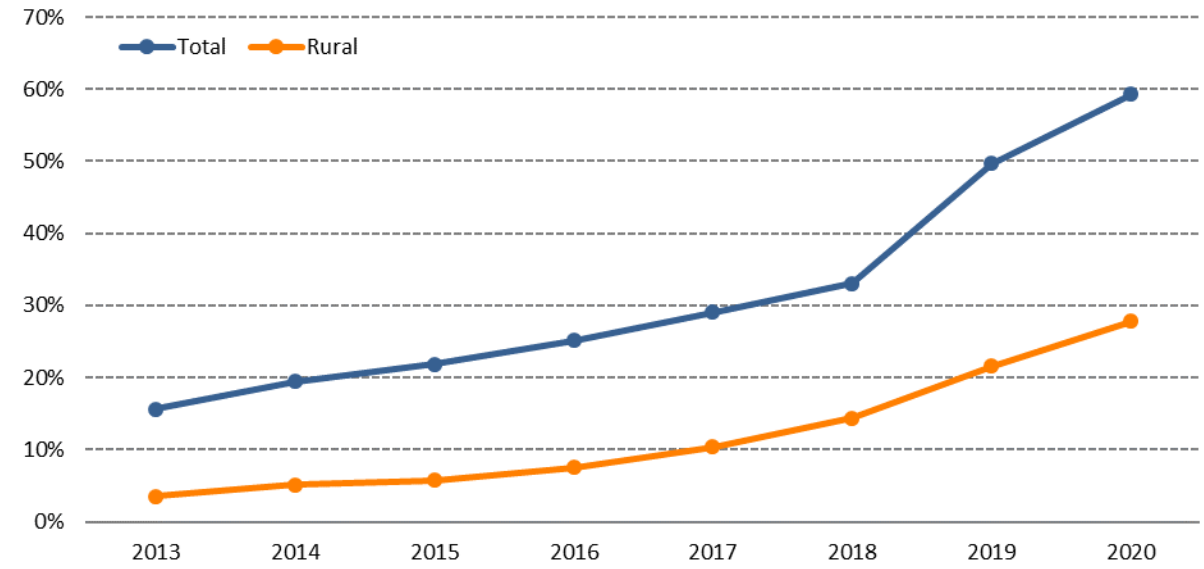


Source: Eurostat, Labour Force Survey

Broadband connectivity

The Digital Compass sets the target that gigabit networks should be available to all by 2030. While the EU has full coverage of basic broadband infrastructure, only 59% of households can benefit from fixed very high capacity network (VHCN) connectivity with the potential of offering gigabit connectivity. Fixed VHCN includes fibre-to-the-premises (FTTP) and cable DOCSIS (data over cable service interface specification) 3.1 technologies. Both types of networks expanded during the past year faster than they did before the crisis: FTTP from 37.5% in 2019 to 42.5% in 2020 and DOCSIS 3.1 cable from 22% in 2019 to 28% in 2020. Rural VHCN also improved – from 22% in 2019 to 28% – but a large gap between rural and national figures remains. Malta, Luxembourg, Denmark and Spain are the European leaders on total VHCN coverage (all with more than 90% of homes covered). By contrast, in Greece, less than 1 in 5 households have access to VHCN.

Figure 5 Fixed very high capacity network (VHCN) coverage (% of households) in the EU, 2013-2020



Source: IHS Markit, Omdia, Point Topic and VVA, Broadband coverage in Europe studies.

According to the Digital Compass target, all populated areas should have 5G coverage by 2030. As of mid-2020, commercial 5G network deployments started in 13 Member States, and coverage reached 14% at EU level. The Netherlands and Denmark are the most advanced countries, with 80% coverage. A precondition for the commercial launch of 5G is the assignment of 5G spectrum in every country. 25 Member States already assigned 5G spectrum in any of the three 5G pioneer bands by 31 August 2021.

It is assumed that, following the COVID-19 crisis, more citizens will work or study from home, more companies will use digital communication to reach customers and operate industrial processes remotely, and more government institutions will use digital technologies to stay in contact with citizens and companies. The availability of very high capacity digital connectivity is, therefore, expected to increase more sharply in the coming years. The deployment of 5G wireless networks will also depend on optical fibre backhaul infrastructures' providing very high quality wireless connectivity.

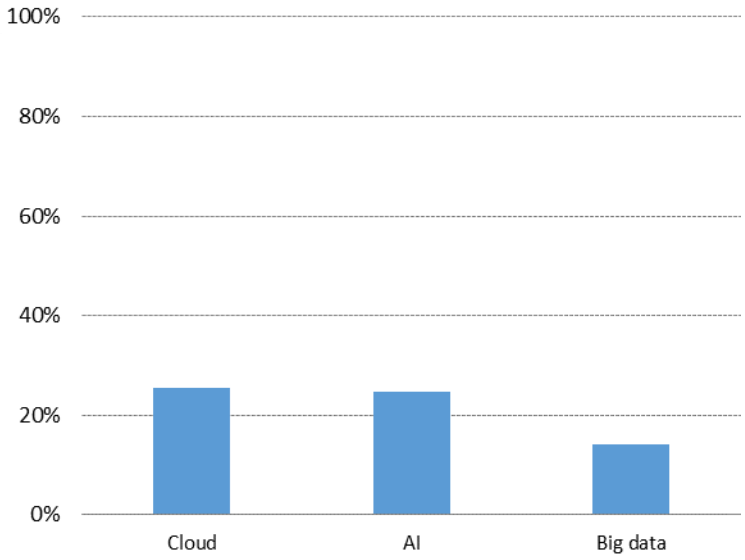
As regards overall take-up, 89% of Europeans had a broadband subscription at home, and 77% of households relied on fixed broadband technologies in 2020. Over a third of households (34%) had at least a 100Mbps service, up from 2% eight years ago. Gigabit take-up is, however, still very low at 1.3% of households.

Integration of digital technology by businesses

To reach the Digital Compass 2030 target, at least 90% of small and medium-sized enterprises (SMEs) in the EU should have a basic level of digital intensity. In 2020, only 60% of SMEs were at that level in the adoption of digital technologies. Denmark and Finland are already very close to the EU target with 88%, while Bulgaria and Romania are lagging far behind (33%).

The Digital Compass targets that at least 75% of companies use AI, cloud and big data technologies by 2030. Businesses are getting more and more digitalised, but the use of advanced digital technologies remains low. Only one in four companies use AI or cloud computing and 14% big data.

Figure 6 Adoption of advanced technologies (% of enterprises) in the EU, 2020



Source: Eurostat, European Union survey on ICT usage and e-commerce in enterprises for cloud and big data and Ipsos and i-Cite for AI

There is a substantial gap between large companies and SMEs, not only in the use of advanced technologies, but also of basic digital solutions, such as having an enterprise resource planning (ERP) software package and engaging in e-commerce.

Finland, Denmark and Sweden rank highest in the digital transformation of businesses.

Digital public services

The Digital Compass sets the target that all key public services for citizens and businesses should be fully online by 2030.

In 2020, 64% of internet users interacted with public administration online, compared to 58% in 2015. The online availability of public services has been growing steadily over the last decade, and was accelerated by the COVID-19 pandemic, during which digital interaction had to become the norm. A number of Member States are already close to this target, but progress is uneven across and within Member States, with services for citizens less likely to be available online compared to services for businesses.

The roll-out of basic digital public services is progressing steadily (e.g. access to online forms, online appointment booking etc.), but the availability of more advanced public services that use innovative digital technologies (such as AI, big data, robotics etc.) still requires significant investment. The Digital Compass target aims to boost Member States' efforts in making all key public services available online, while also strongly supporting the adoption of innovative ICTs to help digitalise public services with optimal quality and efficiency.

DESI monitors the online provision of public services by scoring Member States on whether or not it is possible to complete each step of key services completely online. The quality scores reached 75 out of 100 for digital public services for citizens and 84 out of 100 for businesses in 2020. Estonia, Denmark, Finland and Malta have the highest scores for Digital public services in DESI, while Romania and Greece have the lowest.

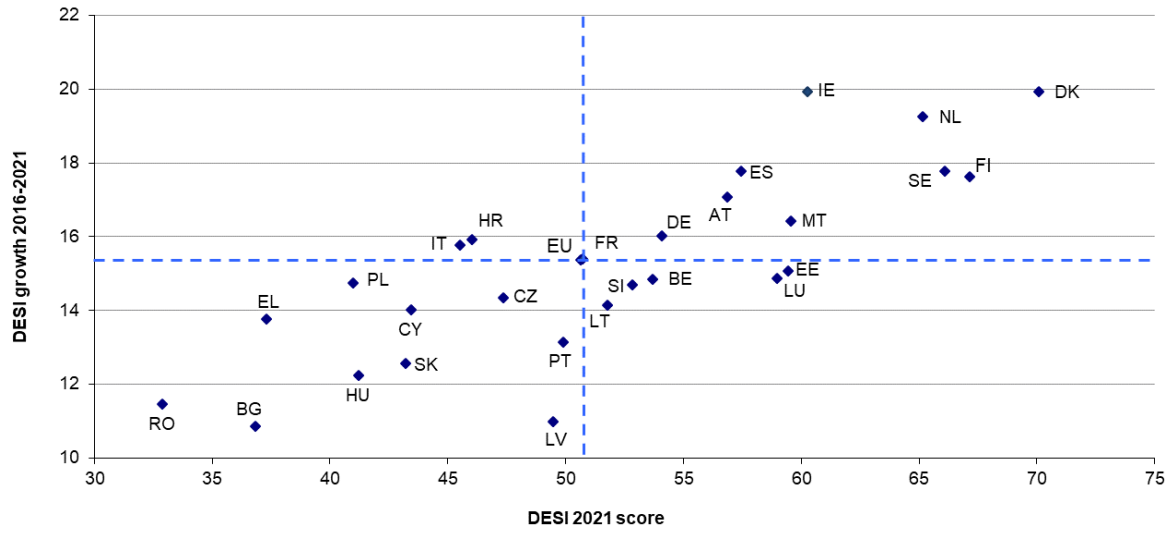
How do Member States perform on this year's DESI?

The below figure shows the progress of Member States as regards the overall level of digitalisation of the economy and of society over the last 5 years. It is measured in terms of the progression of their DESI score over that period of time.

The most significant progression is noted in Ireland and Denmark, followed by the Netherlands, Spain, Sweden and Finland. These countries also perform well above the EU DESI average based on their scores in DESI 2021.

Most countries, which are below the EU digitalisation average, have not progressed much in the last 5 years. This is the case especially for Bulgaria and Romania.

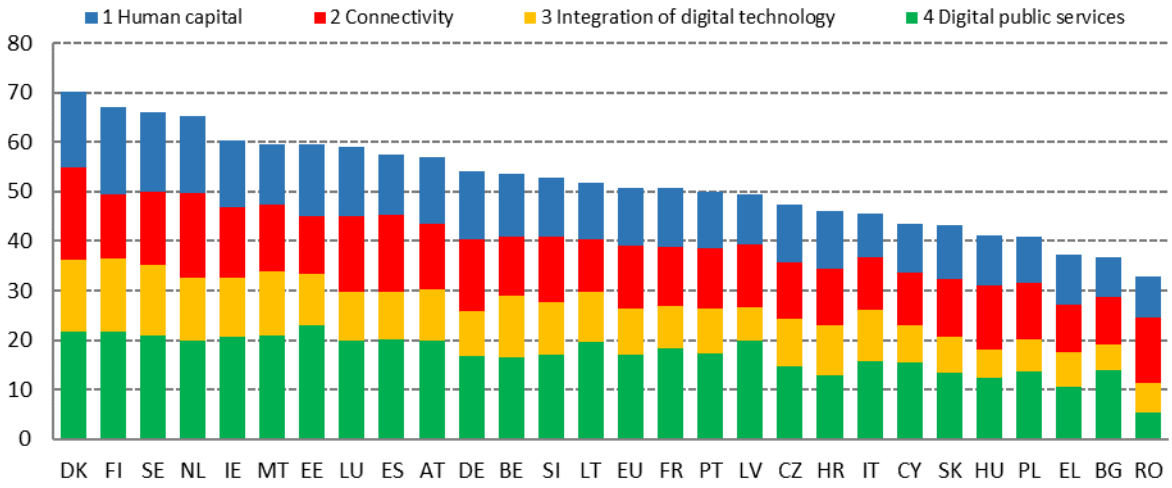
Figure 7 Digital Economy and Society Index – Member States' progress, 2016-2021



Source: DESI 2021, European Commission.

The below figure shows the 2021 DESI ranking of Member States. Denmark, Finland, Sweden and the Netherlands have the most advanced digital economies in the EU, followed by Ireland, Malta and Estonia. Romania, Bulgaria and Greece have the lowest DESI scores.

Figure 8 Digital Economy and Society Index, 2021



Source: DESI 2021, European Commission.

2 Human Capital

In the world of tomorrow, we must rely on digitally empowered and capable citizens, a digitally skilled workforce and digital experts. Clear responses will be needed to successfully manage demographic trends and close existing skills gaps in the context of the digital and green transitions[29]. Basic digital skills for all citizens and the opportunity to acquire new specialised digital skills for the workforce are a prerequisite to participate actively in the Digital Decade[30] and to reinforce our collective resilience as a society. In addition to the target on basic digital skills (80% of people) established in the Digital Education Action Plan[31] and the European Pillar of Social Rights Action Plan[32], a Digital Compass proposes to reach by 2030 a target of 20 million employed ICT specialists in the EU, with convergence between women and men.

Already 84% of people used the internet in 2019 regularly. Nevertheless, only 56% possesses at least basic digital skills and only about one third of Europeans possesses above basic digital skills (31%). Therefore, having an internet connection and using the internet is not sufficient; it must be paired with the appropriate skills to take advantage of the digital society. Digital skills range from basic usage skills that enable individuals to take part in the digital society and consume digital goods and services, to advanced skills that empower to acquire new specialised digital skills, develop new digital goods and services.

Table 3 Human capital indicators in DESI

	EU	
	DESI 2019	DESI 2021
1a1 At least basic digital skills % individuals	**55%** 2017	**56%** 2019
1a2 Above basic digital skills % individuals	**29%** 2017	**31%** 2019
1a3 At least basic software skills % individuals	**58%** 2017	**58%** 2019
1b1 ICT specialists % individuals in employment aged 15-74	**3.8%** 2018	**4.3%** 2020
1b2 Female ICT specialists % ICT specialists	**17%** 2018	**19%** 2020
1b3 Enterprises providing ICT training % enterprises	**22%** 2018	**20%** 2020
1b4 ICT graduates % graduates	**NA** 2016	**3.8%** 2018

Source: DESI 2021, European Commission.

2.1 Human capital in DESI 2021

The human capital dimension of the DESI has two sub-dimensions covering 'internet user skills' and 'advanced skills and development'. The former draws on the European Commission's Digital Skills Indicator, calculated based on the number and complexity of activities involving the use of digital devices and the internet. The latter includes indicators on ICT specialists, ICT graduates and

[29] Strategic foresight report 2021, COM(2021)750 final

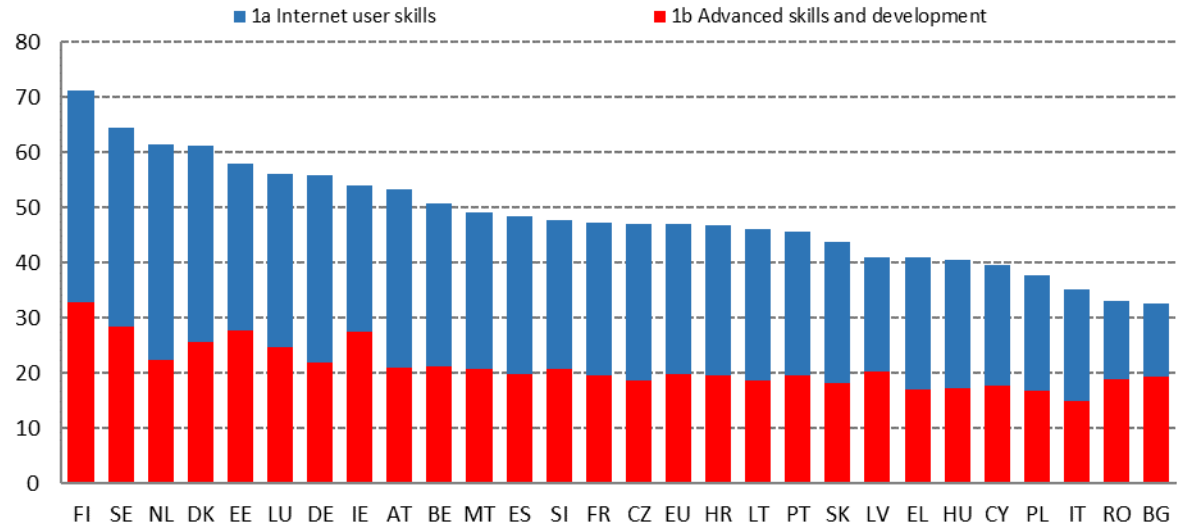
[30] https://ec.europa.eu/info/strategy/priorities-2019-2024/europe-fit-digital-age/europes-digital-decade-digital-targets-2030_en

[31] The Digital Education Action Plan (2021-2027) COM/2020/624 final. Adopted on 30 September 2020.

[32] The European Pillar of Social Rights Action Plan COM (2021) 102. Adopted on 3 March 2021.

enterprises providing dedicated ICT training. According to the latest data, Finland is leading in Human capital, followed by Sweden, the Netherlands and Denmark. Italy, Romania and Bulgaria rank the lowest. In comparison to last year, the largest increases in Human capital were observed in Finland (+2.6 percentage points), Estonia (+1.7 percentage points) and Greece (+1.6 percentage points).

Figure 9 Human capital dimension (Score 0-100), 2021



Source: DESI 2021, European Commission.

2.2 Digital skills

Since 2015, the level of digital skills has continued to grow slowly, reaching 56% of individuals having at least basic digital skills, 31% with above basic digital skills and 58% of individuals having at least basic software skills. The skills indicators are strongly influenced by socio-demographic aspects. For example, 80% of young adults (aged 16-24), 84% of individuals with high formal education[33], and 87% of students have at least basic digital skills. By contrast, only 33% of those aged 55-74 and 28% of the retired and the inactive possess at least basic digital skills. There is still substantial gap between rural and urban areas when looking at the digital skills of the population: only 48% of individuals living in rural areas possess at least basic digital skills, in contrary to the ones living in the cities (62%). For more detailed description of the digital skills, please see the Human Capital Chapter for 2020[34].

It should be noted that youth is not a determinant of digital skills and growing up in a digital world does not automatically make one digitally competent. As demonstrated by the International Computer and Information Literacy Study (ICILS)[35], which assesses digital skills of 8th-graders based on a competence test, rather than self-reporting, young people do not develop sophisticated digital skills just by growing up using digital devices. In 9 out of 14 EU Member States who have participated in ICILS, more than one third of the pupils achieved scores below the threshold for underachievement in digital competence.

[33] ISCED11 levels from 5 to 8 - formal tertiary (or higher) education

[34] The EU averages of the digital skills indicators have been recalculated. The DESI 2020 reports referred to EU28 (including the United Kingdom), while DESI 2021 EU averages refer to EU27 https://ec.europa.eu/newsroom/dae/document.cfm?doc_id=67077

[35] https://www.iea.nl/studies/iea/icils/2018.

2.3 Use of Internet

In 2020, 91% households had access to the internet at home. 86% of individuals were regular internet users (using it at least weekly), while almost 80% were using it either every day or almost every day. Nevertheless, there are still countries where people are not using the internet, for example in Bulgaria and Greece where one in five individuals has never used it. In comparison, only about 1% of the adult population in Sweden, Luxembourg and Denmark have never used the internet.

2.4 Access barriers

Despite many Europeans using internet regularly, we observe some barriers persisting. The top reasons for not having internet access at home in 2019 remained the lack of need or interest (45% of households without internet access in 2019), insufficient skills (45%), equipment costs (25%) and high cost barriers (23%). The deterring effect of each of these factors varies significantly in strength across Member States. For example, only 5% of Estonian households without internet access mentioned costs as a barrier, but as many as 53% did so in Portugal. A lack of relevant skills is an important factor deterring households from having internet access at home. Moreover, given that this factor limits awareness of potential benefits from digitisation, it may also be among the reasons behind the large numbers of EU households that still claim not to have internet access at home, because they do not need it.

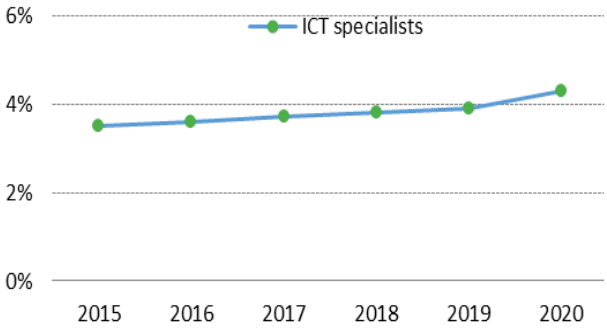
2.5 ICT specialists

The *advanced skills and development* sub-dimension looks at the workforce and its potential to work in and develop the digital economy. This takes into account the percentage of people in the workforce with ICT specialist skills, with a breakdown for female ICT specialists. At the same time, it looks at the share of ICT graduates. Following the Digital Decade communication, the key target for Europe is to reach 20 million employed ICT specialists in the EU by 2030, with convergence between women and men.

In 2020, 8.4 million persons worked as ICT specialists across the European Union. The highest number was reported in Germany (1.9 million ICT specialists) followed by France (1.2 million) and their combined share accounted for less than 40% of the EU's ICT workforce.

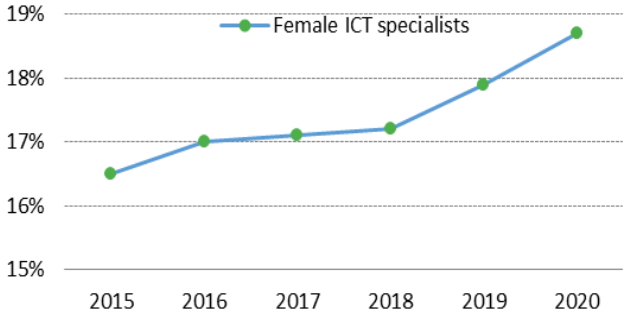
The share of ICT specialists is slowly progressing and reached 4.3% of total employment in 2020. The vast majority of ICT specialists in the EU are men (81.5% of ICT specialists were male in 2020). In Czechia, Hungary and Malta, almost every 9 out of 10 ICT specialists were men, while in Bulgaria almost every third ICT specialist was a woman.

Figure 10 ICT specialists (% of total employment), 2015 -2020



Source: Eurostat, European Union Labour Force Survey.

Figure 11 Female ICT specialists (% of ICT Specialists), 2015 - 2020



Source: Eurostat, European Union Labour Force Survey.

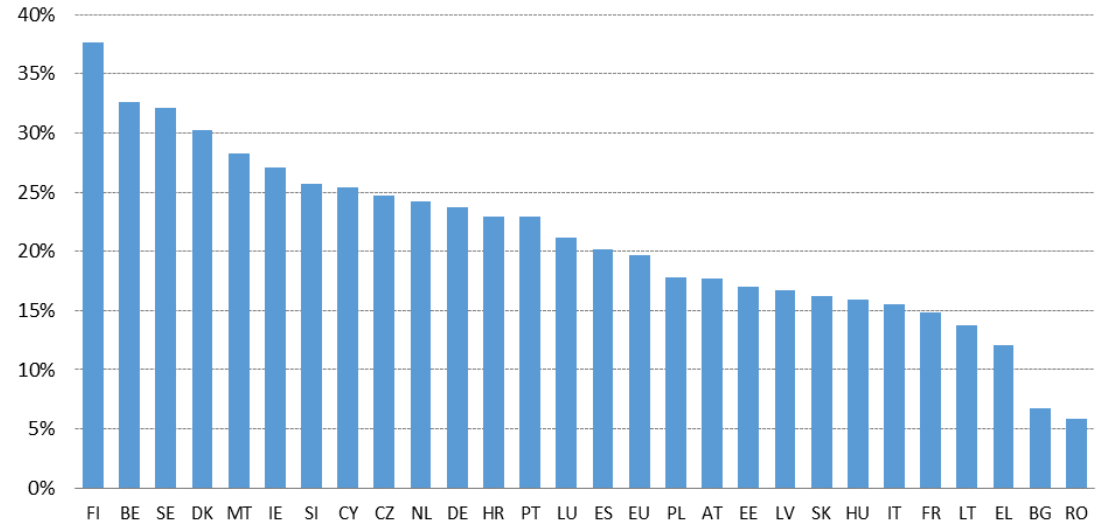
2.6 Enterprises recruiting ICT specialists and providing ICT training

In 2020, 19% of EU enterprises employed ICT specialists. Among the EU Member States, Ireland and Belgium presented the highest proportion of enterprises employing ICT specialists, with 30% each. Italy, with 13%, presented the lowest ratio of enterprises employing ICT specialists in 2020.

In 2019 55% of the EU enterprises that recruited or tried to recruit ICT specialists reported difficulties in filling vacancies. In Czechia, more than 3 out to 4 enterprises that recruited ICT specialists reported difficulties in filling those vacancies. In Austria and the Netherlands respectively 74% and 70% of enterprises which recruited or tried to recruit ICT specialists reported difficulties in filling ICT vacancies.

Enterprises are providing more and more training to their personnel to develop or upgrade their ICT skills. Overall 20% of the EU enterprises provided ICT training for their personnel. The leaders in this domain are Finland (38%) and Belgium (33%). In countries like Lithuania (14%), Greece (12%), Bulgaria (7%) and Romania (6%), the provision of such a training was considerably lower. When looking at company size, 68% of large enterprises actively provided the training, while only 18% of SMEs did so.

Figure 12 Enterprises providing ICT training (% enterprises), 2020

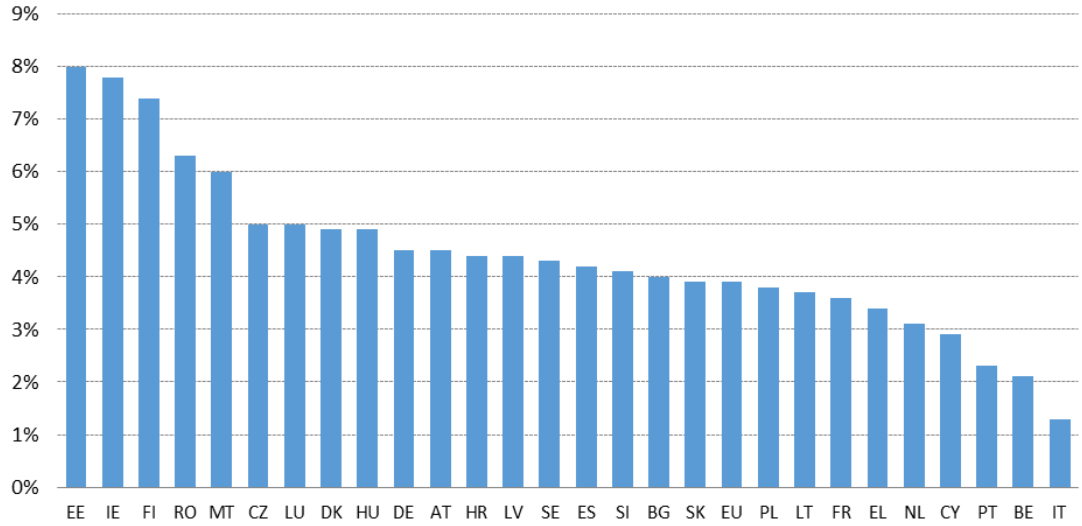


Source: Eurostat, European Union survey on ICT usage and e-commerce in enterprises.

2.7 ICT Graduates

With growing demand for ICT specialists and jobs becoming even more driven by digital technology, the EU employers are looking for staff with the necessary skills to satisfy the growing demand for ICT specialists and workers able to properly use the digital technologies. We observe a slow but overall increase of students pursuing and graduating in ICT domains. In 2019, 3.9% of Europeans graduated with an ICT diploma. The countries with the highest share are Estonia (8%), Ireland (7.8%) and Finland (7.4%). Estonia has also recorded the highest increase (+1.3 percentage point) in comparison to 2018. While, Italy, Belgium, Portugal and Cyprus are among the countries with the lowest share of ICT graduates (below 3%) in European Union.

Figure 13 ICT Graduates (% of graduates), 2019



Source: Eurostat, Education and training statistics (table educ_uoegrad03, using selection ISCED11=ED5-8 and ISCEDF_13).

2.8 EU Code Week 2020

EU Code Week[36] is a grassroots movement run by volunteer ambassadors, teachers and coding enthusiasts around the world. The initiative is backed by the European Commission and education ministries in the EU and Western Balkans.

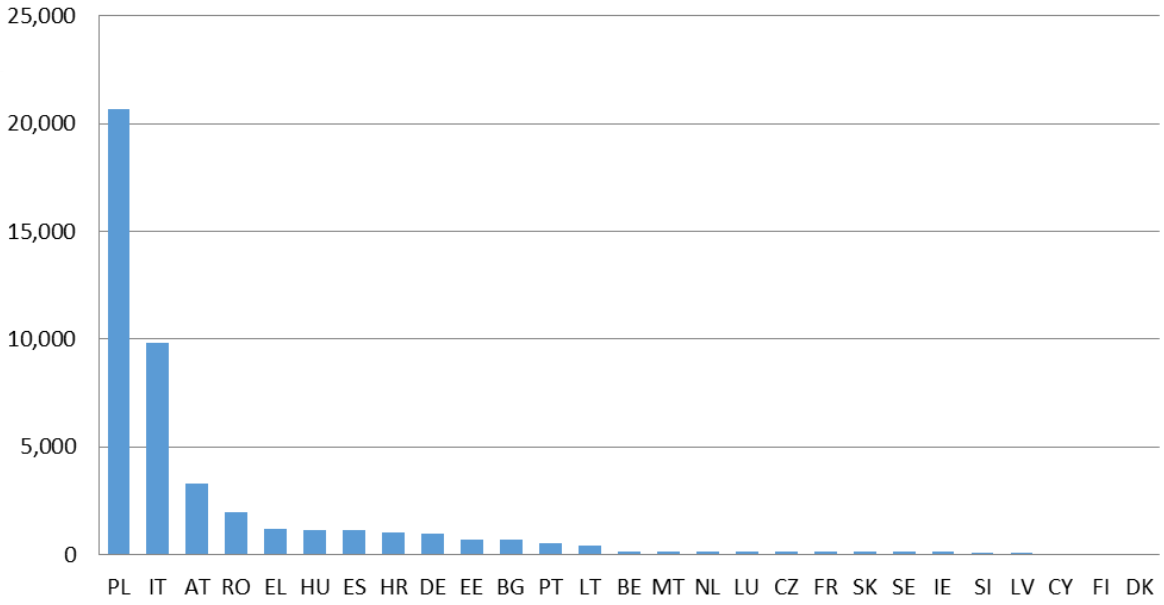
The Commission's aim is to contribute to the reduction of the number of 13-14 year olds who do not have sufficient computing and digital literacy skills by half by 2030, as outlined in the Digital Education Action Plan 2021-2027. Moreover, the initiative contributes to the targets of the Digital Decade: increasing the number of European with basic digital skills and the number of digital experts.

EU Code Week provides teachers with free resources, ready-made lesson plans, free online introductory courses and other materials to help them bring coding and technology to all subjects and classrooms.

In 2020, more than 3.4 million – mostly young people – participated in EU Code Week in schools all around Europe and the world, despite the pandemic. 84% of the activities took place in schools even with lockdowns and 44% of participants were girls. Poland (20,653) and Italy (9,833) were the top EU countries with the highest number of activities organised in 2020. There were also attracting the highest number of participants in the EU, Poland attracted 632,305 coding enthusiasts and Italy 330,021.

[36] https://codeweek.eu/

Figure 14 EU Code Week 2020 – number of EU Code Week activities in Europe



Source: European Commission

The next edition of the Code Week took place between 9 and 24 October 2021 with organisers actively registering their activities on the EU Code Week map.

3 Digital infrastructures

3.1 Broadband connectivity

The Digital Decade defines two targets in the area of broadband connectivity for 2030: gigabit coverage for all households and 5G in all populated areas.

The connectivity dimension of the Digital Economy and Society Index (DESI) looks at both the demand and the supply side of fixed and mobile broadband. Under fixed broadband, it assesses the take-up of overall, at least 100 Mbps and at least 1 Gbps broadband, the availability of fast broadband (next generation access of at least 30 Mbps) and of fixed very high capacity networks (VHCNs)[37]. Under mobile broadband, it includes the population coverage of 4G and 5G[38] networks, the assignment of radio spectrum for 5G (5G readiness) as well as the take-up of mobile broadband[39]. In addition, it captures the retail prices of fixed and mobile offers and also those of converged bundles (consisting of fixed and mobile service components).

Table 4 Connectivity indicators in DESI

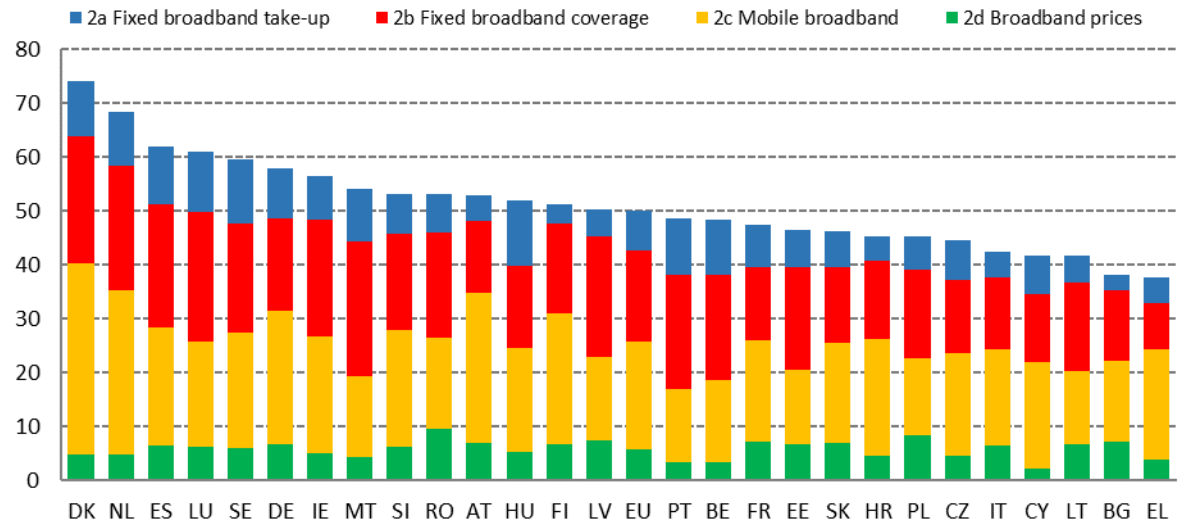
	EU	
	DESI 2019	**DESI 2021**
2a1 Overall fixed broadband take-up % households	**74%** 2018	**77%** 2020
2a2 At least 100 Mbps fixed broadband take-up % households	**21%** 2018	**34%** 2020
2a3 At least 1 Gbps take-up % households	**NA**	**1.3%** 2020
2b1 Fast broadband (NGA) coverage % households	**80%** 2018	**87%** 2020
2b2 Fixed Very High Capacity Network (VHCN) coverage % households	**33%** 2018	**59%** 2020
2c1 4G coverage % populated areas	**98.8%** 2018	**99.7%** 2020
2c2 5G readiness Assigned spectrum as a % of total harmonised 5G spectrum	**15%** 2019	**51%** 2021
2c3 5G coverage % populated areas	**NA**	**14%** 2020
2c4 Mobile broadband take-up % individuals	**65%** 2018	**71%** 2019
2d1 Broadband price index Score (0-100)	**NA**	**69** 2020

Source: DESI 2021, European Commission.

In connectivity, Denmark has the highest score, followed by the Netherlands and Spain. Greece and Bulgaria has the weakest performance on this dimension of the DESI.

[37] Fixed VHCN coverage refers to the combined coverage of FTTP and DOCSIS 3.1 cable networks.
[38] 5G coverage was introduced in DESI in 2021.
[39] The mobile broadband take-up indicator has been revised, see the DESI methodological note for further details.

Figure 15 Digital Economy and Society Index 2021, Connectivity



Source: DESI 2021, European Commission.

As for the mobile broadband sub-dimension (including indicators 2c1, 2c2, 2c3 and 2c4, indicated in yellow in the above chart), the Netherlands, Denmark and Austria lead Europe, while Portugal and Lithuania registered the lowest scores.

3.1.1 Broadband coverage

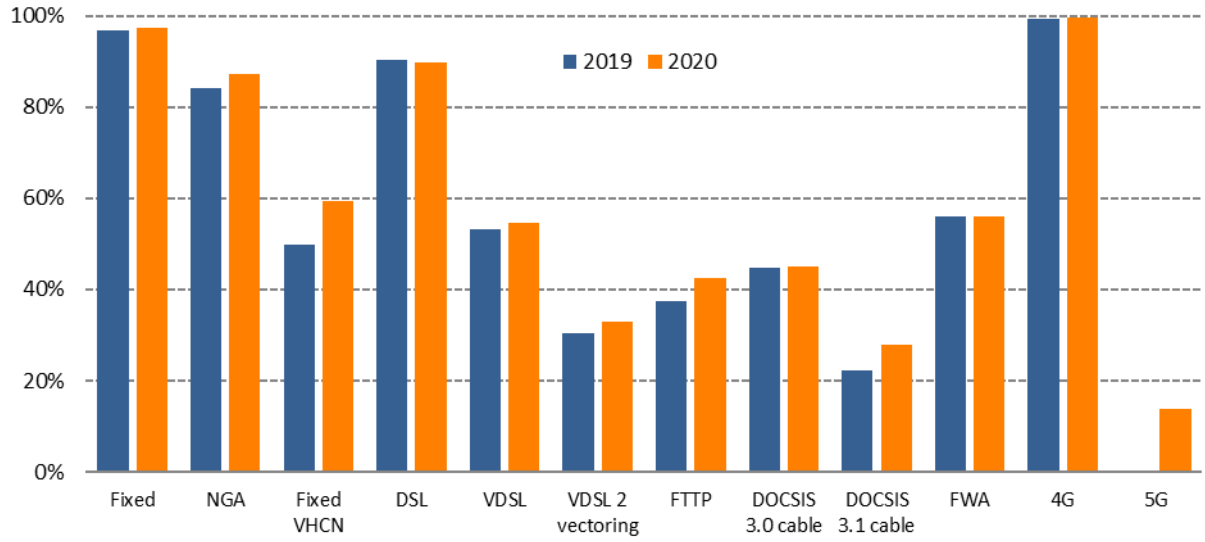
At least one basic broadband network has been available to all households in the EU since 2013, when considering all major technologies (xDSL, cable, fibre to the premises - FTTP, Fixed wireless access - FWA, 4G and satellite). Internet access at home is provided mainly through fixed technologies, the coverage of which remained stable at 97%. Among these technologies, xDSL continued to have the largest footprint (90%) followed by FWA (56%), DOCSIS 3.0 cable (45%) and FTTP (42%).

Coverage of Next generation access (NGA) technologies (VDSL, VDSL2 vectoring, FTTP, DOCSIS 3.0, DOCSIS 3.1) capable of delivering download speeds of at least 30 Mbps reached 87% in 2020, following a slight increase of 3.1 percentage points compared to the previous year. This mainly resulted from a 5-point growth in FTTP. VDSL coverage went up by 1.5 percentage points, while cable DOCSIS 3.0 remained unchanged at 45%.

Fixed very high capacity networks (VHCN), having the capabilities of offering gigabit connectivity, covered 59% of EU homes in 2020, up from 50% a year earlier. FTTP deployments and cable network upgrades to DOCSIS 3.1 (coverage went up from 22% to 28%) were equally important in growing VHCN coverage in 2020.

Regarding mobile technologies, while 4G is almost universal reaching 99.7% of populated areas, 5G commercial services were launched in about half of the member states by mid-2020 covering 14% of populated areas.

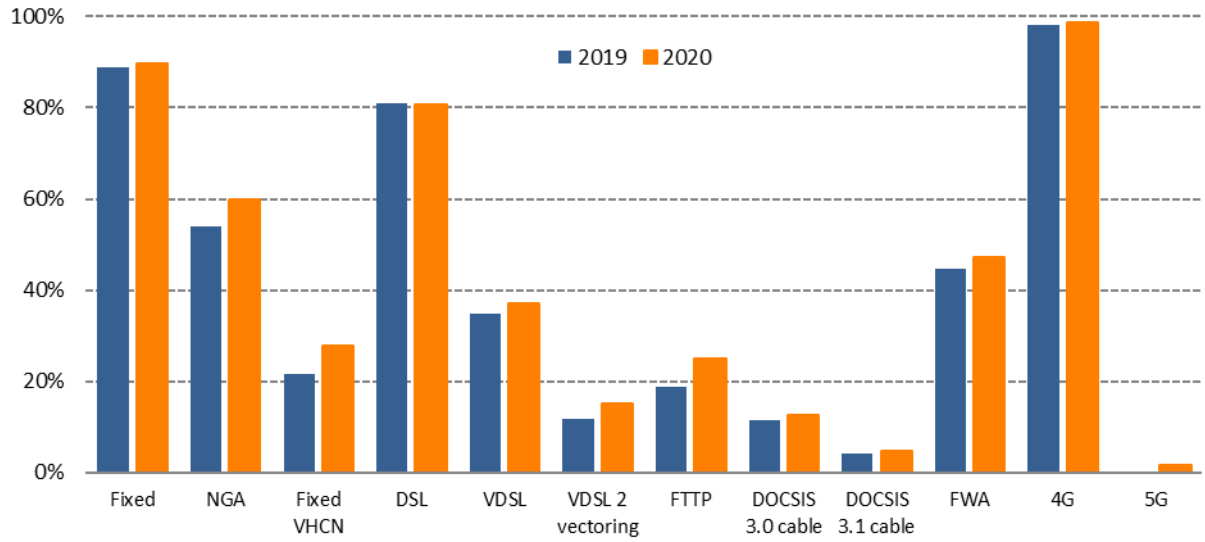
Figure 16 Total coverage by technology at EU level (% of households), 2019-2020



Source: IHS Markit, Omdia and Point Topic, Broadband coverage in Europe studies.

Broadband coverage of rural areas[40] remains challenging, as 10% of households are not covered by any fixed network, and 40% are not served by any NGA technology. Nevertheless, 4G is widely available also in rural areas (98.6%). Regarding fixed technologies, there was a marked increase in the rural coverage of FTTP (from 19% in 2019 to 25% in 2020).

Figure 17 Rural coverage by technology at EU level (% of households), 2019 – 2020

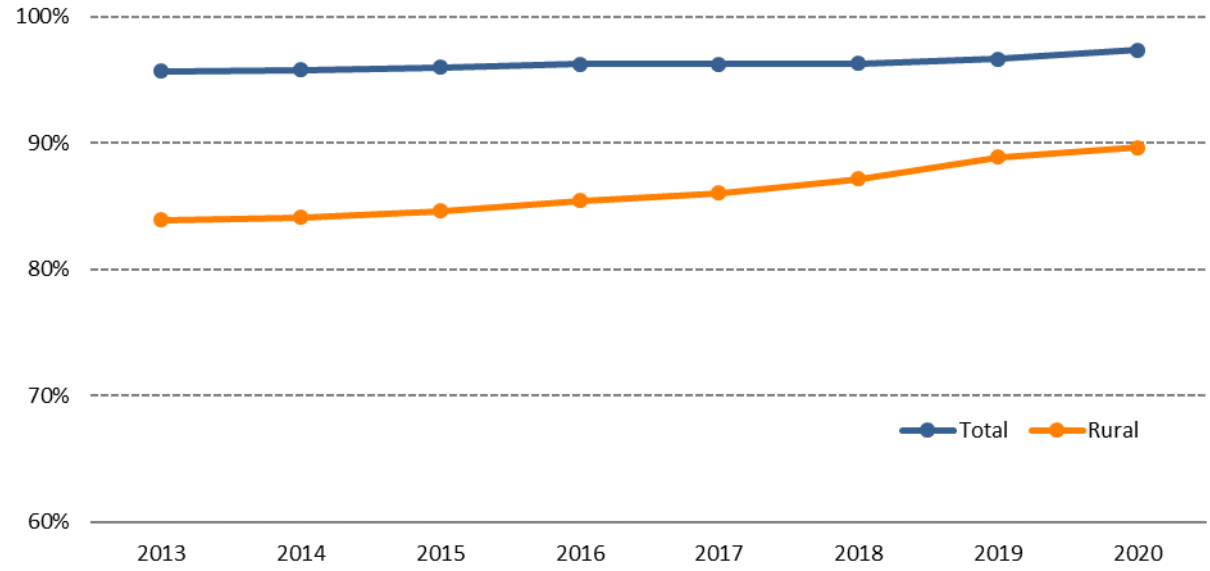


Source: IHS Markit, Omdia and Point Topic, Broadband coverage in Europe studies.

Overall coverage of fixed broadband has only marginally increased since 2013 from 95.7% to 97.4%. Rural coverage improved from 83.9% in 2013 to 89.7% in 2020.

[40] For the definition of rural areas see sub-chapter "3.2 Defining households and rural areas" in the methodology of the study "Broadband Coverage in Europe 2018", page 16, by IHS Markit and Point Topic (https://ec.europa.eu/digital-single-market/en/news/study-broadband-coverage-europe-2018).

Figure 18 Fixed broadband coverage in the EU (% of households), 2013 - 2020

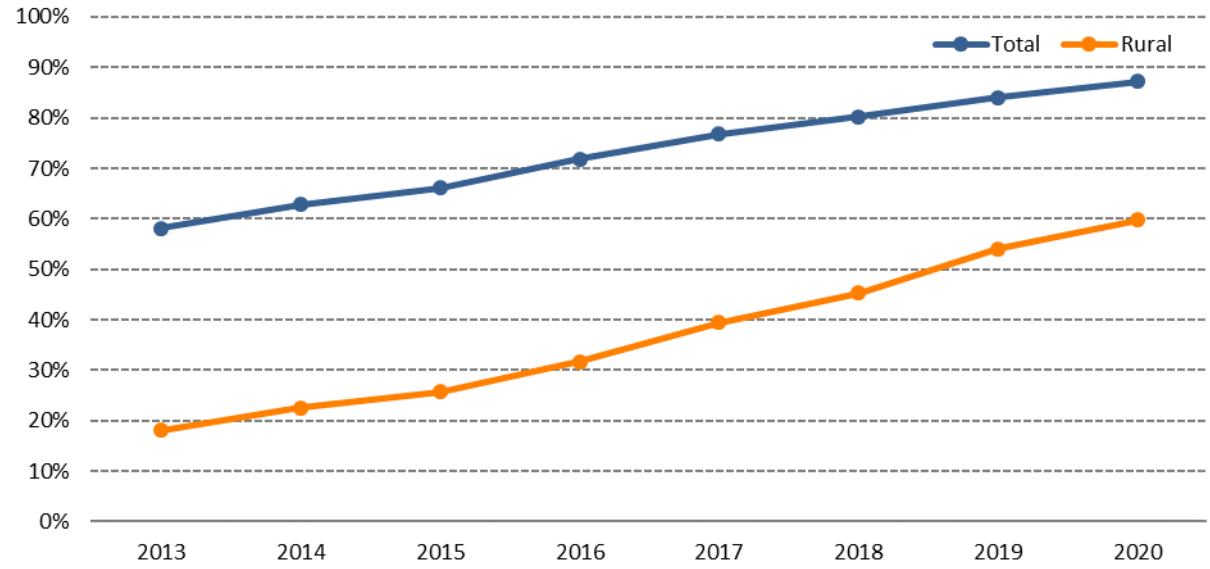


Source: IHS Markit, Omdia, Point Topic and VVA, Broadband coverage in Europe studies.

Fixed coverage is close to universal in the majority of the EU with less than 3% uncovered households in 19 Member States. On the other hand, Lithuania, Poland and Romania are lagging behind with less than 90% of households covered.

NGA is available in the vast majority of EU homes (87%), but only 60% can benefit from such services in rural areas. VDSL has the largest coverage among NGA technologies (55%), followed by cable (45%) and FTTP (42%).

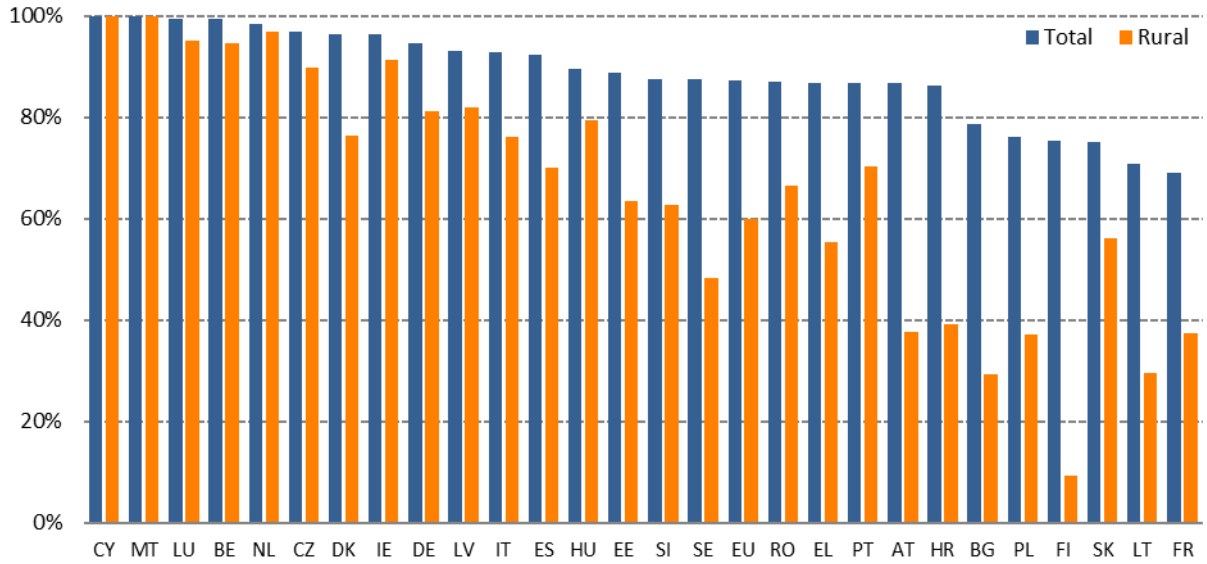
Figure 19 Next generation access (NGA) broadband coverage in the EU (% of households), 2013-2020



Source: IHS Markit, Omdia, Point Topic and VVA, Broadband coverage in Europe studies.

In Cyprus, Malta, Luxembourg and Belgium, NGA is available in more than 99% of households. The situation remained challenging in France (69%) and Lithuania (71%), despite the fact that both countries improved in 2020 (France by 7 and Lithuania by 2 percentage points).

Figure 20 Next generation access (NGA) broadband coverage in the EU (% of households), mid-2020

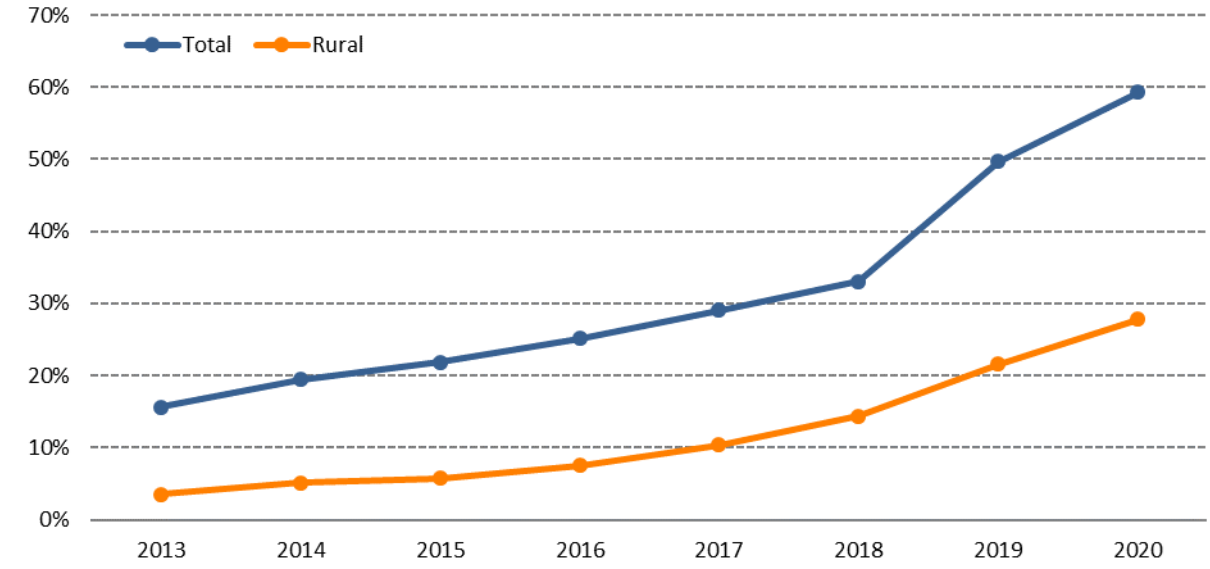


Source: IHS Markit, Omdia and Point Topic, Broadband coverage in Europe studies.

VHCN coverage increased significantly between 2013 and 2020 from 16% to 59%. Coverage almost doubled in the last two years, as the upgrade of cable networks to DOCSIS 3.1 started in several Member States and FTTP deployments also accelerated.

In rural areas, growth was lower, but still substantial, from 4% to 28% over the same time period. The large gap between total and rural VHCN coverage shows the regional disparities in digital opportunities and confirms that more investment is needed in rural areas in order to catch up.

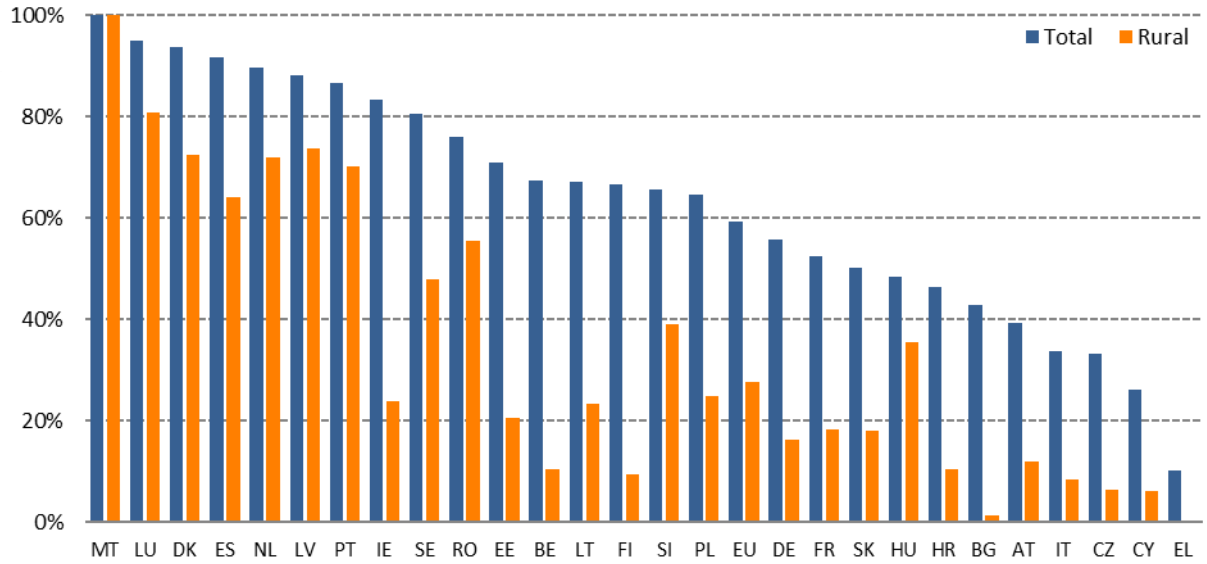
Figure 21 Fixed very high capacity network (VHCN) coverage (% of households) in the EU, 2013-2020



Source: IHS Markit, Omdia and Point Topic, Broadband coverage in Europe studies.

In mid-202, Malta was leading with 100% of VHCN coverage, followed by Luxembourg, Denmark and Spain with above 90% coverage. The poorest performers were Greece (10%), Cyprus (26%) and Czechia (33%), although they all improved in 2020. There has been spectacular progress in Ireland (48 percentage points), Austria (25 percentage points) and Germany (23 percentage points).

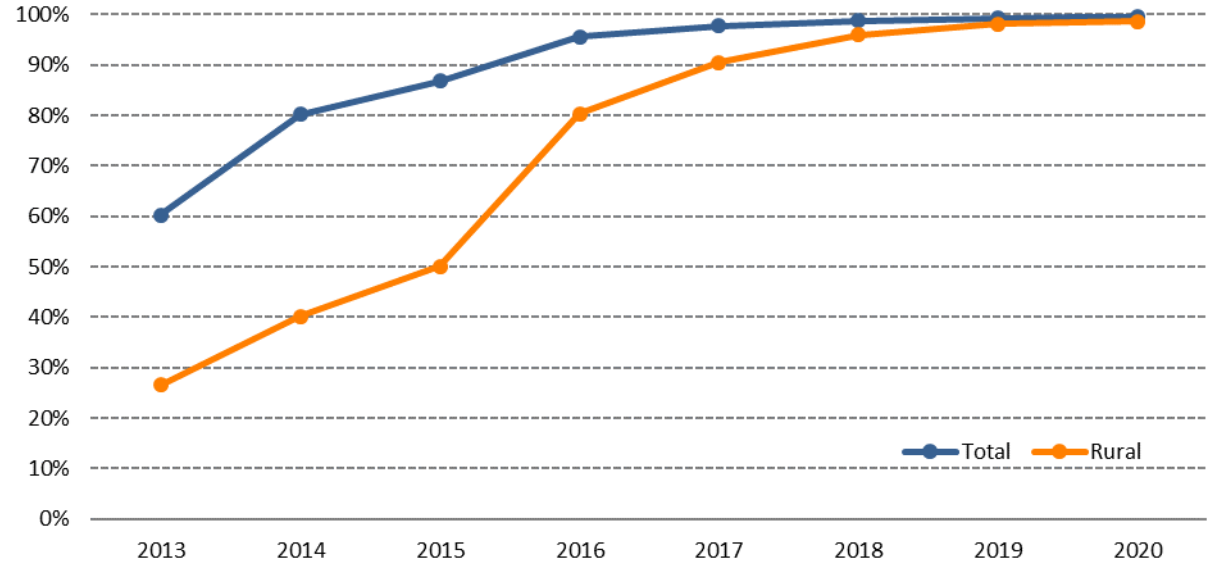
Figure 22 Fixed very high capacity network (VHCN) coverage (% of households), mid-2020



Source: IHS Markit, Omdia and Point Topic, Broadband coverage in Europe studies.

4G (LTE) is almost ubiquitous with 99.7% of populated areas covered by at least one operator in the EU, being even more widely available than fixed broadband (97.4%). In the last three years, the gap between rural and overall 4G coverage almost closed. Rural coverage stood at 98.6% in 2020.

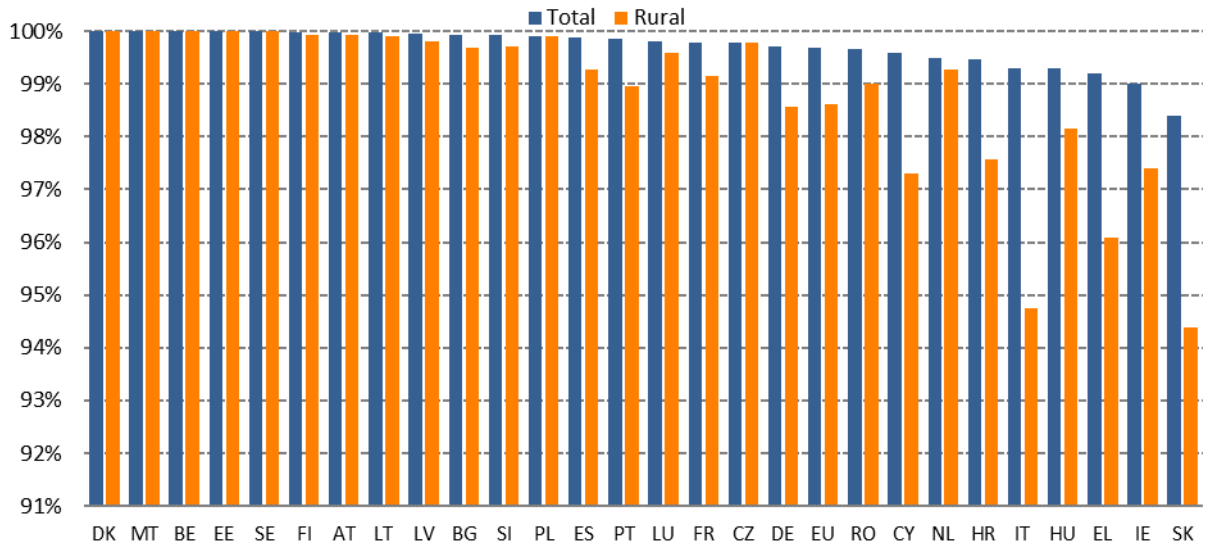
Figure 23 4G mobile coverage in the EU (% of households), 2013-2020



Source: IHS Markit, Omdia, Point Topic and VVA, Broadband coverage in Europe studies.

All Member States have well above 95% coverage of 4G.

Figure 24 4G mobile coverage (% of populated areas), mid-2020



Source: IHS Markit, Omdia and Point Topic, Broadband coverage in Europe studies.

The 5G readiness indicator in the DESI shows the portion of spectrum assigned for 5G purposes in each Member State in the 5G pioneer bands. The percentage score of the 5G readiness indicator is based on the amount of spectrum assigned in a specific Member State and ready for 5G use by the end of 2020 within the 5G pioneer bands identified in Europe.

This score is calculated based on the portion of spectrum assigned in each 5G pioneer band in comparison with the maximum feasible amounts, which are as follows:

- 700 MHz band: 60 MHz (703-733 & 758-788 MHz),
- 3.6 GHz band: 400 MHz (3,400-3,800 MHz),
- 26 GHz band: 1000 MHz within 24,250-27,500 MHz.

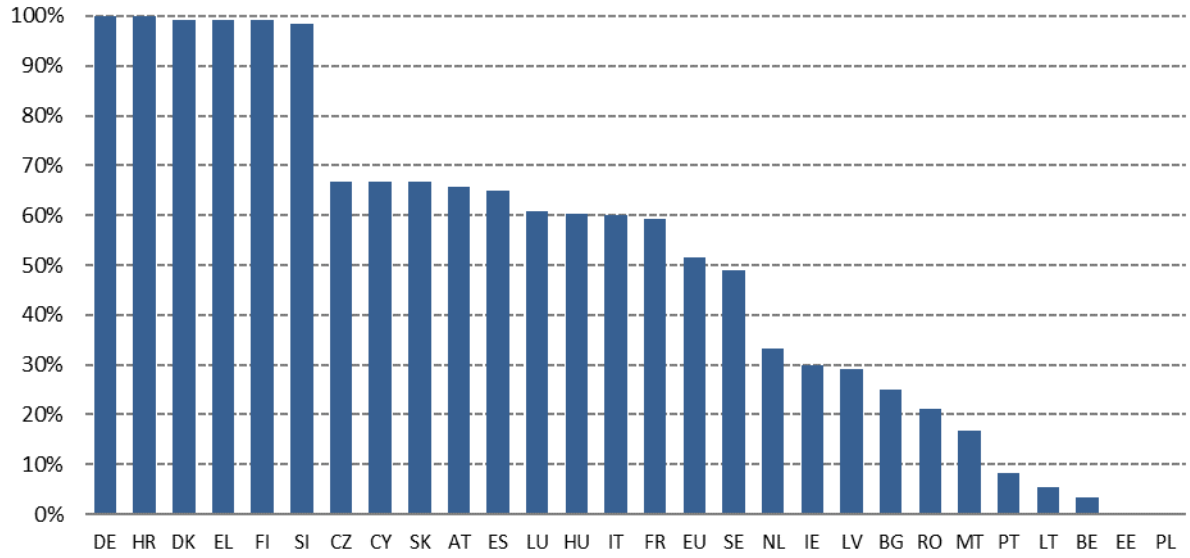
All three spectrum bands have an equal weight, so having the maximum feasible amount assigned – and ready for 5G use – in the range of one of these bands will result in a score of 33.3%, i.e. one third of the total maximum score.

Remarks:

1. For the 700 MHz band, there are a number of derogations allowing for a delay until 2022; however, the 5G readiness indicator is about factual reporting, not a judgement on legal compliance.
2. For the 3,400-3,800 MHz band, only licences aligned with the latest technical conditions (in accordance with Commission Implementing Decision (EU) 2019/235) were considered ready for 5G use.
3. For the 26 GHz band, at least a portion of 1,000 MHz within the band must be assigned and ready for 5G use by the end of 2020, as required by the European Electronic Communications Code.

By the end of August in 2021, 25 of the 27 Member States had assigned spectrum in the 5G pioneer bands, compared to 16 a year earlier. Germany, Croatia, Denmark, Greece, Finland and Slovenia assigned more than 90% of spectrum. On the other hand, Estonia and Poland have not yet assigned any 5G spectrum (according to the above conditions).

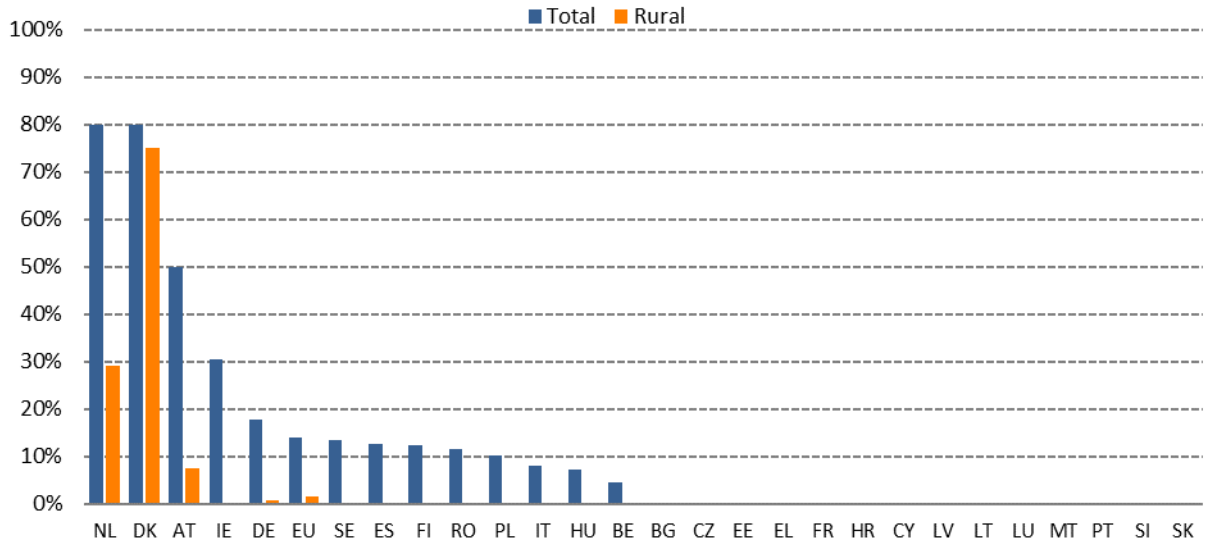
Figure 25 5G readiness (assigned spectrum as a % of total harmonised 5G spectrum), end of August, 2021



Source: Communications Committee (COCOM) based on iDATE.

Following the spectrum assignments, 13 Member States started commercial 5G network deployments by mid-2020. Highest coverage levels were recorded in the Netherlands and Denmark (80% of populated areas each), followed by Austria (50%), Ireland (30%) and Germany (18%).

Figure 26 5G mobile coverage (% of populated areas), mid-2020

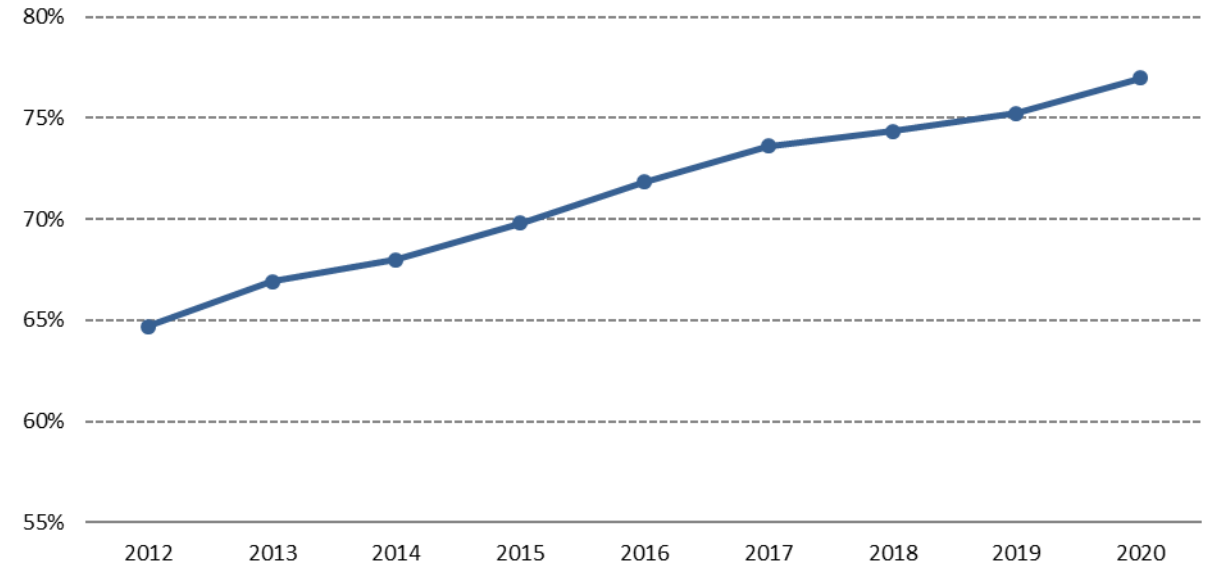


Source: IHS Markit, Omdia and Point Topic, Broadband coverage in Europe studies.

3.1.2 Fixed broadband take-up

Over three quarter of EU households (77%) had a fixed broadband subscription in 2020, following a steady growth (an annual growth rate of 2.1%) over the last 8 years.

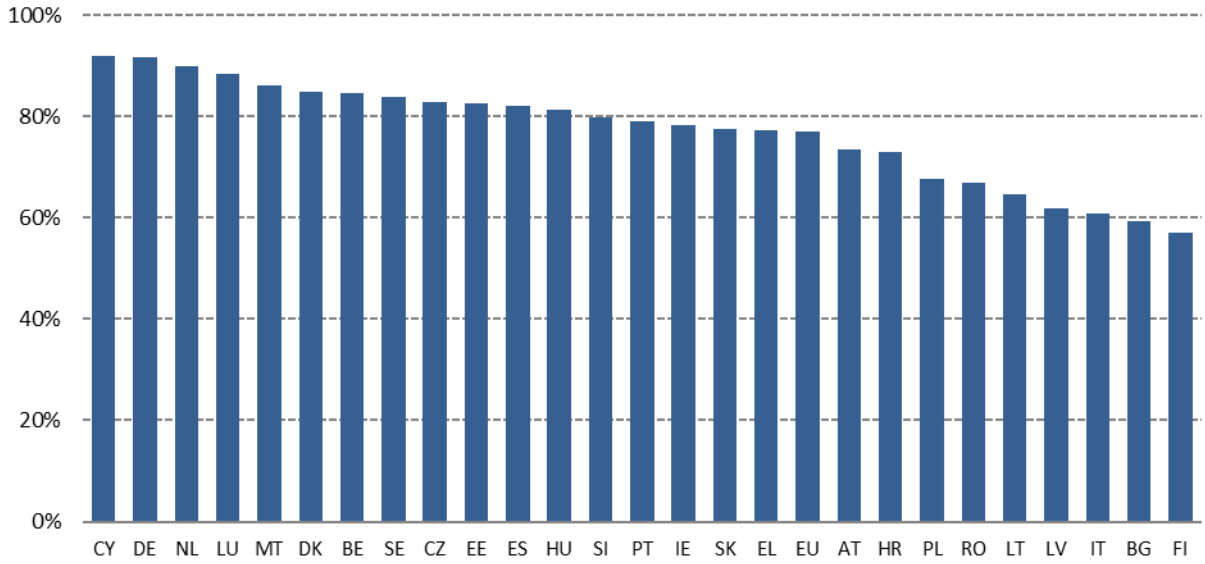
Figure 27 Households with a fixed broadband subscription in the EU (% of households), 2012-2020



Source: Eurostat, European Union survey on ICT usage in Households and by Individuals.

National take-up rates ranged from only 57% to 92%. Cyprus, Germany and the Netherlands registered the highest figure, while Finland, Bulgaria, Italy, Latvia and Lithuania the lowest. The relatively low take-up rates in Finland, Italy, Poland and Latvia may partly be due to fixed-mobile substitution.

Figure 28 Households with a fixed broadband subscription (% of households), 2020

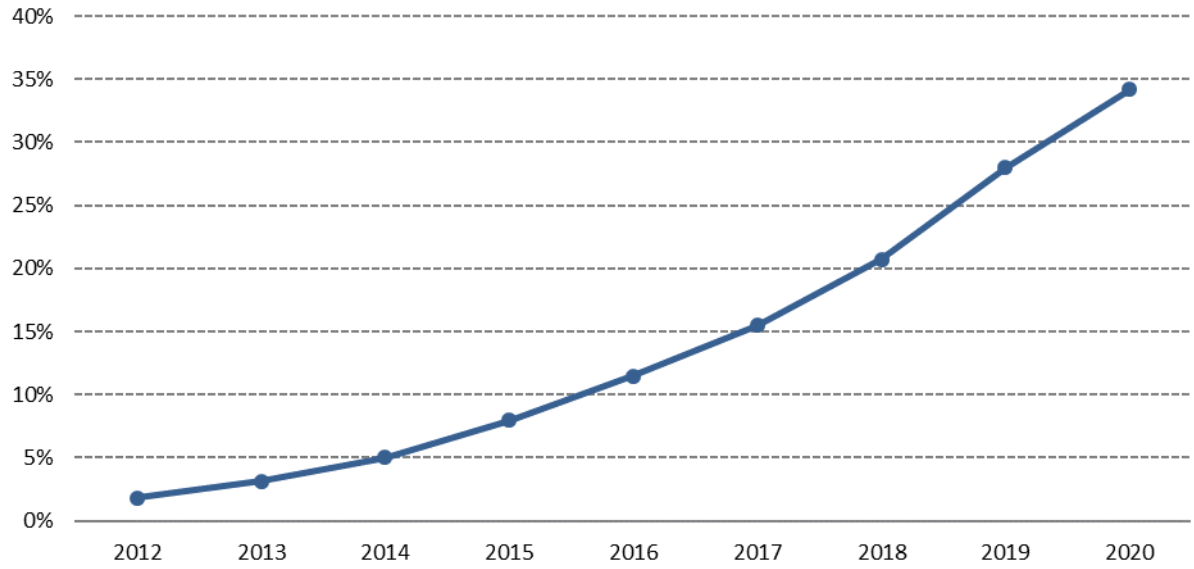


Source: Eurostat, European Union survey on ICT usage in Households and by Individuals.

Similarly to broadband coverage, there is still a large difference between urban and rural figures. Only 69% of rural homes has a fixed broadband subscription compared with 81% in urban areas. The rural-urban gap is the largest in Bulgaria (40% vs. 72%), Finland (42% vs. 70%) and Romania (54% vs. 81%).

Looking at broadband speeds, there has been a sharp upward trend in at least 100 Mbps fixed broadband penetration since 2012. In 2020, more than one third of EU households subscribed to such a service (34%), up from 2% eight years ago.

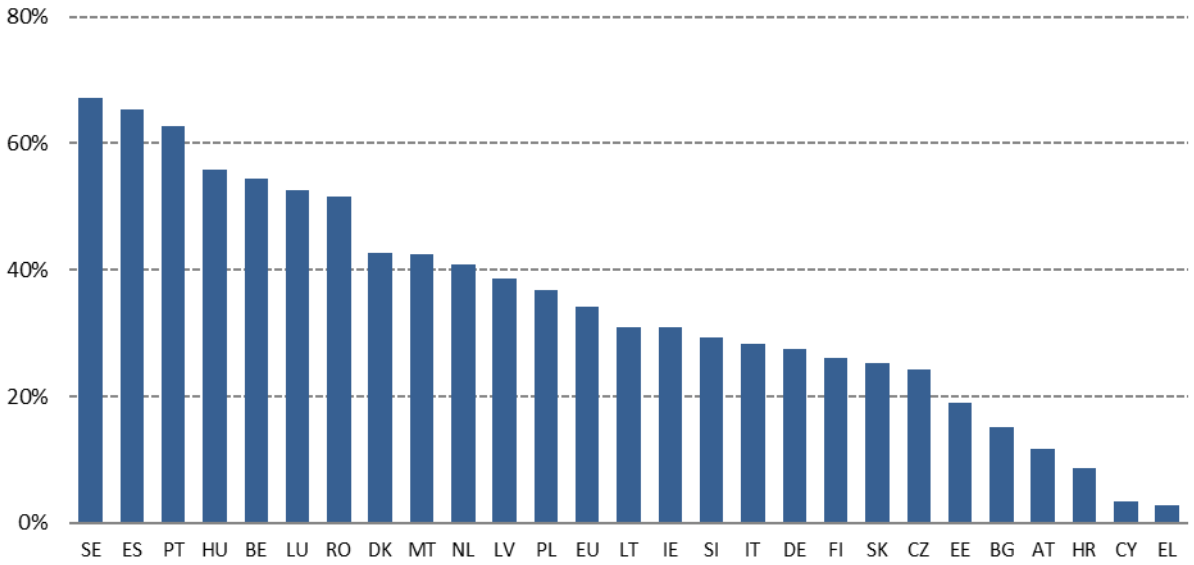
Figure 29 Households with a fixed broadband subscription of at least 100 Mbps (% of households) 2012 – 2020



Source: Estimated based on the European Union survey on ICT usage in Households and by Individuals and data from the Communications Committee (COCOM).

Sweden, Spain, Portugal, Hungary, Belgium, Luxembourg and Romania lead on this indicator with over 50% of households subscribing to at least 100 Mbps. In Greece, Cyprus and Croatia, by contrast, take-up is very low (less than 10%).

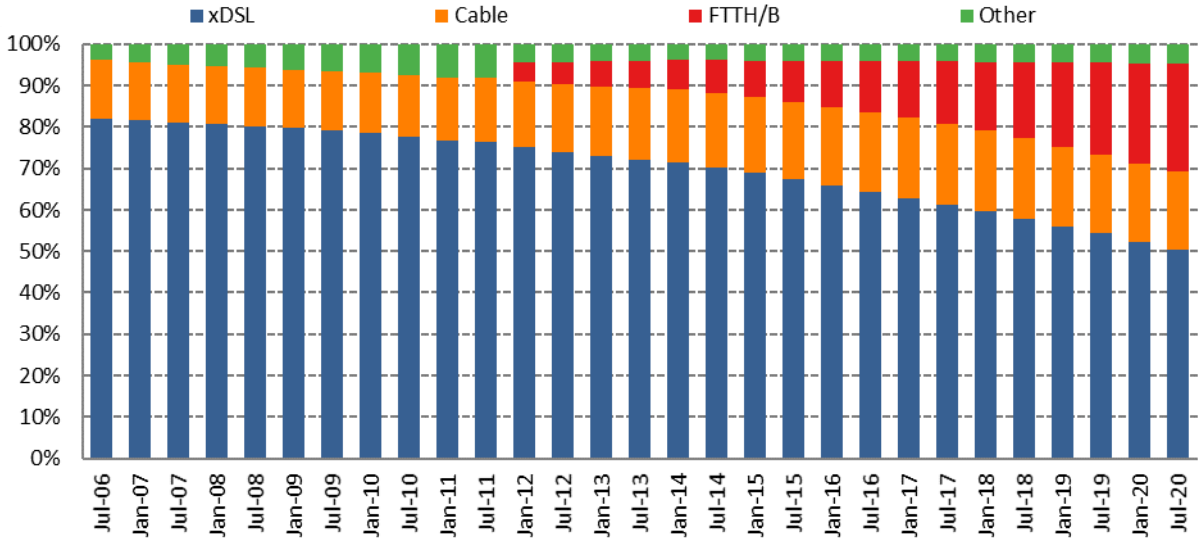
Figure 30 Households with a fixed broadband subscription of at least 100 Mbps (% of households), 2020



Source Estimated based on the European Union survey on ICT usage in Households and by Individuals and data from the Communications Committee (COCOM).

xDSL remained the most widely used fixed broadband technology, although its market share decreased to 50% in 2020 from 82% in 2006. Fibre to the home/building (FTTH/B) became DSL's main challenger over the last years: the share of FTTB/H lines increased from 5% in 2012 to 26% in 2020. Cable lines represented 19% of fixed broadband lines in 2020, compared with 14% in 2006.

Figure 31 Fixed broadband subscriptions – technology market shares in the EU (% of subscriptions), July 2006-July 2020[41]



Source: Communications Committee (COCOM).

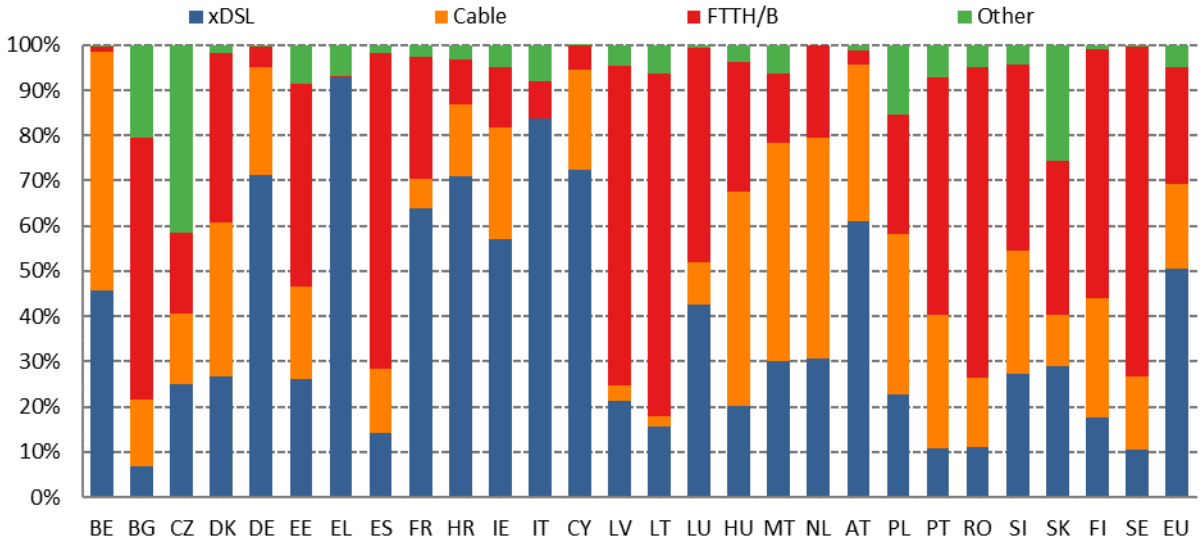
The market share of xDSL varies from 7% to 93% and is generally lower in Eastern Europe, where FTTH/B is more widely used. Cable is present in all but two Member States (Greece and Italy).

xDSL is particularly prevalent in Greece and Italy, and have the lowest market share in Bulgaria, Romania, Portugal, Sweden and Spain.

FTTH/B is the most widely used technology in a growing number of Member States, and has the highest market share in Lithuania, Sweden, Latvia, Spain and Romania.

On the other hand, cable is dominant in Belgium, the Netherlands, Malta and Hungary.

Figure 32 Fixed broadband subscriptions – technology market shares in the EU (% of subscriptions), July 2020



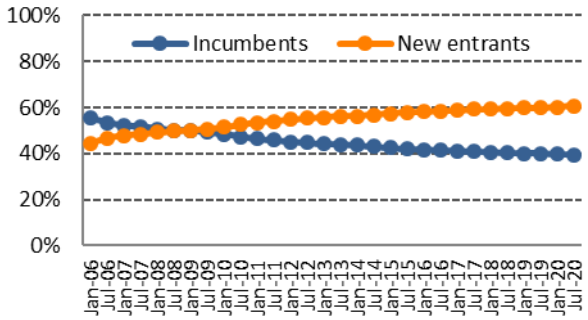
Source: Communications Committee (COCOM).

New entrant operators continued to slightly gain market share and held 61% of fixed lines in 2020 compared with 45% in 2006. The market share of incumbents is the highest in Luxembourg (63%), Cyprus (55%), Latvia (55%) and Austria (54%), and the lowest in Romania (17%) and Czechia (22%).

[41] FTTH/B is part of 'other' technologies until June 2011 on the chart.

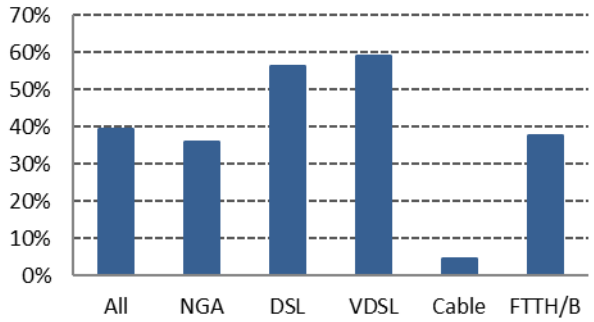
Market shares are calculated at national level for incumbents and new entrants. However, broadband markets are geographically fragmented, suggesting that a large number of households are served by only one provider (most likely the incumbent operator in this case).

Figure 33 Fixed broadband subscriptions – operator market shares in the EU (% of subscriptions), January 2006-July 2020



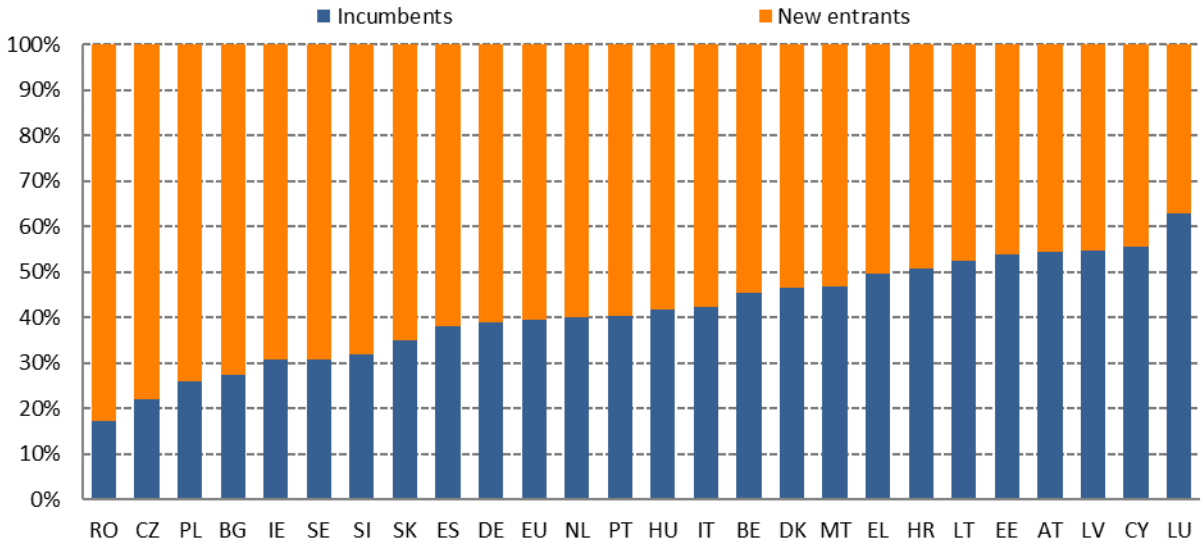
Source: Communications Committee (COCOM).

Figure 34 Incumbent operator market share by technology in the EU (% of subscriptions), July 2020



Source: Communications Committee (COCOM).

Figure 35 Fixed broadband subscriptions – operator market shares in the EU (% of subscriptions), July 2020

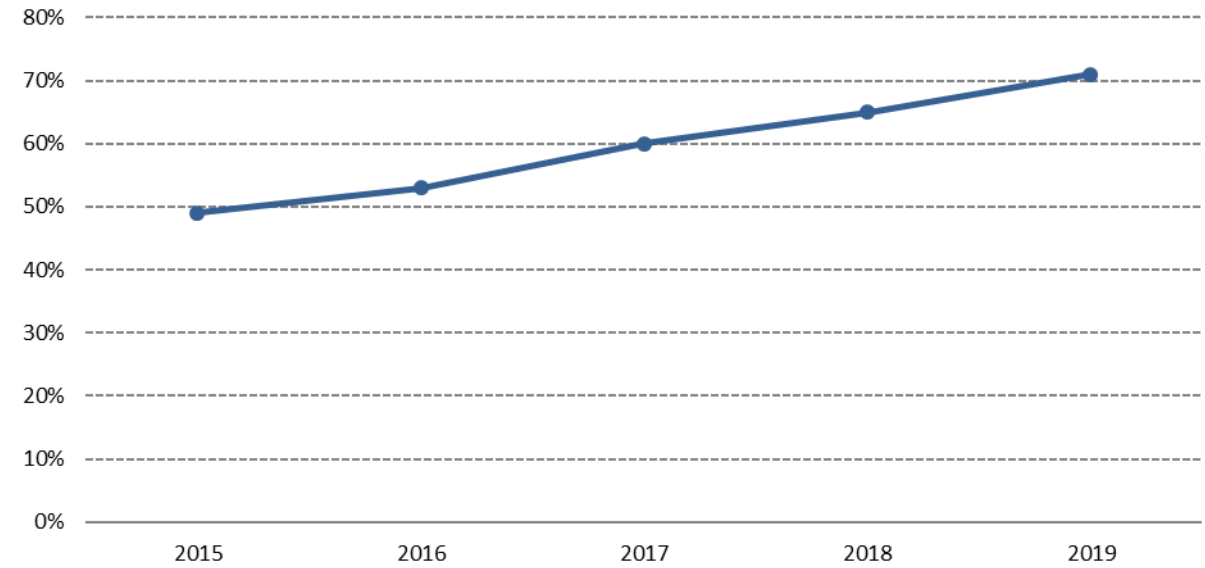


Source: Communications Committee (COCOM).

3.1.3 Mobile broadband take-up

In 2019, 71% of people used a smart phone to access the internet (up from 49% in 2015), which is the vast majority of all regular internet users (84% of people in 2019).

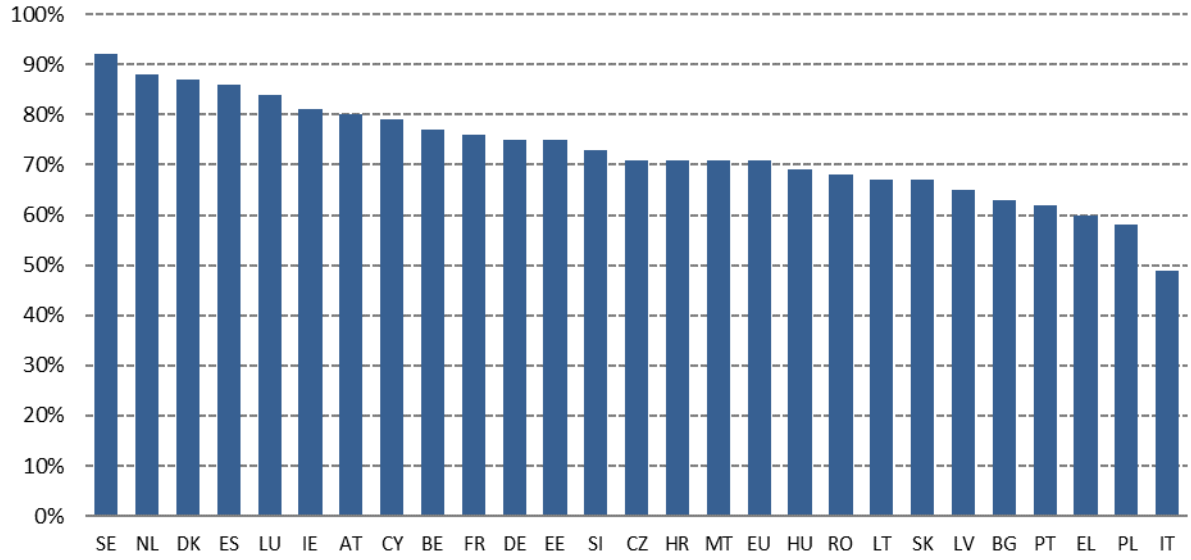
Figure 36 Mobile broadband penetration in the EU (% of individuals), 2015-2019[42]



Source: Eurostat, European Union survey on ICT usage in Households and by Individuals.

Mobile broadband is widely used in every Member State; national penetration rates vary between 49% in Italy and 92% in Sweden.

Figure 37 Mobile broadband penetration (% of individuals), 2019[43]

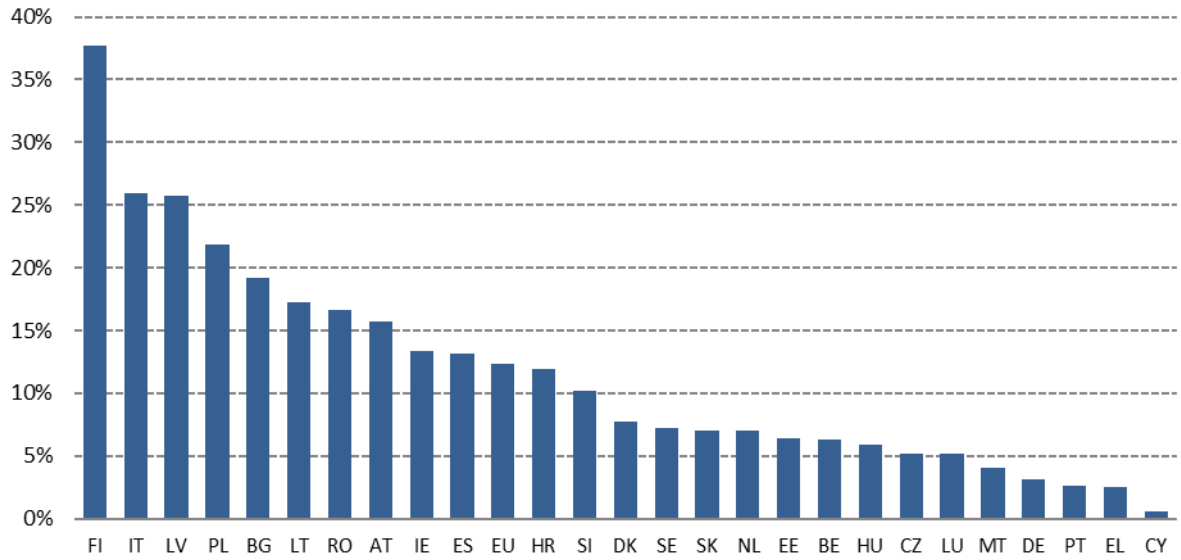


Source: Eurostat, European Union survey on ICT usage in Households and by Individuals.

Mobile broadband is, however, still mainly complementary to fixed broadband, when it comes to subscriptions for households. Europeans primarily use fixed technologies at home to access the internet (even if using a mobile device). In 2020, 12% of EU households accessed the internet only through mobile technologies. Finland (38% of households), Italy (26%) and Latvia (26%) were the leaders in mobile-only access.

[42] Data refers to individuals using a mobile phone to access the internet.
[43] Data refers to individuals using a mobile phone to access the internet.

Figure 38 Households using only mobile broadband at home (% of households), 2020



Source: Eurostat, European Union survey on ICT usage in Households and by Individuals.

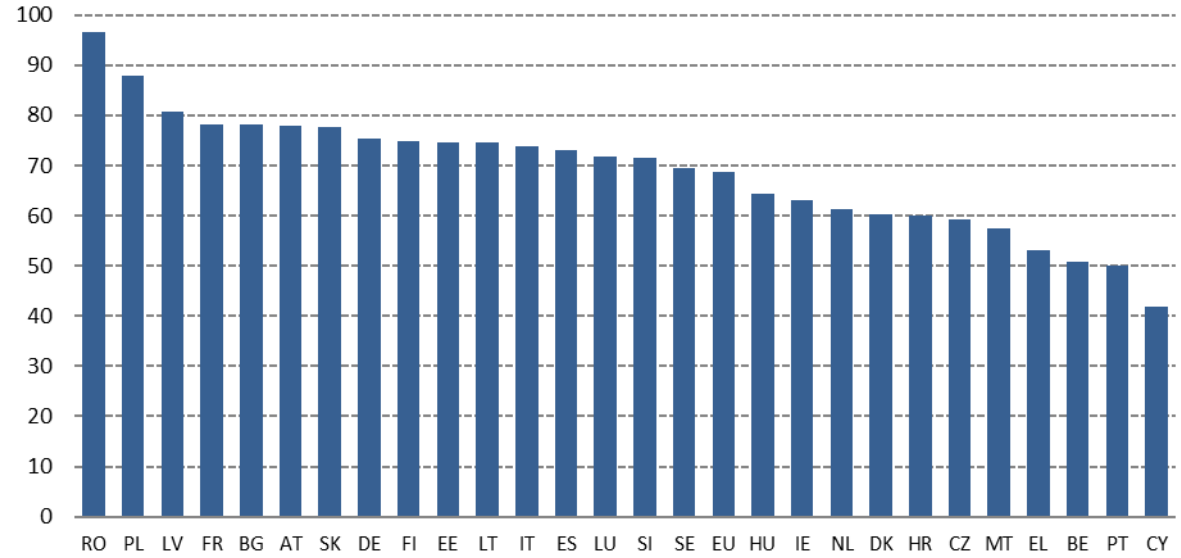
3.1.4 Broadband prices

The Broadband Price Index measures the prices of representative baskets of fixed, mobile and converged broadband offers.

The Broadband Price Index is a score[44] that measures the prices of over 30 representative broadband consumption baskets of different speeds and different products (standalone internet, double play, triple play and quadruple play).

Romania, Poland and Latvia have the lowest broadband prices, while Cyprus, Portugal and Belgium are the most expensive, when considering all fixed, mobile and converged baskets.

Figure 39 Broadband price index – all baskets (score 0-100, 100 meaning the lowest prices) 2020



Source: Commission, based on Empirica (Retail broadband prices studies).

[44] 0 to 100, 100 being the best.

3.1.5 EU support for National Broadband Plan (NBP) implementation

The Commission's strategies on Shaping Europe's digital future[45] and the Digital Decade[46] have confirmed the ambitious Gigabit objectives for fixed and mobile connectivity for all European citizens by 2025 and by 2030. As a recent study on NBP's[47] has identified, only few Member States are close to reaching the DAE targets, despite their ambitious NBPs. While Member states' NBPs differ significantly, all have an overall strategic approach for the deployment of NGA networks that is implemented in practice. There is a variety of conditions that influence the success of broadband roll-out. The NBPs of the Member States usually set one or two focal points out of the following spheres: demand side measures, supply side measures, regulatory and organizational measures and transparency measures. Successful NBPs consider their respective starting positions and describe concrete measures that take advantage of the individual strengths and define measures to mitigate the effect of disadvantages. In view of the new targets for 2025 and 2030, Member States should build on existing successful measures and orient their incentive towards the deployment and take-up of optical networks, which can be considered the most sustainable and future-proof solution in terms of exponentially growing data capacity usage. Incremental approaches to connectivity investments, such as 5G Fixed Wireless Access (FWA), can also be considered especially in remote areas, provided that the deployed infrastructures are scaleable and evolvable toward networks with fibre-based connectivity brought as close as possible to the users.

With at least 20% of expenditure dedicated to the digital transition, the Recovery and Resilience Facility (RRF) is an important opportunity for all Member States to invest in digital connectivity. Member States are planning to invest more than EUR 13bn (for 22 adopted plans) into connectivity deployment, including for supporting the 5G roll-out, especially in rural areas.

In the 2014-2020 period, Member States had already used around EUR 6 billion of European Structural and Investment Funds (ESIFs) for broadband, the equivalent of 14.5 million additional households with access of at least 30 Mbps. Member States will have the possibility to access such support programmes also under in the next 2021-2027 ERDF funding period, especially for VHCN. Telecoms infrastructure projects have also been supported by European Fund for Strategic Investment (EFSI) guarantees and European Investment Bank (EIB) lending. As of 12 December 2019, approx. EUR 12.3 billion of estimated investments are mobilised thanks to a total EIB financing of EUR 3.47 billion, of which EUR 3.01 billion as a budgetary guarantee from EFSI. Under the 2021-2027 funding period, the InvestEU program continues to offer budgetary guarantees for investments in telecom infrastructure projects under its "Sustainable Infrastructure" Policy Window.

The Connecting Europe Broadband Fund (CEBF) launched in June 2018 has closed with an investment capital of EUR 555M in July 2021 and is expected to unlock total investments of between EUR 1.0 billion to 1.7 billion. The CEBF is investing in all EU Member States, as well as EEA Member States participating in the Telecom Connecting Europe Facility (Iceland and Norway). The project pipeline shows solid geographical diversification, as do the projects already signed by the Fund to date. Since its launch, the CEBF has successfully invested into 7 projects in Croatia, Slovenia, the UK, Spain, the Czech Republic, Italy and the Netherlands, respectively. The projects aims to deploy high-quality FTTH open-access networks for residential, business and public administration use and together aim to cover over 1.340.000 locations.

The Commission continues to support in the 2021-2027 funding period the development of administrative capacity to design and implement NBPs through the Broadband Competence Offices

[45] https://ec.europa.eu/commission/presscorner/detail/en/ip_20_273

[46] https://ec.europa.eu/info/strategy/priorities-2019-2024/europe-fit-digital-age/europes-digital-decade-digital-targets-2030_en

[47] Publication expected for October 2021.

Network first launched in 2017 (with currently 115 members). The network brings together national and regional authorities active in this field, and is supported by a permanent secretariat based in Brussels. The Commission provides also technical support through the Technical Support Instrument (TSI) for the Digital Transition, for example in order to enhance the efficiency and effectiveness of broadband investments and the implementation of the goals set for the Digital Decade by accelerating public investment in broadband.

Work to improve the mapping of broadband also continued with the review of existing national initiatives. According to Article 22 of Directive (EU) 2018/1972 (European Electronic Communications Code, EECC) all National Regulatory Authorities (NRAs) and/or Other Competent Authorities (OCAs) shall conduct a geographical survey of the reach of electronic communications networks capable of delivering broadband ('broadband networks') by 21 December 2023 and shall update it at least every three years thereafter. In addition, by early 2022, the revised Guidelines on State Aid for Electronic Communications networks will include mapping requirements for the purpose of the notification of state aid interventions

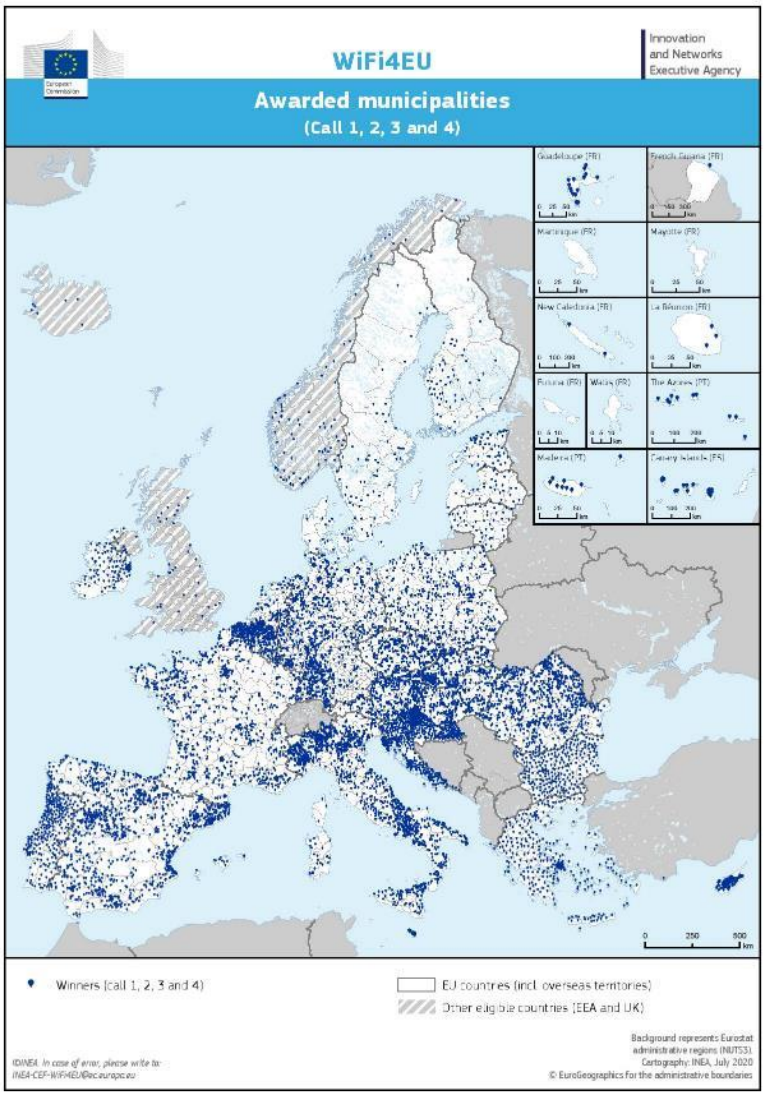
3.1.6 Municipalities need more connectivity – WiFi4EU

The WiFi4EU initiative continues to promote free Wi-Fi access in public spaces including schools, parks, squares, public buildings, libraries, health centres and museums in municipalities throughout Europe. With 4 WiFi4EU calls since November 2018, the initiative has by June 2020 awarded more than 8 800 vouchers to winning municipalities (Figure 42), i.e. around 30% of more than 29,000 municipalities that managed to register their interest.

Each voucher entitles the winning municipality to install a WiFi4EU network, and covers the costs with a fixed amount of EUR 15 000. The vouchers have been awarded on a first-come-first-served basis while ensuring geographical balance throughout the whole initiative. By July 2021 more than 4.700 out of 8800 municipalities had installed their networks, totalling more than 60.000 active access points, with peaks of more than 100.000 connected users per day. In order to mitigate the prolonged Covid-related challenges the deadlines for installing all funded networks has been extended to October 2022.

WiFI4EU represents a positive precedent of EU direct investment in local connectivity, which carries on under the next CEF2 Digital programme with a focus on 5G best practices. This new initiative also could provide blueprints for leveraging investments under other programmes, including Cohesion Funds, Agricultural funds and RRF.

Figure 40 WiFi4EU – Winning Municipalities by Country



Source: Innovation and Networks Executive Agency.

3.1.7 EU harmonised radio spectrum underpins future wireless digital services

The total EU harmonised radio spectrum for terrestrial systems capable of providing wireless broadband electronic communications services amounts to 4340 MHz, including the whole 26 GHz frequency band (24.25-27.5 GHz), while 2090 MHz thereof are subject to authorisation in accordance with the provisions of Directive (EU) 2018/1972 (European Electronic Communications Code, EECC). Under Decision (EU) 2017/899, the deadline for allowing the use of the 700 MHz frequency band (694-790 MHz) and in particular of the frequency division duplex part (703-733 MHz and 758-788 MHz) was 30 June 2020 [48]. In addition, pursuant to Article 54 of the EECC , the deadline for allowing the use of the 3.6 GHz frequency band (3400-3800 MHz) and at least 1 GHz of the 26 GHz frequency band (subject to market demand), was 31 December 2020.

At 31 August 2021, 56% of the EU harmonised radio spectrum for wireless broadband had been awarded across Member States. In particular with relation to the 5G pioneer spectrum, almost half a year after the expiry of the deadline in Article 54 of the EECC, and while some Member States had announced the postponement of spectrum awards due to the COVID-19 crisis or are still in the process of resolving other issues (e.g. pending cross-border coordination), seventeen (17) Member

[48] Decision (EU) 2017/899 of the European Parliament and of the Council of 17 May 2017 on the use of the 470-790 MHz frequency band in the Union (OJ L.138 of 25.05.2017, p.131).

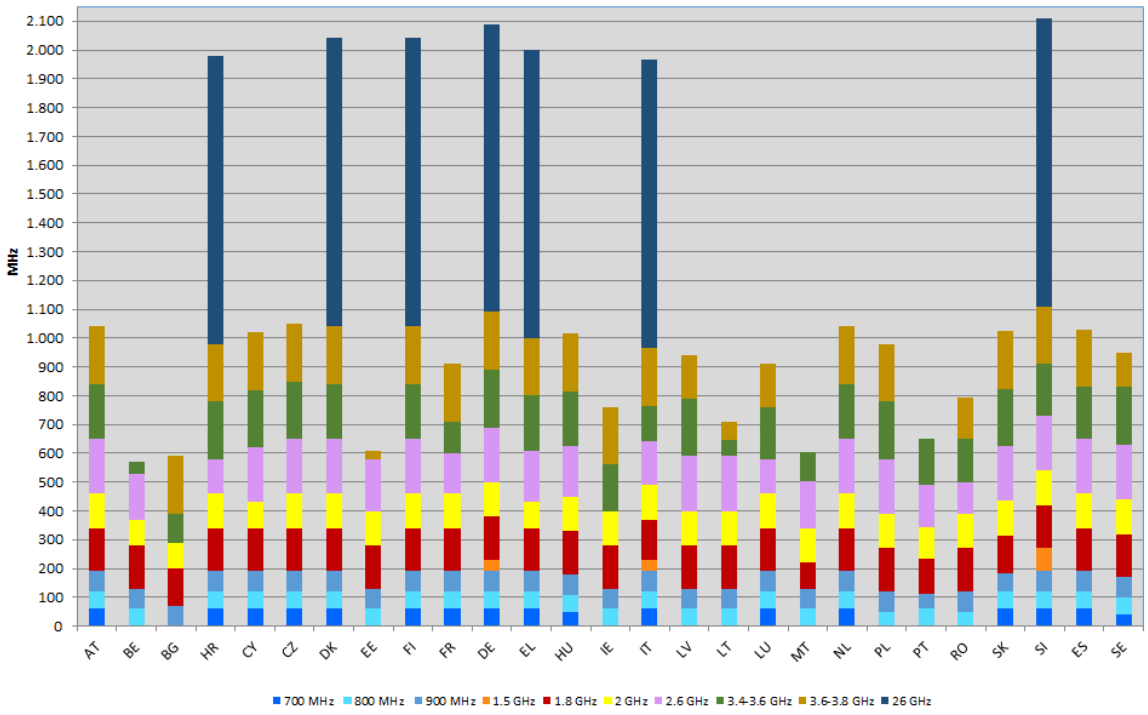
States have assigned the 700 MHz band (two not in full), twenty four (24) Member States have assigned (totally or partially) the 3.6 GHz band, while the 26 GHz band (≥1GHz) has been assigned only by seven (7) Member States. New spectrum auctions of 5G pioneer spectrum are expected by end 2022 or later.

Taking into account the above timeframes as well as the information gathered by the Commission, with relation to the administrative measures taken so far by Member States towards the fulfilment of the above obligations, there is some concern about the delays in the implementation of EU law regarding the authorisation of radio spectrum for 5G.

Current delays may be due to different reasons depending on the circumstances in each Member State, such as cross-border coordination issues or use of radio spectrum for defence purposes. In this context, and given the different regulatory conditions applicable to each band, lack of assignment does not necessarily mean non-compliance with EU law.

Denmark, Slovenia, Bulgaria, Spain, Sweden and Croatia completed the latest auctions in 2021. The Danish auction assigned spectrum in the 1400 MHz (90 MHz), 2100 MHz, 2300 MHz, 3.6 GHz and 26 GHz (2.85 GHz) bands. The Slovenian auction assigned spectrum in the 700 MHz (60 MHz of FDD part and 15 MHz of SDL part), 1400 MHz (80 MHz), 2100 MHz, 2300 MHz (70 MHz), 3.6 GHz (380 MHz) and the 26 GHz (1 GHz) bands. The Bulgarian auction assigned the 3.6 GHz (300 MHz) band, the Spanish auction assigned the remaining part of the 3.4-3.6 GHz (20 MHz) band followed by the 700 MHz (60 MHz) band, the Swedish auction ended up with the assignment of the 3.6 GHz (320 MHz) along with the 2300 MHz (80 MHz) band, and lastly the Croatian auction assigned all the three 5G pioneer bands.

Figure 41 Assigned radio spectrum for wireless broadband in harmonised EU bands, 31 August 2021



Source: European Commission

3.1.8 Convergent radio spectrum management approaches are essential to support 5G investment

700 MHz band (60 MHz):

Assigned in fifteen (17) Member States (AT, HR, CY, CZ, DE, DK, FI, FR, EL, IT[49], HU, LU, NL, SK, SI, ES, SE) so far, while other countries are expected to authorise the band by end-2021. Currently, seven Member States (HR, CY, ITPL, EE, LV, LT) are still in the process of resolving cross border issues (with EU and/or non-EU countries) or freeing up the band from incumbent users, which is causing delays in allowing the use of the 700 MHz band wireless broadband. On average, 61.1% of this band has been assigned in the Union.

This band has generated lower sale prices than the 800 MHz band in most Member States (except for France, where four mobile network operators were competing, and Sweden, where only 40 MHz of radio spectrum out of a total of 60 MHz were made available). Initial licenses last slightly longer than those for the 800 MHz band, with an average of 18.1 years.

3.6 GHz band:

Assigned (at least partially) in twenty four (24) Member States under '5G conditions' in accordance with Commission Implementing Decision (EU) 2019/235 of 24 January 2019. Denmark, Bulgaria, Slovenia, Croatia and Sweden were the latest Member States to assign spectrum in the 3.6 GHz band, boosting the average volume of assigned spectrum in this band to 70.9% in the Union.

26 GHz band:

So far awarded, for 5G use, only in Croatia, Italy, Finland, Greece, Slovenia and Denmark, while Germany has started, as of Q4 2020, assigning spectrum within the whole 26 GHz band on a first come, first served basis. This makes them the seven Member States in the Union to have assigned all the 5G pioneer bands. On average, 25.9% of this band (when considering the harmonized portion thereof) has been assigned in the Union.

The 800 MHz band (the 'digital dividend I') is currently assigned in all Member States (in two cases only partially) except for Bulgaria, which has been exempted due to incumbent military use under Article 1(3) of the Radio Spectrum Policy Programme.

Implementing Decisions

Since 2018, the Commission has adopted the following Decisions, pertinent to wireless broadband:

- Commission Implementing Decision (EU) 2018/661 (amending Decision (EU) 2015/750) as regards the extension of the 1.5 GHz band to provide 50 MHz of additional download capacity for 5G services.
- Commission Implementing Decision (EU) 2019/235 (amending Decision 2008/411/EC) to update the relevant technical conditions applicable to the 3.6 GHz band to make the band 5G-ready as it has been identified as the primary pioneer band for 5G in the EU.
- Commission Implementing Decision (EU) 2019/784 to harmonise the technical conditions applicable to the 26 GHz band. This band will be essential for some of the envisaged 5G use cases such as enhanced mobile broadband, specific vertical services that require short response times and extremely high data rates and fixed wireless access for the provision of high-speed internet to households and businesses in areas with limited availability of fixed broadband technology.

[49] The 700 MHz frequency band will be available for use in Italy from July 2022 as the authorities have obtained an exception as provided for in Decision of the European Parliament and the Council on the use of the 470-790 MHz band in the Union.

Moreover, the Commission further delivered on its 5G spectrum roadmap by recently adopting three Decisions regarding the 26 GHz, the paired terrestrial 2 GHz and the 2.6 GHz frequency bands:

- Commission Implementing Decision (EU) 2020/590 of 24 April 2020 amending the harmonised technical conditions of Decision (EU) 2019/784 for use of the 26 GHz band, taking due account of the international agreement reached at the last World Radiocommunication Conference in 2019. It adapts the technical conditions for the protection of the passive satellite services below 24 GHz, which are used for earth monitoring and climate observation (e.g. for the European Copernicus programme). This amendment strikes a sensitive balance in promoting Union policies on 5G deployment and climate change.
- Commission Implementing Decision (EU) 2020/667 of 6 May 2020 amending the harmonised technical conditions of Decision 2012/688/EC, in order to make the paired terrestrial 2 GHz band fit for 5G use, under the principle of technology neutrality.
- Commission Implementing Decision (EU) 2020/636 of 8 May 2020 amending the harmonised technical conditions of Decision 2008/477/EC, in order to make the 2.6 GHz band fit for 5G use, under the principle of technology neutrality.

It is an established EU policy, enshrined also in the European Electronic Communications Code, that authorisation conditions conducive to investment in 5G deployment should avoid extracting excessive capital from the market and should promote ambitious infrastructure roll-out targets (including along rail and roads). The conditions should also enable innovative services, create opportunities for vertical services to access radio spectrum and not artificially limit or apportion radio spectrum supply, in particular in the 3.6 GHz band where large blocks of contiguous spectrum should be made available to operators to unleash the full 5G potential.

In the same context, Member States are now in the process of implementing the common Union Toolbox for Connectivity, which was adopted end of March 2021, in response to the Commission Connectivity Recommendation 2020/1307 of September 2020. The Connectivity Toolbox is comprised of a common set of 39 best practices that will foster digital network deployment and facilitate access to 5G spectrum. With regard to radio spectrum, the Toolbox includes best practices on conditions conducive to investments, incentivising 5G network rollout and reinforcing coordination of radio spectrum assignment for 5G across borders vertical applications. It also touches upon aspects related to electromagnetic fields and public health. Member States shall report on the progress of the implementation of the toolbox, according to their national roadmap, by end of April 2022.

3.1.9 Ex ante market regulation: state of play

With the exception of the termination markets, *ex ante* market regulation is largely concentrated in the broadband markets.

Nevertheless, *ex ante* market regulation is still maintained in a few Member States for certain markets included in the 2003, 2007 and the 2014 recommendations on relevant markets.

Figure 42 Article 32 cases as at 1 July 2021

Effective competition - no ex ante regulation
No effective competition - ex ante regulation
Partial competition - partial ex ante regulation

n number of rounds of market analysis

	2020 RECOMMENDATION		2014 RECOMMENDATION			2007 REC.		2003 RECOMMENDATION								
	Wholesale local access	Wholesale dedicated capacity	Call term. on fixed network	Voice call term. on mobile networks	Wholesale central access	Access to PSTN for res & non-res.	Call orig. on fixed network	Local/nat. Call for res.	Internat. call for res.	Local/nat. call for non-res.	Internat. call for non-res.	Retail LL	Transit on fixed network	Trunk segments LL	Access & call orig. on mobile network	Broadcast Transmis.
	Market 1	Market 2	ex-Mkt 1	ex-Mkt 2	ex-Market 3b	ex-Mkt 1	ex-Mkt 2	ex-Mkt 3	ex-Mkt 4	ex-Mkt 5	ex-Mkt 6	ex-Mkt 7	ex-Mkt 10	ex-Mkt 14	ex-Mkt 15	ex-Mkt 18
Austria	5	5	3	4	5	4	4	3	2	4	3	4	1	2	1	4
Belgium	3	2	3	3	3	3	2	3	1	3	1	2	2	1	1	2
Bulgaria	3	2	4	4	2	3	3	2	2	2	2	1	1	1		
Croatia	2	3	2	2	2	2	2	1		1		1		3		
Cyprus	4	3	3	4	4	3	3	3	2	3	2	2	3	3	4	4
Czech Republic	3	3	5	5	3	4	4	2	2	2	1	2	1	1	2	2
Denmark	4	4	4	5	4	4	4	2	2	1	1	2	1	1	1	1
Estonia	4	3	4	5	4	3	3	1	1	1	1	1	1	2	1	3
Finland	4	1	2	1	4	2	3	2	1	2	1	2	2	1	1	3
France	6	4	5	5	6	4	4	1	1	1	1	2	1	3	1	4
Germany	5	2	5	6	5	4	4	2	1	2	1	2	2	1	1	5
Greece	4	3	4	4	4	3	3	3	1	3	1	3	3	3	1	1
Hungary	4	4	4	6	4	6	4	3	3	3	3	3	2	2	2	3
Ireland	3	3	5	3	3	3	3	2	2	2	2	2	2	2	1	3
Italy	4	4	3	6	4	3	2	2	2	2	2	2	3	2	2	2
Latvia	4	4	5	5	4	2	3	4	3	4	3	3	2	1	1	1
Lithuania	4	2	5	4	4	2	3	3	2	3	2	2	2	2	1	6
Luxemburg	3	3	4	6	3	3	3	2	2	2	2	2	1	2	1	
Malta	2	3	4	4	2	3	3	2	2	2	2	3	2	2	2	1
Netherlands	5	3	5	5	4	4	3	2	2	2	2	2	2	2	1	2
Poland	3	3	3	3	4	3	4	2	2	2	2	2	1	2	2	3
Portugal	3	3	3	3	3	2	2	2	2	2	2	1	1	3		2
Romania	4	2	3	3	3	2	2	1	1	1	1		3			2
Slovakia	3	4	5	6	3	4	4	2	2	2	2	2	2	1	1	2
Slovenia	4	3	2	5	4	3	3	2	1	1	1	2	3	1	3	3
Spain	4	3	4	4	4	4	3	2	2	2	2	2	2	4	2	4
Sweden	3	3	5	5	4	3	3	1	1	1	1	2	2	1	1	5

Source: European Commission

3.1.10 Open internet rules

Under Regulation (EU) 2015/2120 (the Open Internet Regulation), EU citizens are entitled to distribute and have access to information and content, to use and provide applications and services, and use terminal equipment of their choice, regardless of the location of the end user or provider or the location of the information, content, application or service. These rights are established by the EU Regulation, which is directly applicable and binding in its entirety.

Applicable since 2016, this Regulation is a major achievement for Europe's Digital Strategy. Common EU rules on open internet access ensure that the same provisions apply across Europe. The enforcement of the open Internet access rules is an important task of National Regulatory Authorities (NRAs), which should take utmost account of the reviewed guidelines[50] on the Implementation of the Open Internet Access Regulation, adopted by the Body of European Regulators for Electronic Communications (BEREC) in June 2020 and amending the guidelines of 30 August 2016. The Commission continues to monitor closely the application of the Regulation.

Regulatory developments

Following the introduction of confinement measures to fight the Coronavirus pandemic, the demand for Internet capacity increased, be it for teleworking, e-learning or entertainment purposes. The confinement measures highlighted the crucial role of digital technologies, allowing users to purchase essential goods and access services which would not otherwise be accessible[51]. To respond to this intensified flow of internet traffic, the Commission called upon the cooperation of major platforms, BEREC, telecom operators and the public to ensure connectivity and an open internet across Europe. Streaming platforms were advised to offer standard rather than high definition and to cooperate with telecom operators. Telecom operators had to take preventive and

[50] https://berec.europa.eu/eng/document_register/subject_matter/berec/regulatory_best_practices/guidelines/9277-berec-guidelines-on-the-implementation-of-the-open-internet-regulation

[51] Communication from the Commission to the European Parliament and the Council, New Consumer Agenda: Strengthening consumer resilience for sustainable recovery, COM(2020) 696 final, Chapter II, available here

mitigating measures. Users were invited to apply settings that reduce data consumption, including the use of Wi-Fi or lower resolution content[52].

As a precautionary measure, in March 2020, a joint statement of the Commission and the BEREC set up a Special Reporting Mechanism (SRM) to ensure regular monitoring of the internet traffic situation in each Member State, in order to respond swiftly to possible capacity issues that could follow from increased internet usage due to Covid-19 containment measures.

During the entire reporting period, 33 NRAs have shared their data about the impact of the crisis on electronic communications networks and the actions taken so far at national level. The SRM summarises the status of internet capacity and the actions taken by different NRAs. All iterations of the SRM published by BEREC are available on the BEREC website.

In general, three phases in the evolution of internet traffic have been observed during the crisis: a sharp increase in its early weeks, a subsequent stabilisation and, through the latter part of 2020 and into 2021, a decrease from the peak (experienced early in the crisis). NRAs are monitoring the situation and are collecting data from ISPs and other market players about the status of their networks.

Open internet annual reports

The Open Internet Regulation (Article 5 of Regulation (EU) 2015/2120) requires national regulatory authorities to publish annual reports on their monitoring and findings and to share these reports with the Commission and BEREC. The latest annual country reports (covering 1 May 2020 to 30 April 2021) are available here.

In addition, BEREC publishes an annual report on the implementation of the Open Internet Regulation and the net neutrality guidelines.

Open internet issues

Zero-rating offers were identified by twenty five NRAs, with music/video streaming and social networking the most frequently mentioned types of applications being zero-rated. During the pandemic, there were some examples of temporary zero-rating practices to facilitate education and ensure the flow of information in several Member States. Twenty seven NRAs came across traffic management practices in one or another way, as more and more NRAs have realised the importance of compliance with the Regulation in this area.

In 2020, NRAs pursued their analysis of individual commercial offers emerging on the market on a case-by-case basis. 10 NRAs (BG, CY, ES, FR, HR, IT, MT, NO, SE, SK) carried out formal assessments of traffic management practices.

With the view to implementing Article 4 on monitoring ISPs' compliance with transparency and contractual terms, most (24) NRAs had recourse to formal and informal requests for information from the ISPs, analysis of end-users' reports and complaints, as well as market surveys. Most of the NRAs (23 out of 28) monitor end-user complaints regarding the performance of the IAS, while two thirds of the NRAs (18 out of 28) offer an IAS quality monitoring mechanism to consumers. On 15 September 2020, the Court of Justice of the European Union (CJEU) interpreted for the first time Regulation 2015/2120[53] in Joined Cases C-807/18 and C-39/19 Telenor Magyarország Zrt. v Nemzeti Média-és Hírközlési Hatóság Elnöke, the Court was asked to give a preliminary ruling in

[52] Communication from the Commission to the European Parliament and the Council, New Consumer Agenda: Strengthening consumer resilience for sustainable recovery, COM(2020) 696 final, Chapter II, available at EUR-Lex - 52020DC0696 - EN - EUR-Lex (europa.eu)

[53] https://curia.europa.eu/juris/liste.jsf?num=C-807/18

relation to the additional services offered by Telenor Magyarország Kft relating to social media (chat) applications and music streaming and online radio applications. The Court ruled that this practice entails a traffic management measure which infringes the requirement of fair and non-discriminatory treatment laid down in Article 3(3) of Regulation 2015/2120. The Court also clarified that once that infringement has been established under Article 3(3) of Regulation 2015/2120 concerning traffic management, it is no longer necessary to specify whether there has also been an infringement of Article 3(2) of Regulation 2015/2120 about commercial agreements. Therefore a detailed assessment of the market and the impact of the measure is not needed.

3.1.11 Widespread use of roam-like-at-Home (RLAH) & multiplication of roaming traffic under RLAH

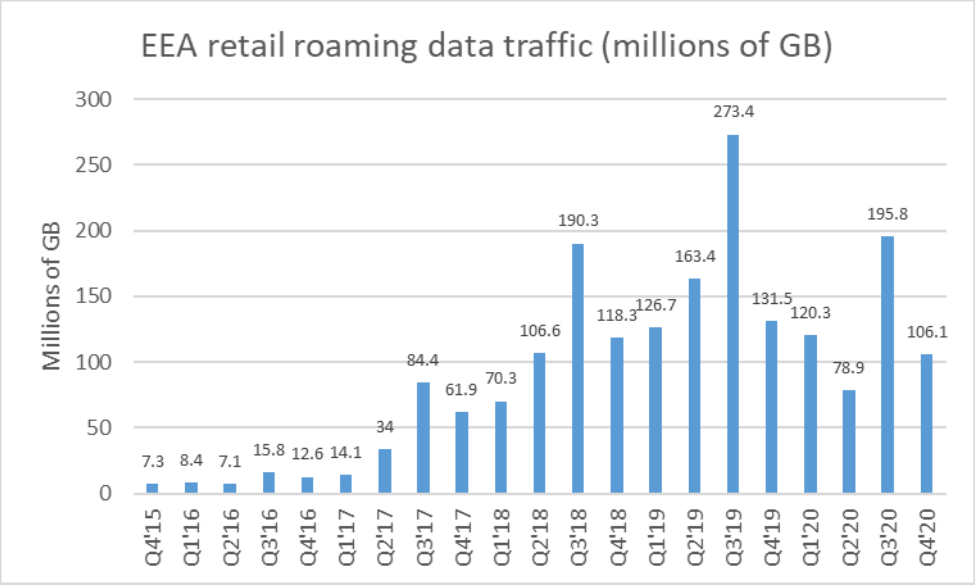
As of 15 June 2017, mobile operators are not allowed to impose charges other than domestic ones when they provide (retail) roaming services to customers periodically travelling in the EU/EEA. There are two main exceptions to this "Roam-like-at-home" (RLAH) rule. To prevent abusive or anomalous use of roaming at domestic prices, mobile operators may apply a fair use policy. Furthermore, when mobile operators are able to demonstrate that RLAH is objectively not sustainable without detrimental effects on the domestic markets, they may obtain an authorisation from their national regulator to impose a small surcharge for providing roaming services (sustainability derogation surcharge).

Roaming traffic

The rapid and massive increase in roaming traffic since June 2017 (Figure 45) has shown that the RLAH reform has met its objective to unleash the untapped demand for mobile consumption by travellers in the EU, as assessed in the Commission review report[54]. Between summer 2016 and summer 2019, retail roaming traffic increased 3-fold for voice and 17-fold for data. Between summer 2018 and summer 2019, roaming traffic remained stable for voice, while it increased further, by more than 40%, for data. Despite such increases, roaming traffic remains a small fraction of domestic traffic. Overall, consumers are highly satisfied with their higher roaming consumption and the benefits they derive from it.

[54] Commission Report on the review of the roaming market, COM(2019)616 final and accompanying Commission staff working document SWD(2019)416 final, both available here.

Figure 43 EEA retail roaming data traffic (millions GB)



Source: Based on the 27th BEREC Benchmark Data Report, April 2020-September 2020[55]. Please note that EEA average includes United Kingdom operators' data only until Q3 2019.

As an effect of the COVID-19 pandemic and the lockdowns and limitations to travelling, the roaming data traffic has decreased by almost 39% in 2020 compared to 2019. In particular, although some restrictions were lifted during the summer of 2020, the reduction of roaming data traffic amounted to -28% compared to the summer of 2019. In addition, part of the decrease is also a consequence of the fact that due to Brexit UK operators' data are not included in the reported roaming traffic since Q3 2019. RLAH rules no longer apply to the UK after the end of the transition period (*i.e.* after 31 December 2020). This means that roaming traffic in the United Kingdom should be treated like any other roaming traffic to countries outside the EU. EU-based operators are not obliged to offer calls, SMS or data services at domestic prices when their customers travel in the United Kingdom.

Fair use policies and sustainability derogations served their purpose in ensuring the sustainability of the RLAH regime, although their use remains marginal. In summer 2019, voice or data roaming traffic subject to a surcharge due to a fair use policy or a sustainability derogation did not exceed 6% of total roaming traffic in the EU. Apart from mobile virtual network operators, derogations are mainly used in some countries where data prices are very low, revenues per user are low and/or roaming imbalances are high (e.g. Estonia, Finland, Lithuania and Poland).

Roaming issues

Overall, mobile operators are complying with the roaming rules. However, certain issues were observed.

For instance in the Netherlands, the NRA noted problems with quality of service in roaming where the roaming provider (home operator) blocks access to 4G roaming, only enabling 3G access or limiting the available data speed on certain visited networks. The NRA did not take any formal steps due to lack of legal clarity regarding quality of roaming services.

Furthermore, in the context of the review of the EU Roaming Regulation, the Joint Research Centre (JRC) undertook a study (Smart 2018/0011) on roaming performance assessment by field measurements on mobile broadband involving 40 mobile networks in 13 EU countries. JRC's mobile

[55] International Roaming BEREC benchmark data report April 2020 - September 2020, available here.

app netBravo was used to carry out the measurements and analysis of data. Download speed, upload speed and latency were measured for all roaming tests and results were analysed. The study found that 25% of customers at least once had worse quality of service in roaming compared to at home even when technical conditions were available for better quality.

Regulatory developments

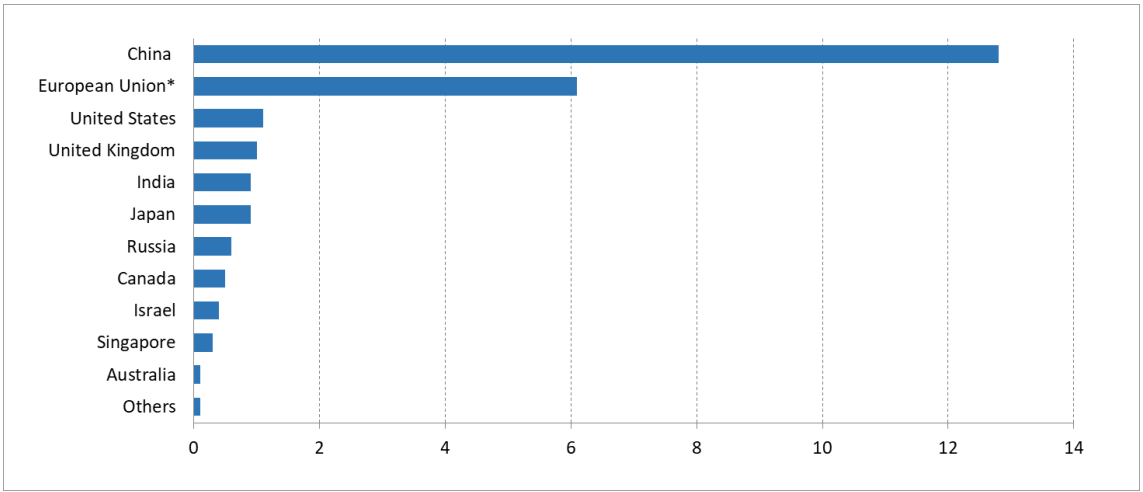
The Roaming Regulation will expire on 30 June 2022. In this light, the Commission has adopted a RECAST proposal on 24 February 2021 for extending the Roaming Regulation for 10 years to ensure continuation of 'roam like at home' and maintain its benefits for consumers beyond 2022, as well as ensure a genuine roam like at home experience and facilitate innovation. In addition to the prolongation for 10 years of the existing roaming rules and the reduction of wholesale caps to ensure sustainability of roam like at home for operators, the Commission proposed the following new measures; (i) same quality of services while roaming as at home, (ii) increased transparency to avoid bill-shocks for consumers from using value added services, (iii) equivalent access to emergency services for all, and (iv) wholesale roaming access to requested network technologies.

3.2 Quantum computing

Quantum technologies exploit the properties of quantum mechanics and physics to solve complex problems much faster or much better than traditional methods. They make possible the development of radically new technologies in computing, communication, simulation, and sensing. Quantum computing can be applied in many sectors (aerospace, agriculture, health, automotive or energy) and in combination with other digital technologies. For example, quantum cryptography techniques can help develop secure communications and improve detection of network intrusions. In addition, quantum technologies can help improve the ICT performance by for example, increasing energy-efficiency of computing and sensing or the capability to store and analyse growing amounts of data[56].

A great deal of investment and expertise will be needed to help quantum technologies transition from the research and development phase to deployment. Currently, they still rely largely on public funds, and most of fundamental research is done in universities and research facilities. Equity funding is still low for quantum computing compared to other emerging technologies. China, the EU, the US, the UK, India, and Japan are investing strongly in quantum technologies.

Figure 44 Planned public funding in quantum technologies, examples worldwide, in EUR billion



Source: CIFAR, A quantum revolution: report on global policies for quantum technology, April 2021.

**Includes planned public funding by the EU and Member States.*

[56] JRC, *Quantum Technologies: Implications for European Policy, Issues for debate,* 2016

The EU objective in the Digital Decade for quantum is that by 2025, Europe will have its first computer with quantum acceleration paving the way for Europe to be at the cutting edge of quantum capabilities by 2030[57].

In October 2018, the EU launched the ten-year strategic Quantum Technologies Flagship with an expected budget of EUR 1 billion. This large-scale initiative will pool resources of research institutions, industry and public funders to consolidate and expand European scientific leadership and excellence in this field. In its ramp-up phase (from October 2018 to September 2021), it provided EUR 152 million of funding for 24 projects in four core application areas: quantum communication, computing, simulation, and sensing and metrology. In the up-coming research framework programme Horizon Europe (2021-2027) the European Quantum Flagship Initiative will become fully operational with a total investment of EUR 1 billion. In March 2020, the European Quantum Flagship Initiative presented its Strategic Research Agenda(58) setting ambitious goals around the four core application areas. These areas are anchored by a common basis in basic science and they will be supported by work in cross-cutting areas (engineering and control, software and theory, education and training), and further complemented by overarching activities in innovation and international cooperation as well as gender equality.

In June 2019, the European Commission and several Member States signed a ministerial declaration agreeing to explore together, over a period of 12 months, how to develop and deploy a quantum communication infrastructure (QCI) across the EU within the next 10 years(59). In the next multiannual financial framework for the period 2021-2027, the EuroHPC Joint Undertaking (JU) will support at least two generations of widely accessible quantum computers and advanced simulators interconnected with EuroHPC supercomputing facilities as part of a federated European computing infrastructure.

As regards the share of articles in quantum-relevant publications in 2020, the EU was the most active, followed by China and the US. However, in terms of impact[60] the US had a leading position in quantum-relevant publications, followed by the UK, the EU and China.

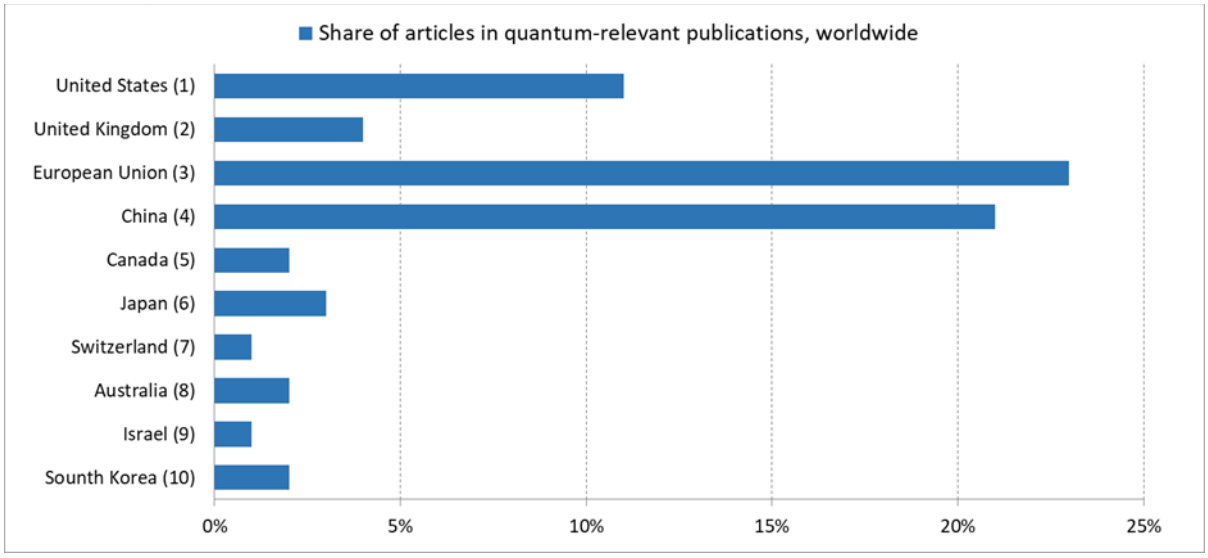
[57] COM(2021) 118 final, 2030 Digital Compass: the European way for the Digital Decade, 9 March 2021.

[58] https://qt.eu/about-quantum-flagship/newsroom/the-quantum-flagship-officially-presents-the-strategic-research-agenda-to-the-european-commission/

[59] https://digital-strategy.ec.europa.eu/en/news/future-quantum-eu-countries-plan-ultra-secure-communication-network

[60] H index evaluates the impact of the scientific publications by measuring the number of articles (h) in a country that received at least h citations.

Figure 45 Top 10 countries worldwide by H index in quantum-relevant publications, 2020



Source: Scopus analyzer, keyword (quantum tecnolog).*

Patenting activity in the field of quantum computing started to accelerate in 2012. Quantum computing and quantum key distribution are the applications for which by far the most patent applications have been filed to date. The US leads in quantum computing and China leads in quantum key distribution[61]. Likewise, quantum metrology and sensing saw an increase in patent applications starting in 2009, but the number of patent applications is still low in absolute terms, and mainly driven by research institutes (patent applications in the field rose from 8 applications in 2009 to 83 in 2017). The leading patent authorities in this sub-sector are China, the US and the EU[62]. Even though commercial products based on quantum-computing are starting to emerge (for example in quantum sensing), the market for quantum technologies still appears to be limited.

Revenues from quantum computing market worldwide are expected to be €10 to €89 billion in 2040[63]. This preliminary market estimate includes revenues generated directly by quantum companies. It does not reflect the much broader, overall revenue impact the technology will have across the industries that use it.

[61] JRC, *Patent analysis of selected quantum technologies*, 2019.
[62] European Patent Office, *Landscape study on patent filling, quantum metrology and sensing,* 2019.
[63] Preliminary result of the final assessment report: Financing a quantum technologies industry in Europe, EIB/McKinsey, September 2021.

4 Integration of digital technology

Digital technologies enable businesses to gain competitive advantage, improve their services and products and expand their markets. Digital transformation of businesses opens up new opportunities and boosts the development of new and trustworthy technologies. The EU's digital sovereignty will depend on the capacity to store, extract and process data while satisfying the requirement of trust, security and fundamental rights[64]. This dimension measures the digitalisation of businesses and e-commerce.

Table 5 Integration of digital technology indicators in DESI

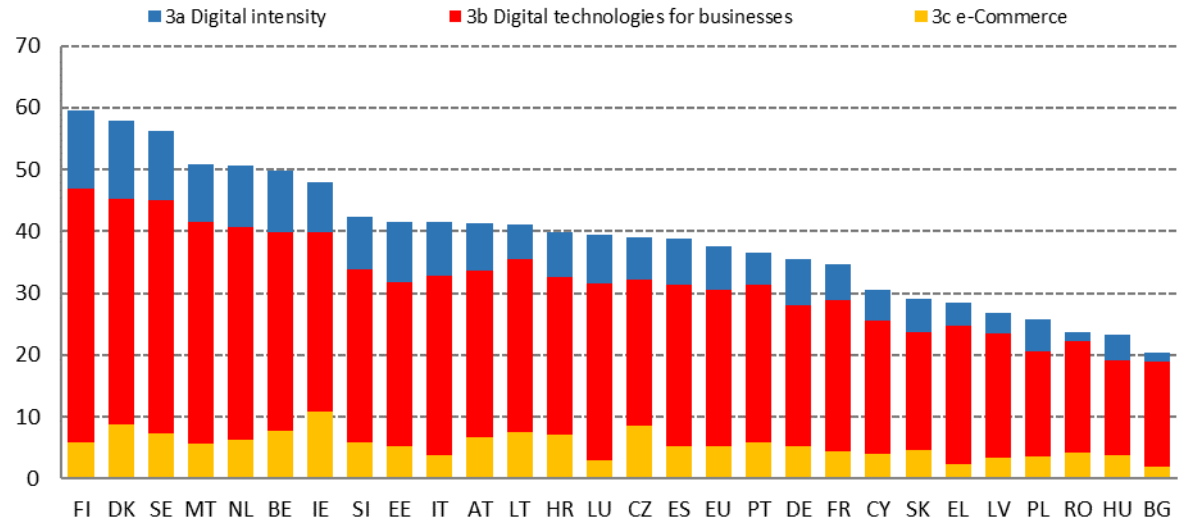
	EU	
	DESI 2019	DESI 2021
3a1 SMEs with at least a basic level of digital intensity % SMEs	NA	60% 2020
3b1 Electronic information sharing % enterprises	36% 2017	36% 2019
3b2 Social media % enterprises	18% 2017	23% 2019
3b3 Big data % enterprises	12% 2018	14% 2020
3b4 Cloud % enterprises	16% 2018	26% 2020
3b5 AI % enterprises	NA	25% 2020
3b6 ICT for environmental sustainability % enterprises having medium/high intensity of green action through ICT	NA	66% 2021
3b7 e-Invoices % enterprises	25% 2018	32% 2020
3c1 SMEs selling online % SMEs	16% 2018	17% 2020
3c2 e-Commerce turnover % SME turnover	10% 2018	12% 2020
3c3 Selling online cross-border % SMEs	8% 2017	8% 2019

Source: DESI 2021, European Commission.

The top performers in the integration of digital technologies are Finland, Denmark and Sweden. Bulgaria, Hungary and Romania have the weakest performance.

[64] Strategic Foresight Report 2021, COM (2021)750 final.

Figure 46 Digital Economy and Society Index (DESI) 2021, Integration of digital technology



Source: DESI 2021, European Commission.

4.1 Digital intensity index

The Digital Intensity Index (DII) measures the use of different digital technologies at enterprise level. The DII score of an enterprise is based on counting how many out of 12 selected technologies are used. Figure 47 presents the composition of the DII in 2020. It also shows the degree of penetration and speed of adoption of the different technologies monitored by the DII. Large companies are more digitised than SMEs. While some aspects seem to be reaching saturation, at least for large companies, for most aspects there is still room for improvement.

According to the Digital Compass target, by 2030 more than 90% of SMEs should reach at least a basic level of digital intensity.

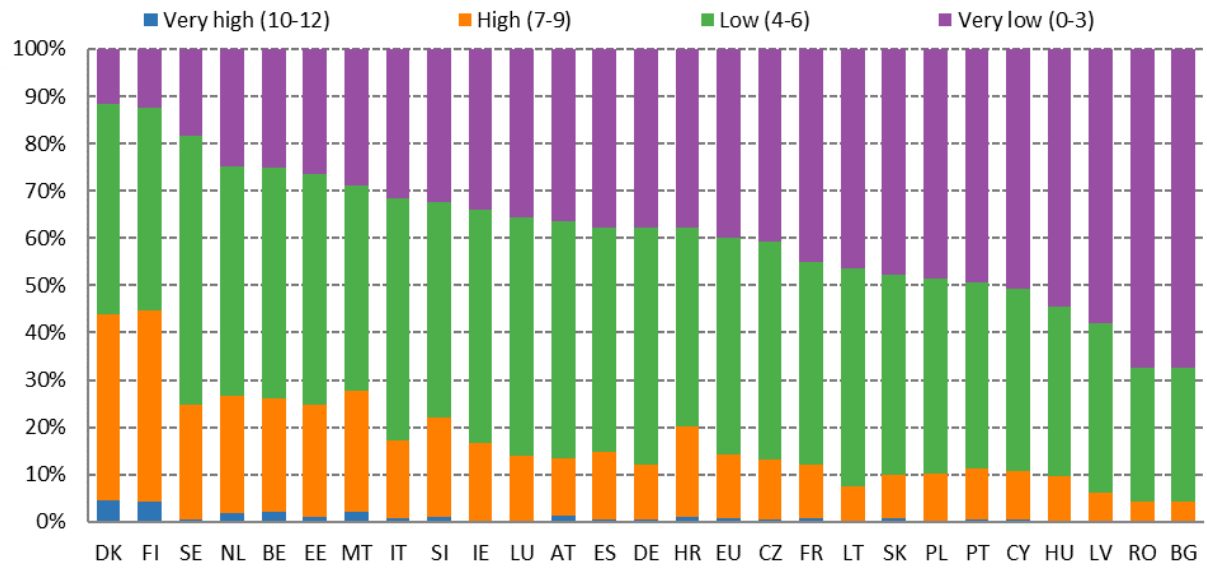
Figure 47 Digital Intensity Index indicators tracking digitisation processes (% enterprises), 2020

	Large	SMEs
Have a website	94%	76%
The maximum contracted download speed of the fastest fixed line internet connection is at least 30 Mb/s	92%	76%
Website has at least one of : description of goods or services, price lists; possibility for visitors to customise or design online goods or services; tracking or status of orders placed; personalised content in the website for regular/ recurrent visitors	78%	62%
Enterprises where more than 50% of the persons employed used computers with access to the internet for business purposes	56%	46%
Provide more than 20% of the employed persons with a portable device that allows internet connection via mobile telephone networks, for business purposes	47%	39%
eInvoices sent, suitable for automated processing	53%	32%
Buy medium-high CC services	48%	25%
Employ ICT specialists	76%	18%
Enterprises with e-commerce sales of at least 1% turnover	39%	17%
Analyse big data internally from any data source or externally	34%	14%
Use industrial or service robots	28%	6%
Use 3D printing	17%	5%

Source: Eurostat, European Union survey on ICT usage and e-commerce in enterprises.

Denmark and Finland are the only countries in the EU where the percentage of enterprises with a very high DII (i.e. possessing at least 10 out of the 12 monitored digital technologies) is above 5%, followed by Belgium, Malta and the Netherlands with above 2%. By contrast, in countries such as Bulgaria, Romania, Latvia, Hungary and Cyprus the majority of businesses (over 50%) have made only a small investment in digital technologies (i.e. have a very low DII).

Figure 48 Digital Intensity Index by level (% of enterprises), 2020

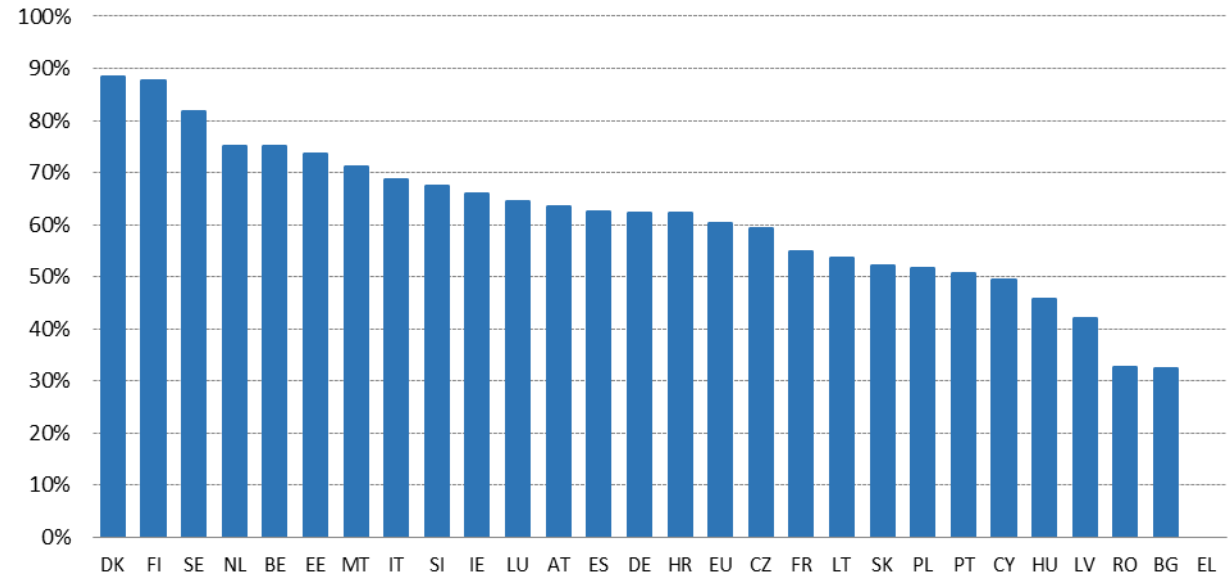


Source: Eurostat, European Union survey on ICT usage and e-commerce in enterprises.

** Data for Greece are available, but unreliable for high and very high DII.*

Figure 49 depicts the percentage of SMEs with basic DII score. Basic DII level requires usage of at least four technologies and comprises SMEs with very high, high and low DII. More than 80% of enterprises in the Nordic countries (Denmark, Finland and Sweden) reached at least basic level of digital intensity, while in Romania and Bulgaria it is below 35%.

Figure 49 SMEs with at least basic level of digital intensity, 2020



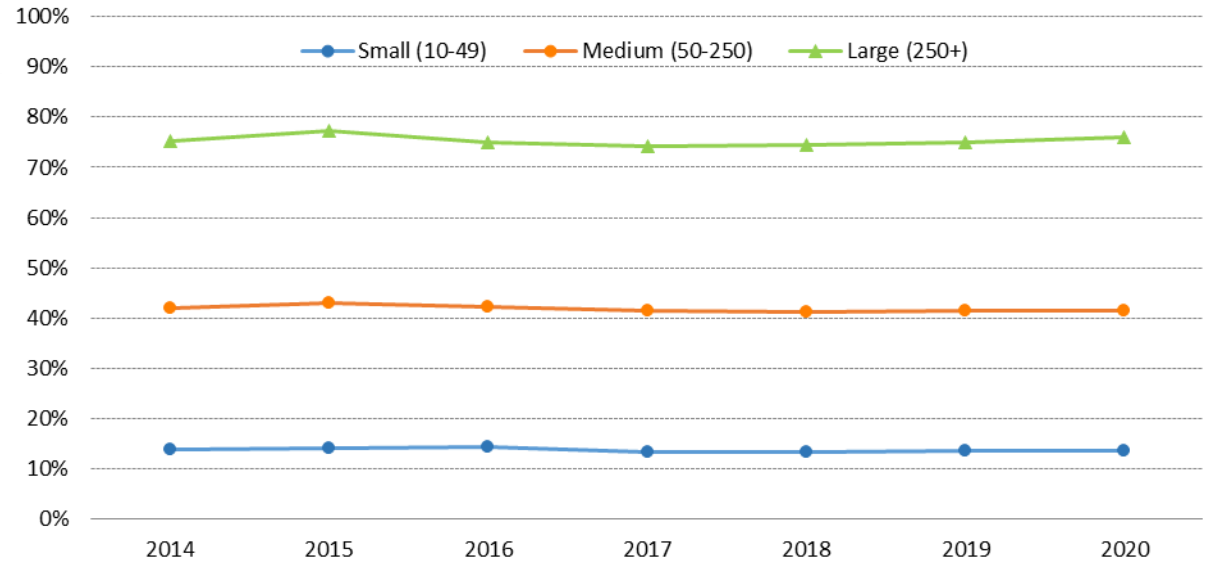
Source: Eurostat, European Union survey on ICT usage and e-commerce in enterprises.

** Data for Greece is available, but unreliable.*

4.2 ICT specialists in enterprises

Large enterprises have a scale advantage, and as a result 76% of them employ internal ICT specialists. The share of small enterprises in the EU employing ICT specialists has stayed roughly at the same level (14%) for the last 6 years and similarly for medium-sized ones at 42%. Not surprisingly, in the computer programming and consultancy sectors the share is above 80%, but it is also high in telecommunication (68%) and publishing activities (48%). On the other hand, in accommodation and food services it is below 7% and in construction below 9%. More than 30% Belgian and Irish enterprises employ ICT specialists, while in Italy the share is below 13%.

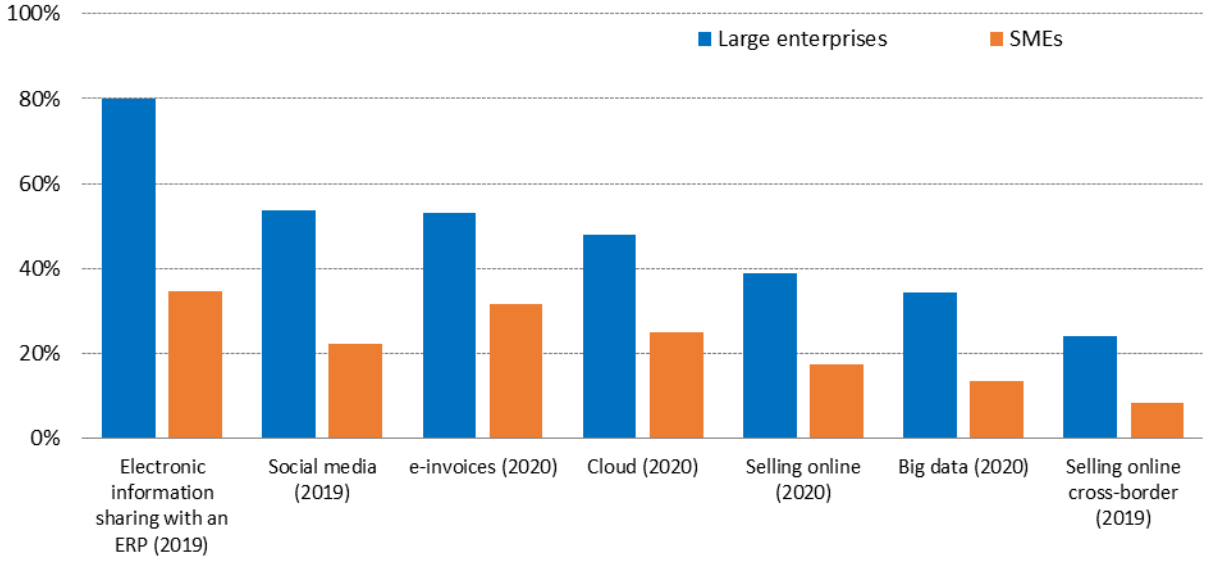
Figure 50 Enterprises employing ICT specialists (% of enterprises), 2014-2020



4.3 Adoption of digital technologies by enterprises

It is evident that large enterprises are more likely to adopt new technologies. For example, electronic information sharing through enterprise resource planning (ERP) software is much more common in large enterprises (80%) than in SMEs (35%). SMEs exploit e-commerce opportunities to a limited extent, as only 17% sell online (versus 39% of large enterprises) and only 8% sell cross-border online (24% for large enterprises). There are many other technological opportunities yet to be exploited by SMEs such as cloud services and big data.

Figure 51 Adoption of digital technologies (% entreprises), 2019, 2020[65]



Source: Eurostat, European Union survey on ICT usage and e-commerce in enterprises.

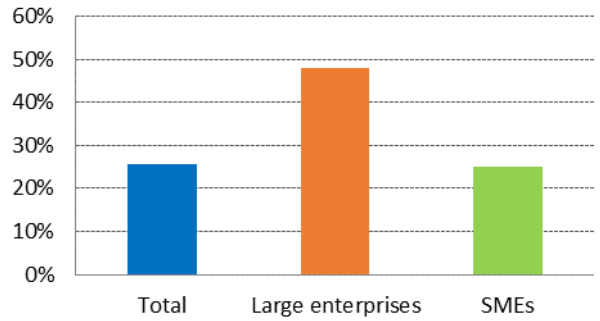
4.4 Cloud computing

The Digital Compass target requires that more than 75% of EU companies adopt cloud computing by 2030. In 2020, 26% of EU enterprises purchased cloud computing services of medium-high sophistication (i.e. hosting of the enterprise's database, accounting software applications, CRM

[65] These are the DESI 2021 indicators under the sub-dimension 3b Digital technologies for businesses. For exact definitions, please see the DESI methodological note.

software and computing power) and incorporated cloud technologies to improve their operations while reducing costs; this was an increase of 15 percentage points since 2014. The cloud uptake of large companies (48%) was higher than for SMEs (25%) in 2020. Cloud adoption is the highest in the computer programming and consultancy (65%) sectors, while in construction, retail trade, transport and storage as well as accommodation and food services the share is about 20%.

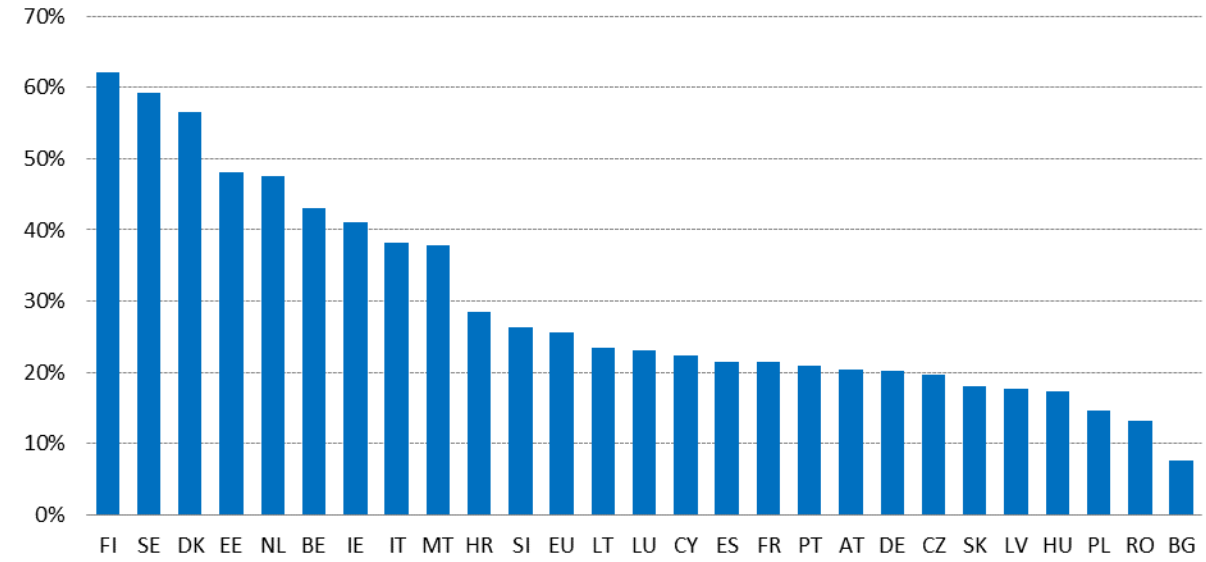
Figure 52 Cloud computing services of medium-high sophistication (% of enterprises), 2020



Source: Eurostat, European Union survey on ICT usage and e-commerce in enterprises.

Nordic enterprises are leaders in incorporating cloud services of medium-high sophistication. More than 60% of Finnish enterprises buy such services, an increase of almost 30 percentage points between 2014 and 2020. Sweden and Denmark follow at more than 55%. However, the gap between top and low performers remains large, with Bulgaria scoring below 10%.

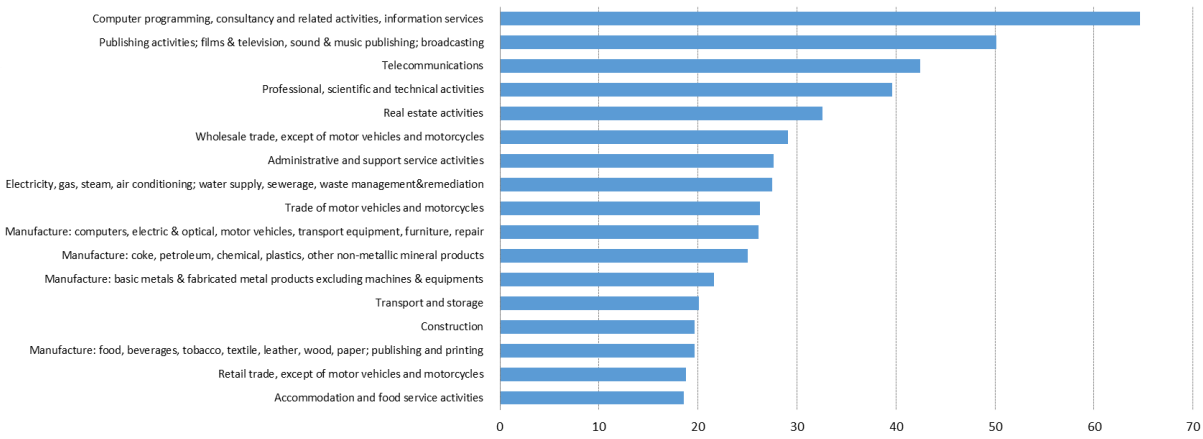
Figure 53 Cloud computing services of medium-high sophistication per country (% of enterprises), 2020



Source: Eurostat, European Union survey on ICT usage and e-commerce in enterprises.

When looking at the performance in cloud usage based on sectors, 65% of enterprises in the computer programming sector use cloud computing services of medium-high sophistication, followed by the publishing activities sector with 50% and the telecommunications sector with 42%. The sectors with the least cloud usage of about 19-20% of enterprises are the transport and storage, construction, manufacturing (food, beverages, tobacco, textile, leather, wood, paper; publishing and printing), retail trade (except of motor vehicles and motorcycles), accommodation and food service activities sectors.

Figure 54 Cloud computing services of medium-high sophistication per sector (% of enterprises), 2020



Source: Eurostat, European Union survey on ICT usage and e-commerce in enterprises.

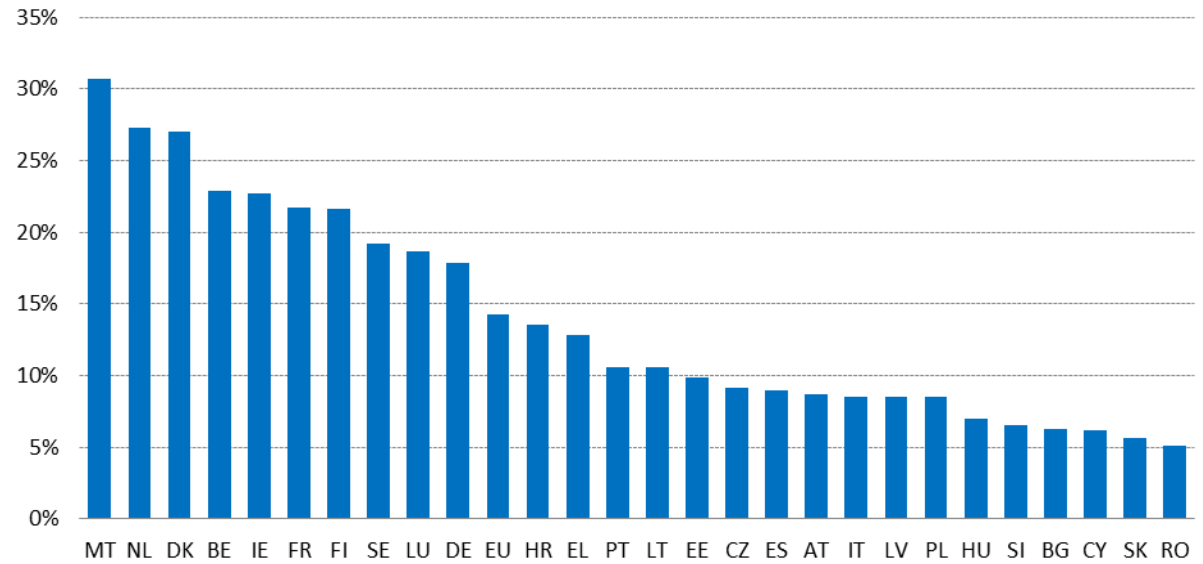
4.5 Big data

The Digital Compass target requires that more than 75% of EU companies adopt Big Data technology by 2030.

Enterprises all over the EU are constantly adapting to new technologies for collecting, storing and analysing data. In 2020, 14% of companies carried out big data analysis. This helped them to produce near time or real time results from data that come in different format types. Large companies have the lion's share in big data processing (with 34% of them using big data), while SMEs have still room for improvement to take advantage of all the benefits of big data (14% use big data).

In Malta, almost a third of enterprises analyse big data. The Netherlands and Denmark follow closely, with 27%. On the other hand, only 5-6% of enterprises in Romania, Slovakia, Cyprus and Bulgaria analyse big data.

Figure 55 Enterprises analysing big data (% of enterprises), 2020



Source: Eurostat, European Union survey on ICT usage and e-commerce in enterprises.

When looking at a sectorial breakdown, enterprises are more likely to analyse big data in the travel agency[66] and publishing activities[67] sectors (both at 28%), followed by the computer programming[68]

[66] Travel agency; tour operator reservation service and related activities

and the information and communication sector (both at 27%). Only 14% of enterprises carry out big data analysis in the retail trade[69] sector, 13% in the construction, 12% in the accommodation and food and beverage service activities and 10% in the manufacturing sector.

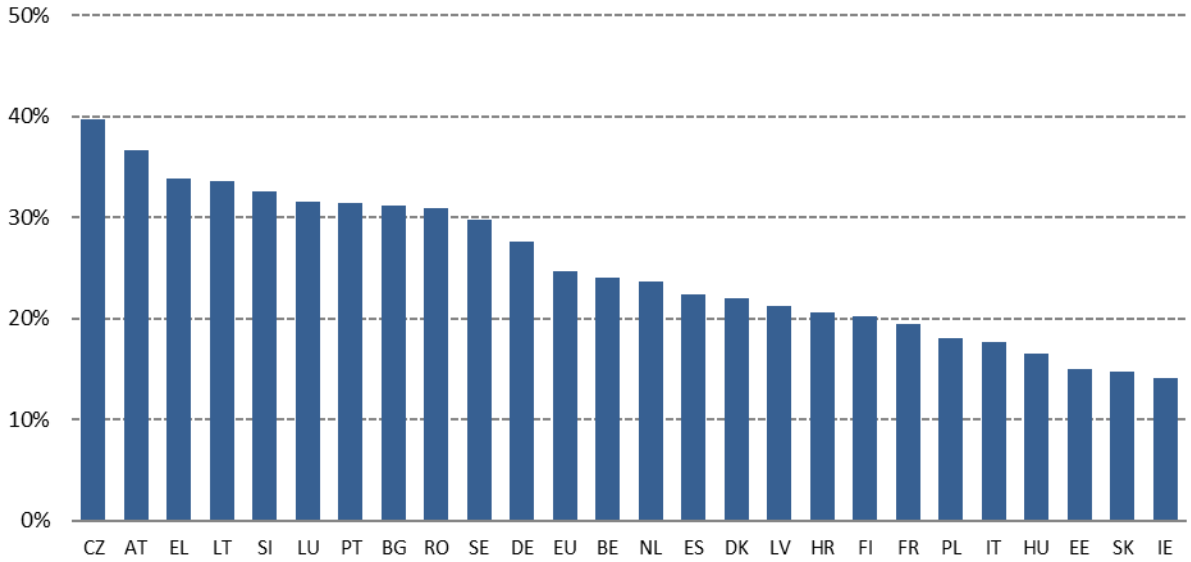
4.6 Artificial intelligence (AI)

Regarding the uptake of AI technologies in the European Union, enterprises can be grouped in three groups: the 'adopters' (42%) who are currently using at least one AI technology, the 'non-adopters' (40%) who do not currently use AI nor intend to use any of the AI technologies (at least in the following two years) and those enterprises, who have plans to adopt AI in the next two years, however they are currently not using AI solutions (18%).

When looking at the intensity of adoption, a quarter (25%) of enterprises use at least two AI technologies. Focusing on enterprises using two or more AI technologies, the following country-level differences can be observed: The adoption of two or more AI technologies is highest in Czechia (40%), followed by Austria (37%), Greece and Lithuania (both at 34%). The uptake of two or more AI technologies is the lowest in Ireland (14%), Slovakia and Estonia (both at 15%).

The Digital Compass target[70] requires that more than 75% of EU companies adopt AI technology by 2030.

Figure 56 Enterprises using at least two AI technologies (% of enterprises), 2020



Data for Cyprus and Malta are not available.

Source: Ipsos, European enterprise survey on the use of technologies based on artificial intelligence, 2020.

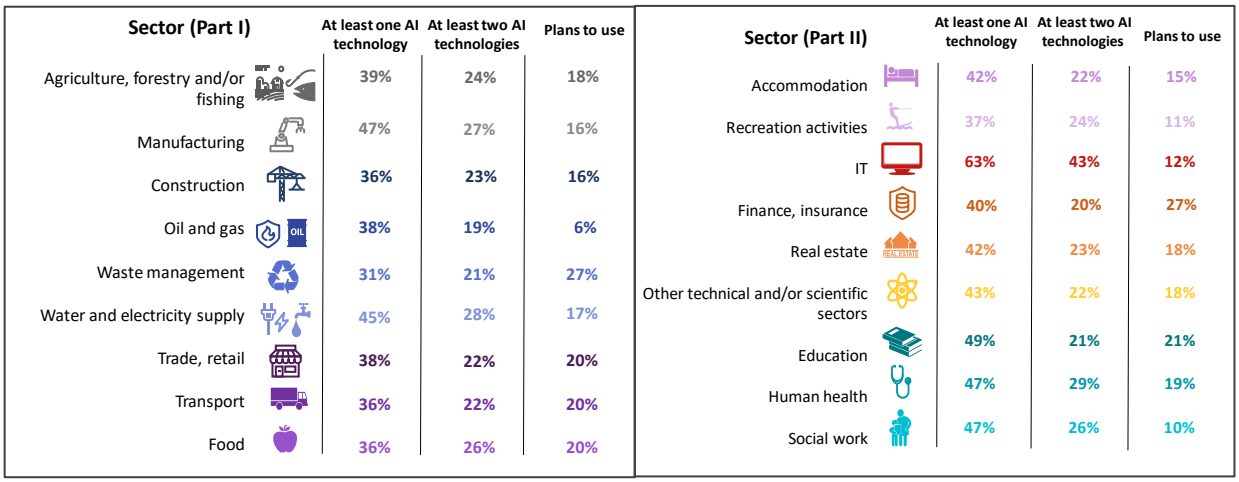
Regarding the overview by sectors, adoption of at least one AI technology is highest in the ICT sector (63%), followed by education (49%), human health, social work, and manufacturing (all 47%). The sectors that have the lowest AI adoption are waste management (31%), construction, transport and food (all 36%).

When looking at adoption of at least two AI technologies, the ICT sector is leading again (43%), followed by human health (29%) and water and electricity supply (28%), whereas the sector with the lowest uptake is oil and gas (19%).

[67] Publishing activities; motion picture, video & television programme production, sound recording & music publishing; programming & broadcasting
[68] Computer programming, consultancy and related activities, information service activities
[69] Retail trade, except of motor vehicles and motorcycles
[70] This indicator is based on the share of enterprises using at least two AI technologies.

Regarding the plans to use AI technologies in the next two years, the most likely are enterprises in the finance and insurance sector (27%), waste management (27%) and education (21%). The least likely to have plans to use AI in the near future are enterprises in the oil and gas sector (6%), social work (10%) and recreation activities (11%).

Figure 57 Levels of adoption of AI by sector (% of enterprises)



Base question Q1: What is the current state of adoption in your firm for [AI technologies]?; Base: EU27, N=8661. (Base size represents only EU27 Member States, excluding the UK, Iceland and Norway).

Source: Ipsos, European enterprise survey on the use of technologies based on artificial intelligence, 2020.

4.7 Sustainability

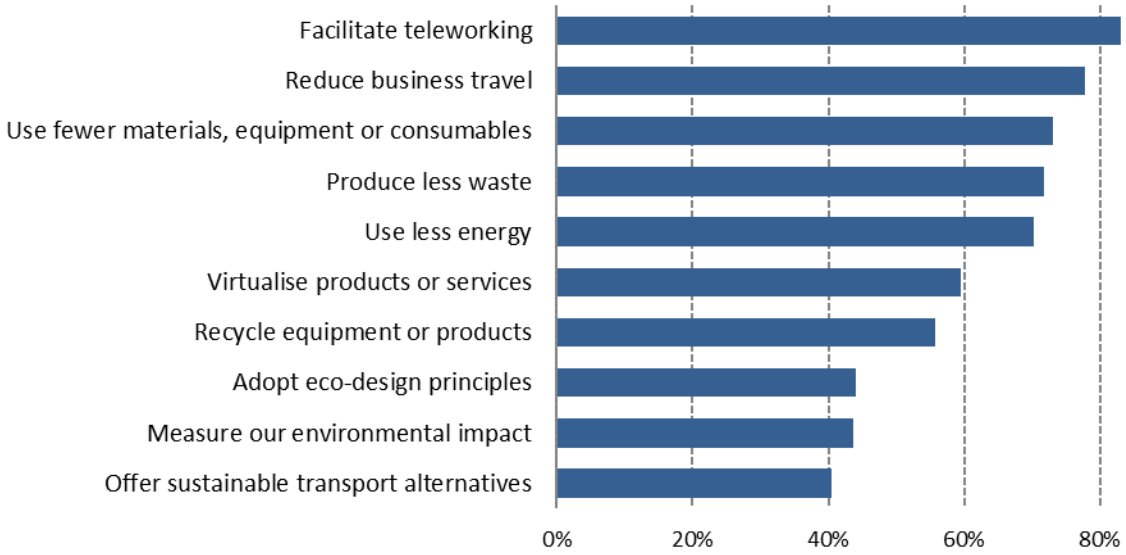
The green and digital 'twin transitions' spurred the European Commission to look at the relationship between the uptake of Information and Communications Technologies (ICTs) and environmental attitudes and actions of enterprises. A survey[71] measured the perceived contribution of digital technologies to the environmental sustainability of EU enterprises[72]. Respondents were asked to indicate whether the ICTs used in the company helped them to implement any of the following ten environmental actions: use less energy; use fewer materials, equipment or consumables; virtualise products or services; facilitate teleworking; reduce business travel; offer sustainable transport alternatives; produce less waste; adopt eco-design principles; recycle equipment or products; measure their environmental impact.

Enterprises reported the highest contribution of ICTs to environmental actions such as facilitate teleworking (83%) and reduce business travel (78%). This could be due to the fact that the survey was carried out during the COVID-19 pandemic, when enterprises have supported working online and business travel was reduced to the minimum. Respondents also stated that in their company digital technologies contributed to use fewer materials, equipment or consumables (73%), to produce less waste (72%) or to use less energy (70%). According to respondents, ICT had the lowest contribution to the following environmental actions: adopting eco-design principles and measuring one's environmental impact (44% each) as well as offering sustainable transport alternatives (40%).

[71] Ipsos and iCite, Survey on the contribution of ICT to the environmental sustainability actions of EU enterprises, 2021.

[72] The environmental footprint of ICT has not been assessed in the survey.

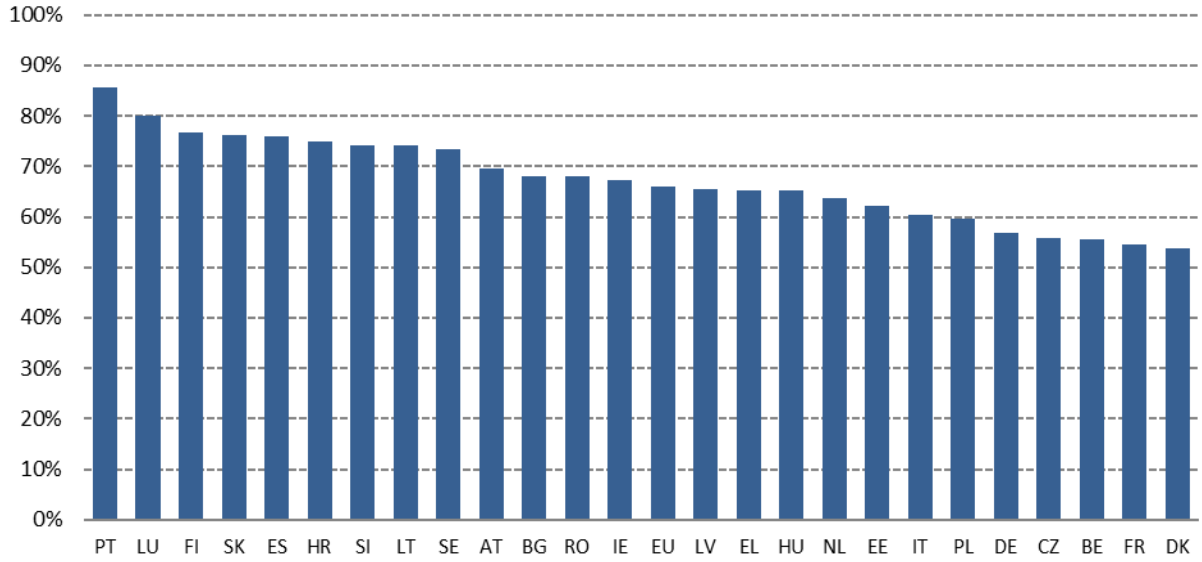
Figure 58 Environmental actions taken by enterprises with the help of ICT at EU level (% of enterprises), 2021



Source: Ipsos and iCite, Survey on the contribution of ICT to the environmental sustainability actions of EU enterprises, 2021.

Based on the findings outlined above an indicator has been developed that measures the level of support that adopted ICTs offered to enterprises to engage in more environmentally-friendly actions. The level of intensity is measured based on the number of environmental actions (maximum 10) reported by enterprises to have been facilitated by the use of ICTs. The following categorisation was developed: low intensity (0 to 4 actions), medium intensity (5 to 7 actions) and high intensity (8 to 10 actions). The chart below shows the share of enterprises by country having medium to high intensity of green action through ICT, i.e. having implemented 5 to 10 green actions.

Figure 59 Enterprises having medium/high intensity of green action through ICT (% of enterprises), 2021



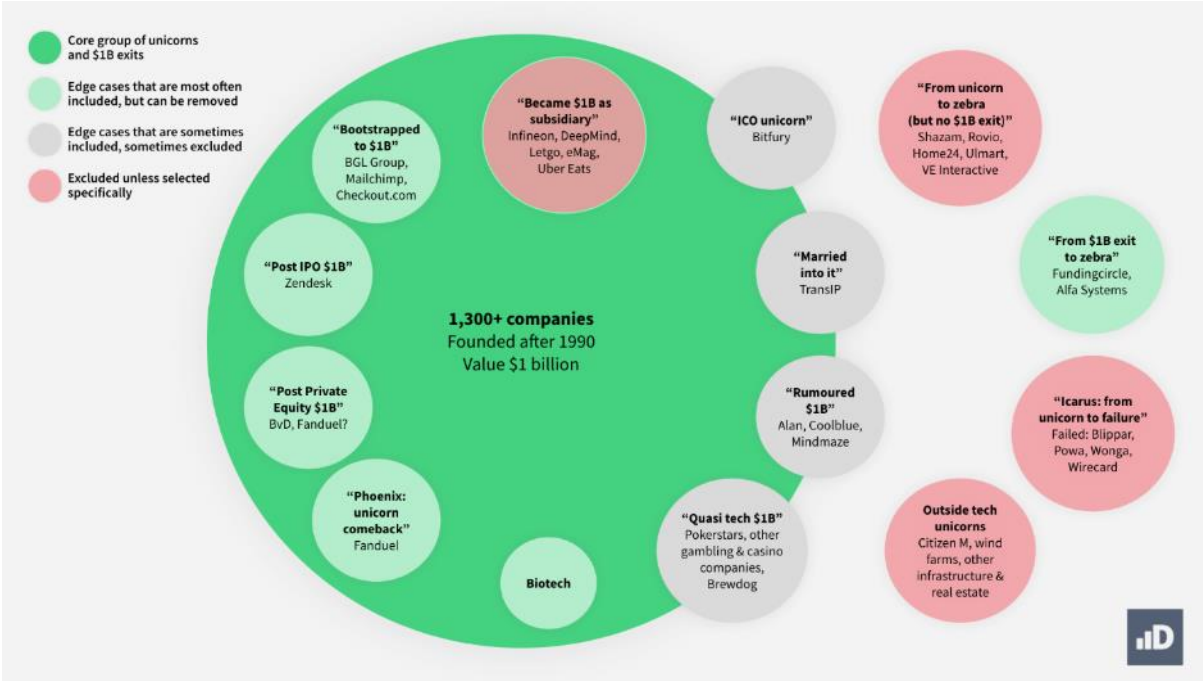
Source: Ipsos and iCite, Survey on the contribution of ICT to the environmental sustainability actions of EU enterprises, 2021.

4.8 Unicorns

The Digital Decade sets the target of doubling the current number of EU27 unicorns by 2030 (baseline 122 as of February 2021).

A unicorn is a privately held start-up company valued at over USD 1 billion. This is a stage of the start-up financial development, which proves its maturity and success on the global market. For the current analysis, we include tech companies founded since 1990 that are currently valued at over USD 1 billion, while companies that passed USD 1 billion as a subsidiary are excluded. Companies that may now be worth less than USD 1 billion but exited at more than USD 1 billion are also included.

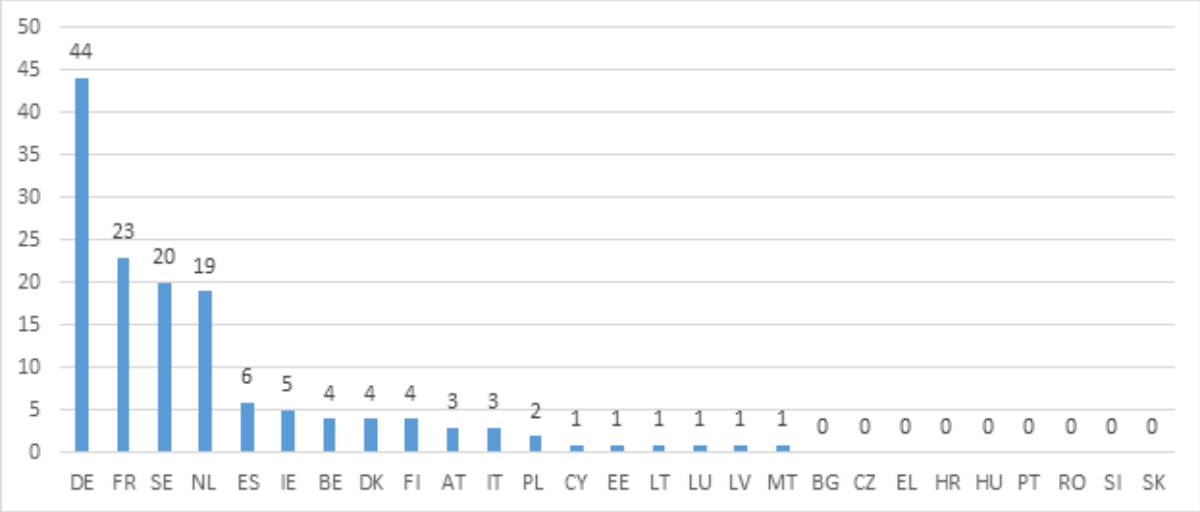
Figure 60 The definition of unicorns included in the analysis



Source: Dealroom

According to Dealroom[1], as of June 2021 there were 1,652 unicorns in the world. The EU has only 143 unicorns, as opposed to 889 in United States, 414 in Asia (out of which 272 in China), 101 in the UK and 105 in the rest of the world. Therefore, there is substantial room for improvement. The leading EU countries are Germany (44), France (23), Sweden (20) and the Netherlands (19). There are nine EU Member States without a single unicorn.

Figure 61 Number of unicorns per EU Member States

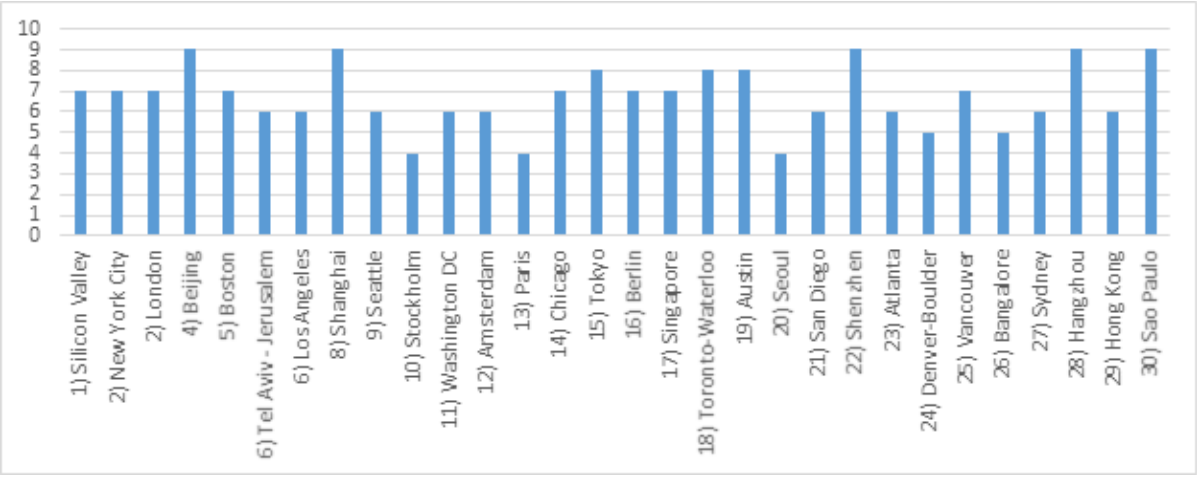


Source: Dealroom, June 2021

In order to reach the stage of a unicorn, a company has to steadily and dynamically grow through all the development phases supported by the start-up ecosystem. According to Startup Genome, the best Global Startup Ecosystems in 2020[2] were Silicon Valley (1st), London and New York City (tied at 2nd). The best EU ecosystem – Stockholm – was ranked 10th worldwide, followed by Amsterdam-Delta (12th), Paris (13th) and Berlin (16th). Only four EU ecosystems are in the first 20 worldwide. Stockholm and Amsterdam improved their ranking from 2019 by 1 and 3 positions respectively, while Paris and Berlin decreased by 4 and 6.

The most dynamically growing ecosystems are located in Asia (e.g. Tokyo, Seoul, Shenzhen and Hangzhou). In general, Asia-Pacific is the region, with the highest growth in the number of billion-dollar startups. According to Startup Genome[3], the region's share increased from 19.5% (2013-2014) to 31.8% in 2018-2019. It grew with a 33.9% compound annual growth rate (CAGR), while North America deals increased with 24.9% CAGR and Europe with 24.1%.

Figure 62 Global start-up ecosystem ranking 2020 (best on the left) and their growth index (bars).

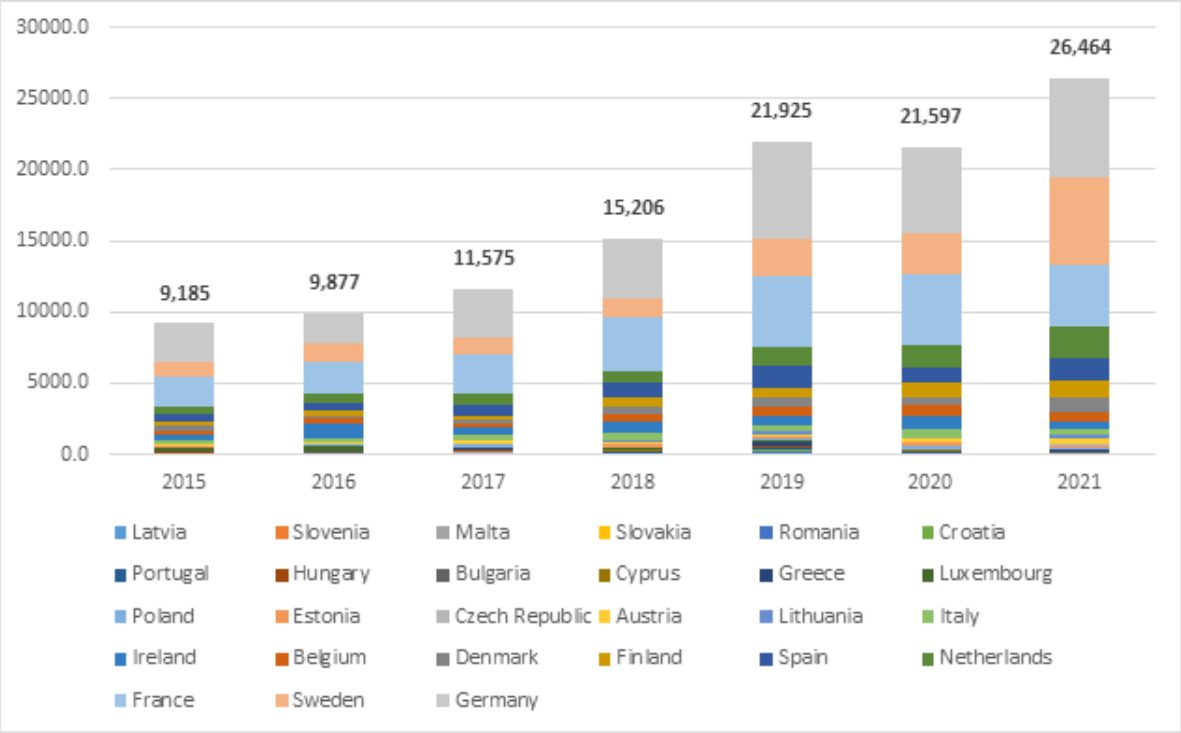


Source: Startup Genome, The Global Startup Ecosystem Report 2020

Out of the ten most valuable unicorns in the world, seven are based in the US and three in China. Amazon, valued at EUR 1.4 trillion, ranks first. In comparison, the most valuable EU unicorn Adyen has a valuation of EUR 52.3 billion (located in Amsterdam), followed by Klarna and Spotify (both based in Stockholm). Out of the twelve most valuable EU unicorns 5 are located in Germany, 4 in Sweden, 2 in the Netherlands and 1 in Denmark.

Looking at the amount of venture capital invested in EU Member States, it is obvious that larger investment generates more start-ups and better ecosystems, which in return attracts more investment and in the end results in more scale ups and unicorns. Figure 63 shows that Germany, Sweden, France and the Netherlands invested the most in venture capital and had the most thriving start-up environment.

Figure 63 Amount invested by venture capital (not only digital) by Member States in 2021

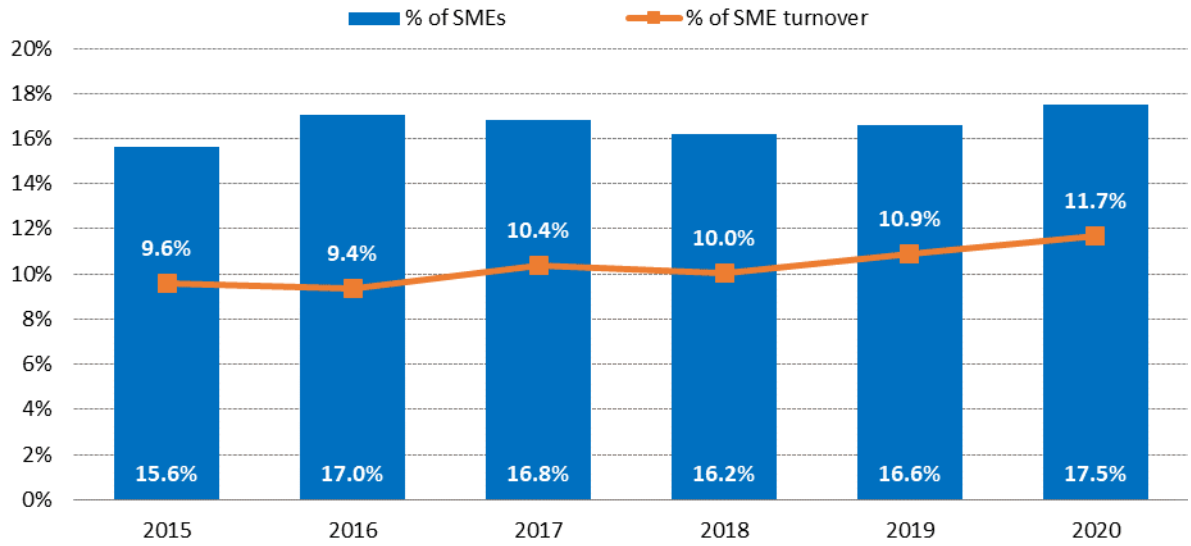


Source: *Dealroom*

4.9 e-Commerce

One in five EU enterprises made online sales in 2020, amounting to 18% of total turnover of companies that employ 10 or more people. Between 2015 and 2020, the percentage of companies selling online increased by 1.9 percentage points and the turnover of these companies realised from online sales increased by 2.1 percentage points.

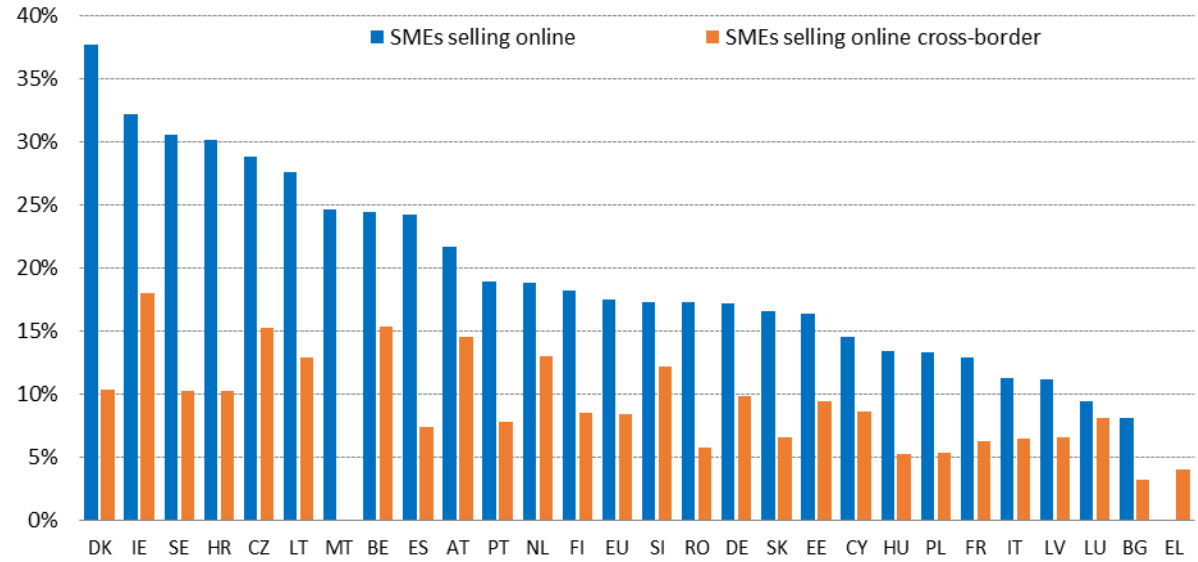
Figure 64 Trends in e-commerce (% of SMEs, % of SME turnover), 2015-2020



Source: Eurostat, European Union survey on ICT usage and e-commerce in enterprises.

Enterprises benefit from cross-border e-commerce by exploiting economies of scale. This helps to reduce costs, increase efficiency, promote competitiveness and improve productivity. Cross-border e-commerce is even more important for enterprises and especially SMEs that are confined to a small home market. Nevertheless, only 8% of SMEs made web sales to customers in other EU countries in 2019. SMEs in Denmark, Ireland, Sweden and Croatia have the largest proportion of online sales (30% or more). Ireland is leader in cross-border online sales (18% of Irish enterprises have web sales across borders), followed by Belgium, Czechia and Austria (all three at 15%).

Figure 65 SMEs selling online (2020), and selling online cross-border (2019) (% of SMEs)



Source: Eurostat, European Union survey on ICT usage and e-commerce in enterprises.

Most of enterprises (63%) with web sales to other EU countries have no difficulties when selling to customers in other EU countries. On the other hand, 37% report at least one obstacle that is mainly related to economic factors (e.g. high costs of delivering or returning products, a problem reported by 27% of enterprises). Other factors such as linguistic and legal problems are also significant. The lack of knowledge of foreign languages and problems related to resolving complaints and disputes are also highlighted as difficulties by 11% of the enterprises selling online to other EU countries.

5 Digital public services

Digital technologies increasingly place new demands and expectations on the public sector. Realising the full potential of these technologies is a key challenge for governmental organisations. Effective e-government can provide a wide variety of benefits including more efficiency and savings for both governments and businesses. It can also increase transparency and openness. This dimension measures both the demand and supply sides of digital public services as well as open data[73].

The Digital Decade has the target that all key public services for businesses and citizens should be fully online by 2030. Indicators 4a3 and 4a4 are monitoring the progress of these targets.

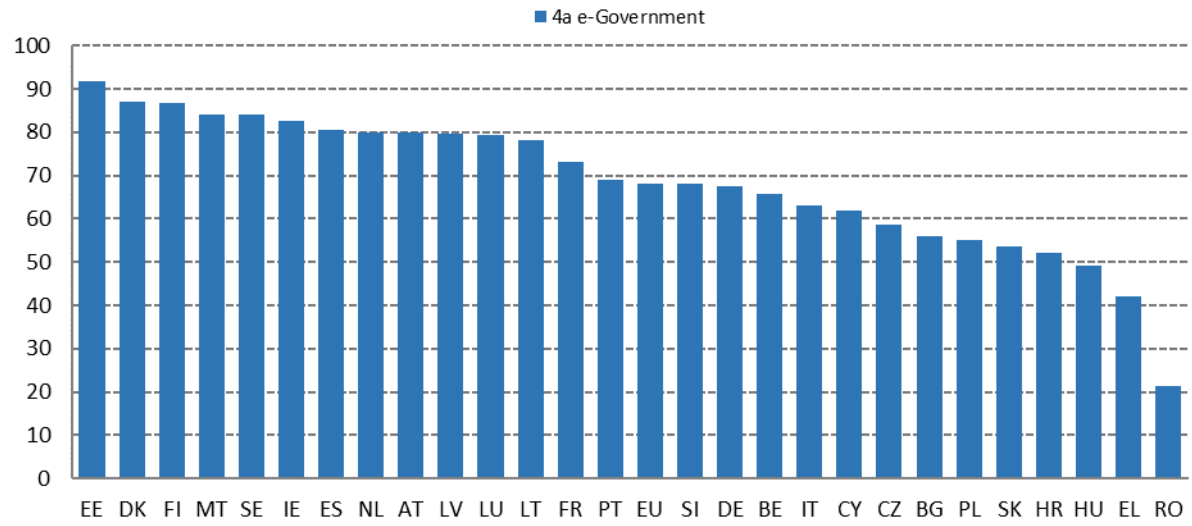
Table 6 Digital public services indicators in DESI

	EU	
	DESI 2019	DESI 2021
4a1 e-Government users % internet users	**60%** 2018	**64%** 2020
4a2 Pre-filled forms Score (0 to 100)	**NA** 0	**64** 2020
4a3 Digital public services for citizens Score (0 to 100)	**NA** 0	**75** 2020
4a4 Digital public services for businesses Score (0 to 100)	**NA** 0	**84** 2020
4a5 Open data % maximum score	**NA** 0	**78%** 2020

Source: DESI 2021, European Commission.

The top performers are Estonia, Denmark and Finland, while Romania, Greece and Hungary have the lowest score.

Figure 66 Digital Economy and Society Index (DESI) 2021, Digital public services



Source: DESI 2021, European Commission.

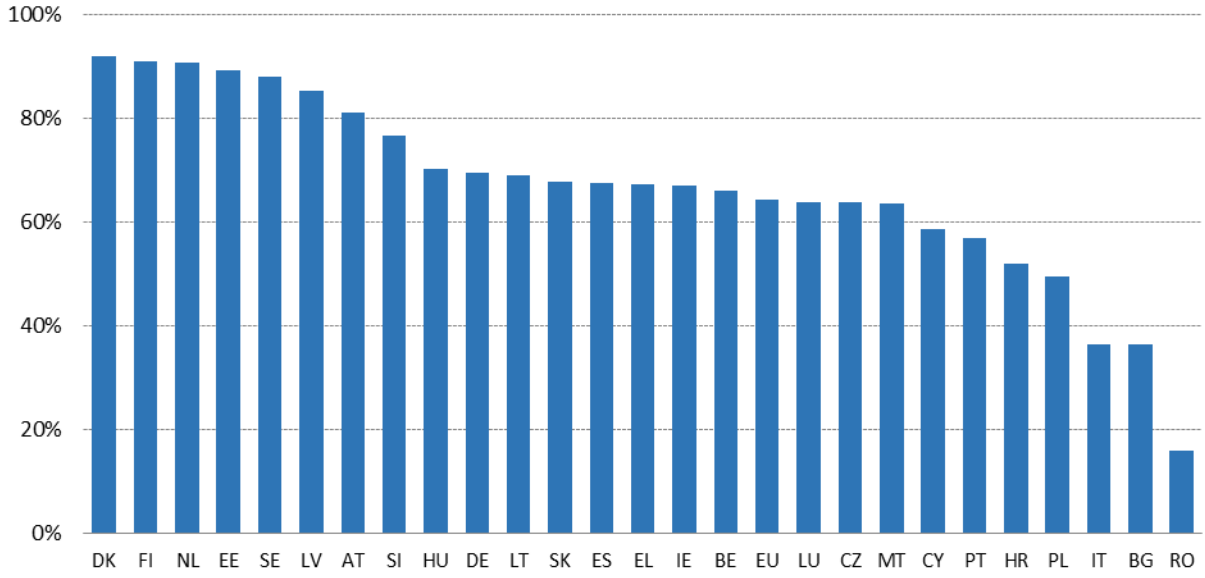
[73] This analysis can be complemented with the factsheets on digital public administration and interoperability of the National Interoperability Framework Observatory: https://joinup.ec.europa.eu/collection/nifo-national-interoperability-framework-observatory/digital-public-administration-factsheets

5.1 e-Government users

This indicator considers out of all internet users, the percentage of individuals who used the Internet in the last 12 months for interacting with public authorities. The indicator was updated to better cover the volume of interaction of citizens with public authorities online. The previous indicator was measuring solely the percentage of citizens submitting forms through online means, and who needed to do so.

Denmark, Finland, and the Netherlands performed very well on this measure, with more than 90% of internet users (aged 16-74) interacting with the public administration choosing governmental portals. Romania, Bulgaria and Italy were less strong in this measure, and were the only three countries where the percentage of citizens interacting with public administrations was less than 40%.

Figure 67 e-Government users interacting online with public authorities over the Internet in the last 12 months (% of internet users), 2020



Source: Eurostat, Community survey on ICT usage in Households and by Individuals.
**Data for France was not collected for 2020*

5.2 Pre-filled forms

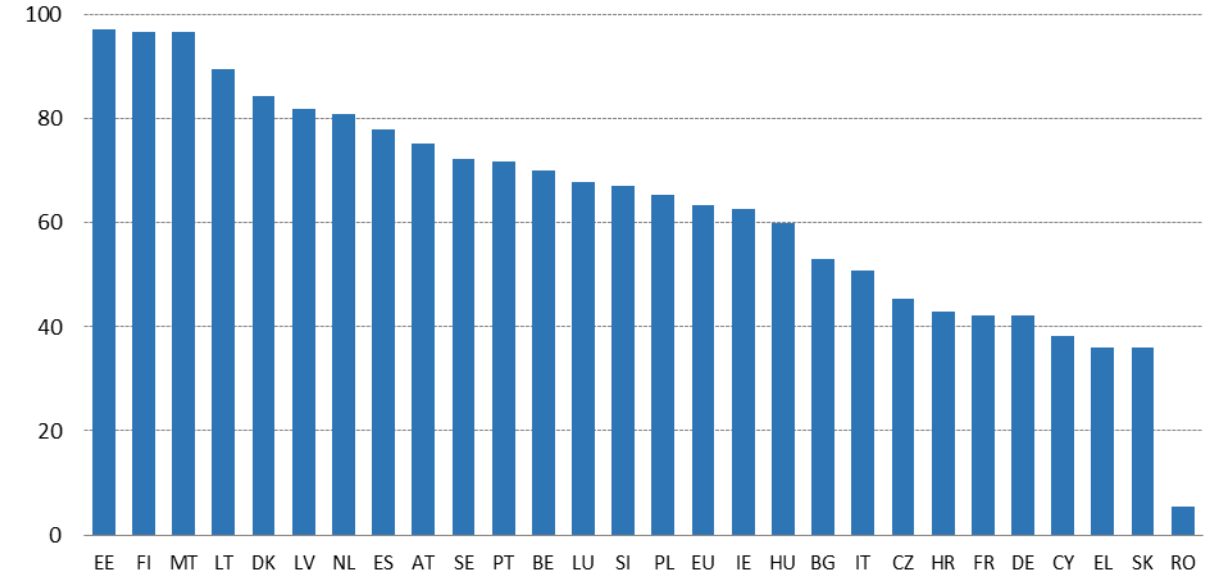
This indicator[74] measures the extent to which data that is already known to the public administrations is pre-filled in forms presented to the user, awarding a maximum overall score of 100. The use of inter-connected registers is key to ensuring that users do not have to resubmit the same data to the public administration (Once-only principle).

In 2020, the indicator was updated compared to 2019 to align with policy advancements and goals in the field (e.g. alignment with the Single Digital Gateway Regulation[75]). The eGovernment Benchmark method was updated, and the total number of services assessed[76] was simplified.

The best performing countries in 2020 were Estonia, Finland and Malta, all of which had scores above 95 points. However, there is a substantial gap between the best and worst performing countries, with Romania scoring below 10 points, and Slovakia, Greece and Cyprus below 40.

[74] The input for this indicator is the authentic sources indicator of the eGovernment benchmark.
[75] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=uriserv:OJ.L_.2018.295.01.0001.01.ENG
[76] The number of national services assessed in 2020 was 90 (63 for citizens and 27 for businesses), while in 2019 the number of services was 114 (70 for citizens and 44 for businesses).

Figure 68 Pre-filled forms (Score 0 to 100), 2020



Source: eGovernment Benchmark, Capgemini.

5.3 Digital public services for citizens

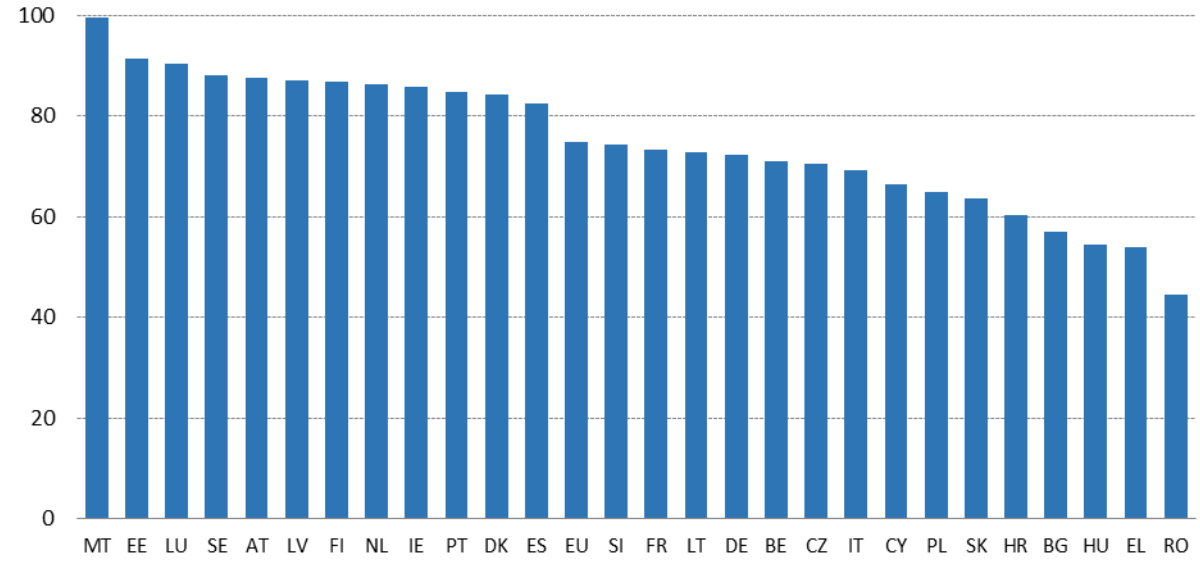
This is a new indicator[77] that measures the extent to which a service or information concerning service for citizens is provided online, and via a portal. Services that are offered fully, partially or not at all online. The indicator represents the share of steps that can be done online for major Life Events (e.g. birth of a child, new residence, etc.) for citizens. It is calculated as the average of the national and cross-border online availability for informational and transactional services[78].

Malta, Estonia and Luxembourg performed the best on this measure, scoring more than 90 points. Altogether 12 countries (Malta, Estonia, Luxembourg, Sweden, Austria, Latvia, Finland, the Netherlands, Ireland, Portugal, Denmark and Spain) scored above 80 points. Romania, Greece, Hungary and Bulgaria scored less than 60.

[77] In 2020, the indicator replaced the Online service completion indicator that measured the online availability of all (business and citizen) national services, of which some were already covered by the Digital public services for businesses indicator. The input for this indicator is the Online Availability indicator and the Cross-Border Online Availability indicator of the citizen-related life events from the eGovernment Benchmark. The number of national services assessed in 2020 was 63, and for cross border services was 28.

[78] Informational services: services and procedures that provide users with adequate and personalised insight into his/her situation. Transactional services: services and procedures needed to fulfil the essential requirements of a life event through online interaction.

Figure 69 Digital public services for citizens (score 0 to 100), 2020



Source: eGovernment Benchmark, Capgemini.

5.4 Digital public services for businesses

This indicator[79] measures the degree to which public services for businesses are interoperable and work cross-border.

The indicator assesses to what extent informational and transactional services[78] public services for businesses, when starting a business and conducting regular business operations, are available online and across borders in other EU Member States. Services provided through a portal receive a higher score, while services that only provide information online but which require operations to be carried out offline receive a lower score.

In 2020, the indicator was updated compared to 2019 to align with policy advancements and goals in the field (e.g. alignment with the Single Digital Gateway Regulation[75]). The eGovernment Benchmark method was updated, and the total number of services assessed[80] was simplified.

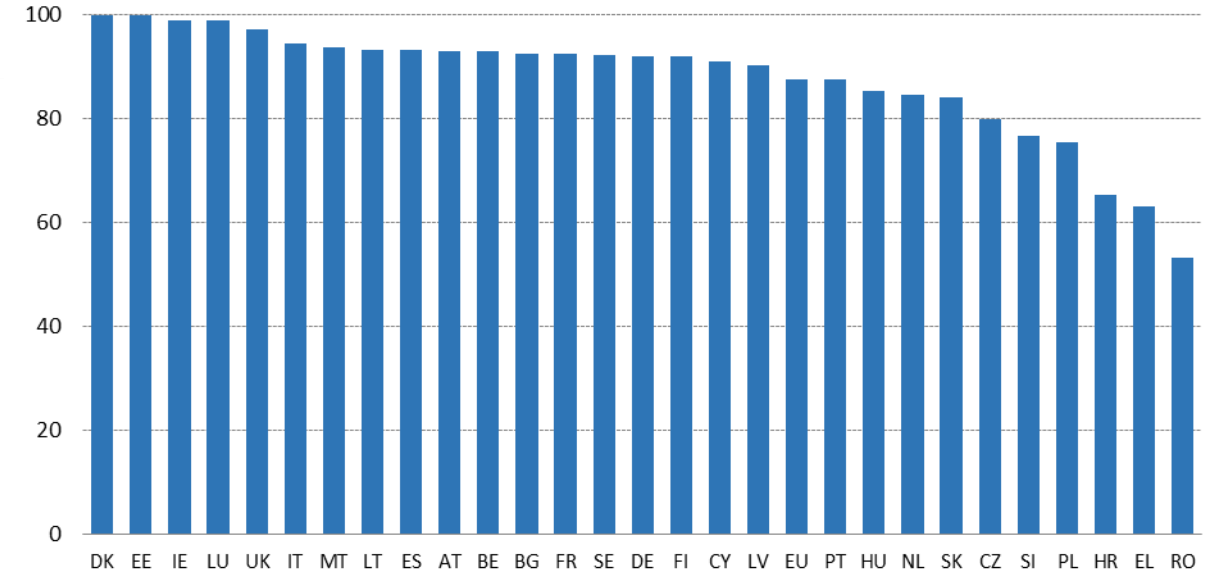
This indicator and the Digital public services for citizens are fully complementary and together cover the entire range of services assessed by the eGovernment Benchmark, both from a national and a cross-border perspective.

Altogether, 10 countries (Ireland, Estonia, Luxembourg, Lithuania, Denmark, Malta, Sweden, Spain, Finland and France) scored more than 90 points (out of 100). On the other hand, Romania, Greece and Poland scored below 70.

[79] The input for this indicator is the Online Availability indicator and the Cross-Border Online Availability indicator of the business-related life events from the eGovernment Benchmark.

[80] The number of national services assessed in 2020 was 27, and for cross border services was 13. In 2019, the number of services assessed was 44 and 24 accordingly.

Figure 70 e-Government services for businesses (Score 0 to 100), 2020



Source: eGovernment Benchmark, Capgemini.

5.5 Open data

This indicator measures the government's commitment to open data[81].

The level of maturity of open data has been based on the four following indicators.

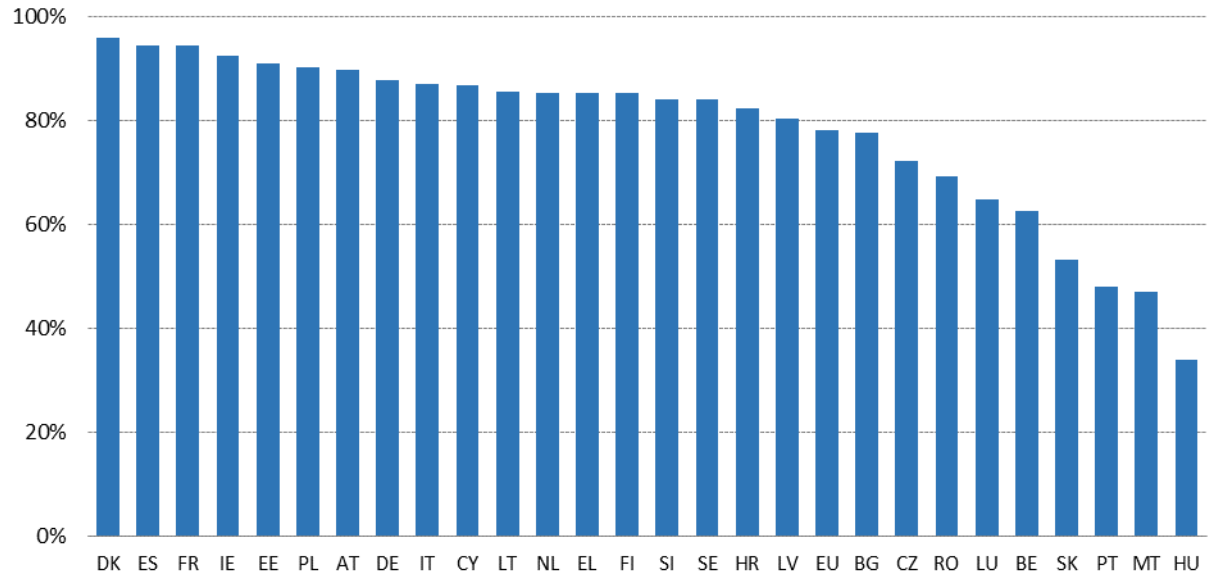
1. Open data policy:
   (i) the presence at national level of specific policies on open data and licensing norms; and
   (ii) the extent of coordination at national level to: (a) provide guidelines to national, local and regional administrations; and (b) set up coordinated approaches towards data publication.
2. Open data impact:
   (i) the extent to which activities are in place to estimate the impact of open data at country level; and
   (ii) the estimated impact of open data at country level in four areas: political, social, environmental, and economic.
3. Open data portal: the development of national portals and their level of sophistication in featuring available open data.
4. Open data quality:
   (i) the extent to which national portals have a systematic and automated approach to harvesting metadata from sources across the country; and
   (ii) the extent to which national portals comply with the metadata standard DCAT-AP (specification for metadata records).

The overall results across the EU show broad diversity in the speed of transformation and in the priorities that countries have set. The countries that are less advanced in open data typically choose to take what they deem to be the natural first steps. This means investment in modernising their national portals so the portals become the main gateways to open data available throughout the country. The more 'mature' open-data countries take a slightly different approach, focusing instead on improving the quality of their data publication. The middle-performing countries have a different approach to both the less advanced and the more 'mature' countries: they are now focusing on: (i) understanding the impact derived from open data; and (ii) activities to monitor and capture this impact.

[81] Open Data in Europe 2020: https://data.europa.eu/en/dashboard/2020

Denmark, Spain, France, Ireland, Estonia, Poland, and Austria performed well on this measure, scoring 90% or more. On the other hand, Hungary, Malta, Portugal and Slovakia underperformed, with scores below 60%.

Figure 71 Open data (% of the maximum open data score), 2020



Source: European Data Portal.

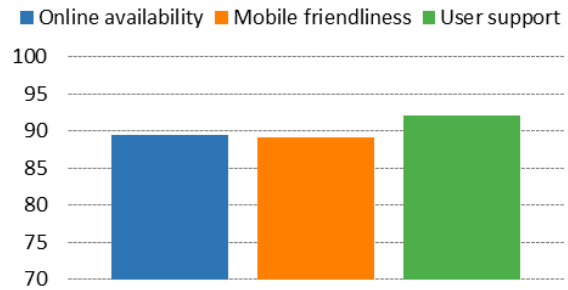
5.6 User centricity

This indicator includes the following three key elements[82] of online service provision.

1. Online availability: the extent to which informational and transactional services and information concerning these services is provided online, and can be reached via a portal website.
2. User support: the extent to which online support, help features, and feedback mechanisms are available on government portals.
3. Mobile friendliness: the extent to which services are provided through a mobile-friendly interface, an interface that is responsive to the mobile device.

Similarly to the previous indicators, in 2020, this indicator was updated to align with policy advancements and goals in the field by simplifying the total number of services assessed.

Figure 72 User centricity breakdown (Score 0 to 100), 2020

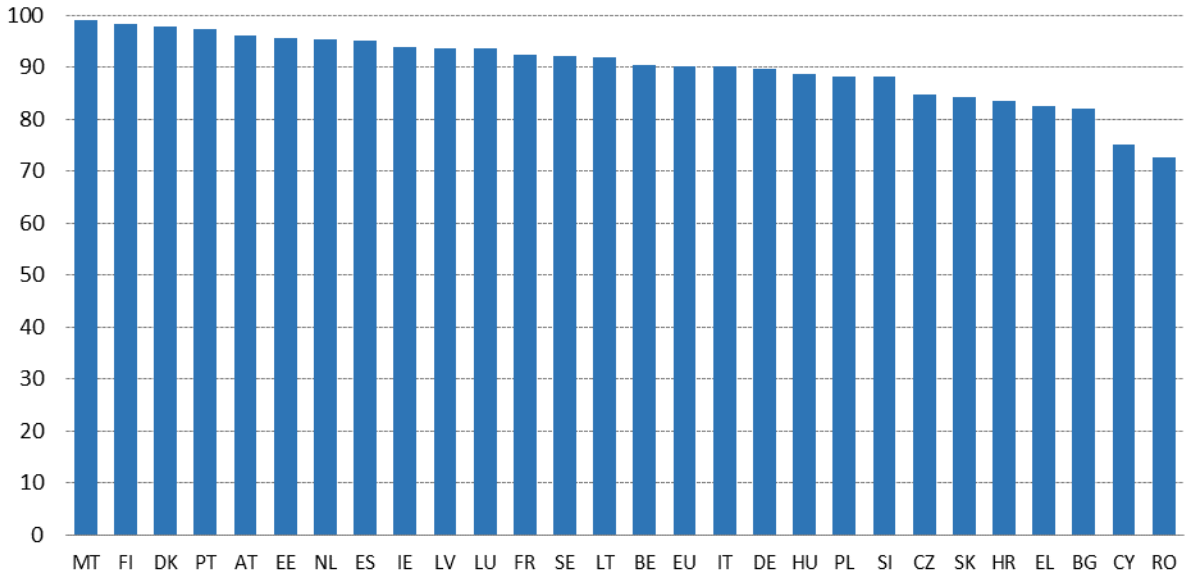


Source: eGovernment Benchmark, Capgemini.

[82] User support is a revised element. The goal is to develop a better usability indicator that fully captures user experience and user satisfaction. The former indicator was limiting the existence of FAQ-pages and the provision of online support channels. A pilot towards the development of a new usability indicator is scheduled to be launched in autumn 2021.

For 2020, online availability stands at 89.5 (out of 100), with Malta, Denmark, Portugal, Finland, Austria, Estonia and Spain scoring more than 95 points; mobile friendliness stands at 89.1, with Sweden, Finland and Denmark leading with scores close to 100; and the new indicator, user support stands at 92, with Finland, Malta and Italy scoring 100, while all the countries score more than 75 points. n total, Malta, Finland, Denmark, Portugal, Austria, Estonia, the Netherlands and Spain are in the lead on user centricity, all scoring more than 95 points. Romania, Cyprus, Bulgaria, Greece, Croatia, Slovakia and Czechia are lagging behind, all scoring less than 85 points.

Figure 73 User centricity status in Member States (Score 0 to 100), 2020



Source: eGovernment Benchmark, Capgemini.

5.7 Transparency

Transparency assesses the extent to which service processes are transparent, services are designed with user involvement and users can manage their personal data[83]. This indicator includes the following three key elements[84].

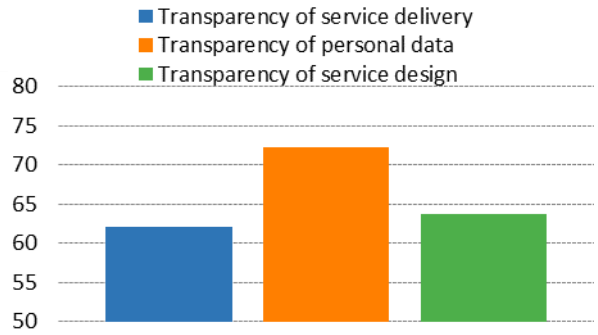
1. Transparency of service delivery: the extent to which the service process and expectations are clarified.
2. Transparency of personal data: the extent to which user can manage their personal data held by government organisations.
3. Transparency of service design: the extent to which user are informed on and involved in policy and service design processes.

Similarly to the previous indicators, in 2020, this indicator was updated to align with policy advancements and goals in the field by simplifying the total number of services assessed.

[83] The Transparency of personal data indicator analyses the availability and degree of digitalisation regarding online modalities of exercising data subject rights. Importantly, it does not provide a GDPR compliance review (reserved to competent data protection authorities) and does not form any restriction that could be provided by Member State law.

[84] Transparency of public organisations was discontinued and replaced by transparency of service design. Transparency of public organisations was assessing the extent to which public organisations are transparent about their organisational structure, mission and responsibilities, access to information, the possibility to request additional information and where to find corresponding legislation.

Figure 74 Transparency breakdown (Score 0 to 100), 2020

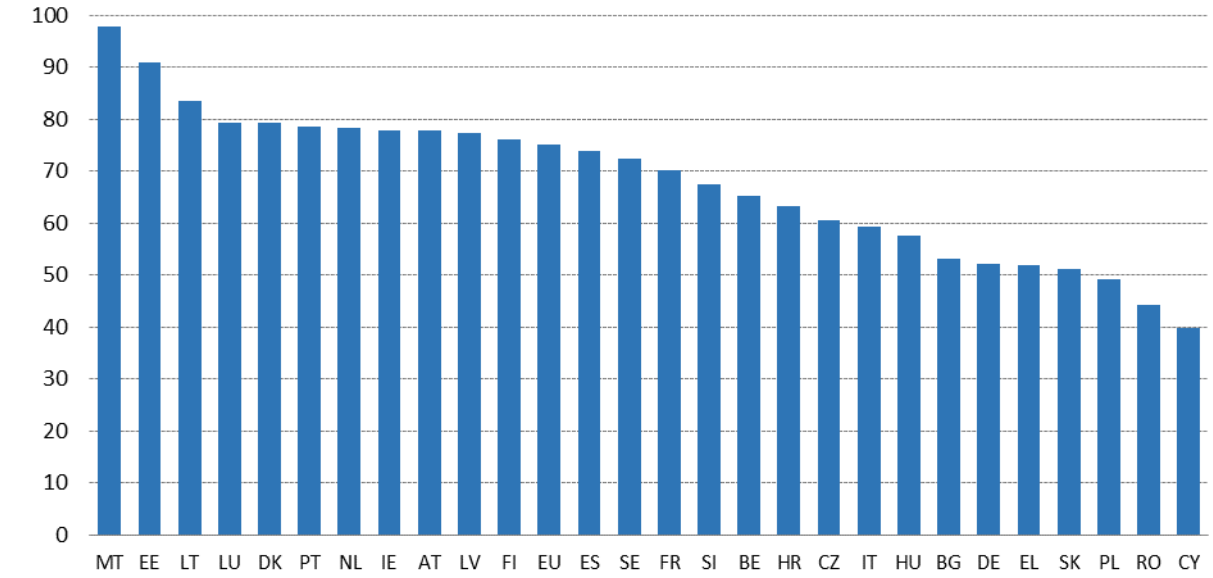


Source: eGovernment Benchmark, Capgemini.

For 2020, transparency of service delivery stands at 62 (out of 100), with Malta, Estonia, Latvia and Lithuania scoring more than 85 points; transparency of personal data stands at 72.2, with Malta, Lithuania, Luxembourg, Estonia, Austria and Poland leading with scores close over 85; and the new indicator, transparency of service design stands at 63.7, with Malta, Luxembourg, the Netherlands, Ireland, Denmark, Finland, Sweden, Estonia, Portugal, France and Slovakia scoring over 100.

In total, Malta, Estonia, Lithuania, Luxembourg, Denmark, Portugal, the Netherlands, Ireland, Austria, Latvia and Finland are in the lead on transparency, all scoring more than 75 points. Cyprus, Romania, Poland, Slovakia, Greece, Germany and Bulgaria are lagging behind, all scoring less than 55 points.

Figure 75 Transparency status in Member States (Score 0 to 100), 2020



Source: eGovernment Benchmark, Capgemini.

5.8 Key enablers

The key enabler indicator includes the following four elements of online service provision and availability.

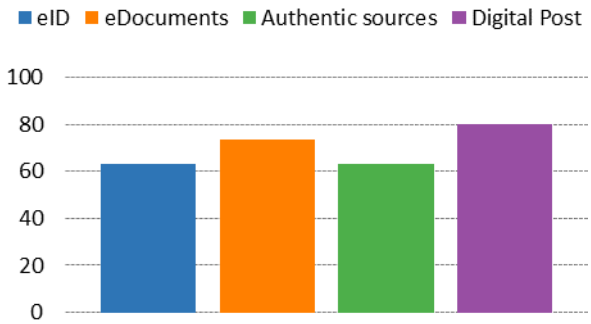
1. eID: the extent to which electronic Identification (eID), any means accepted by eGovernment services (e.g. smartcards, username and password) for online identification, can be used during service processes.
2. eDocuments: the extent to which electronic documents (eDocuments), any document in digital form that the user needs to submit/upload in order to complete an eGovernment service, or that the user obtains as a proof or a result of the service (e.g. certificate, diploma, proof of registration) can be used during service processes.

3. Authentic sources (named as Pre-filled forms in DESI): the extent to which Authentic Sources, base registries used by governments to automatically validate or fetch data relating to citizens or businesses, can be used during the service process.
4. Digital post: the extent to which public authorities allow citizens to receive communications digitally only and opt-out for paper mailings. Digital Post refers to the possibility that governments communicate electronically-only with citizens or entrepreneurs through e.g. personal mailboxes or other digital postal solutions.

Similarly to the previous indicators, in 2020, this indicator was updated to align with policy advancements and goals in the field by simplifying the total number of services assessed.

For 2020, the eID indicator stands at 63 (out of 100), with Malta, and Estonia leading, while Romania, Cyprus and Greece lagging behind; eDocuments stands at 73.8, with Portugal, Denmark, Malta and Estonia leading, while Romania, Greece and Czechia scoring less than 50; authentic sources stands at 63.4, with Estonia, Malta and Finland scoring more than 95, while Romania, Slovakia, Greece and Cyprus lagging behind; and digital post stands at 80.3, with several countries scoring 100, while Romania, Greece, Ireland and Poland scoring less than 50.

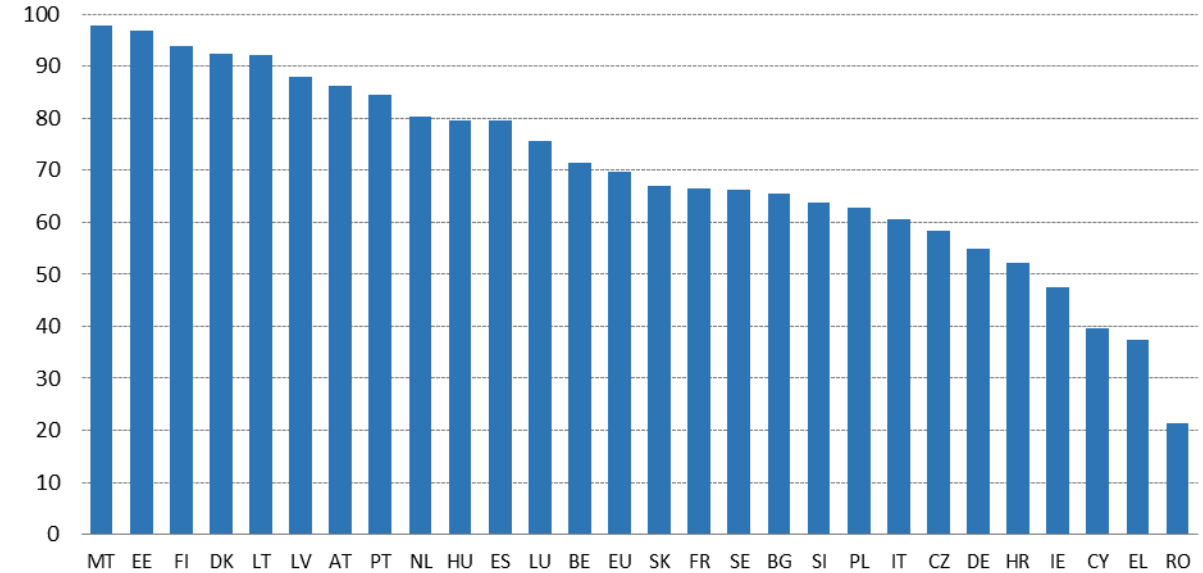
Figure 76 Key enablers (Score 0 to 100), 2020



Source: eGovernment Benchmark, Capgemini

In total, Malta, Estonia, Finland, Denmark and Lithuania are in the lead on key enablers, scoring more than 90 points in 2020. Romania, Greece, Cyprus and Ireland are lagging behind, scoring less than 40 points.

Figure 77 Key enablers status in Member States (Score 0 to 100), 2020



Source: eGovernment Benchmark, Capgemini.

5.9 Cross border services

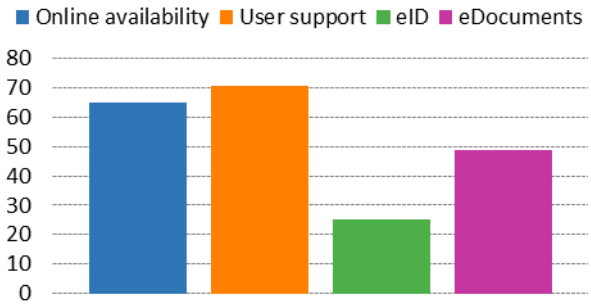
Cross-border mobility indicates the extent to which information and services are available online, usable, supported with help and feedback functionalities and integrated with eIDs and eDocuments for users from other European countries.

Cross-border mobility includes four indicators, assessed in a cross-border scenario.

1. Cross-border online availability: the extent to which informational and transactional services and information concerning these services are provided online for users from other European countries.
2. Cross-border user support: the extent to which online support, help features, and feedback mechanisms are available for users from other European countries.
3. Cross-border eID: the extent to which electronic Identification (eID) can be used during service processes by users from other European countries, a government-issued document for online identification, and authentication.
4. Cross-border eDocuments: the extent to which electronic documents (eDocuments) can be used during service processes by users from other European countries, documents that have been authenticated by its issuer using any means recognised under applicable national law, specifically through the use of electronic signatures, e.g. not a regular PDF or Word file.

For 2020, online availability stands at 65 (out of 100), with Luxembourg, Italy, Germany, Portugal and Croatia scoring above 85, while Slovenia, Poland, France and Denmark scoring below 30; user support stands at 70.7, with Luxembourg, Malta, the Netherlands and Ireland scoring above 95, while Hungary, Poland and Romania scoring below 40; eID stands at 25.3, with Austria, Luxembourg and Malta scoring above 60, while Romania, Poland, Germany, Bulgaria, Ireland and Cyprus lagging behind; eDocuments stands at 48.4, with Finland and Germany leading, while Poland, Romania, Italy and Bulgaria scoring below 20.

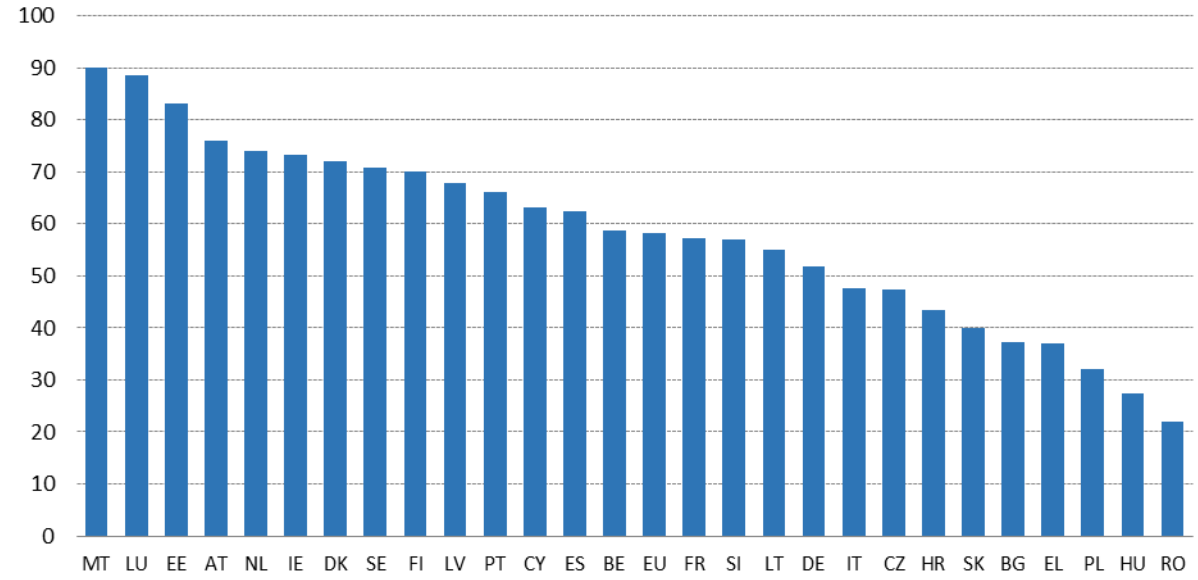
Figure 78 Cross border services (Score 0 to 100), 2020



Source: eGovernment Benchmark, Capgemini

Malta, Luxembourg, Estonia and Austria lead the EU in this measure, all scoring more than 75 points. The countries with less cross-border flexibility and advancement are Romania, Hungary, Poland and Greece and Bulgaria, all of which have scores below 40.

Figure 79 Cross border services status in Member States (Score 0-100), 2020



Source: eGovernment Benchmark, Capgemini.

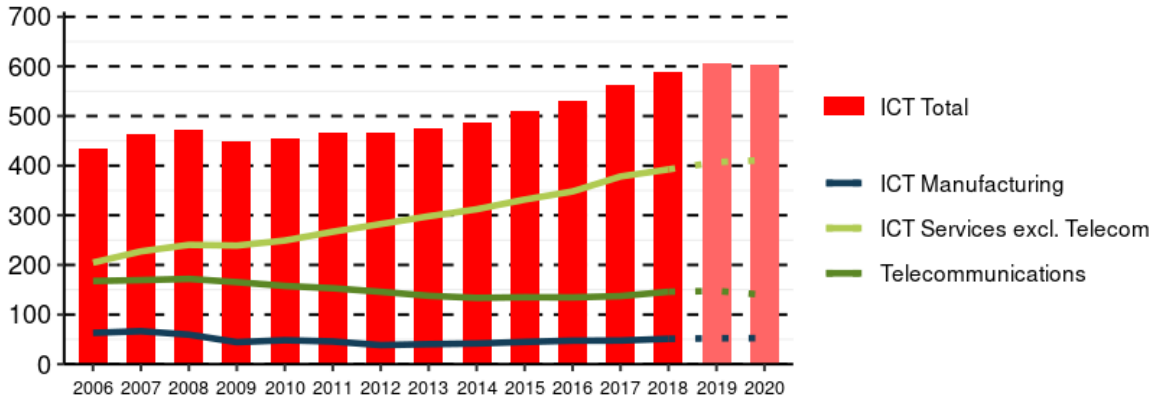
6 The EU ICT Sector and its R&D Performance

6.1 Value added

The value added of the EU27 ICT sector was EUR 590 billion in 2018[85], and it is expected to continue to have grown in 2019, although it should probably have stagnated in 2020 due to the COVID-19 crisis impact. A breakdown by sub-sector shows, as in previous years, the predominance of ICT services (EUR 537 billion and 91% of total ICT sector value added in 2018) over ICT manufacturing.

The ICT services sub-sector (excluding telecommunications) was the only ICT sub-sector that saw an increase in value added between 2006 and 2018, growing to EUR 390 billion. Both the telecommunications and ICT manufacturing sub-sectors experienced a decline in the same period, only slightly recovering some of this decline in the last 3 years.

Figure 80 ICT sector Value Added, EUR billion, 2006-2020

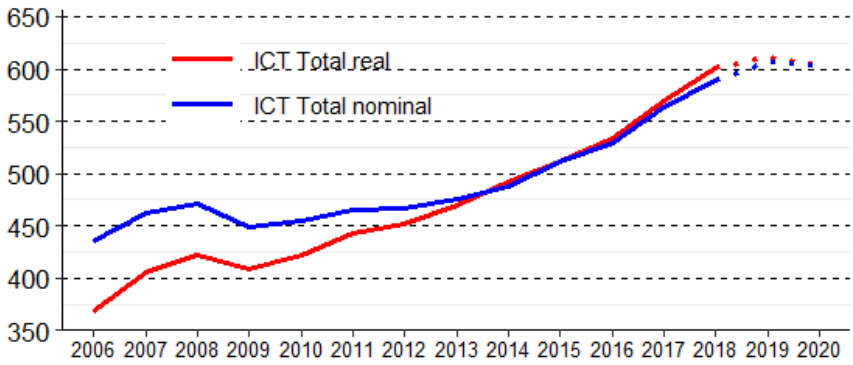


Note: Values for the years 2019 and 2020 are nowcasted data.

Source: Commission calculations and estimates based on PREDICT project.

The value added of the ICT sector grew much faster in real terms than the rest of the economy. Although the value added of the ICT sector increased by 35% in nominal terms (in line with GDP, which grew by 34%), it increased by 60% in real terms in 2006-2018 (while GDP grew by 14% in real terms). However, this difference was more accentuated until 2013. These trends are expected to have decreased in 2019 and 2020 due to the stagnation of the value added in 2020 and the increase in prices in the ICT sector in 2019 and 2020 (see *Prices*).

Figure 81 ICT sector Value Added, nominal and deflated, EUR billion, 2006-2020



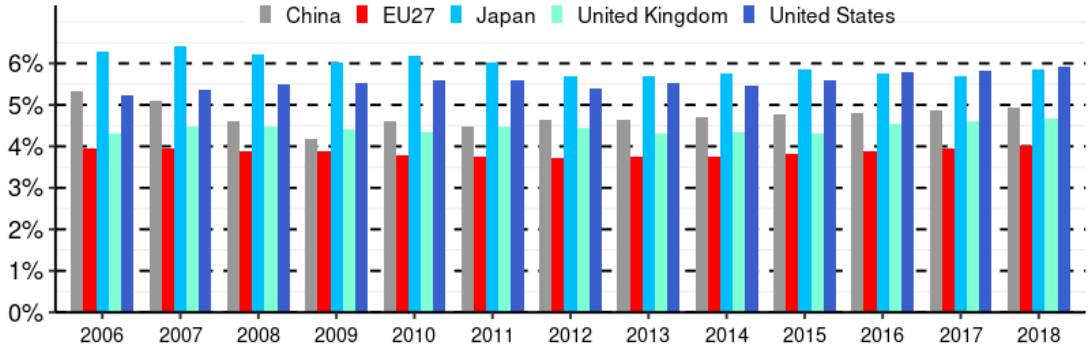
Note: Values for the years 2019 and 2020 are nowcasted data.

Source: Commission calculations and estimates based on PREDICT project.

[85] All the EU indicators and time series have been calculated based on 27 countries. Therefore, the values presented are not directly comparable with the DESI 2020 report that is based on 28 countries for the EU.

The value added of the ICT sector accounted for 4.4% of EU GDP in 2018 according to the comprehensive definition (*see Methodological note*). According to the operational definition (*see Methodological note*), which enables world comparisons, the value added of the ICT sector in the EU27 (4.0%) was lower than that of the US (5.9%), Japan (5.8%), China (4.9%) and the UK (4.7%) in 2018. The EU's ICT sector only grew marginally as a percentage of GDP in 2018 compared to 2016, but so did most of its competitors. The exception were China and Japan where the ICT sector as a percentage of GDP decreased. Already in 2017, Japan was surpassed by the US as the country where the ICT sector accounts for the highest percentage of GDP.

Figure 82 ICT sector share of GDP 2006-2018

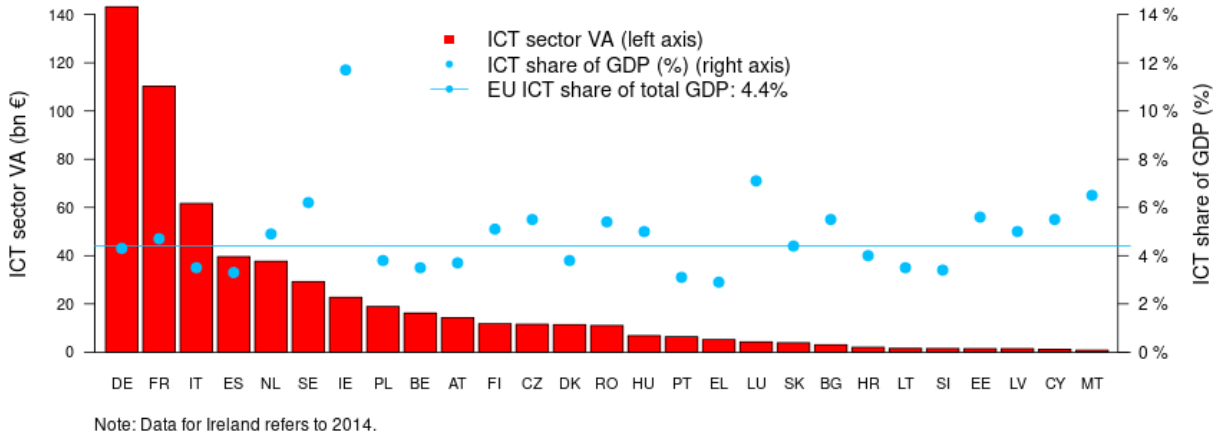


Source: Commission calculations and estimates based on PREDICT project.

In the EU27, Germany, France, Italy, Spain and the Netherlands were the five biggest contributors to ICT sector value added in 2018: Germany (EUR 143 billion or 24% of EU value added in ICT), France (EUR 110 billion or 19%), Italy (EUR 62 billion or 10%), Spain (EUR 40 billion or 7%) and the Netherlands (EUR 38 billion or 6%). Together, these five countries accounted for 66% of total EU ICT sector value added in 2018.

However, Ireland had the largest ICT sector as percentage of GDP, at 11.6% in 2014 (the latest year for which data were available), while Greece lagged behind at 2.9%. After Ireland, the countries with the largest ICT sector as percentage of GDP were Luxembourg (7%), Malta (6.5%), Sweden (6.2%), Estonia (5.6%), and Cyprus, Czechia and Bulgaria (all at 5.5%). Romania, Finland, Hungary and Latvia also had a large ICT as percentage of GDP (5% or higher). ICT as a percentage of GDP remained broadly unchanged between 2006 and 2018, except in Ireland where it grew by 3.7 percentage points and in Finland, where it fell by 3.5 percentage points.

Figure 83 ICT sector Value Added, EU27, EUR billion, 2018 (left axis) and ICT sector share of GDP, EU27, percentage, 2018 (right axis)



Note: Data for Ireland refers to 2014.

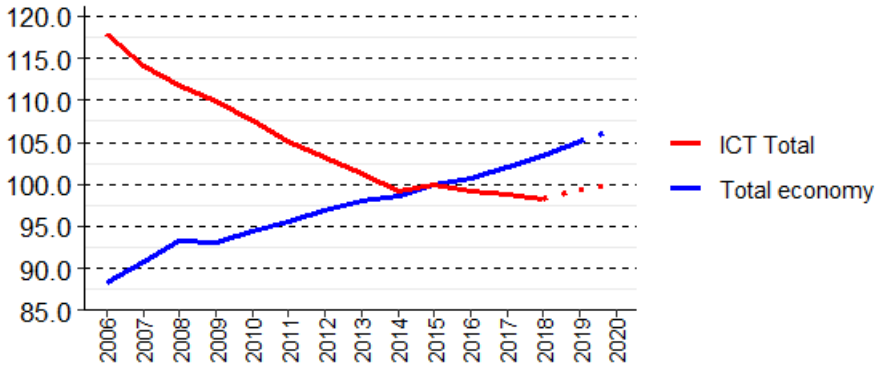
Source: Commission calculations and estimates based on PREDICT project.

6.2 Prices

ICT prices continued to fall in 2016-2018 after a spike in 2015. However, the decline in prices is forecasted to have slowed down in 2018 to start increasing in 2019 and 2020.

Prices in the ICT sector fell by 16.5% between 2006 and 2018, while prices in general grew by 17% over the same period. This highlights the particular nature of product prices in the ICT sector, which also incorporates improvements in the quality of products.

Figure 84 Price index, ICT sector and overall economy, index base 2015=100, 2006-2020

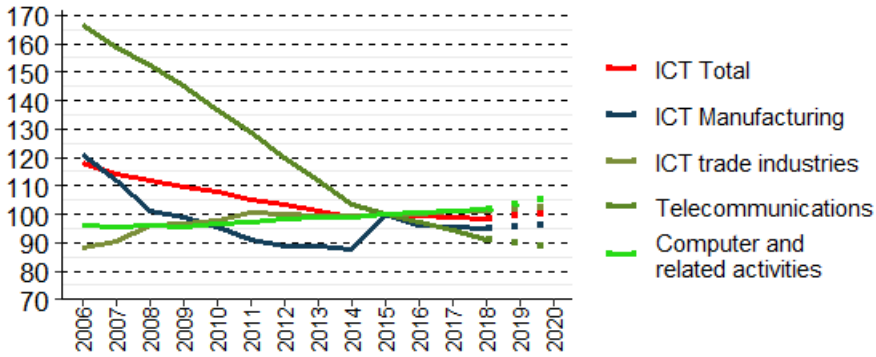


Note: Values for the year 2020 and ICT sector in 2019 are nowcasted data.

Source: Commission calculations and estimates based on PREDICT project.

An analysis by sub-sector shows a contrast: while some sub-sectors experienced a dramatic drop in prices (the percentage drop in telecommunications was double than in ICT manufacturing), others saw growth (prices in the ICT trade industry increased 15%; in computer and related activities, they increased 6%) between 2006 and 2018. However, following the general trend of the ICT sector, the prices in all sub-sectors except in telecommunications are expected to have increased in 2019 and 2020.

Figure 85 Price index, ICT by sub-sector, index base 2015=100, 2006-2020



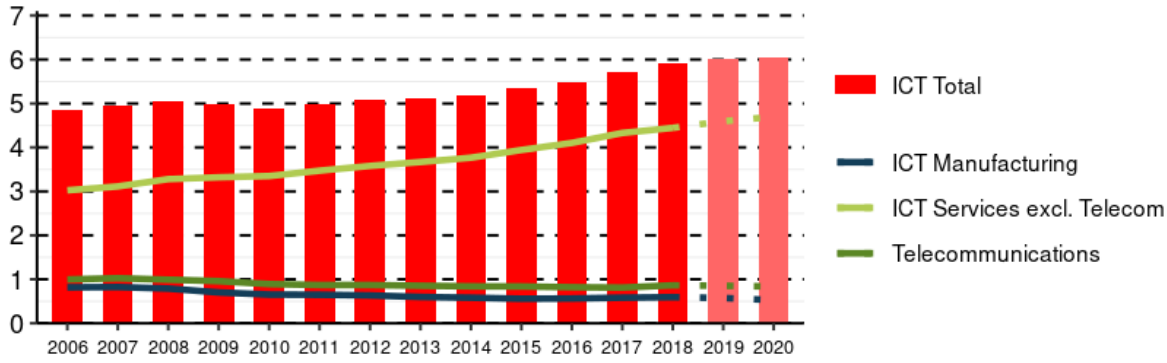
Note: Values for the years 2019 and 2020 are nowcasted data.

Source: Commission calculations and estimates based on PREDICT project.

6.3 Employment

The EU27 ICT sector employed 5.9 million people in 2018, continuing an upward trend since 2010. The ICT services sub-sector (excluding telecommunications) was the main employer with 4.4 million people in 2018, accounting for 75% of total ICT employment. This is the only sub-sector that recorded growth (of 47%) between 2006 and 2018. The telecommunications sub-sector employed 864,000 people in 2018, down by 13% since 2006. The ICT manufacturing sub-sector employed 593,500 people in 2018, a drop of 27% since 2006.

Figure 86 Employment in the ICT sector, million individuals, 2006-2020

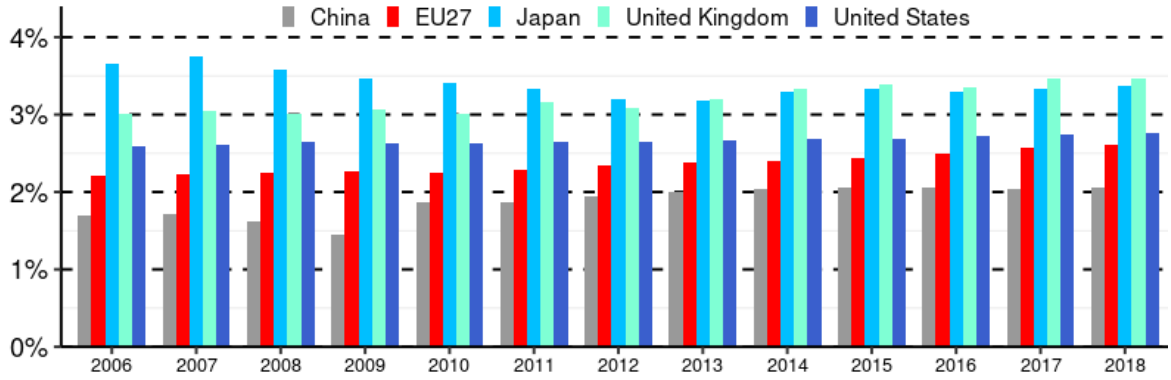


Note: Values for the years 2019 and 2020 are nowcasted data.

Source: Commission calculations and estimates based on PREDICT project.

The EU27 employment of the ICT sector accounted for 2.9% of EU total employment in 2018 according to the comprehensive definition (*see Methodological note*). In the operational definition (see *Methodological note)*, which makes it possible to compare with non-EU countries, the US (where the ICT sector accounts for 2.7% of total employment) was slightly ahead of the EU (2.6%), which in turn was ahead of China (2.1%). However, all three lagged well behind Japan (3.3%) and the UK (3.4%) in 2018.

Figure 87 ICT sector share of total employment, percentage, 2006-2018

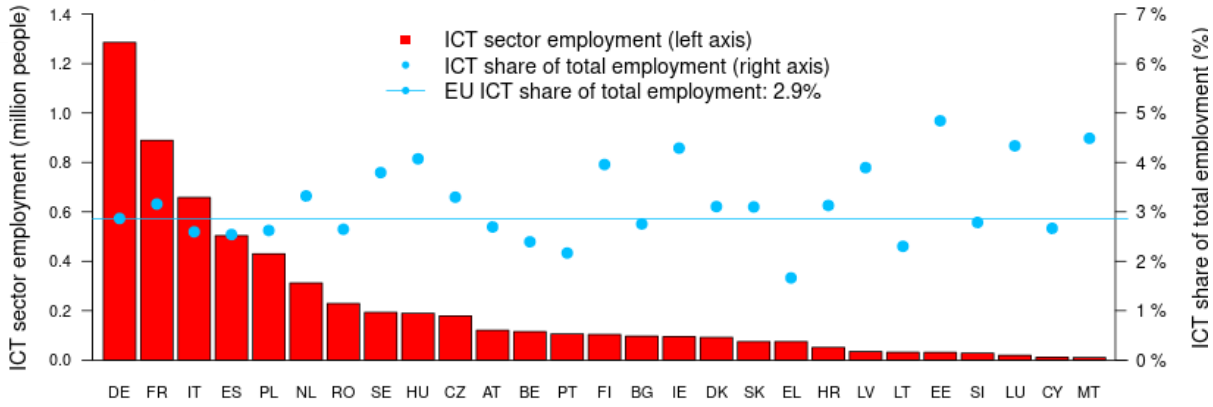


Source: Commission calculations and estimates based on PREDICT project.

The five largest employers in the EU27 ICT sector in 2018 were Germany, France, Italy, Spain and Poland. Germany (over 1.3 million people, or 22% of total EU ICT sector employment), France (889,000 people or 15%), Italy (658,000 people or 11%), Spain (504,000 people or 9%) and Poland (430,000 people or 7%). Together, the five largest employers accounted for 64% of total ICT sector employment in the EU in 2018.

In 2018, Estonia had the largest ICT sector share over total employment (4.8%) and Greece the smallest (1.7%). Other countries that performed well in 2018 included Malta (4.5%) and Luxembourg (4.3%). Ireland and Hungary were close behind at around 4%. Between 2006 and 2018, ICT sector employment as a share of total employment remained stable in most countries, although, small countries like Estonia and Latvia made significant progress, showing growth of 2.3 percentage points each.

Figure 88 Employment in the ICT sector, EU27, million individuals, 2018 (left axis) and ICT sector share of total employment, EU27, percentage, 2018 (right axis)

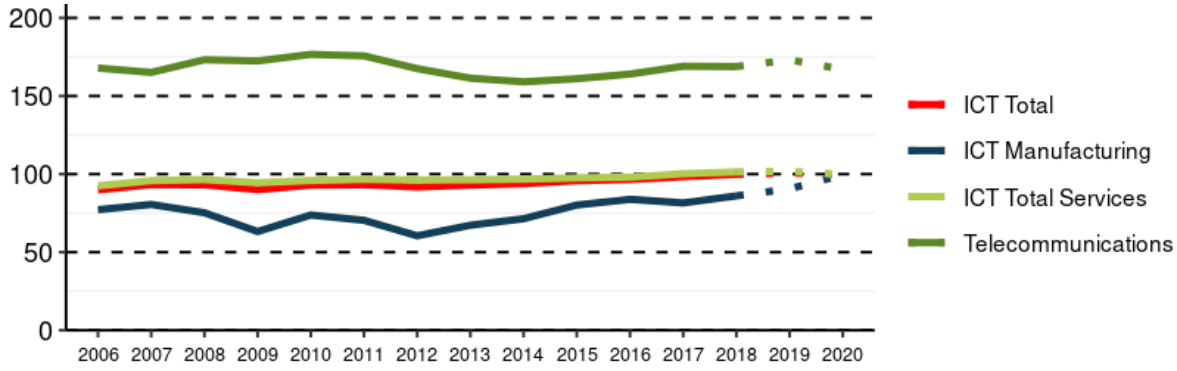


Source: Commission calculations and estimates based on PREDICT project.

6.4 Productivity

Labour productivity in the EU27 ICT sector (for a comprehensive definition - see *Methodological note*) was EUR 100,000 per person employed in 2018, an 11% increase compared to 2006. Labour productivity in the ICT manufacturing sub-sector (EUR 86,000 per person employed in 2018) was below the average for the broader ICT sector. However, it is expected to have increased closer to the broader ICT sector in 2019 and 2020. Labour productivity in ICT services (i.e. services and trade), which was EUR 101,000 per person employed in 2018, is less sensitive to business cycles and was closer to the total ICT sector average than that of ICT manufacturing. Labour productivity in the telecommunications sub-sector was by far the highest (at EUR 169,000 per person employed in 2018), but it is on a downward trend that is expected to have continued in 2019 and 2020.

Figure 89 Productivity in the ICT sub-sector, thousand EUR per individual employed, 2006-2020

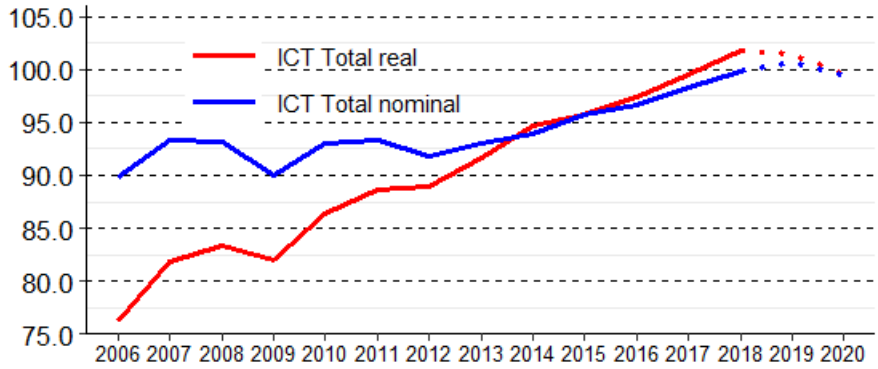


Note: Values for the years 2019 and 2020 are nowcasted data.

Source: Commission calculations and estimates based on PREDICT project.

The ICT sector had higher labour productivity (in nominal terms) and grew faster (in real terms) between 2006 and 2018 than the overall economy. Labour productivity in the ICT sector was greater than in the rest of the economy (EUR 100,000 per person employed versus EUR 65,000 per person employed in 2018). Although it grew less quickly in nominal terms (up 11% against 26% nominal growth between 2006 and 2018), labour productivity in the ICT sector grew faster than that of the overall economy in real terms (up 33% against 8% real growth between 2006 and 2018). However, this trend is expected to have decreased in 2019 and 2020, explained by the negative impact of the COVID-19 crisis on value added and the increase in prices in the ICT sector over the same period (see *Prices*). Likewise, the trend in nominal terms is expected to have decreased, mainly explained by the increase of employment, especially in ICT services.

Figure 90 Productivity, nominal and deflated, thousand EUR per individual employed, 2006-2020

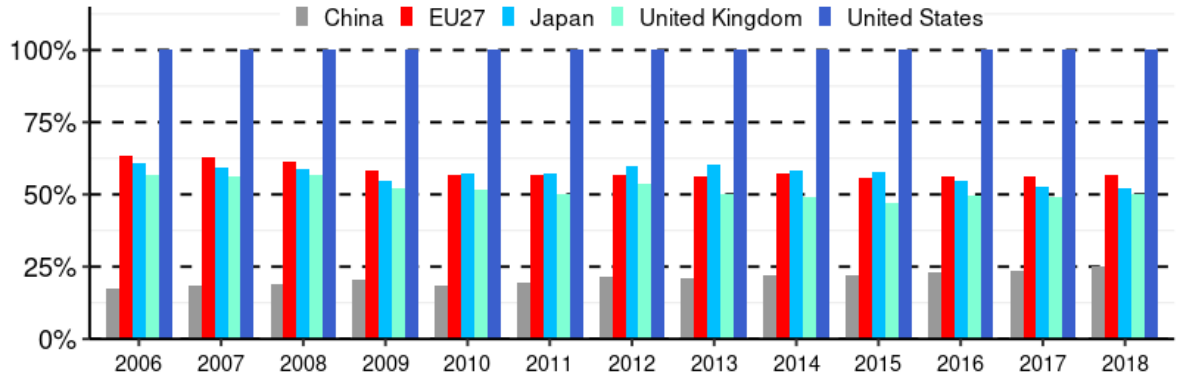


Note: Values for the years 2019 and 2020 are nowcasted data.

Source: Commission calculations and estimates based on PREDICT project.

According to the operational definition (see *Methodological note*), which makes it possible to compare with non-EU countries, labour productivity in the EU27 ICT sector is considerably below that of the US (the EU index is 57 against the US index of 100). Labour productivity in the EU ICT sector is ahead of Japan (which has an index of 52) and the UK (which has an index of 50) and far ahead of China (index of 25).

Figure 91 ICT sector productivity, EUR PPS per individual employed, index US=100, 2006-2018

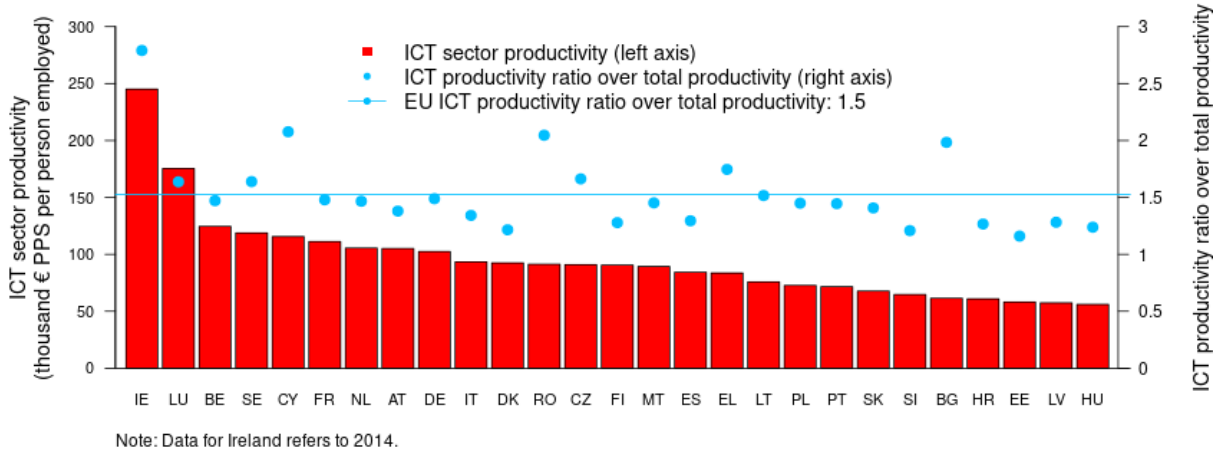


Source: Commission calculations and estimates based on PREDICT project.

In terms of labour productivity in the ICT sector, Ireland (PPS EUR 254,000 per person employed) by far led the way in 2014 (the latest year for which data were available), but Luxembourg (PPS EUR 175,000 per person employed) and Belgium (PPS EUR 125,000 per person employed) also fared well in 2018. At the opposite end of the scale were Hungary (PPS EUR 56,000 per person employed), Latvia (PPS EUR 57,000 per person employed), and Estonia (PPS EUR 58,000 per person employed).

The picture for labour productivity in the economy was similar. Ireland (PPS EUR 127,000 per person employed), Luxembourg (PPS EUR 107,000 per person employed) and Belgium (PPS EUR 84,500 per person employed) were the best-performing countries, while Bulgaria (PPS EUR 31,000 per person employed) and Romania (PPS EUR 45,000 per person employed) were at the bottom of the scale. However, the ratio of labour productivity in the ICT sector over the economy indicated a good performance of countries at the bottom of the scale (e.g. Bulgaria).

Figure 92 Productivity in the ICT sector, EU27, thousand EUR PPS per individual employed, 2018 (left axis) and ratio of ICT productivity over total productivity, EU27 (right axis)



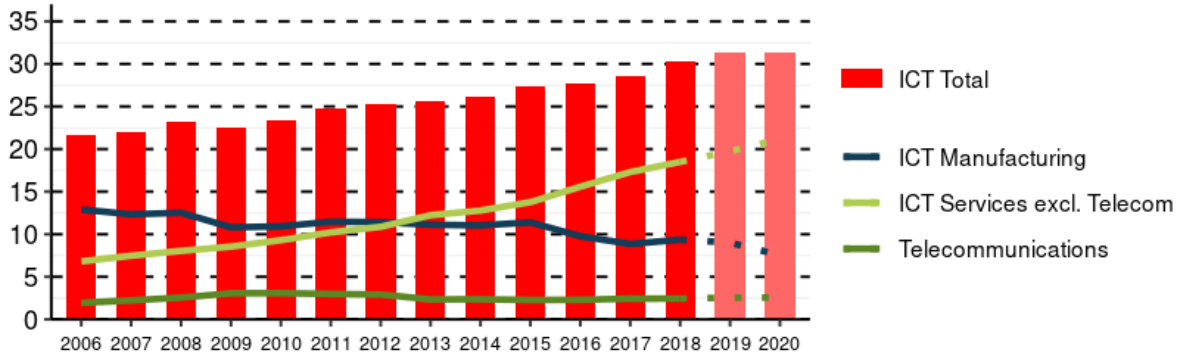
Source: Commission calculations and estimates based on PREDICT project.

6.5 R&D expenditure

R&D expenditure by business enterprises (BERD) in the EU27 ICT sector amounted to EUR 30 billion in 2018, its highest value in the 2006-2018 period, and well above its low point of EUR 22 billion in 2006. A breakdown by sub-sector reveals a more balanced situation for BERD than for value added. Despite accounting for only 9% of ICT sector value added, the ICT manufacturing sub-sector was responsible for 30% of total ICT BERD (EUR 9 billion), while the ICT services sub-sector was responsible for 70% (EUR 21 billion) of ICT BERD in 2018.

Between 2006 and 2018, there was a divergence in R&D expenditure in the ICT sector. The ICT manufacturing sub-sector experienced structural decline in R&D expenditure over this period (falling by 27% between 2006 and 2018), whereas the ICT services sub-sector saw a structural increase in R&D expenditure (rising by 139% between 2006 and 2018). The ICT services sub-sector excluding telecommunications saw particularly strong growth with R&D expenditure between 2006 and 2018.

Figure 93 R&D expenditure by business enterprises (BERD) in the ICT sector, EUR billion, 2006-2020

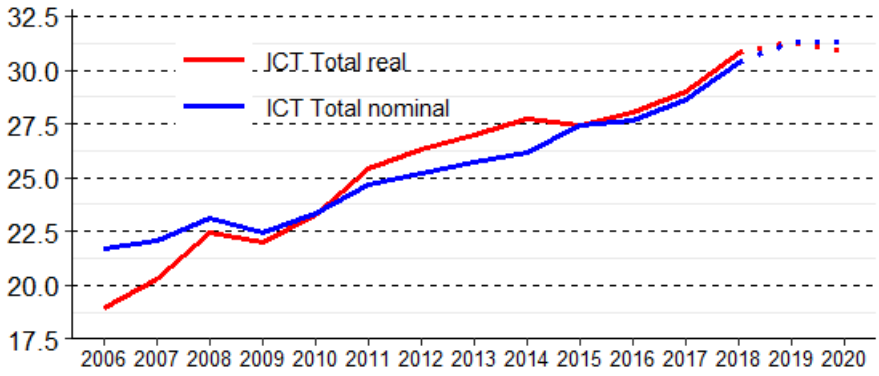


Note: Values for the years 2019 and 2020 are nowcasted data.

Source: Commission calculations and estimates based on PREDICT project.

In real terms, R&D expenditure by business enterprises in the ICT sector grew faster than in the general economy (by 62% versus 44% in 2006-2018). Like productivity, this trend is expected to have decreased in 2019 and 2020, explained by the negative impact of the COVID-19 crisis and the increase in prices in the ICT sector over the same period (see *Prices*).

Figure 94 R&D expenditure by business enterprises (BERD) in the ICT sector, nominal and deflated, EUR billion, 2006-2020

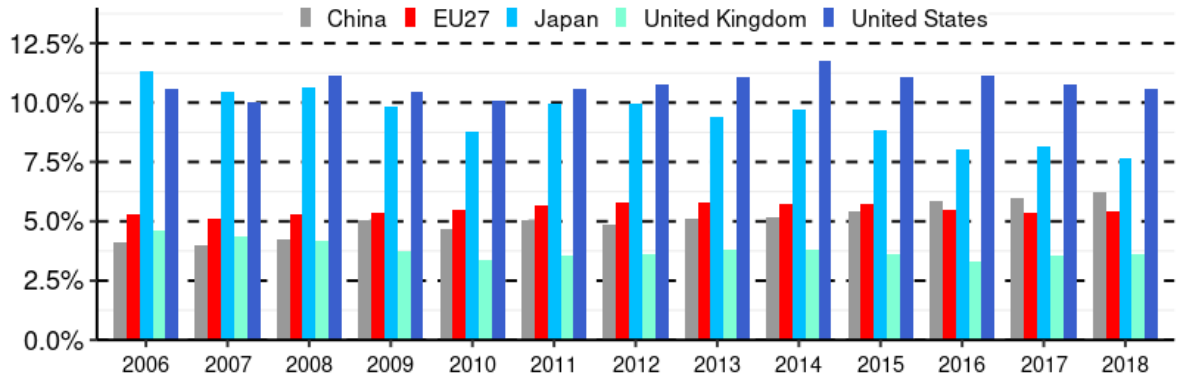


Note: Values for the years 2019 and 2020 are nowcasted data.

Source: Commission calculations and estimates based on PREDICT project.

R&D intensity (BERD/VA) in the ICT sector (for a comprehensive definition - see *Methodological note*) was 5.1% in 2018. According to the operational definition (see *Methodological note*), which makes it possible to compare with non-EU countries, the EU (at 5.4% R&D intensity) lagged behind China (at 6.2%) but gained over the UK (at 3.6%). While the EU, the UK and China, lagged behind the US (10.6%) and Japan (7.7%) in R&D intensity in 2018.

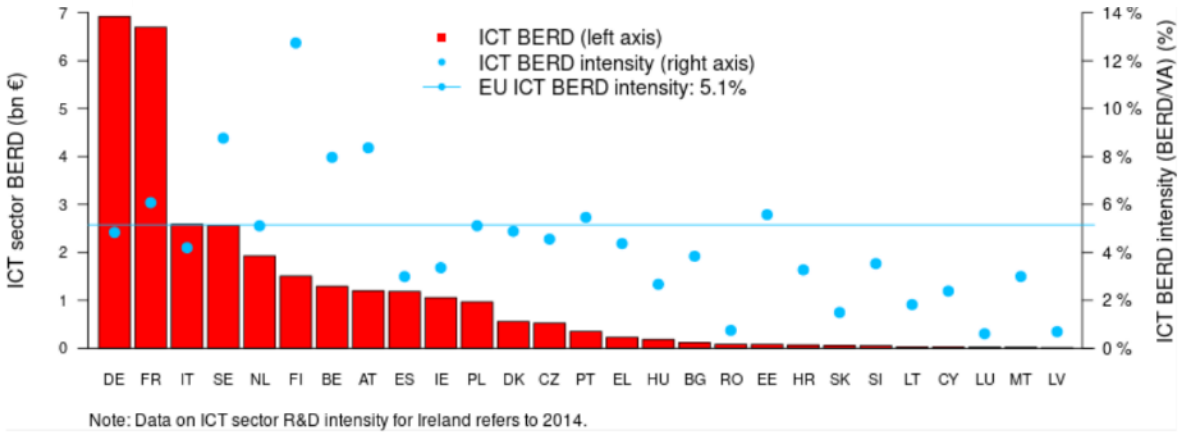
Figure 95 ICT sector R&D Intensity (BERD/VA), percentage, 2006-2018



Source: Commission calculations and estimates based on PREDICT project.

The EU's six main contributors in terms of R&D expenditure by business enterprises in the ICT sector in 2018 were Germany, France, Italy, Sweden, the Netherlands and Finland. R&D expenditure in Germany was EUR 6.9 billion or 23% of the EU total; in France was EUR 6.7 billion or 22% of the EU total; in Italy it was EUR 2.6 billion or 9% of the EU total; and in Sweden it was EUR 2.5 billion or 8% of the EU total. In the Netherlands, R&D expenditure in the ICT sector was EUR 1.9 billion or 6% of the total, and in Finland it was EUR 1.5 billion or 5% of the total. Together, these six countries accounted for 73% of total R&D expenditure by business enterprises in the ICT sector in the EU.

Figure 96 R&D expenditure by business enterprises (BERD) in the ICT sector, EU27, EUR billion, 2018 (left axis) and ICT sector R&D intensity (BERD/VA), EU27, percentage, 2018 (right axis)



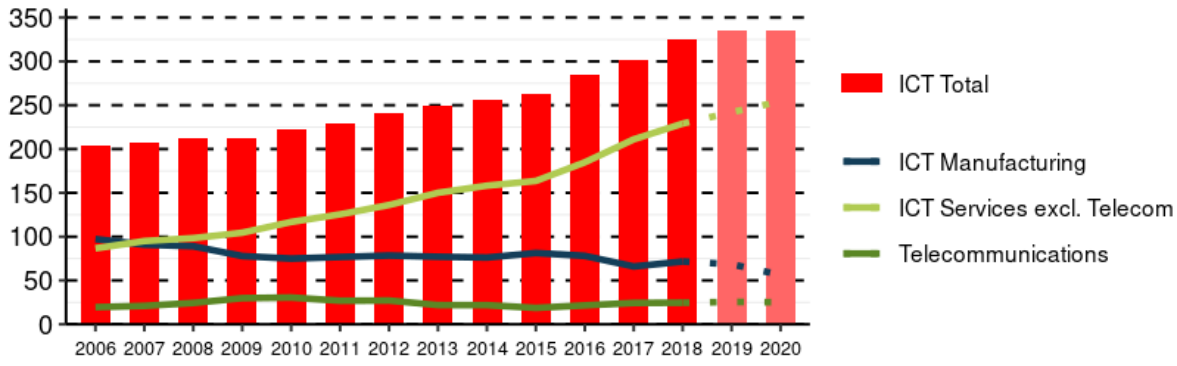
Source: Commission calculations and estimates based on PREDICT project.

Finland led the EU with a 12.7% R&D intensity rate (BERD/VA) in ICT in 2018. Sweden and Austria had rates close to 8.5%. Other strong performers included Belgium (8%) and France (6%). Between 2006 and 2018, R&D intensity in ICT remained broadly stable. However, some countries, such as Poland, Belgium and Bulgaria, made significant progress.

6.6 R&D personnel

R&D personnel in the EU27 ICT sector accounted for 325,000 full-time equivalents (FTEs) in 2018, a figure which rose between 2006 and 2018, with particularly strong growth after 2011. The ICT services sub-sector (excluding telecommunications) employed 229,000 FTEs in 2018 (accounting for 70% of R&D personnel in the ICT sector, making it the top employer), with a rising trend. The ICT manufacturing sub-sector employed 72,000 FTEs in 2018, fewer than in 2006 despite an increase in the number of people employed in 2015 and 2018. The telecommunications sub-sector employed 24,500 FTEs in 2018 (7.5% of R&D personnel in the ICT sector), down by about 20% from a peak of 30,500 FTEs in 2010.

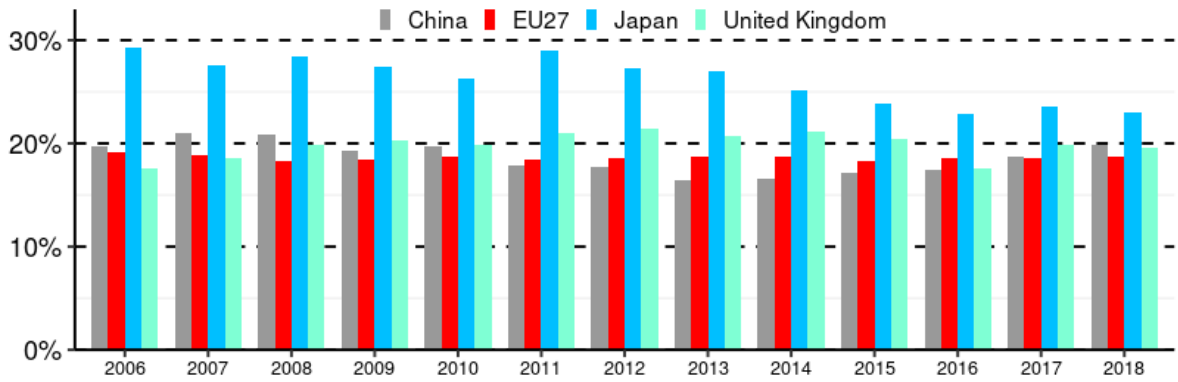
Figure 97 R&D Personnel (PERD) in the ICT sector, thousand FTEs, 2006-2020



Source: Commission calculations and estimates based on PREDICT project.

R&D personnel in the ICT sector (for a comprehensive definition - see *Methodological note*) made up 19.3% of total R&D personnel in 2018, a figure roughly unchanged since 2006. However, according to the operational definition (see *Methodological note*) which makes it possible to compare countries, the EU (where R&D personnel in the ICT sector make up 19% of total R&D personnel), China (where they make up 20%) and the UK (19.5%) were behind Japan (23%) in 2018. China, the UK and the EU also lagged behind Japan on this metric for every year from 2006 to 2016 (no data available for the US).

Figure 98 ICT sector share of total R&D personnel, percentage, 2006-2018

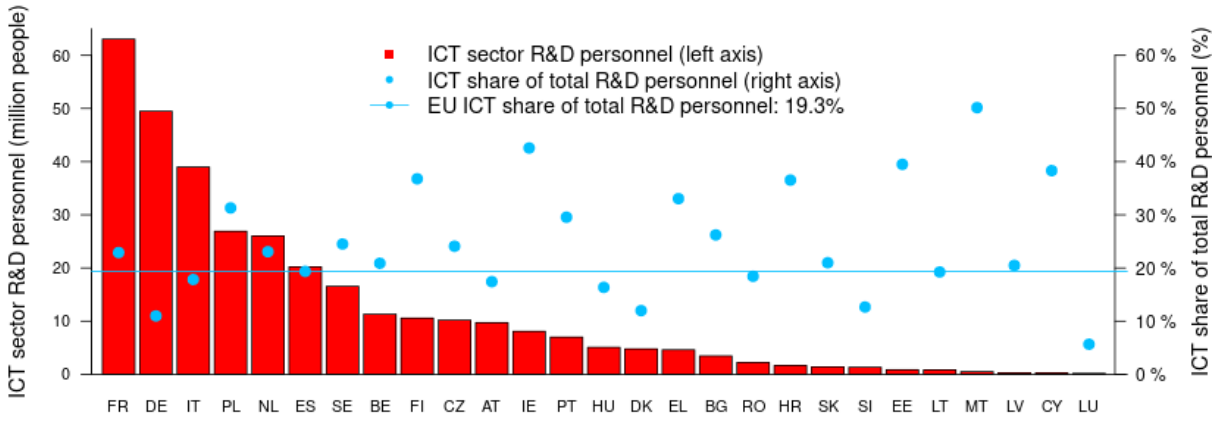


Source: Commission calculations and estimates based on PREDICT project.

The EU27 four biggest employers of R&D personnel in the ICT sector in 2018 were France (63,000 FTEs or 19.5% of R&D personnel in the EU ICT sector), Germany (49,500 FTEs or 15%), Italy (39,000 FTEs or 12%) and Poland (27,000 FTEs or 8.5%). Together, the four biggest employers represented 55% of total R&D personnel in the ICT sector in 2018.

Malta (50%) and Ireland (42.5%) were the two EU countries with the highest concentration of R&D personnel in the ICT sector in 2018. Luxembourg had the lowest concentration (5.6%). Other strong performers were Estonia (39%), Cyprus (38%), Finland (37%), and Croatia (36%).

Figure 99 R&D personnel (PERD) in the ICT sector, EU27, thousand FTEs, 2018 (left axis) and ICT sector share of total R&D personnel (PERD), EU27, percentage, 2018 (right axis)

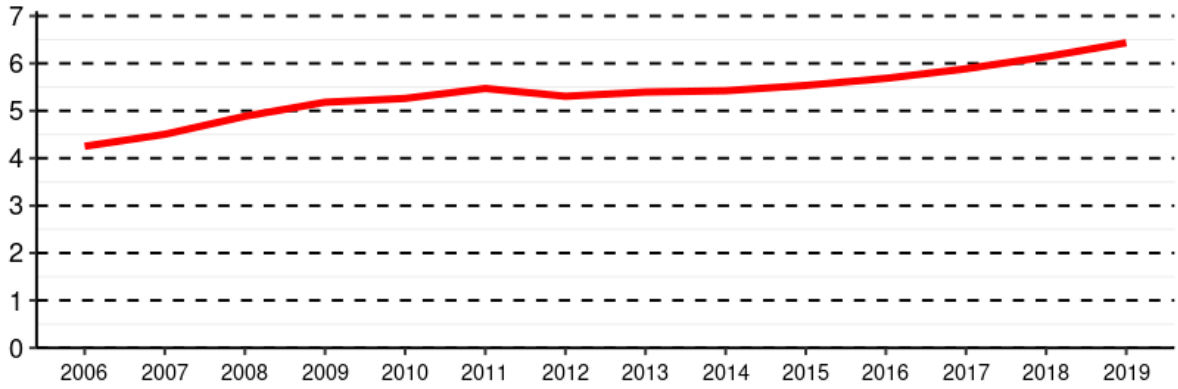


Source: Commission calculations and estimates based on PREDICT project.

6.7 Public funding of ICT R&D

The estimated level of publicly funded expenditure on ICT R&D in the EU27 increased between 2006 and 2019 interrupted only by a fall in 2012 and reached EUR 6.4 billion in 2019. The EU's Digital Agenda target of doubling publicly funded ICT R&D between 2007 and 2020 requires an annual growth rate of 5.5% (assuming a constant rate of annual growth). Estimated public, ICT R&D expenditure was below the necessary trend line in 2019 but had still reached 4.8% annual growth. In 2019, public funding of ICT R&D represented 7% of EU total government budget allocations for R&D (GBARD), a percentage broadly unchanged since 2006.

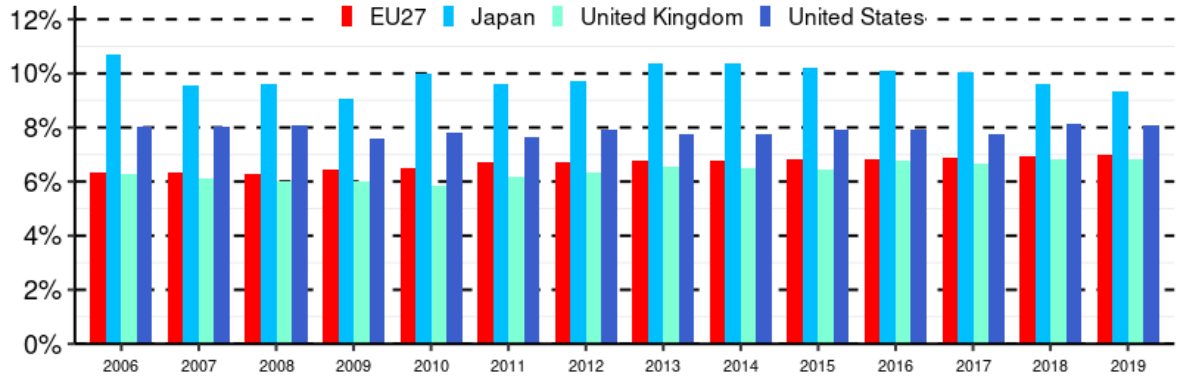
Figure 100 Public funding of ICT R&D (ICT GBARD), EUR billion, 2006-2019



Source: Commission calculations and estimates based on PREDICT project.

Since 2006, the EU has continuously lagged behind the US (where ICT accounted for 8.1% of GBARD in 2019) and Japan (where ICT accounted for 9.3% of GBARD in 2019) since 2006 (no data are available for China). The UK (where ICT accounted for 6.8% of GBARD in 2019) follows closely the EU (6.9%).

Figure 101 ICT GBARD share of total GBARD, percentage, 2006-2019

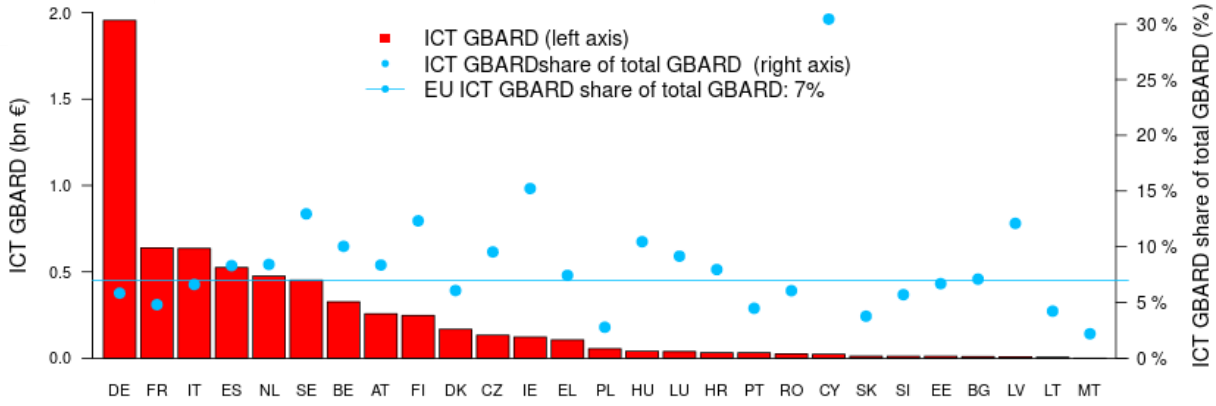


Source: Commission calculations and estimates based on PREDICT project.

The EU27's five biggest public funders of ICT R&D in 2019 were Germany (EUR 1.9 billion or 30.5% of public funding in the EU for ICT R&D), followed by France (EUR 639 million or 10%), Italy (EUR 636 million or 9.5%), Spain (EUR 525 million or 8%) and the Netherlands (EUR 476 million or 7%). Together, those five countries accounted for 65% of total public funding for ICT R&D in the EU.

As in previous years, Cyprus led the way in the EU with the highest rate (30%) of ICT GBARD as a proportion of total GBARD in 2019. The ranking in 2019 again reveals strong performances by Ireland (15%), Sweden (13%), and Finland and Latvia (both close to 12%). In addition, some other countries also pay special attention to ICT in their public spending on R&D, such as Hungary and Belgium (both close to 10%).

Figure 102 Public funding of ICT R&D (ICT GBARD), EU27, EUR billion, 2019 (left axis) and ICT GBARD as share of total GBARD, EU27, percentage, 2019 (right axis)



Source: Commission calculations and estimates based on PREDICT project.

6.8 Methodological note

Definition of the ICT sector

In this section, the ICT sector is defined according to the definition provided by the OECD and based on the NACE (Statistical Classification of Economic Activities in the European Community) Rev.2 (2008) nomenclature. The ICT sector has 12 industries:

ICT manufacturing

- C261 Manufacture of electronic components and boards
- C262 Manufacture of computers and peripheral equipment
- C263 Manufacture of communication equipment
- C264 Manufacture of consumer electronics
- C268 Manufacture of magnetic and optical media

ICT services

- G4651 Wholesale of computers, computer peripheral equipment and software
- G4652 Wholesale of electronic and telecommunications equipment and parts
- J5820 Software publishing
- J61 Telecommunications
- J62 Computer programming, consultancy and related activities
- J631 Data processing, hosting and related activities; web portals
- S951 Repair of computers and communication equipment

Comprehensive versus operational definition

The comprehensive definition of the ICT sector applies to EU Member States for the period 2008-2018. It corresponds to the definition provided by the OECD in 2007. The operational definition of the ICT sector enables the EU to be compared with non-EU countries over a longer period (2006-2018), as some of these countries do not have the necessary disaggregated information to estimate all the ICT industries included in the comprehensive definition.

The operational definition does not include the following industries: manufacture of magnetic and optical media (268) and ICT trade industries (465).

Sector analysis

In the previous section, an analysis by ICT sub-sectors is made for each indicator. The 12 industries are aggregated into two sub-sectors: ICT manufacturing and ICT services, the latter being subdivided into ICT services (excluding telecommunications) and telecommunications.

Source

Joint Research Centre – Dir. B Growth and Innovation (JRC– Dir. B). Calculations and estimates from the JRC's PREDICT[86] project are based on Eurostat, the OECD's structural analysis database (STAN), EU-KLEMS data and other national sources. All data contained in these databases come from official sources (e.g. Eurostat, OECD, national statistical institutes). Discrepancies with the original sources are due to updates of the original data or the use of multiple auxiliary sources and variables. For more details, see the 2021 PREDICT Dataset Methodology.

[86] https://ec.europa.eu/jrc/en/predict

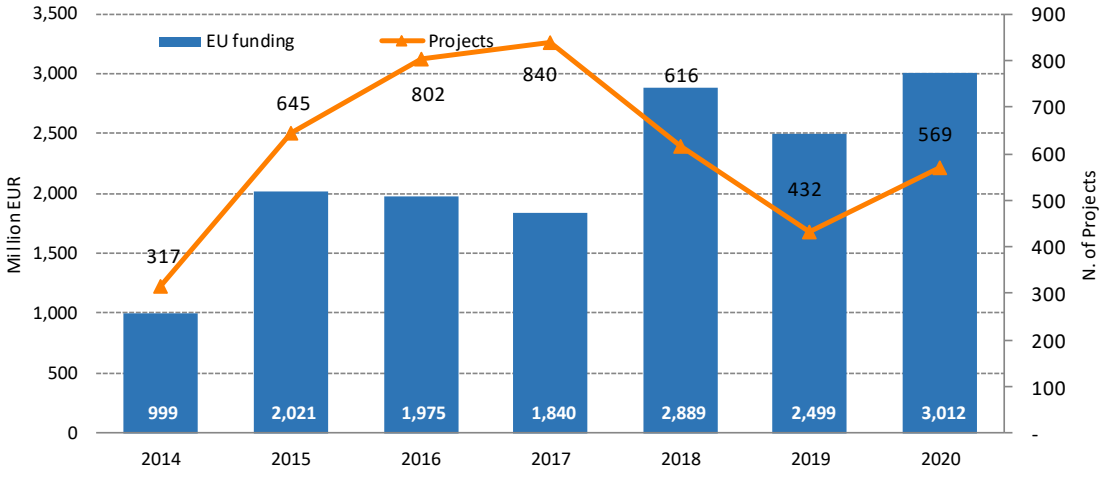
7 Research and Innovation: ICT projects in Horizon 2020

7.1 Projects and EU funding

Between 2014 and 2020, Horizon 2020 allocated more than €15.2 billion of EU funding to about 4,220 projects in ICT-related areas.

In 2020, there were around 570 projects signed, for a total EU funding of approximately €3 billion. After the decreasing trend recorded between 2017 and 2019, the number of ICT-related projects increased again in 2020, although it remained below the peak reached in 2017. In 2020, there was also a notable increase in EU funding.

Figure 103 EU Funding and projects by year, 2014-2020



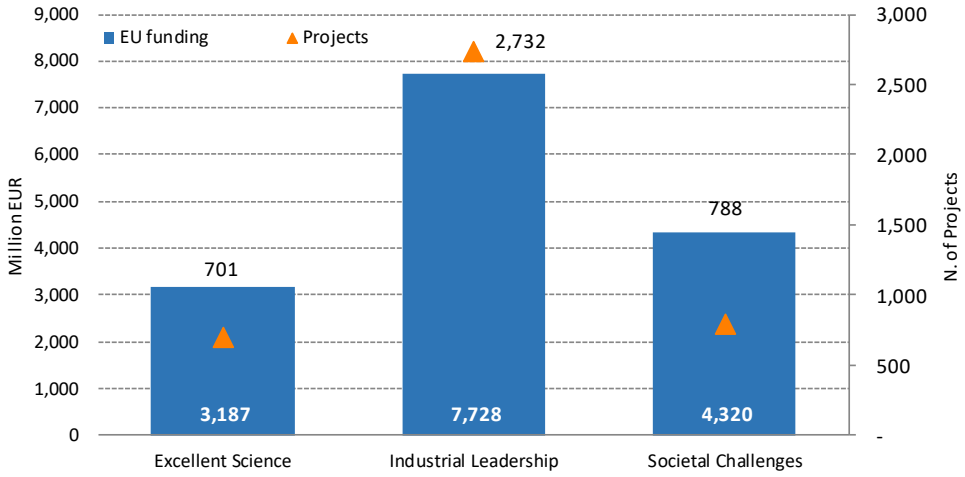
Source: European Commission services

Most of the support has been assigned through the Industrial Leadership pillar, which covers R&I activities on generic ICT technologies driven by either industrial roadmaps or bottom-up processes. This pillar, which includes the component "Leadership in Enabling and Industrial Technologies (LEIT)", accounted for about €7.7 billion, or more than half of all EU funding for ICT related projects. Industrial Leadership also accounts for about 2,700 projects (65 % of the total). Within Industrial Leadership, more than half of the projects (56 %) and of the funding (83 %) could be attributed to LEIT ICT.

The Societal Challenges pillar addresses application-driven R&I from a multi-disciplinary perspective. Projects to some extent involving ICT were financed in all of the seven societal challenges, but in particular: secure, clean and efficient energy; health, demographic change and wellbeing; and secure societies. This pillar accounted for about 28 % of EU funding (€4.3 billion) and 19 % of projects (788 projects).

The Excellent Science pillar supports research to uncover radically new technological possibilities and ICT contributions. It includes "e-infrastructures" and Future&Emerging Technologies (FET). Areas covered include high performance computing (HPC), quantum technologies and neuromorphic computing technologies. It accounted for 21 % of EU funding (€3.2 billion) and 17 % of ICT-related projects (around 700 projects).

Figure 104 EU Funding and projects by pillar, cumulated values 2014-2020



Source: European Commission services

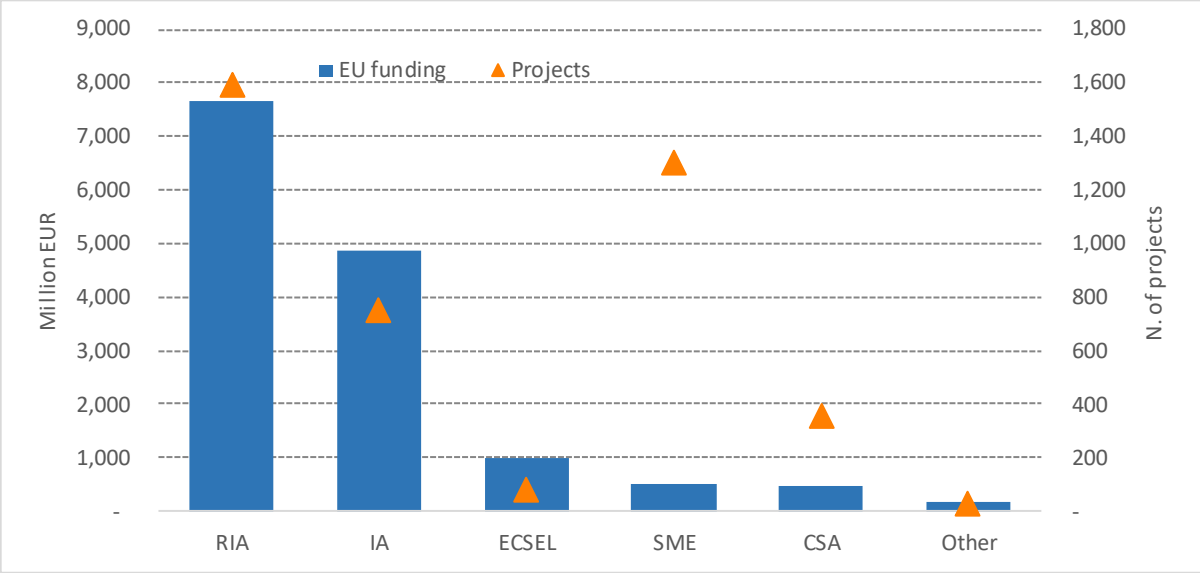
Regarding the distribution of projects and funding by type of actions, research and innovation actions (RIA) accounted for the largest share of EU funding in ICT-related projects under Horizon 2020. Between 2014 and 2020, 51 % of total EU funding was channelled through RIA, corresponding to approximately €7.8 billion. RIA aim to uncover new knowledge and/or explore the feasibility of a new or improved technology, products, processes, services or solutions.

Innovation actions (IA) are the second most important instrument in terms of funding (€4.8 billion or 32 % of total EU funding between 2014 and 2020). They aim to produce plans and arrangements or designs, and may include prototyping, testing, demonstrating, piloting, large-scale product validation and market replication.

During the same period, other important action types included:

- SME instrument projects, which accounted for about €512 million of EU funding and, given their smaller size, a large share of projects (over 1,300 or 31 % of all ICT-related projects).
- Around 80 projects were channelled through the ECSEL Joint Undertaking (i.e. the Public-Private Partnership for Electronic Components and Systems), accounting for more than €984 million (or 6 %) of the total EU funding for ICT.
- Coordination and support actions (CSA), which focus on accompanying measures such as standardisation, dissemination, awareness-raising and communication, received €453 million (3 % of the funding).
- The remaining action types, such as pre-commercial procurement (PCP), public procurement for innovation (PPI) and European research area (ERA-NET) actions, have a more limited scope of application and accounted for a limited share of both projects and funding.

Figure 105 EU Funding and projects by type of action, cumulated values 2014-2020



Source: European Commission services

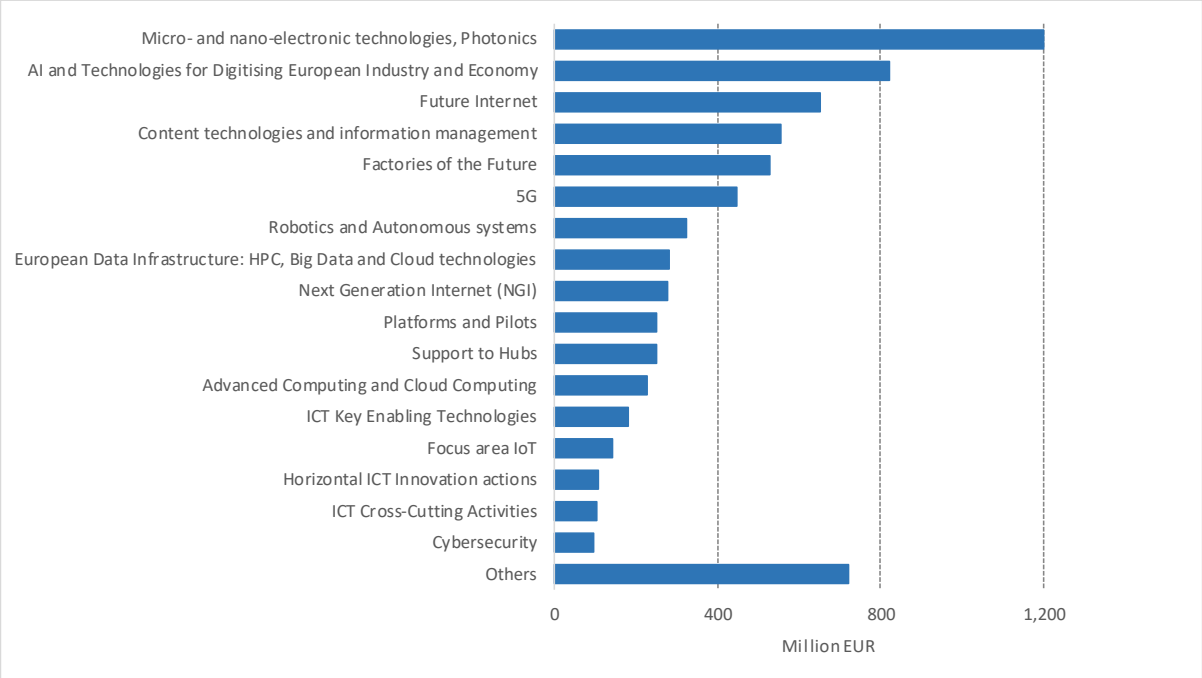
Others include: ERA-NET-Cofund; PCP; SGA-RIA; FPA; COFUND-PCP; PPI; IA-LS; COFUND-PPI.

Looking at the distribution by areas of the work programmes, within the Industrial Leadership pillar, projects under the LEIT components span across a number of areas: from micro- and nano-electronic technologies and photonics, to AI and technologies for digitising European industry, factories of the future, future internet and content technologies and information management (about €3.8 billion, taken all together). This pillar also includes the component "Innovation in SMEs", which offers opportunities for ICT SMEs.

Within Excellent Science, Future and Emerging Technologies (FET) are the major area of work. It includes: FET Open (which received approximately €940 million); FET proactive (around €617 million); and FET flagships (about €526 million). Research infrastructure, which include e-Infrastructures, also received significant funding (about €1 billion).

Under the Societal Challenges, ICT-relevant projects were mainly funded in the area of "secure, clean and efficient energy" (almost €1.8 billion between 2014 and 2020), and in the areas of "health, demographic change and wellbeing" and "secure societies" (respectively €952 million and €637 million).

Figure 106 EU funding, Industrial Leadership pillar- LEIT, by area, cumulated values 2014-2020



Source: European Commission services

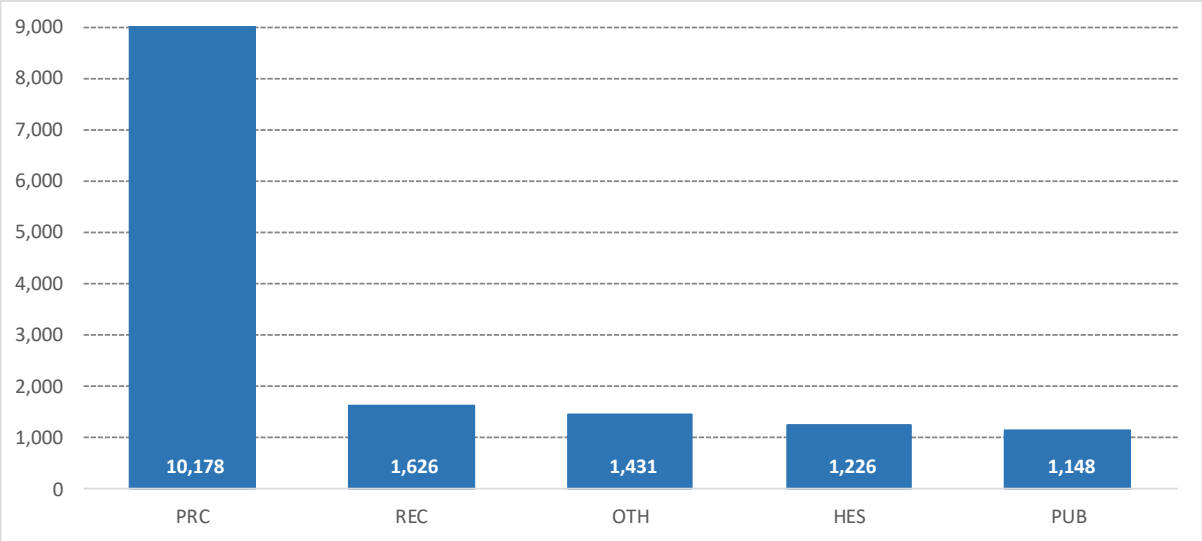
7.2 Participants and geographical distribution

Regarding participants, between 2014 and 2020 there were more than 15,600 participations in Horizon 2020 projects related to ICT topics.

Business involvement was significant, with private for-profit companies (PRC) accounting for 39 % of the funding and 65 % of participations. Secondary and higher education establishments (HES) and research organisations (REC), taken together, accounted for about 18 % of participations and almost half (i.e. 53 %) of total funding.

Public organisations (PUB) other than those involved in research and education accounted for a relatively small share of both funding and participations (about 3.7 % and 7.4 % respectively).

Figure 107 Number of participations, by category, cumulated values 2014-2020

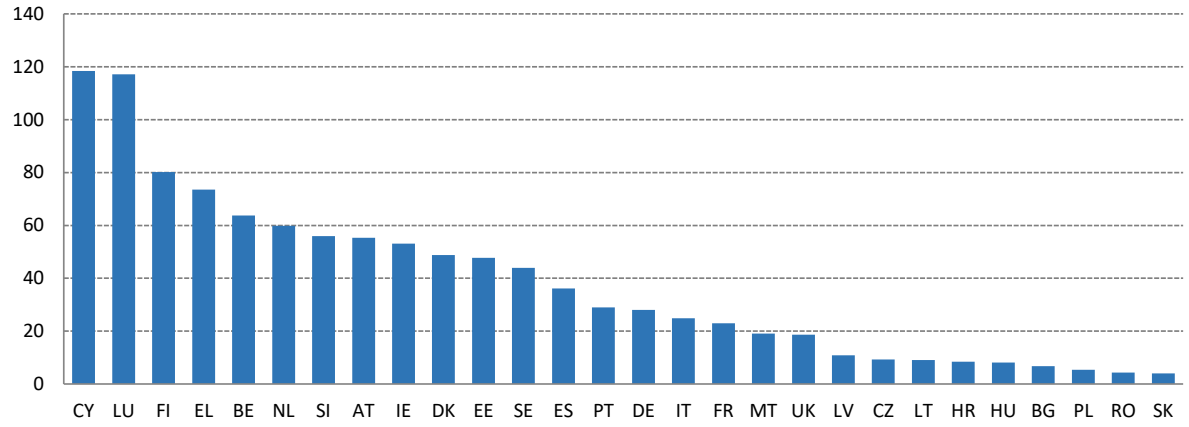


Source: European Commission services

When looking at the geographical distribution, EU-28 Member States accounted for the vast majority of funding and participations in ICT-related Horizon 2020 projects. Between 2014 and 2020, beneficiaries from EU-28 Member States accounted for 92 % of funding and 89 % of participations.

In absolute terms, the EU's largest economies were the main recipients of EU funding for ICT-related projects under Horizon 2020. Germany, Spain, France and Italy accounted for 42 % of participations and 46 % of total EU funding in the period 2014-2020. The United Kingdom was also a large beneficiary, accounting for 7.3 % of the total participations and 8.2 % of the total funding. When considering the country population, Cyprus, Luxembourg, Finland and Greece were among the Member States with the highest amounts of funding per capita.

Figure108 EU funding per capita, cumulated values 2014-2020



Source: European Commission services

The remaining share of funding and participations was mainly absorbed by Associated Counties[87]. Associated countries (primarily Switzerland, Norway and Israel) received 7.3 % of total funding, and 95 % of funding that went to non-EU 28 beneficiaries.

7.3 Methodological notes

Source: The report is based on CORDA data elaborated by DG CONNECT.

Coverage: This report considers projects supported through Horizon 2020 funding in ICT-related topics, as defined in the Commission's "Guide to ICT related activities" covering the period in the scope of the analysis (i.e. 2014-2020). Specifically, the analysis has been based on the following documents, further updated to take into consideration revisions of the Horizon 2020 Work Programmes:

- https://ec.europa.eu/programmes/horizon2020/sites/default/files/ICT%20in%20H2020%20WP2014-15_0.pdf;
- https://ec.europa.eu/programmes/horizon2020/sites/default/files/Guide%20to%20ICT-related%20activities%20in%20WP2016-17.pdf;
- https://digital-strategy.ec.europa.eu/en/library/guide-ict-related-activities-horizon-2020-work-programme-2018-20.

The Fast Track to innovation pilot and the European Innovation Council pilot are excluded from the analysis.

The report considers projects signed until 31 December 2020. Only projects for which the signature year was known at the time of writing are taken into account.

[87] Associated countries (art. 7 of the H2020 Regulation): Iceland, Norway, Albania, Bosnia and Herzegovina, the former Yugoslav Republic of Macedonia, Montenegro, Serbia, Turkey, Israel, Moldova, Switzerland (partial association: Excellent Science Pillar only), Faroe Islands.

8 DESI methodological note

The European Commission has monitored Member States' progress on digital and published annual Digital Economy and Society Index (DESI) reports since 2014. Each year, the reports include country profiles, which help Member States identify areas for priority action, and thematic chapters providing an EU-level analysis in the key digital policy areas.

In 2021, the Commission adjusted DESI to reflect the two major policy initiatives that will have an impact on digital transformation in the EU over the coming years: the Recovery and Resilience Facility and the Digital Decade Compass.

To align DESI with the four cardinal points and the targets under the Digital Compass, to improve the methodology and take account of the latest technological and policy developments, the Commission made a number of changes to the 2021 edition of the DESI. The indicators are now structured around the four main areas in the Digital Compass, replacing the previous five-dimension structure. 11 of the DESI 2021 indicators measure progress towards targets set in the Digital Compass. In future, the DESI will be aligned even more closely with the Digital Compass to ensure that all targets are discussed in the reports.

In addition, DESI now includes an indicator measuring the level of support that adopted ICT technologies provided companies in taking more environmentally-friendly measures (ICT for environmental sustainability) and the take up of gigabit services, plus the percentage of companies offering ICT training and using e-invoicing.

The DESI scores and rankings of previous years were re-calculated for all countries to reflect the changes in the choice of indicators and corrections made to the underlying data.

With the DESI, four main types of analysis are possible:

- A general performance assessment: to obtain a general characterisation of the performance of individual Member States by observing their overall index score and the scores of the main dimensions of the index.
- Zooming-in: to pinpoint the areas where Member State performance could be improved by analysing the scores of the index's sub-dimensions and individual indicators.
- Follow-up: to assess whether there is progress over time.
- Comparative analysis: to cluster Member States according to their index scores, comparing countries in similar stages of digital development in order to flag up the need for improvement in relevant policy areas.

The DESI was developed according to the guidelines and recommendations in the OECD's 'Handbook on constructing composite indicators: methodology and user guide'[88]. The data included in the index were mostly collected from the relevant authorities of the Member States by the European Commission (Directorate-General for Communications Networks, Content and Technology as well as Eurostat) and from ad hoc studies launched by the Commission.

[88] http://www.oecd.org/els/soc/handbookonconstructingcompositeindicatorsmethodologyanduserguide.htm

8.1 Structure of the DESI

The DESI has a three-level structure as depicted in the three columns in the below table.

Table 7. DESI structure

Dimension	Sub-dimension	Indicator
1 Human capital	1a Internet user skills	1a1 At least basic digital skills
		1a2 Above basic digital skills
		1a3 At least basic software skills
	1b Advanced skills and development	1b1 ICT specialists
		1b2 Female ICT specialists
		1b3 Enterprises providing ICT training
		1b4 ICT graduates
2 Connectivity	2a Fixed broadband take-up	2a1 Overall fixed broadband take-up
		2a2 At least 100 Mbps fixed broadband take-up
		2a3 At least 1 Gbps take-up
	2b Fixed broadband coverage	2b1 Fast broadband (NGA) coverage
		2b2 Fixed Very High Capacity Network (VHCN) coverage
	2c Mobile broadband	2c1 4G coverage
		2c2 5G readiness
		2c3 5G coverage
		2c4 Mobile broadband take-up
	2d Broadband prices	2d1 Broadband price index
3 Integration of digital technology	3a Digital intensity	3a1 SMEs with at least a basic level of digital intensity
	3b Digital technologies for businesses	3b1 Electronic information sharing
		3b2 Social media
		3b3 Big data
		3b4 Cloud
		3b5 AI
		3b6 ICT for environmental sustainability
		3b7 e-Invoices
	3c e-Commerce	3c1 SMEs selling online
		3c2 e-Commerce turnover
		3c3 Selling online cross-border
4 Digital public services	4a e-Government	4a1 e-Government users
		4a2 Pre-filled forms
		4a3 Digital public services for citizens
		4a4 Digital public services for businesses
		4a5 Open data

At the dimension level, DESI now addresses the four principal policy areas of the 2030 Digital Compass. These are not isolated areas that contribute separately to digital development but in fact interconnected areas. As such, developments in the digital economy and society cannot be achieved through isolated improvements in particular areas but through concerted improvement in all areas. The following sections present the list of indicators in DESI 2021.

8.1.1 Human capital dimension

Table 8. Human capital dimension

Indicator	Description	Unit	Source
1a1 At least basic digital skills	Individuals with 'basic' or 'above basic' digital skills in each of the following four dimensions: information, communication, problem solving and software for content creation (as measured by the number of activities carried out during the previous 3 months).	% individuals	Eurostat - European Union survey on ICT usage in Households and by Individuals
1a2 Above basic digital skills	Individuals with 'above basic' digital skills in each of the following four dimensions: information, communication, problem solving and software for content creation (as measured by the number of activities carried out during the previous 3 months).	% individuals	Eurostat - European Union survey on ICT usage in Households and by Individuals
1a3 At least basic software skills	Individuals who, in addition to having used basic software features such as word processing, have used advanced spreadsheet functions, created a presentation or document integrating text, pictures and tables or charts, or written code in a programming language.	% individuals	Eurostat - European Union survey on ICT usage in Households and by Individuals
1b1 ICT specialists	Employed ICT specialists. Broad definition based on the ISCO-08 classification and including jobs like ICT service managers, ICT professionals, ICT technicians, ICT installers and servicers.	% individuals in employment aged 15-74	Eurostat - Labour force survey (isoc_sks_itspt)
1b2 Female ICT specialists	Employed female ICT specialists. Broad definition based on the ISCO-08 classification and including jobs like ICT service managers, ICT professionals, ICT technicians, ICT installers and servicers.	% ICT specialists	Eurostat - Labour force survey (isoc_sks_itsps)
1b3 Enterprises providing ICT training	Enterprises who provided training in ICT to their personnel	% enterprises	Eurostat - European Union survey on ICT usage and eCommerce in Enterprises (E_ITT2)
1b4 ICT graduates	Individuals with a degree in ICT	% graduates	Eurostat (table educ_uoe_grad03, using selection ISCED11=ED5-8) and and ISCEDF_13 [F06] Information and Communication Technologies

The Human capital dimension assesses both internet user skills of citizens and advanced skills of specialists. At least basic skills, ICT specialists and Female ICT specialists measure targets of the Digital Decade Compass.

8.1.2 Connectivity dimension

Table 9. Connectivity dimension

Indicator	Description	Unit	Source
2a1 Overall fixed broadband take-up	% of households subscribing to fixed broadband	% households	Eurostat - European Union survey on ICT usage in Households and by Individuals [H_BBFIX]
2a2 At least 100 Mbps fixed broadband take-up	% of households subscribing to fixed broadband of at least 100 Mbps, calculated as overall fixed broadband take-up (source: Eurostat) multiplied with the percentage of fixed broadband lines of at least 100 Mbps (source: COCOM)	% households	European Commission, through the Communications Committee (COCOM) and Eurostat - European Union survey on ICT usage in Households and by Individuals
2a3 At least 1 Gbps take-up	% of households subscribing to fixed broadband of at least 1 Gbps, calculated as overall fixed broadband take-up (source: Eurostat) multiplied with the percentage of fixed broadband lines of at least 1 Gbps (source: COCOM)	% households	European Commission, through the Communications Committee (COCOM) and Eurostat - European Union survey on ICT usage in Households and by Individuals
2b1 Fast broadband (NGA) coverage	% of households covered by fixed broadband of at least 30 Mbps download. The technologies considered are FTTH, FTTB, Cable Docsis 3.0 and VDSL	% households	Broadband coverage in Europe studies for the European Commission by IHS Markit, Omdia and Point Topic
2b2 Fixed Very High Capacity Network (VHCN) coverage	% of households covered by any fixed VHCN. The technologies considered are FTTH and FTTB for 2015-2018 and FTTH, FTTB and Cable Docsis 3.1 for 2019 onwards	% households	Broadband coverage in Europe studies for the European Commission by IHS Markit, Omdia and Point Topic
2c1 4G coverage	% of populated areas with coverage by 4G	% populated areas	Broadband coverage in Europe studies for the European Commission by IHS Markit, Omdia and Point Topic
2c2 5G readiness	The amount of spectrum assigned and ready for 5G use within the so-called 5G pioneer bands. These bands are 700 MHz (703-733 MHz and 758-788 MHz), 3.6 GHz (3400-3800 MHz) and 26 GHz (1000 MHz within 24250-27500 MHz). All three spectrum bands have an equal weight	Assigned spectrum as a % of total harmonised 5G spectrum	European Commission services, through the Communications Committee (COCOM)
2c3 5G coverage	% of populated areas with coverage by 5G	% populated areas	Broadband coverage in Europe studies for the European Commission by IHS Markit, Omdia and Point Topic
2c4 Mobile broadband take-up	Individuals who used a mobile phone (or smart phone) to access the internet	% individuals	Eurostat - European Union survey on ICT usage in Households and by Individuals [I_IUMP]
2d1 Broadband price index	The broadband price index measures the prices of representative baskets of fixed, mobile and converged broadband offers	Score (0-100)	Broadband retail prices study, annual studies for the European Commission realised by Empirica

Under Connectivity, both fixed and mobile broadband are analysed with indicators measuring the supply and the demand side as wells as retail prices. Fixed VHCN and 5G coverage measure targets of the Digital Decade Compass.

8.1.3 Integration of digital technology dimension

Table 10. Integration of digital technology dimension

Indicator	Description	Unit	Source
3a1 SMEs with at least a basic level of digital intensity	The digital intensity score is based on counting how many out of 12 selected technologies are used by enterprises. A basic level requires usage of at least 4 technologies.	% SMEs	Eurostat - European Union survey on ICT usage and eCommerce in Enterprises
3b1 Electronic information sharing	Enterprises who have in use an ERP (enterprise resource planning) software package to share information between different functional areas (e.g. accounting, planning, production, marketing)	% enterprises	Eurostat - European Union survey on ICT usage and eCommerce in Enterprises (E_ERP1)
3b2 Social media	Enterprises using two or more of the following social media: social networks, enterprise's blog or microblog, multimedia content sharing websites, wiki-based knowledge sharing tools. Using social media means that the enterprise has a user profile, an account or a user license depending on the requirements and the type of the social media.	% enterprises	Eurostat - European Union survey on ICT usage and eCommerce in Enterprises (E_SM1_GE2)
3b3 Big data	Enterprises analysing big data from any data source	% enterprises	Eurostat - European Union survey on ICT usage and eCommerce in Enterprises (E_BDA)
3b4 Cloud	Enterprises purchasing at least one of the following cloud computing services: hosting of the enterprise's database, accounting software applications, CRM software, computing power	% enterprises	Eurostat - European Union survey on ICT usage and eCommerce in Enterprises (E_CC_GE_ME)
3b5 AI	Enterprises using at least 2 AI technologies	% enterprises	European enterprise survey on the use of technologies based on artificial intelligence by Ipsos and iCite
3b6 ICT for environmental sustainability	The indicator measures the level of support that adopted ICT technologies offered to enterprises to engage in more environmentally-friendly actions. The level of intensity is measured based on the number of environmental actions (maximum 10) reported by enterprises to have been facilitated by the use of ICT. The following categorisation was achieved: low intensity (0 to 4 actions), medium intensity (5 to 7 actions) and high intensity (8 to 10 actions).	% enterprises having medium/high intensity of green action through ICT	Survey of businesses on the use of digital technologies by Ipsos and iCite
3b7 e-Invoices	Enterprises sending e-invoices, suitable for automated processing	% enterprises	Eurostat - European Union survey on ICT usage and eCommerce in Enterprises (E_INV4S_AP)
3c1 SMEs selling online	SMEs selling online (at least 1% of turnover)	% SMEs	Eurostat - European Union survey on ICT usage and eCommerce in Enterprises (E_ESELL)
3c2 e-Commerce turnover	SMEs' total turnover from e-commerce	% SME turnover	Eurostat - European Union survey on ICT usage and eCommerce in Enterprises (E_ETURN)
3c3 Selling online cross-border	SMEs that carried out electronic sales to other EU countries	% SMEs	Eurostat - European Union survey on ICT usage and eCommerce in Enterprises (E_AESEU)

The Integration of digital technology dimension is made up of 3 sub-dimensions: digital intensity, take-up of selected technologies by enterprises and e-commerce. SMEs with at least a basic level of digital intensity, take-up of Big data, Cloud and AI are targets of the Digital Decade Compass.

8.1.4 Digital public services dimension

Table 11. Digital public services dimension

Indicator	Description	Unit	Source
4a1 e-Government users	Individuals who used the Internet, in the last 12 months, for interaction with public authorities	% internet users	Eurostat - European Union survey on ICT usage in Households and by Individuals (I_IUGOV12)
4a2 Pre-filled forms	Amount of data that is pre-filled in public service online forms	Score (0 to 100)	eGovernment Benchmark
4a3 Digital public services for citizens	The share of administrative steps that can be done online for major life events (birth of a child, new residence, etc.) for citizens	Score (0 to 100)	eGovernment Benchmark
4a4 Digital public services for businesses	The indicator broadly reflects the share of public services needed for starting a business and conducting regular business operations that are available online for domestic as well as foreign users. Services provided through a portal receive a higher score, services which provide only information (but have to be completed offline) receive a more limited score.	Score (0 to 100)	eGovernment Benchmark
4a5 Open data	This composite indicator measures to what extent countries have an open data policy in place (including the transposition of the revised PSI Directive), the estimated political, social and economic impact of open data and the characteristics (functionalities, data availability and usage) of the national data portal.	% maximum score	European data portal

The Digital public services dimension describes the demand and supply of e-government as well as open data policies. The Digital public services for citizens and businesses indicators assess targets of the Digital Decade Compass.

8.1.5 Data sources

Most of the data in the DESI have been collected directly by national authorities. The below table presents the data sources and the role of national authorities in data collection and validation.

Table 12. Data sources and the role of national authorities

Data source	Data collection process
Eurostat	Data collected and verified by the national statistical offices or by Eurostat.
Communications Committee (COCOM)	Data collected and verified by the national regulatory authorities (by data experts appointed by the members of the Communications Committee in every Member State).
Broadband coverage studies	Data collected by IHS Markit, Omdia and Point Topic and verified by the national regulatory authorities (by data experts appointed by the members of the Communications Committee in every Member State).
Retail broadband prices studies	Data collected by Empirica and verified by the national regulatory authorities (by data experts appointed by the members of the Communications Committee in every Member State).
e-Government benchmark	Data collected by Capgemini and verified by relevant ministries in every Member State.
Survey of businesses on the use of digital technologies	Data collected by Ipsos and iCite, survey results have been reviewed by the Digital Single Market Strategic Group.
European data portal	Data collected by Capgemini from representatives appointed by the relevant ministries in every Member State.

It is important to note that the Commission organises two technical workshops annually under the Digital Single Market Strategic Group to discuss the future evolution of data collections and the index. Changes made in DESI 2021 have been agreed with Member States in the Strategic Group.

8.1.6 Data flags

A limited number of data points include explanatory notes (data flags), which can be consulted directly on the website of Eurostat at https://ec.europa.eu/eurostat/web/digital-economy-and-society.

8.2 Methodological considerations

8.2.1 Indicator requirements

Indicators used in the DESI comply with the following requirements:

- *Must be collected on a regular basis*. In order to fulfil the monitoring function, the indicators used in the index must be collected ideally on a yearly basis (or at least with a pre-defined regularity).
- *Must be relevant for a policy area of interest*. All indicators in the index must be accepted as relevant metrics in their specific policy areas.
- *Must not be redundant*. The index should not contain redundant indicators, either statistically or in terms of interpretation.

8.2.2 Data updates and corrections

Updates and corrections are part of the lifecycle and nature of statistical data. It is typical that the values for one indicator suffer small amendments and only stabilise completely months or even years after the indicator was originally computed. This is the case for a significant number of indicators used in the construction of the DESI.

At each publication, historical data are also reviewed to accommodate such changes. The current report takes account of changes notified to the European Commission before 31 August 2021. Any modification made after this date will be included in the next report, which is expected in 2022.

8.2.3 Normalisation

In order to aggregate indicators expressed in different units into the sub-dimensions and dimensions of the DESI, those indicators were normalised. In DESI, normalisation was done using the *min-max* method, which consists in a linear projection of each indicator onto a scale between 0 and 1. For indicators with positive direction (i.e. where higher is better), the 0 value in the normalised scale was anchored to the minimum value in the indicator original scale, and the value 1 in the normalised scale was anchored to the maximum value in the indicator's scale.

To allow for inter-temporal comparisons of index scores, the minima and maxima for the normalisation of each indicator were fixed and will be used for normalisation in the future versions of the DESI. Table 7 presents the values that were chosen as the minimum and maximum of each indicator for normalisation purposes.

Due to the choice of normalisation minima and maxima that are fixed over time, the values of one or another indicator may surpass the indicator's normalisation maximum or fall below its minimum in the future. The score for such values will become higher than 1 or lower than 0 respectively. While this is not a major methodological concern, the choice of minima and maxima was performed carefully, taking into account the likely evolution of each indicator and the balance between indicators, in an attempt to minimise the occurrence of such events.

Table 13. Minima and maxima used in indicator normalisation

Indicator	Minima	Maxima
1a1 At least basic digital skills	0%	100%
1a2 Above basic digital skills	0%	66%
1a3 At least basic software skills	0%	100%
1b1 ICT specialists	0%	10%
1b2 Female ICT specialists	0%	50%
1b3 Enterprises providing ICT training	0%	50%
1b4 ICT graduates	0%	10%
2a1 Overall fixed broadband take-up	50%	100%
2a2 At least 100 Mbps fixed broadband take-up	0%	100%
2a3 At least 1 Gbps take-up	0%	50%
2b1 Fast broadband (NGA) coverage	25%	100%
2b2 Fixed Very High Capacity Network (VHCN) coverage	0%	100%
2c1 4G coverage	40%	100%
2c2 5G readiness	0%	100%
2c3 5G coverage	0%	100%
2c4 Mobile broadband take-up	0%	100%
2d1 Broadband price index	25	100
3a1 SMEs with at least a basic level of digital intensity	25%	100%
3b1 Electronic information sharing	0%	60%
3b2 Social media	0%	50%
3b3 Big data	0%	75%
3b4 Cloud	0%	75%
3b5 AI	0%	75%
3b6 ICT for environmental sustainability	30%	100%
3b7 e-Invoices	0%	100%
3c1 SMEs selling online	0%	50%
3c2 e-Commerce turnover	0%	33%
3c3 Selling online cross-border	0%	25%
4a1 e-Government users	0%	100%
4a2 Pre-filled forms	0	100
4a3 Digital public services for citizens	35	100
4a4 Digital public services for businesses	40	100
4a5 Open data	0%	100%

8.2.4 Imputation of missing observations

Some indicators presented missing observations for some countries. Values for those observations were estimated using different methodologies, such as:

- using available figures from the previous year,
- using available figures from the following year,
- using proxy indicators to identify trends to complete time series.

In DESI 2021, 0.2% of all observations were imputed.

8.2.5 Weights

The four dimensions of the Digital Compass are of equal importance, which is reflected in the equal weights of each dimension.

Table 14. Weights attributed to the DESI dimensions

Dimension	Weight
1 Human capital	25%
2 Connectivity	25%
4 Integration of digital technology	25%
5 Digital public services	25%

Weights were also assigned at the sub-dimension and individual indicator level. Compared to the previous edition of the report, Mobile broadband has a higher weight, as 5G coverage is now included in the index. For the Integration of digital technology dimension, a new sub-dimension has been added to report on the target on digital intensity. In addition, the weight of the Digital technologies for businesses sub-dimension has been increased, as this sub-dimension includes 3 indicators measuring targets of the Digital Decade Compass.

Table 15. Weights attributed to the DESI sub-dimensions

Sub-dimension		Weight
1 Human capital		
	1a Internet user skills	50%
	1b Advanced skills and development	50%
2 Connectivity		
	2a Fixed broadband take-up	25%
	2b Fixed broadband coverage	25%
	2c Mobile broadband	40%
	2d Broadband prices	10%
3 Integration of digital technology		
	3a Digital intensity	15%
	3b Digital technologies for businesses	70%
	3c e-Commerce	15%
4 Digital public services		
	4a e-Government	100%

The majority of individual indicators within each sub-dimension were considered of equal importance and therefore weighted equally within the respective sub-dimension. However, indicators measuring the targets of the 2030 Digital Compass were considered as having higher importance and they therefore have double weights within their sub-dimension. These indicators are presented in the below table.

Table 16. DESI indicators with double weights

1 Human capital	At least basic digital skills ICT specialists Female ICT specialists
2 Connectivity	Gigabit for everyone (Fixed very high capacity networks coverage) 5G coverage
3 Integration of digital technology	SMEs with a basic level of digital intensity AI Cloud Big data
4 Digital public services	Digital public services for citizens Digital public services for businesses

8.2.6 Method of aggregation

In DESI, the aggregation of indicators into sub-dimensions, of sub-dimensions into dimensions, and of dimensions into the overall index was performed from the bottom up using simple weighted arithmetic averages following the structure of the index (Table 7).

As an example, the top-level DESI score for country C was calculated using the formula:

*DESI(C) = Human_capital(C) * 0.25 + Connectivity(C) * 0.25 + Integration_of_Digital_Technology(C) * 0.25 + Digital_Public_Services(C) * 0.25*

Where $Connectivity(C)$ is the score obtained by country C in the Connectivity dimension.

Annex 1 Methodology for the Broadband price index indicator

Scope

The Broadband price index includes all the baskets identified in the Broadband retail prices study by Empirica. It covers 34 baskets altogether:

- 13 with fixed services only,
- 12 with mobile service only and
- 9 with converged fixed and mobile services.

Treatment of outliers

For the data series of each basket, the skewness and kurtosis tests are performed. When the absolute value of skewness is larger than 2 and kurtosis is larger than 3.5, the outliers are treated.

Normalisation

The min-max approach is used to normalise data for each basket separately. Minimum and maximum values were fixed based on the 2019 data and were computed as follows:

- Minimum: Actual minimum value in the basket multiplied by 0.75.
- Maximum: Actual maximum value in the basket multiplied by 1.25.

Minimum and maximum values have not been updated based on the 2020 data to avoid updating 2019 figures. All prices are normalised to a score between 0 and 100, where 100 is the best performance.

Aggregation and missing data

The Broadband price index score is calculated as the arithmetic average of the normalised scores for all baskets in each member state. When data is not available (as no such offers exist that meet the criteria of a given basket), missing data is not estimated, so the index score is calculated based on the available baskets.

Annex 2 Abbreviations

Abbreviation	Explanation
4G / 5G	Fourth/Fifth generation technology standard for cellular networks
AI	Artificial Intelligence
BCO	Broadband competence office
BERD	Business expenditure on R&D
CAGR	Compound annual growth rate
CEF	Connecting Europe Facility
CRM	Customer Relationship Management
CSA	Coordination and Support Actions
DIH	Digital Innovation Hubs
DII	Digital Intensity Index
DOCSIS	Data over cable service interface specification
DSL	Digital subscriber line
DTT	Digital terrestrial television
EBP	European Blockchain Partnership
EBSI	European Blockchain Services Infrastructure
eForm	Electronic Form
EFSI	European Fund for Strategic Investments
eID	Electronic Identification
eider's	Electronic Identification, Authentication and Trust Services
EIF	European Investment Fund
ERA-NET	European Research Area
ERM	Enterprise Risk Management
ERP	Enterprise Resource Planning
Euro HPC JU	Euro High Performance Computing Joint Undertaking
FET	Future & Emerging Technologies
FTTB	Fibre-to-the-building
FTTH	Fibre-to-the-home
FTTP	Fibre-to-the-premises
FWA	Fixed wireless access
GBARD	Government Budget Allocations for R&D
GDP	Gross Domestic Product
GHz	Gigahertz
HES	Secondary and Higher Education Establishments
HPC	High Performance Computing
IA	Innovation Action
IaaS	Infrastructure as a service
ICOs	Initial Coin Offerings
ICT	Information and communication technology
IMSI	International mobile subscriber identity
IoT	Internet of Things
JRC	Joint Research Centre
LEIT	Leadership in Enabling and Industrial Technologies
LTE	Long-term evolution
Mbps	Megabits per second
MHz	Megahertz
MNO	Mobile network operator

MVNO	Mobile virtual network operator
NACE	Statistical Classification of Economic Activities in the European Community
NBP	National broadband plan
NGA	Next generation access
NRA	National regulatory authority
OTT	Over-the-top
PaaS	Platform as a Service
PCP	Pre-Commercial Procurement
PERD	R&D personnel
PPI	Public Procurement for Innovation
PPS	Purchasing Power Standards
PRC	Private for-Profit Companies
PSAP	Public safety answering point
QCI	Quantum Communication Infrastructure
R&D	Research and Development
R&I	Research and Innovation
REC	Research Organisations
RRF	Recovery and Resilience Facility
RRP	Recovery and Resilience Plan
SaaS	Software as a Service
SMEs	Small and Medium Enterprises
USO	Universal service obligation
VDSL	Very-high-bit-rate digital subscriber line
VHCN	Very high capacity network