OECD Digital Economy Outlook 2024 (Volume 2)

STRENGTHENING CONNECTIVITY, INNOVATION AND TRUST

OECD

OECD Digital Economy Outlook 2024 (Volume 2)

STRENGTHENING CONNECTIVITY, INNOVATION AND TRUST

OECD
BETTER POLICIES FOR BETTER LIVES

Please cite this publication as:
OECD (2024), *OECD Digital Economy Outlook 2024 (Volume 2): Strengthening Connectivity, Innovation and Trust*, OECD Publishing, Paris, *https://doi.org/10.1787/3adf705b-en*.

ISBN 978-92-64-45881-9 (print)
ISBN 978-92-64-59635-1 (PDF)
ISBN 978-92-64-18948-5 (HTML)
ISBN 978-92-64-84877-1 (epub)

Photo credits: Cover design by Fabio Parmeggiani using images from © Metamorworks/Shutterstock.com and © Omelchenko/Shutterstock.com.

Corrigenda to OECD publications may be found at: *https://www.oecd.org/en/publications/support/corrigenda.html*.

Foreword

The *OECD Digital Economy Outlook* (*DEO*) is a flagship publication that analyses trends in technology development, digital policies and digital performance in OECD countries and partner economies. The 2024 edition draws on indicators from the OECD Going Digital Toolkit, the OECD *ICT Access and Usage* database, the OECD *Broadband Statistics* database, and the OECD AI Policy Observatory, among other data. It also benefits from responses to the *DEO* Questionnaire and the OECD Connectivity Services and Infrastructures Questionnaires that provide insights into digital priorities and policies in OECD countries and partner economies.

This edition is prepared in two volumes. *Volume 2* examines digital priorities, policies and governance arrangements. It then considers the foundations of digital transformation, analysing trends in access and connectivity, as well as the skills needed to thrive in the digital age. *Volume 2* also explores how to push out the digital technology frontier by harnessing the untapped potential of women and how to use digital technologies to reach net-zero targets and protect the planet. Finally, *Volume 2* considers trust in digital environments by analysing digital security trends and presenting new evidence on media consumption, attitudes towards privacy and control over personal data, and information integrity.

The *DEO 2024* represents the collective work of staff in the Digital Connectivity, Economics and Society Division and the Artificial Intelligence and Emerging Digital Technologies Division of the OECD Directorate for Science, Technology and Innovation (STI). The Secretariat prepared *Volume 2* under the auspices of the OECD Digital Policy Committee (DPC), chaired by Yoichi Iida (Japan). The publication benefited from valuable comments from delegates to the DPC and its Working Parties. The DPC declassified *Volume 2* content on 4 April 2024 and 6 September 2024.

Molly Lesher (Senior Economist and Acting Head of Division) led the orientations and development of this publication with support from Elif Koksal-Oudot (Economist) under the leadership of Audrey Plonk (Deputy Director).

The authors are Louis Holt, Molly Lesher and Elif Koksal-Oudot (Chapter 1: “Digital priorities, policies and governance”); Alexia González Fanfalone and Frédéric Bourassa (Chapter 2: “Trends in access and connectivity”); Elif Koksal-Oudot (Spotlight “Skills for the digital age”); Celine Caira, Johannes Kirnberger and Alexia González Fanfalone (Chapter 3: “Digital technologies and the environment”); Hanna Pawelec and Molly Lesher (Spotlight “The potential of women for digital innovation”); Bénédicte Schmitt and Laurent Bernat (Chapter 4: “Key trends in digital security”); Molly Lesher and Hanna Pawelec (Spotlight “Media consumption and privacy”); and Frédéric Bourassa and Pierre Montagnier (Statistical Annex).

The following OECD colleagues provided valuable input to *Volume 2* in their respective areas of expertise: Hanna Pawelec (Chapter 1); Verena Weber (Chapter 2); Luis Aranda, Marc Fuster Rabella, Glenda Quintini and Angelica Salvi del Pero (Spotlight on skills); Sarah Bérubé and Hanna Pawelec (Chapter 3); Willem Adema, Marius Berger, Celine Caira, Hélène Dernis, Milenko Fadic, Akash Kohli, Laurent Moussiegt, Valentina Patrini, Ricardo Chiapin Pechansky and Lucia Russo (Spotlight on women and digital innovation); Jeremy West (Chapter 4); Giorgia Bergamo, Achim Edelmann, Kinga Makovi, Craig Matasick and Christian Müller (Spotlight on media consumption and privacy); and Giorgia Bergamo, Alexia González Fanfalone and Elif Koksal-Oudot (Statistical Annex).

The publication benefited from comments, support and input by Jerry Sheehan (Director), Jens Lundsgaard (Deputy Director), Hanna-Mari Kilpeläinen (Senior Counsellor) and Gallia Daor (Senior Advisor) of STI.

Angela Gosmann and Mark Foss provided editorial support. Andreia Furtado and Sebastian Ordelheide led the communications strategy. Julian Jaramillo, Paola Avellaneda and Diego Pinilla (Bestiario) created the data visualisations and infographics. Fabio Parmeggiani provided design support. Marion Barberis, Sarah Ferguson, Shellie Phillips and Alice Weber provided secretarial assistance.

Table of Contents

Reader's guide

Acronyms

5G	Fifth generation of wireless cellular technology
6G	Sixth generation of wireless cellular technology
ACMA	Australian Communications and Media Authority
AI	Artificial intelligence
CAGR	Compound annual growth rate
DEO	*Digital Economy Outlook*
DMA	Digital Markets Act (European Commission)
DSA	Digital Services Act (European Commission)
EECC	European Electronic Communications Code
ENISA	European Network and Information Security Agency
ESG	Environmental, social and governance
EU	European Union
EUR	Euro
FCC	Federal Communications Commission (United States)
FHE	Fully homomorphic encryption
GDP	Gross domestic product
GHG	Global greenhouse gas
GIS	Geographic information system
ICT	Information and communication technology
IEA	International Energy Agency
IMF	International Monetary Fund
IoT	Internet of Things
ITU	International Telecommunication Union
MNO	Mobile network operator
MSP	Managed service provider
MSSP	Managed security service provider
NDS	National digital strategy
NIST	National Institute of Standards and Technology (United States)
PIAAC	Programme for the International Assessment of Adult Competencies (OECD)
PISA	Programme for International Student Assessment (OECD)
pp	Percentage point
QKD	Quantum key distribution
QRC	Quantum-resistant cryptography
R&D	Research and development
RAN	Radio access network
SDG	Sustainable Development Goal (United Nations)
SMEs	Small and medium-sized enterprises
STEM	Science, technology, engineering and mathematics
TIEC	Technology Innovation and Entrepreneurship Center
UN	United Nations
UNITAR	United Nations Institute for Training and Research
USD	United States dollar
VC	Venture capital
W	Watts

WEEE Waste from electrical and electronic equipment
WLAN Wireless local area networks
WMO World Meteorological Organization

Country groupings

Euro Area Austria, Belgium, Croatia, Cyprus, Estonia, Finland, France, Germany, Greece, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, the Netherlands, Portugal, the Slovak Republic, Slovenia and Spain.

EU Austria, Belgium, Bulgaria, Croatia, Cyprus, the Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, the Netherlands, Poland, Portugal, Romania, the Slovak Republic, Slovenia, Spain and Sweden.

G7 Canada, France, Germany, Italy, Japan, the United Kingdom and the United States.

G20 Argentina, Australia, Brazil, Canada, the People's Republic of China, France, Germany, India, Indonesia, Italy, Japan, Mexico, the Russian Federation, Saudi Arabia, South Africa, Korea, Türkiye, the United Kingdom, the United States, the African Union and the European Union.

OECD Austria, Australia, Belgium, Canada, Chile, Colombia, Costa Rica, the Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Israel, Italy, Japan, Korea, Latvia, Lithuania, Luxembourg, Mexico, the Netherlands, New Zealand, Norway, Poland, Portugal, the Slovak Republic, Slovenia, Spain, Sweden, Switzerland, Türkiye, the United Kingdom and the United States.

Abbreviations

For most charts, this publication uses ISO codes for countries or economies.

ARG	Argentina	IND	India
AUS	Australia	IRL	Ireland
AUT	Austria	ISL	Iceland
BEL	Belgium	ITA	Italy
BEL-FR	Belgium (French speaking)	JOR	Jordan
BEL-NL	Belgium (Flemish speaking)	JPN	Japan
BGR	Bulgaria	KOR	Korea
BRA	Brazil	LTU	Lithuania
CAN	Canada	LUX	Luxembourg
CHE	Switzerland	LVA	Latvia
CHL	Chile	MEX	Mexico
COL	Colombia	MLT	Malta
CRI	Costa Rica	NLD	Netherlands
CYP	Cyprus	NOR	Norway
CZE	Czech Republic	NZL	New Zealand
DEU	Germany	PER	Peru
DNK	Denmark	POL	Poland
EGY	Egypt	PRT	Portugal
ESP	Spain	ROU	Romania
EST	Estonia	SVK	Slovak Republic
FIN	Finland	SVN	Slovenia
FRA	France	SWE	Sweden
GBR	United Kingdom	THA	Thailand
GRC	Greece	TUR	Türkiye
HRV	Croatia	UKR	Ukraine
HUN	Hungary	USA	United States
IDN	Indonesia	ZAF	South Africa

Executive Summary

Rapid technological changes characterise the most recent phase of digital transformation, bringing opportunities and risks for the economy and society. *Volume 1* of the *OECD Digital Economy Outlook 2024* offered insights on key technologies that underpin digital transformation and their impacts. *Volume 2* examines new directions in digital priorities, policies and governance across countries. It further analyses trends in the foundations that support digital transformation, drive digital innovation and foster trust in the digital age. A Statistical Annex completes the volume.

Key findings

National digital strategies are changing quickly, with dedicated digital ministries playing a more important role in their design and co-ordination

Digital government, connectivity and skills were the top three digital policy priorities in 2023 for 38 OECD countries and partner economies. National digital strategies, increasingly developed at a high level of government, are the primary approach to co-ordinating digital policies. A dedicated digital ministry designed almost half of the national digital strategies of the 38 countries surveyed in 2023, up from just under a quarter in 2016. Among the almost 1 200 policy initiatives collected across OECD countries and partner economies in 2023, about one-third aim to increase effective use of digital technologies, promote social prosperity and boost innovation. Artificial intelligence (AI) and 5G are the most often-cited technologies.

Demand for high-quality and affordable connectivity is rising, and countries increasingly prioritise network security, resilience and environmental sustainability

The demand for high-quality and affordable broadband services continues to increase. Over the last decade, fibre was the fastest growing fixed broadband access technology in OECD countries and it is now dominant. Deployment of 5G continues, while mobile data usage per subscription in OECD countries almost tripled from 2018 to 2023. Affordability, availability and quality are key aspects of bridging connectivity divides. People living in cities (metropolitan areas) in OECD countries faced median fixed broadband download speeds 50% higher than people living in regions far from metropolitan areas in Q4 2023. Alongside promoting the transition to more future-proof networks and addressing divides, policy priorities include addressing changes to market structures and ensuring secure, resilient and environmentally sustainable communication networks.

Foundational, information and communication technology, as well as complementary skills, are essential to thrive in the digital age

Foundational skills are a prerequisite for the effective use of digital technologies. The share of top-performing 15-year-old students in science, mathematics and reading decreased from 4% in 2012 to 3% in 2022 in OECD countries. Information and communication technology (ICT) skills strengthen the ability to cope with change and to keep learning. Complementary skills can significantly enhance individuals' effectiveness and productivity. Technological progress in AI and robotics will further transform skills demand. Policy makers should encourage investments in education and training systems; promote lifelong learning; facilitate access to training resources; recognise non-traditional forms of learning; attract talent through visa programmes and scholarships; and engage in public-private partnerships.

Technological innovations offer solutions to reach net-zero targets and protect the planet

The digital and green "twin transitions" should be harnessed to protect the planet. Digital technologies such as the Internet of Things (IoT) and digital twins enabled by AI can improve energy efficiency, reduce costs and accelerate innovation across energy grids and supply chains. Communication infrastructures and services are needed to deploy technologies like smart electrical grids and IoT-based precision agriculture, which support decarbonisation. Such infrastructures and services also have an environmental footprint that needs to be minimised. Sectors such as global transportation systems stand to benefit from digital technologies that help reduce environmental impacts through fuel efficiency gains, predictive maintenance and shared mobility, as well as by low-carbon transport systems and multimodal mobility services.

Women are an untapped source of digital innovation

In 2023, women represented 11-24% of all ICT specialists in OECD countries. Women also contributed to significantly fewer ICT-related patents and started fewer ICT businesses. On average across the OECD, merely 4% of ICT-related patent families were attributed to women (only) and 20% were attributed to at least one woman in 2018-21. On average over the last two decades, 6% of start-ups in digital-related activities in OECD countries funded by venture capital were founded by women (only) and 15% were founded by at least one woman. Action is needed to encourage women to develop the skills needed to work in ICT and digital-intensive sectors, nurture female entrepreneurship and help women become ICT inventors.

New policy approaches and evolutions in cryptography and quantum information technologies hold promise for making digital environments safer

Addressing the multifaceted challenges of digital security requires mitigating risks posed by managed service providers, which have become a systemic risk in global supply chains. A wide range of approaches to certifications and labels for product and service security likewise represents another important part of reducing digital security risk by increasing market transparency and trust in digital environments. Technological advances in quantum information technologies also hold promise to strengthen digital security, but their potential to break some of today's widely used encryption methods poses risks to cryptography.

Age influences media consumption and trust; most people are concerned about privacy on line and a rethink of approaches to media literacy is needed

Data from the 2024 OECD Truth Quest Survey show that those aged 18-24 are 25 percentage points more likely to source and 20 percentage points more likely to trust information from social media than those aged 65 and older. On average across countries, those who trust information on social media a lot demonstrated lower ability to identify its veracity (54%) compared to those who trust information on social media somewhat (59%) and not much or not at all (62%). Over half the individuals surveyed avoid using certain websites, applications or social media due to privacy concerns, and one-third feel they do not have control over their personal data. Reading more context about a headline does not always increase the odds of correctly identifying its veracity, raising questions about the design of media literacy initiatives.

Chapter 1

Digital priorities, policies and governance

Digital technologies and data affect all sectors of the economy and every aspect of life. As such, it becomes more important and challenging to develop, implement and co-ordinate flexible policy frameworks that make the most of the opportunities of digital technologies while mitigating their risks. Using the Going Digital Integrated Policy Framework as a guide, as well as the responses to the *OECD Digital Economy Outlook (DEO) 2024* Questionnaire, this chapter examines trends in digital policy priorities across countries. It analyses national digital strategies in the countries for which they exist and the governance approaches in place to design, implement and monitor them. Finally, it explores the broader digital policy landscape across countries.

Digital policies are fast changing and highly prioritised

National digital strategies are on the rise.

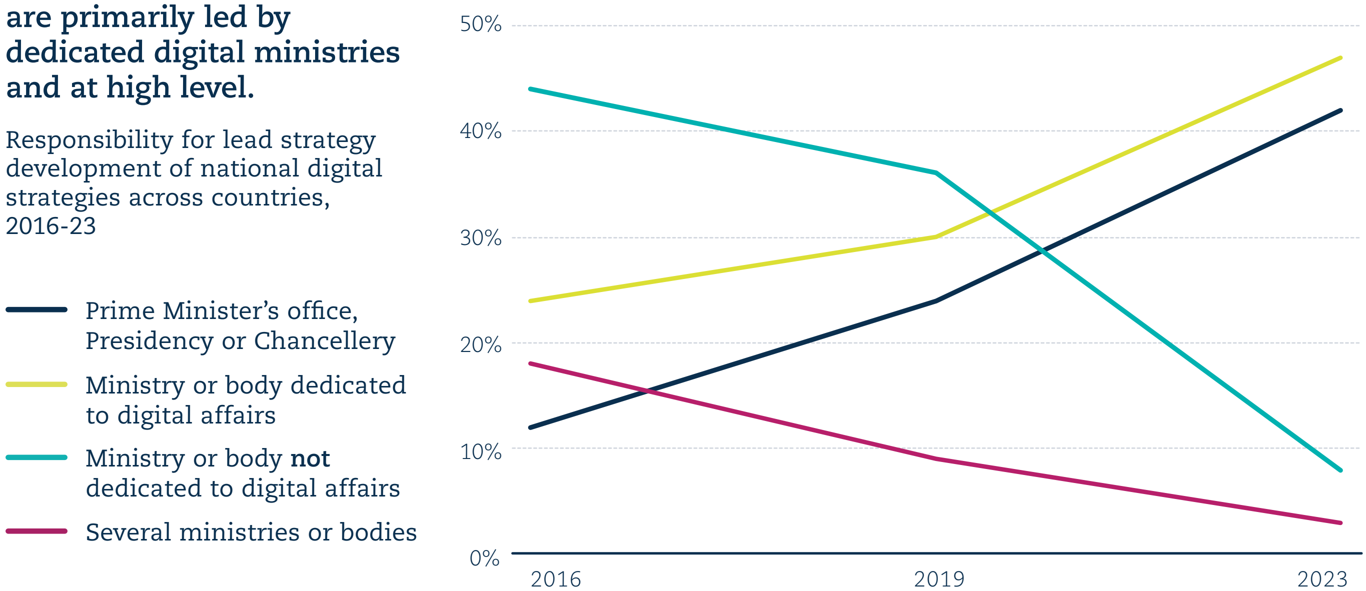
In 2023, over

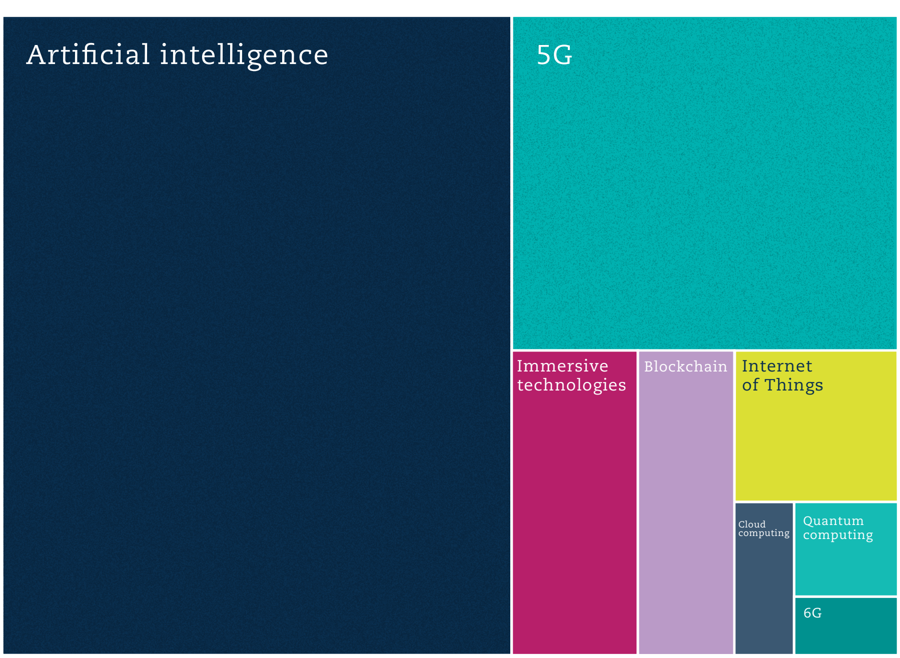
90% of countries

had a national digital strategy or were developing one.

National digital strategies are primarily led by dedicated digital ministries and at high level.

Responsibility for lead strategy development of national digital strategies across countries, 2016-23





AI and 5G dominate the digital policy landscape.

Emerging technologies and related terms cited in digital policy initiatives, 2023

- Artificial intelligence
- 5G
- Immersive technologies
- Blockchain
- Internet of Things
- Cloud computing
- Quantum computing
- 6G

Key findings

Despite the many changes brought about by digital technologies, digital policy priorities remain relatively constant

- In 2023, digital government, connectivity and skills were identified as the top three digital policy priorities among 38 OECD countries and partner economies. These priorities have been relatively constant since 2016.

National digital strategies are the primary approach to co-ordinating digital policies, and they are frequently revised

- Over 90% of the OECD countries and partner economies for which data were available in 2023 reported having a national digital strategy (NDS) in place or being in the process of developing one.

Responsibility for developing and co-ordinating national digital strategies is increasingly at a high governmental level, but approaches to budget allocation vary

- The share of OECD countries and partner economies that assign primary responsibility for developing their NDS above ministerial level (such as the Prime Minister's office, Presidency or Chancellery) has more than tripled from 12% in 2016 to 42% in 2023. Of these countries, 38% also assign co-ordination at above ministerial level.
- The share of national digital strategies developed by dedicated digital ministries in OECD countries and partner economies rose from just under a quarter (24%) in 2016 to almost half (47%) in 2023.
- There is a roughly even split between countries that allocate a dedicated budget to their NDS and those that do not, with large differences in expenditure as a share of gross domestic product (GDP).

The national digital policy landscape differs across countries, but there are some commonalities

- Countries without an overarching NDS tend to have several specific strategies and a range of other policies that constitute their national digital policy landscape.
- Among the almost 1 200 policy initiatives collected across OECD countries and partner economies in 2023, about one-third aim to increase effective use of digital technologies, promote social prosperity and boost innovation. Artificial intelligence (AI) and 5G are the most often-cited technologies.
- "Data" is a transversal part of the digital policy landscape. While it is reflected in policies in all seven dimensions of the Going Digital Integrated Policy Framework, it is most often present in policies related to promoting innovation and fostering trust.

Economies, governments and societies across the globe are going digital. Although already under way for nearly half a century, the pace of digitalisation has quickened. Ubiquitous computing has become the norm and fast-evolving digital technologies, like generative AI, immersive technologies and quantum computing, are evolving and spreading.

These technologies generate huge volumes of data of all kinds, making data an important, strategic asset. At the same time, the development and deployment of next generation networks are changing how and where people and firms use and access the Internet and the broader digital technology ecosystem.

Digital technologies and data affect all sectors of the economy and every aspect of life. Consequently, it becomes more important and challenging to develop and co-ordinate flexible policy frameworks. In this way, countries can make the most of the opportunities of digital technologies while mitigating their risks.

The challenge is compounded by the global free flow of data across the Internet. As such, multilateral and cross-border co-operation is essential for critical global infrastructures and on key policy issues like privacy and security. Mapping digital policies and their governance approaches across countries provides policy makers with useful input as they adapt to changes in the digital technology ecosystem and the related impacts on the economy and society.

The OECD Going Digital Integrated Policy Framework (the Framework) (OECD, 2020[1]) provides a flexible, whole-of-government approach to developing digital policies (Annex 1.A). Using the Framework as a guide, this chapter maps the digital policy landscape at high level across countries. To that end, it examines trends in digital policy priorities across countries; analyses national digital strategies in the countries for which they exist and the governance approaches in place to design, implement and monitor them; and explores the broader digital policy landscape across countries.

Surveying digital policies yields valuable insights, but challenges remain

The digital policy data on which this chapter is based is derived from the *DEO 2024 Questionnaire* which reflects self-reported information on policies from OECD countries and partner economies. The *DEO 2024* Questionnaire has three parts: digital policy priorities, national digital strategies (if applicable) and governance arrangements; the major digital policies in countries beyond national digital strategies; and a special section on targeted policy initiatives related to immersive technologies, mental health, and false and misleading content on line.

Part 1 collected data from 42 countries[1] on digital policy priorities and 38 countries[2] on national digital strategies and governance arrangements. Part 2 gathered data on 1 195 different policy initiatives from 46 countries,[3] including their main objectives, budgets and governance arrangements. Part 3 collected information from 38[4] countries on policy initiatives in the special focus areas.

References to "countries" in this chapter reflect the OECD countries and partner economies that responded to the *DEO 2017*[5], *2020*[6] and *2024*[1,2,3,4] Questionnaires.

Surveying governments' policy initiatives, as well as categorising and quantifying that information, is a highly valuable activity. Understanding how one country compares to another, for example, can help policy makers design and implement digital policies. In addition, establishing an empirical link between policies and outcomes requires comparable data on what governments do; policy surveys are one of the only ways to collect this information.

However, data from policy questionnaires generally suffer from biases. For example, such data capture the existence of policy initiatives (quantity) rather than their effectiveness (quality). Moreover, policy surveys require input from policy makers who may have different views on what is the right set of policies. Given ambiguities in what constitutes a "digital policy", surveys do not likely collect every initiative from every country that participated in the survey.

Despite the many changes brought about by digital technologies, digital policy priorities remain relatively constant

Identifying a government's digital policy priorities is the first step in mapping its digital policy landscape. Over the years, this type of analysis has helped identify emerging policy issues such as digital inclusion, gender equality and data governance. These issues have since become important policy concerns for many governments. This section explores priorities identified in the *DEO 2024* Questionnaire and compares them across countries and over time.

Digital government, connectivity and skills are countries' top priorities for the next five years

Digital government, connectivity and skills remain the major digital policy priorities in 2023 and have been relatively constantly since data collection began in 2016 (Table 1.1).[1,5,6] These priorities are also frequently cited in national digital strategies, a trend also observed in 2019. For the first time in 2023, increasing the digitalisation of businesses entered the top five priorities. Countries also identified the promotion of economic growth and increased international competitiveness as separate but similar themes. Fostering innovation, including by reference to specific technologies such as AI, fell out of the top five most commonly mentioned priorities from its third-place ranking in 2019. Meanwhile, cybersecurity remains in fifth place.

Table 1.1. Digital policy priorities have been relatively constant over time

Policy priority	2016 (ranking)	2019 (ranking)	2023 (ranking)	National digital strategies featuring the priority in 2023 (number)
Digital government	1	1	**1**	20
Connectivity	2	2	**2**	15
Skills	3	4	**3**	20
Business transformation	6	7	**4**	12
Cybersecurity	4	5	**5**	11

Notes: The rankings are based on self-reported priorities from 38 countries for 2016, 38 countries for 2019 and 42 countries for 2023. Business transformation refers to the uptake of digital technologies by businesses.

Source: Authors' calculations based on the *DEO 2017*, *2020* and *2024* Questionnaires.

In addition to the top digital policy priorities for the next five years reported by countries, a country's policy priorities may also be observed by examining existing policies. Using a text-mining approach, the 40 most frequently occurring bigrams (or clusters of two words) have been extracted from all of the policy initiatives submitted in response to the *DEO 2024* Questionnaire (Figure 1.1).[3]

Figure 1.1. Innovation and AI feature prominently in policy initiatives, despite no longer being rated as a top priority

Top bigrams (clusters of two words) extracted from policy initiative descriptions across all dimensions, 2023

Notes: The data are based on survey responses from 46 countries. Each term was counted a maximum of once per policy initiative submitted.

Source: Authors' calculations based on the *DEO 2024* Questionnaire.

StatLink *https://stat.link/sd1n9w*

This approach highlights some clear differences between the self-reported top priorities of countries for the next five years and the most frequent terms in the submitted policy descriptions. "Fostering innovation" (including AI) was less frequently mentioned as a top priority by countries in 2023. However, "artificial intelligence" was the second most commonly occurring bigram across the policies submitted. In addition, innovation-related terms such as "research development" and "research innovation" featured prominently. This suggests that policies related to innovation in general, and AI in particular, remain prominent for countries despite occurring less frequently in self-reported top priorities.

National digital strategies continue to grow and evolve

In many countries, national digital strategies have emerged as a key part of the digital policy landscape. They play an important role in facilitating policy co-ordination and coherence across many policy areas. This section explores changes in national digital strategies since 2019, provides an update of the OECD national digital strategy comprehensiveness (NDSC) indicator, and discusses current NDS governance approaches and trends.

Countries tend to revise their national digital strategies frequently

National digital strategies are an established tool to address cross-cutting digital policy opportunities and challenges. Today, most OECD countries and many others have an NDS in place. The scope and form of such strategies differ across countries, reflecting domestic contexts and priorities. However, an NDS usually serves to guide and co-ordinate national digital policies, provide key objectives and measurable targets, and includes the policies needed to achieve them.

The aims and content of national digital strategies can vary significantly. Some are more aspirational, while others are specific and action-oriented. Some contain many policy measures, including from co-ordinated strategies. Others include fewer measures but are well co-ordinated with related strategies and policies.

In this chapter, an NDS is understood as the government's most comprehensive digital strategy at the national level that exclusively or primarily addresses digital policy issues across policy domains affected by or affecting digital transformation (Gierten and Lesher, 2022[2]). As such, an NDS as defined in this chapter contains and/or co-ordinates the major policy measures in a country's digital policy landscape.

From a policy perspective, knowing the comprehensiveness of an NDS provides useful insights. The data suggest that governments frequently revise national digital strategies. Identifying how well a strategy covers the dimensions of the Framework, then, can provide a useful guide when considering policies for a new strategy. When combined with performance measures, such as the dashboards on the *OECD Going Digital Toolkit* (OECD, 2024[3]), policy makers can link performance in the seven Framework dimensions to the comprehensiveness of their strategies.

Since 2021, 22 OECD countries and partner economies have developed a new or updated NDS that meets this definition. This shows national digital strategies have become close to ubiquitous as a method of co-ordinating digital policy. Nonetheless, the aims of an NDS and how it interacts with the wider policy landscape vary significantly among countries.

Only slightly less than 1 in 5 (19%) of the 27 national digital strategies evaluated in 2021 remain in place today. This suggests that national digital strategies are frequently updated to reflect technological developments and changing policy priorities. Indeed, while major government strategies tend to operate over a time horizon of three to five years, national digital strategies appear to be in a near constant state of evolution. This allows them to remain well adapted to the rapidly developing policy environment.

Using the methodology established by the OECD to assess NDS comprehensiveness (Gierten and Lesher, 2022[2]), the authors evaluated new national digital strategies.[7] Updated NDSC scores for 27 countries,[8] broken down by the seven dimensions of the Framework, are presented in Figure 1.2. For each dimension, the darker shades of blue indicate more comprehensiveness and the lighter shades indicate less comprehensiveness of the country's NDS. The NDSC provides insights into how well a country's NDS co-ordinates the policies needed to make digital transformation work for growth and well-being. It does not assess the quality or breadth of a country's entire digital policy landscape.

The results show that Access continues to be the most comprehensively covered dimension, in addition to being the one in which full coverage is most frequently achieved. This reflects the maturity of connectivity policies, often included in Broadband strategies. Many countries have had such strategies since the beginning of the information and communication technology revolution. Consequently, these strategies have been updated as networks have evolved from the early Internet and 2G mobile services through fibre-to-the-cabinet and 3G and 4G mobile services to the fibre-to-the-home and 5G being implemented today.

The Innovation, Society and Use dimensions follow as the next most comprehensively covered dimensions. While this pattern is similar to the 2021 NDSC, the difference in coverage between Access, Use and the other dimensions has narrowed. This may partly reflect the success of prior digitalisation initiatives in increasing access to and use of digital technologies and thus shifting the policy focus towards other areas. Comprehensiveness in the Trust dimension was roughly evenly situated between the most covered dimensions and the laggards.

Jobs and Market openness continue to be the least comprehensive dimensions in the national digital strategies considered. However, among those countries that have revised their NDS since 2021, Market openness (alongside Trust) is the dimension in which most improved their score. These are also the two dimensions with the greatest variance in the level of comprehensiveness, which suggests policies in these areas are still emerging. This implies, in turn, that the scope for mutually beneficial knowledge sharing and collaboration is the greatest in these dimensions. Such collaboration could expand as solutions to labour market issues – and shared responses to taxation, trade and competition – are developed.

Figure 1.2. The comprehensiveness of national digital strategies varies, with Access the most covered dimension

NDSC per dimension of the Framework, 2023

Notes: NDS = National digital strategy, NDSC = National digital strategy comprehensiveness. The responses for Austria, Greece, Italy, Norway and Portugal have not changed since 2021 as their NDSs remain the same. The response from New Zealand was compiled based on policies developed under a previous administration. As of June 2024, Norway's NDS is being revised.

Source: OECD (2024[5]), OECD Going Digital Toolkit, based on the OECD National Digital Strategy Database, *https://oe.cd/ndsc*.

StatLink *https://stat.link/uyich5*

Exploring the NDSC at a domain level shows countries' top three overall priorities for the next five years (see above) tend to be clearly reflected in their NDSC scores (Table 1.2). Of the 27 national digital strategies analysed, the digital government domain was included in at least one of the relevant Framework dimensions in all strategies. Meanwhile, 26 strategies included the skills domain in at least one relevant Framework dimension, and 23 included connectivity (or communications infrastructures and services). Security, which was among the top five overall priorities for the next five years, was covered in at least one relevant Framework dimension in all the 27 strategies analysed.

Table 1.2. National digital policies priorities are clearly reflected in national digital strategies

Domain-level NDSC score, 27 countries, 2023

Dimension	Domain	Count
Access	Investment	23
	Communications infrastructures and services	23
	Competition	9
	Regional development	23
Use	Digital government	27
	Investment	16
	Business dynamism	17
	Small and medium-sized enterprises (SMEs)	19
	Skills	26
	Digital security	26
	Privacy	14
Innovation	Entrepreneurship	20
	SMEs	20
	Competition	4
	Science and technology	23
	Digital government	24
	Sectoral policies and regulations	22
Jobs	Labour markets	16
	Skills	26
	Social protection	9
	Tax and benefits	6
	Regional development	7
Society	Social policies	23
	Skills	25
	Tax and benefits	4
	Environment	18
	Health care	23
	Digital government	19
Trust	Digital risk management	14
	SMEs	12
	Privacy	14
	Digital security	27
	Consumer protection	10
Market openness	Trade	16
	Investment	19
	Financial markets	12
	Competition	7
	Taxation	8

Notes: NDSC = National digital strategy comprehensiveness. This table shows the domain-level NDSC scores for 27 countries (see Figure 1.2 for the country list). The count can range from 0 to 27. It reflects how many of the national digital strategies for which scores are available include each of the Framework's policy domains.

Source: Authors' calculations.

The domains of competition, and tax and benefits, are among the least covered. This suggests two possible explanations. First, it could mean that policy measures in these areas would benefit from greater focus from policy makers. Second, it could mean that measures from these two domains relevant to digital transformation could be better linked with national digital strategies.

Only one-third of countries had qualifying policy measures for the social protection domain in the Jobs dimension. However, almost 85% of countries had a qualifying policy measure for the social policies domain in the Society dimension. This suggests that despite a clear effort to tackle digital divides in everyday life, greater policy focus on social policies aimed at helping workers transition from one job to the next could be useful. This would be especially true if such policies were co-ordinated within national digital strategies.

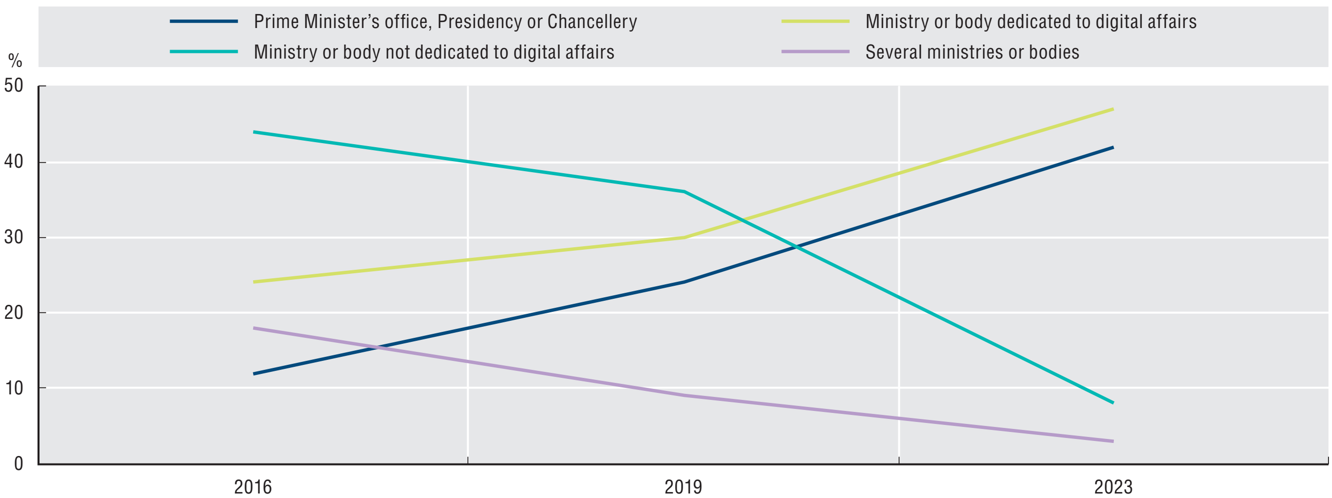
National digital strategies are increasingly developed and co-ordinated by the highest levels of government

Any approach to national digital policy making requires effective governance. Key objectives of such governance include avoiding policy inconsistencies, leveraging synergies and enhancing effectiveness. These are achieved most notably through co-ordinating all entities and actors involved in national digital policy making and its implementation. Allocating sufficient budget, monitoring progress, and evaluating strategies and/or policies are equally important.

In recent years, there has been a trend for more senior levels of government (Prime Minister's office, Presidency or Chancellery) or dedicated digital ministries to develop and co-ordinate national digital strategies (Figure 1.3).[2,5,6] Data suggest a significant increase (from 12% in 2016 to 42% in 2023) in the proportion of governments that assign the primary responsibility for developing their NDS above the ministerial level (such as the Prime Minister, Presidency or Chancellery). Of these countries, 38% also assign co-ordination at above ministerial level. There has been a similar increase in the proportion of national digital strategies developed by dedicated digital ministries: the percentage rose from just under a quarter (24%) to almost half (47%) during the same period.

Figure 1.3. National digital strategies are primarily led by dedicated digital ministries and at the most senior levels of government

Responsibility for lead strategy development of NDS across countries, 2016-23



Note: NDS = National digital strategy. Data for survey responses are based on the following: 38 countries (2016); 38 countries (2019); and 38 countries (2024).

Source: Authors' calculations based on the *DEO 2017*, *2019* and *2024* Questionnaires.

StatLink https://stat.link/lhk8wj

This coincides with a significant fall in the share of respondents whose NDS is primarily developed by a ministry or body not dedicated to digital affairs (Table 1.3). In 2016, non-dedicated organisations developed 44% of national digital strategies, whereas they developed only 8% in the latest survey. Likewise, multiple ministries or bodies developed just under one-fifth (18%) of strategies in 2016; in 2023, only the Netherlands chose this approach.

The allocation of responsibility for co-ordination of national digital strategies has followed a similar, if less marked, trend. For two-thirds of countries, a dedicated digital ministry or body co-ordinates the NDS. This represents a more than doubling of the share of countries that use this arrangement since data collection began in 2016. The number of countries allocating co-ordination to a ministry or body not dedicated to digital affairs has decline notably, falling from 39% of countries to less than one in ten (8%). More than one in five (21%) countries co-ordinate their NDS at above ministerial level, with this category becoming the second most popular for the first time in 2023.

The move towards leading and co-ordinating national digital strategies at increasingly senior and specialised levels of government, alongside the growth in ministries with a dedicated digital function, points to their growing importance in the overall policy landscape. While multiple public and private stakeholders contribute to and help implement national digital strategies, specialist knowledge and senior oversight seem to be becoming more important as national digital strategies evolve over time.

Table 1.3. Allocation of NDS responsibility by country

	Prime Minister's office, Presidency or Chancellery	Ministry or body dedicated to digital affairs	Ministry or body not dedicated to digital affairs	Several ministries or bodies
Lead strategy development	Austria, Belgium, Costa Rica, Croatia, Czech Republic, Denmark, Greece, Hungary, Iceland, Ireland, Italy, Jordan, Korea, Portugal, Romania, Switzerland	Brazil, Bulgaria, Canada, Estonia, Finland, Germany, Japan, Lithuania, Luxembourg, Norway, Peru, Singapore, Slovak Republic, Slovenia, Spain, Thailand, Türkiye, United Kingdom	Latvia, Mexico, New Zealand	Netherlands
Co-ordination	Austria, Brazil, Iceland, Ireland, Jordan, Mexico, Romania, Switzerland	Belgium, Bulgaria, Canada, Costa Rica, Croatia, Czech Republic, Estonia, Finland, Germany, Greece, Hungary, Italy, Japan, Korea, Lithuania, Luxembourg, Norway, Portugal, Singapore, Slovak Republic, Slovenia, Spain, Thailand, Türkiye, United Kingdom	Latvia, Netherlands, New Zealand	Peru

Note: NDS = National digital strategy.

Source: Authors' calculations based on the *DEO 2024* Questionnaire.

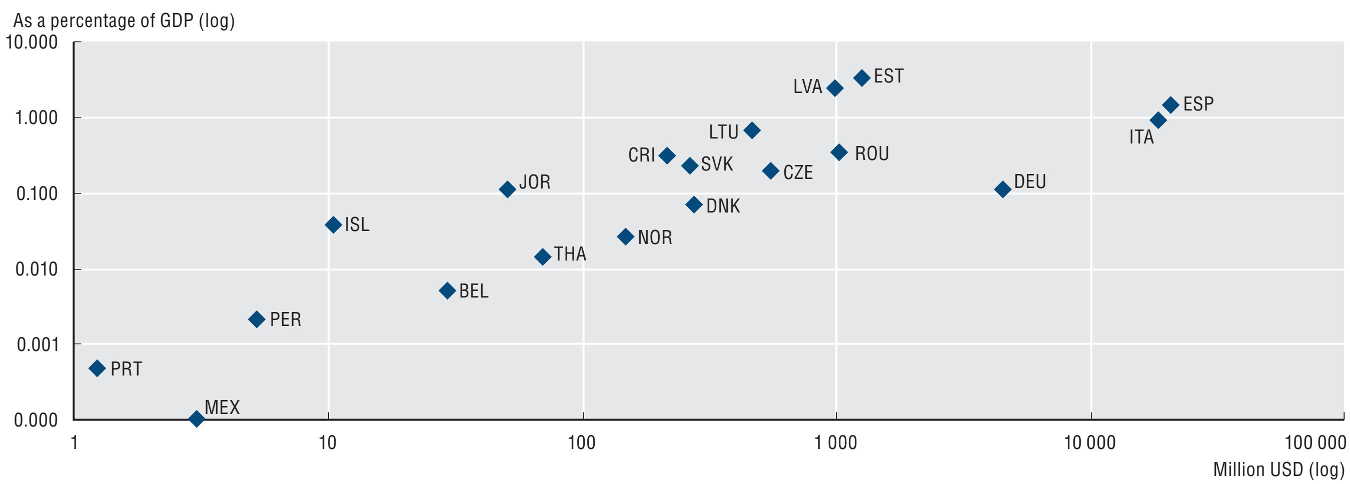
While governance arrangements for national digital strategies seem to follow similar trends across countries, data indicate that budget arrangements for national digital strategies are more mixed. There is a relatively even split between countries that have not allocated a budget to their NDS (47%) and those allocating either a dedicated (45%) or repurposed budget (8%).

With respect to the type of budget allocated to national digital strategies, approaches are diverse. Slightly more respondents allocated a multi-year budget than an annual one (11 to 9, respectively). Estonia, Korea and Thailand indicated their NDS budget contained both annual and multi-year elements. In addition, countries are almost evenly split between those that allocated a centralised budget to their NDS (48%) and those that chose a decentralised one (52%) in 2023.

As shown in Figure 1.4, the size of the budget allocated to national digital strategies also varies greatly among countries. Budget size ranges from USD 1.2 million (Portugal) to more than USD 20 billion (Spain) when EU recovery funding is included. When calculated as a share of GDP, Estonia has the largest NDS budget at 3.3% of GDP. Meanwhile, half of respondents whose NDS has a budget allocated 0.1% of GDP or less to their NDS.

Figure 1.4. National digital strategy budgets vary significantly

NDS budget (million USD) as a share of GDP, 2023



Notes: NDS = National digital strategy. The data are based on survey responses from 18 countries and may incorporate different elements; caution is advised when making direct country comparisons. USD exchange rates were collected from the International Monetary Fund (IMF), except for Mexico for which data were provided in USD. GDP data are based on the 2022 OECD SNA series, except for Jordan, Peru and Thailand, for which IMF data are used, and Mexico, for which data were provided as a share of GDP.

Source: Authors' calculations based on the *DEO 2024* Questionnaire.

StatLink https://stat.link/fhc28j

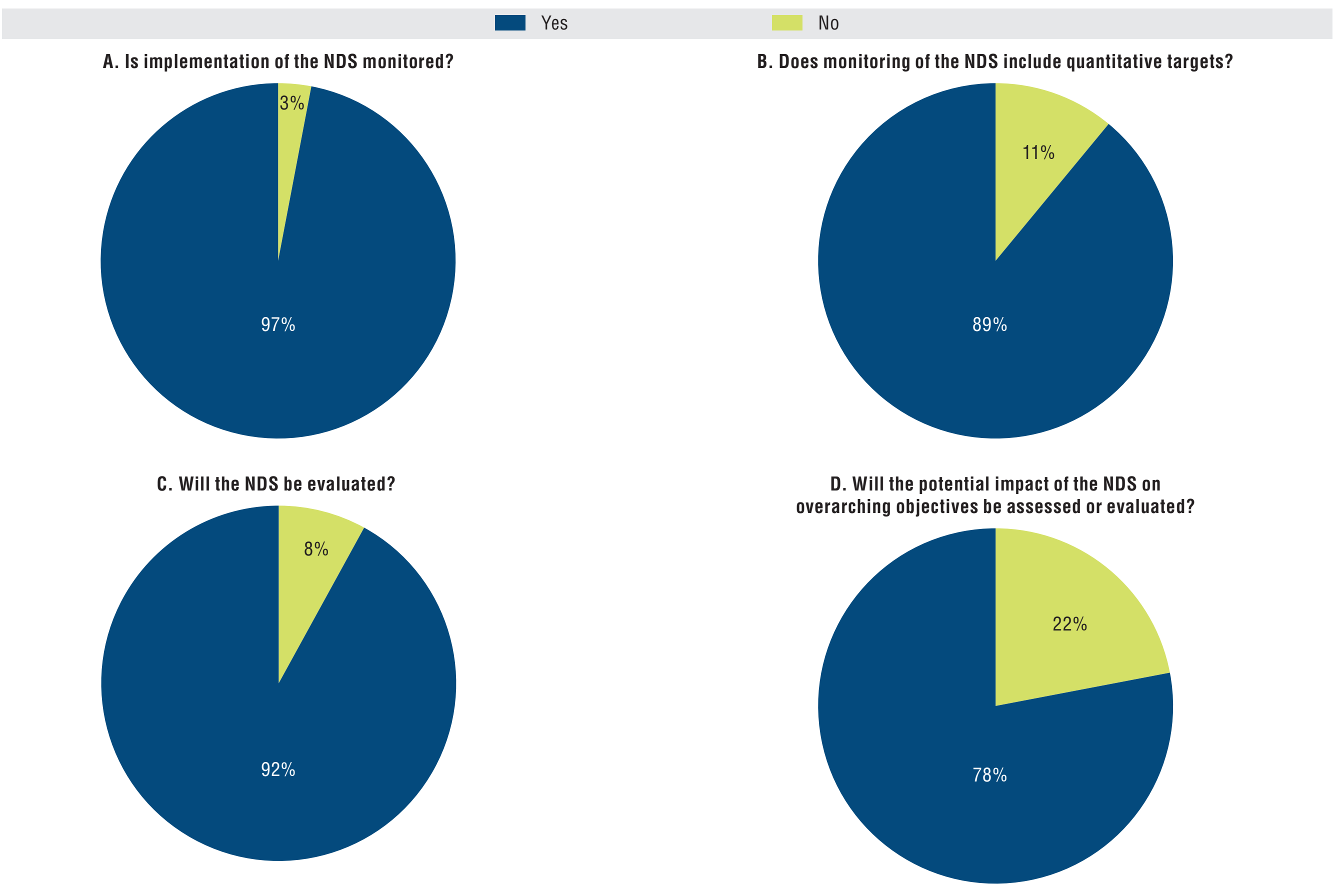
This indicates that budgetary decisions related to national digital strategies depend highly on context. The wide variance in approaches and amounts likely indicates differences in how national budgets are organised and how NDS budgets are calculated. Some countries choose to allocate sufficient budget to their NDS to cover all of the measures it contains and co-ordinates. Others establish a smaller centralised budget with decentralised budgets allocated to each individual measure.

Effective monitoring and evaluation are essential to ensuring that national digital strategies achieve their stated goals and ambitions. All respondents to the *DEO 2024* Questionnaire indicated their NDS is monitored, except for Canada, which individually monitors and evaluates the initiatives in its digital charter rather than the charter as a whole (Figure 1.5).[1] Only two other countries do not evaluate their NDS (Luxembourg and the Netherlands). This is in line with findings in 2019 (OECD, 2020[4]) and 2021 (Gierten and Lesher, 2022[2]).

In addition, almost nine in ten (89%) countries use quantitative targets to monitor their NDS, increasing from two-thirds in 2021. This suggests the level of monitoring is increasing with successive iterations of national digital strategies. Just over three-quarters of countries (78%) also assess the potential impact of their NDS on overarching objectives, such as increasing economic growth.

Figure 1.5. Almost all countries monitor and evaluate their national digital strategies

Monitoring and evaluation of national digital strategies, 2023



Notes: NDS = National digital strategy. The data are based on survey responses from 38 countries. The United Kingdom did not answer question B. Estonia and Romania did not answer question D.

Source: Authors' calculations based on the *DEO 2024* Questionnaire.

StatLink https://stat.link/qan0k2

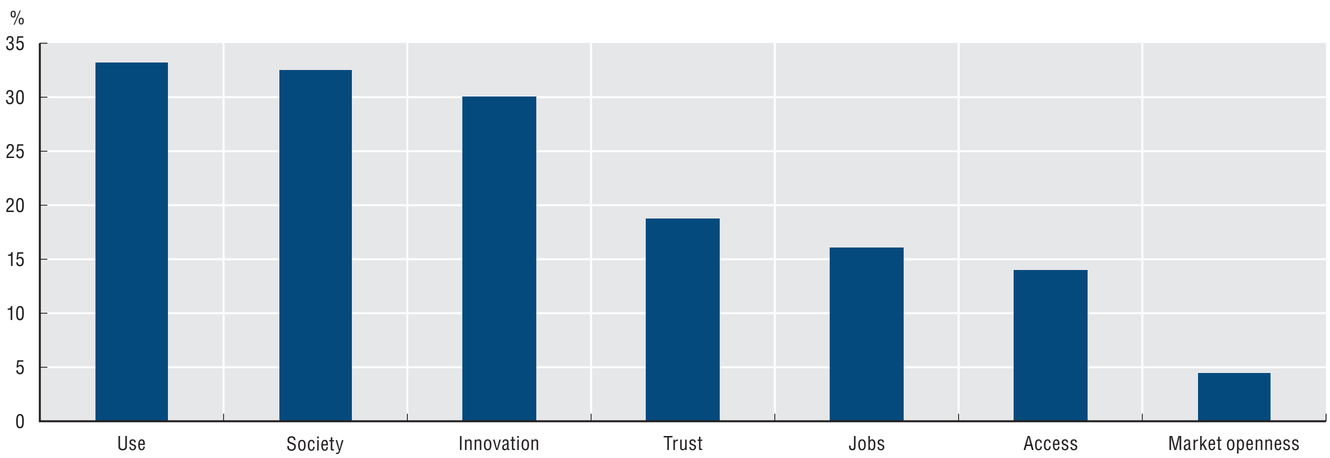
Mapping the national digital policy landscape beyond national digital strategies

The third and final step in mapping the digital policy landscape requires considering all types of policy initiatives in place in a given country. This step is particularly relevant for countries without an NDS, which tend to have several more focused strategies and a range of other policies that constitute their national digital policy landscape. Most countries with an NDS also have policies that pre-date, are more recent or may otherwise be outside the scope of their current NDS. This section analyses the broader digital policy landscape across countries through the lens of the Framework.

An overview of the digital policy initiatives provided by 46 countries[3] is included in Figure 1.6. The digital policy landscape appears to be skewed towards policies aiming to increase effective use, promote social prosperity and unleash innovation. Together, they represent around 30% of all initiatives across countries. This supports the hypothesis that while "fostering innovation" is no longer one of respondents' top five priorities for the next five years, countries are still paying significant policy attention to it.

Figure 1.6. Policy initiatives aim at increasing effective use, promoting social prosperity and unleashing innovation dominate the digital policy landscape

Distribution of digital policy initiatives across policy dimensions, 2023



Notes: Data are based on survey responses from 46 countries. The data are presented as the share of the total number of policies in each dimension. Some initiatives are considered under multiple policy dimensions based on their scope and so the individual bars do not add up to 100%.

Source: Authors' calculations based on the *DEO 2024* Questionnaire.

StatLink *https://stat.link/9mr0oz*

The Use and Society dimensions are both comprehensively covered by national digital strategies (see Figure 1.2) and by a relatively high number of other major digital policies. In contrast, while Access is also among the most comprehensively covered dimensions in national digital strategies, it has relatively fewer major digital policies (Figure 1.6). This is a reflection of Access policies often being large, multi-year transformation projects with big budgets rather than clusters of smaller initiatives.

In contrast, Market openness tends to be the dimension least comprehensively covered both in national digital strategies and by individual policy initiatives. This is the case although Market openness covers domains strongly affected by digital technologies, such as taxation, competition, trade and financial markets. In some of these domains, policies may still be emerging.

While cross-country trends yield valuable insights, it is also important to look at countries in detail. Figure 1.7 maps the digital policies for the 45 countries that provided data on a critical mass of initiatives (i.e. countries that provided at least one initiative in at least three of the Framework's seven dimensions).

Figure 1.7. Beyond national digital strategies, the policy landscape differs between countries

Distribution of digital policy initiatives, by Framework dimension, 2023

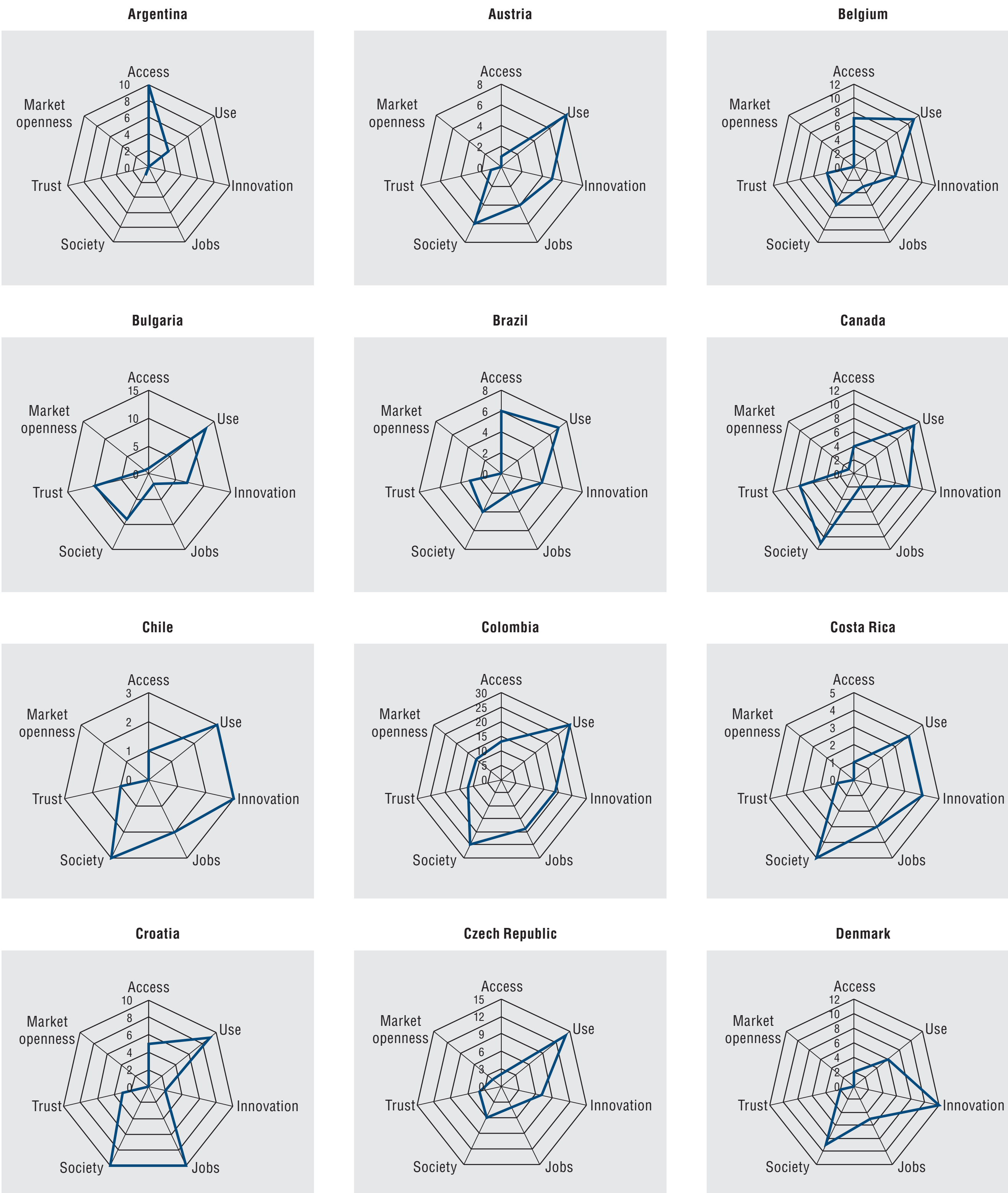


Figure 1.7. Beyond national digital strategies, the policy landscape differs between countries *(cont.)*

Distribution of digital policy initiatives, by Framework dimension, 2023

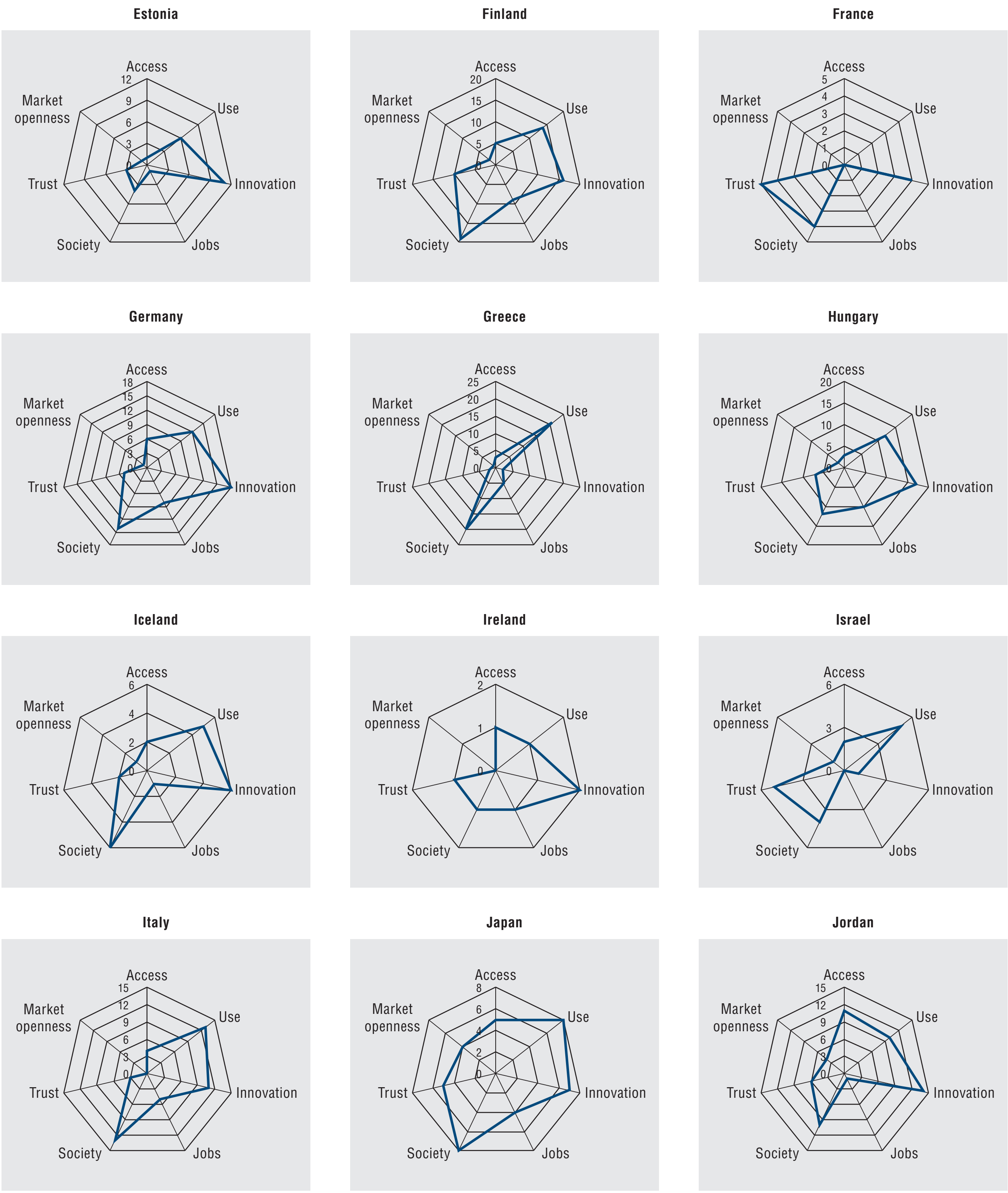


Figure 1.7. Beyond national digital strategies, the policy landscape differs between countries *(cont.)*

Distribution of digital policy initiatives, by Framework dimension, 2023

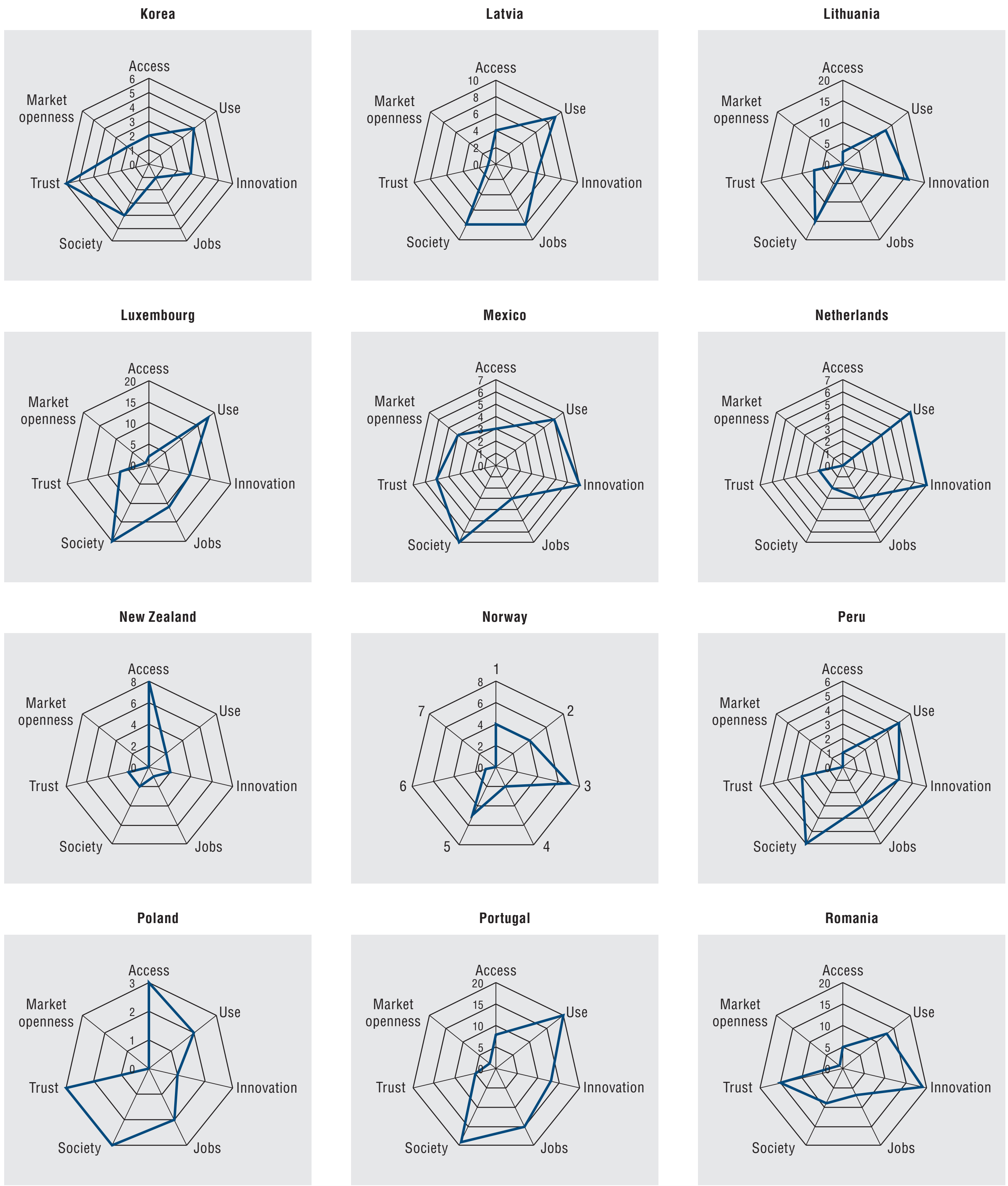
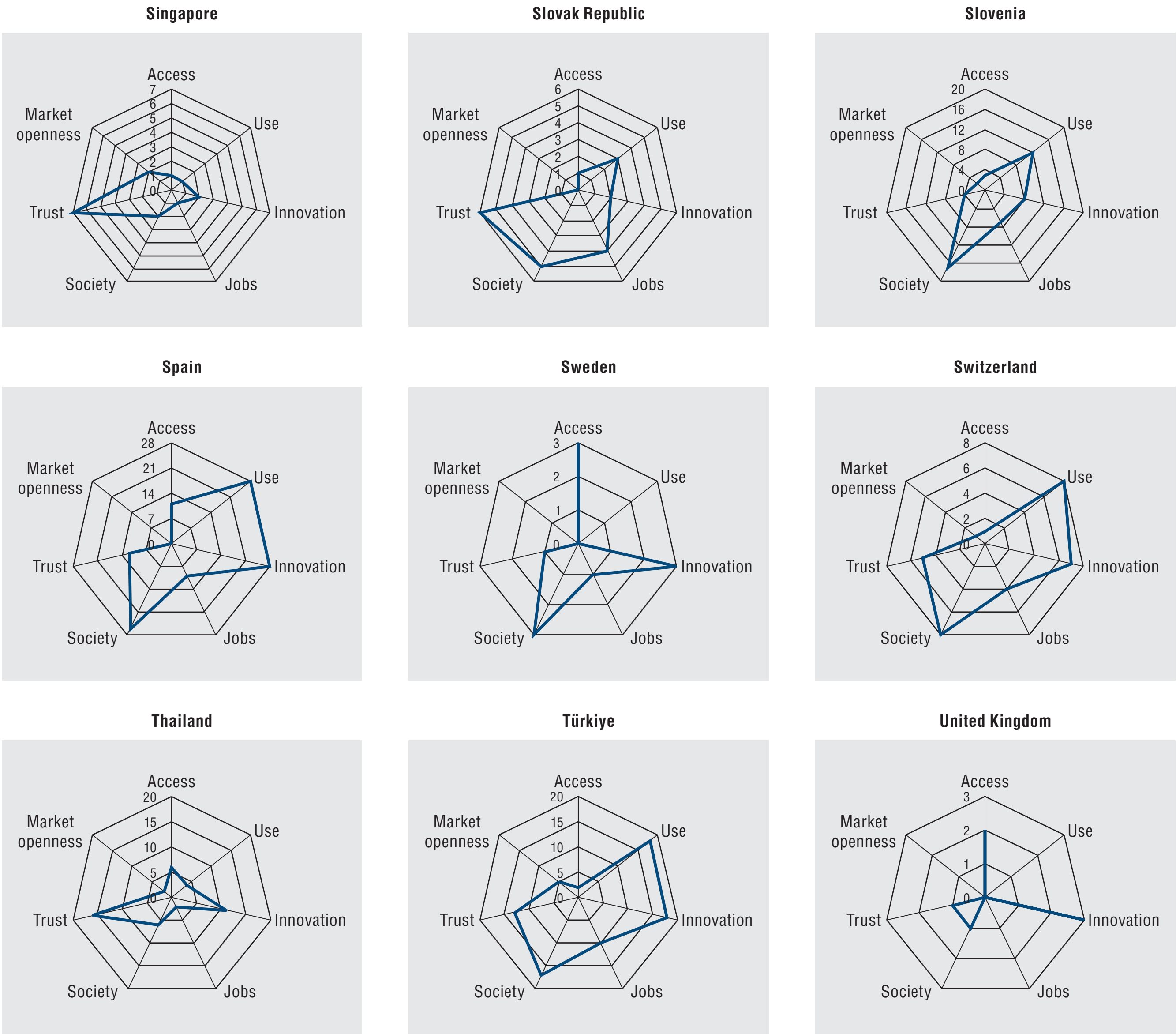


Figure 1.7. Beyond national digital strategies, the policy landscape differs between countries *(cont.)*

Distribution of digital policy initiatives, by Framework dimension, 2023



Notes: Some policy initiatives are considered under multiple policy dimensions based on their scope. Therefore, adding up the numbers of initiatives by Framework dimension does not necessarily equal the total number of policy initiatives collected per country.

Source: Authors' calculations based on the *DEO 2024* Questionnaire.

StatLink *https://stat.link/hxmzug*

As these charts show, there is significant cross-country variation in both the number of policies reported and the extent to which they cover all aspects of the Framework. Some countries, such as Greece and the Netherlands, concentrated many initiatives in a few dimensions. In contrast, Japan and Poland report fewer policy initiatives but cover the Framework more comprehensively. This analysis only considers the quantity of measures submitted for each dimension of the Framework. Therefore, it should not be considered as an assessment of the quality of each country's digital policy landscape.

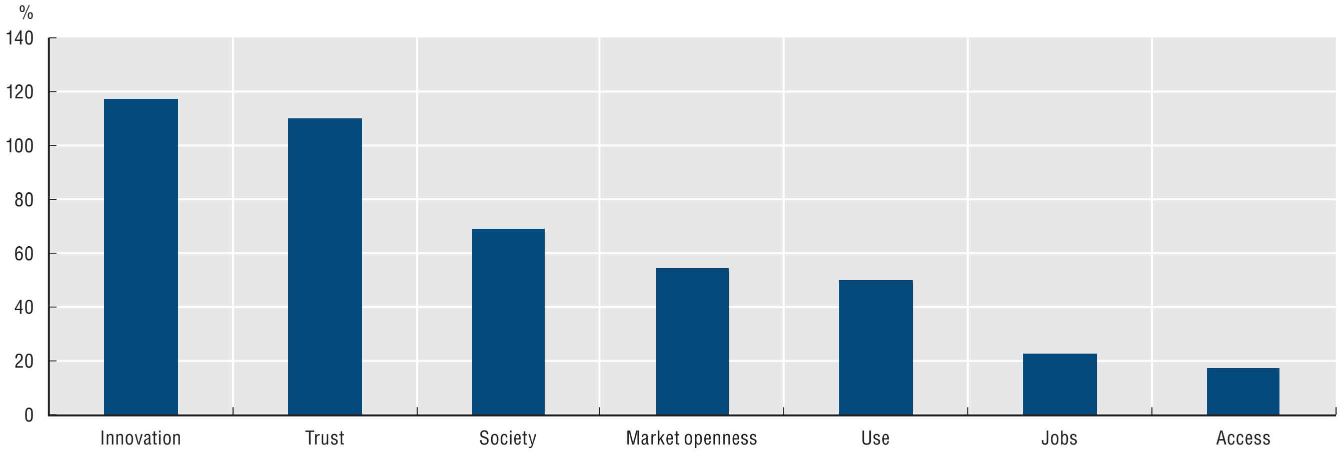
"Data" policies are a transversal part of the policy landscape

Data are the fuel that powers the engine of digital transformation. In the Framework, data and data governance are identified as transversal policy issues given their prevalence across all policy dimensions. Figure 1.8[3] shows the occurrences of the word "data" in policy descriptions in the policy initiatives collected in 2023. The data have been normalised to reflect the number of initiatives included in each Framework dimension.

Even for those dimensions with the fewest mentions of "data" such as Access and Jobs, "data" occurs approximately once in every five policies. Innovation and Trust are the dimensions in which "data" is most frequently cited, with more than one mention per initiative in each. While there is some variance between dimensions, "data" is much more transversal than a more specific term. "AI/artificial intelligence", for example, occurred four times for every five policies in the Innovation dimension. However, it occurred just once for every 25 policies in the Access dimension and not at all in Market openness.

Figure 1.8. "Data" runs through all policy dimensions

Semantic search results of the word "data" in policy initiative descriptions, normalised by the total number of policy initiatives in each dimension, 2023



Note: Data are based on survey responses from 46 countries.

Source: Authors' calculations based on the *DEO 2024* Questionnaire.

StatLink *https://stat.link/vmp3ed*

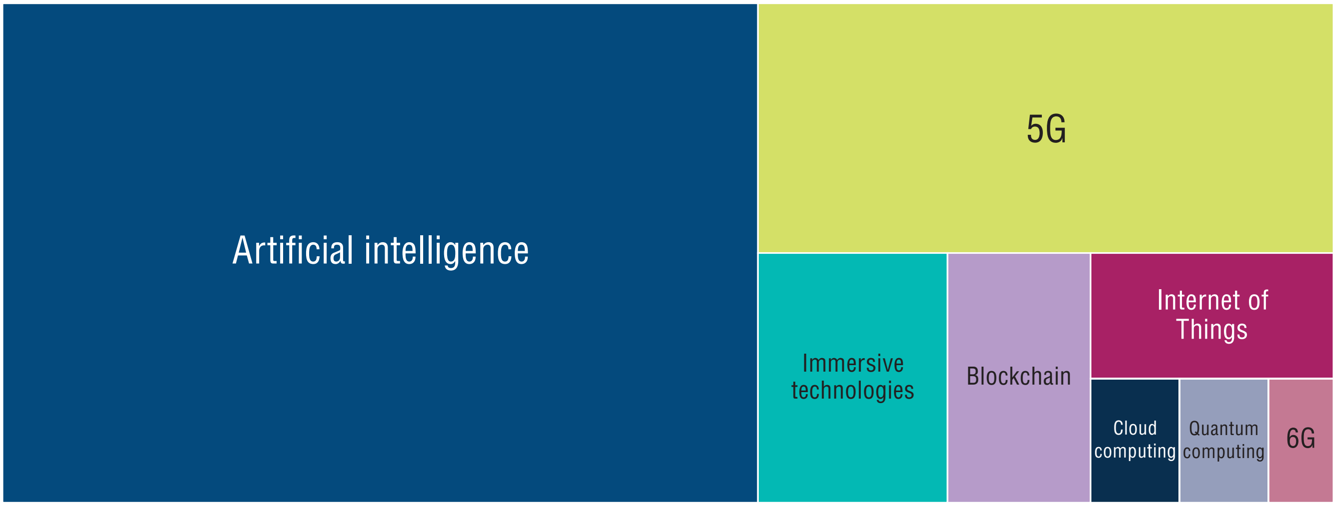
AI is the dominant emerging technology in policy initiatives

Digital transformation policies tend to be technology-agnostic, focusing on broad objectives such as the digitisation of businesses or improving skills. Some technologies, however, have spurred governments to develop a technology-specific policy response. This is particularly true of new and emerging technologies for which the societal impacts may not be fully quantified or understood.

For this study, data on digital policy initiatives were parsed through a custom dictionary to determine which of the most prominent emerging technologies appeared most frequently. The results show that AI is mentioned more than twice as often as 5G, the next closest technology (Figure 1.9).[3] 5G was also mentioned more than all other technologies combined (except AI). While some listed technologies such as 6G have entered policy discussions relatively recently, others have been around for several years. Many countries have developed dedicated AI strategies, but most of the other technologies included in the dictionary are often contained within more generic innovation strategies.

Figure 1.9. Among emerging technologies, AI and 5G dominate the policy landscape

Emerging technologies and related terms cited in policy initiatives, 2023



Notes: Data are based on survey responses from 46 countries. The figure shows occurrences of selected terms from the custom dictionary. "Artificial intelligence" also includes occurrences of "AI". "Internet of Things" also includes occurrences of "IoT". "Immersive technologies" also includes occurrences of "metaverse" and "virtual reality".

Source: Authors' calculations based on the *DEO 2024* Questionnaire.

StatLink https://stat.link/i9bc08

The future of digital policy making

Advances in the digital technology ecosystem will shape the future of digital policy making. Generative AI, immersive technologies and next generation networks have recently arrived, while other technological developments are on the horizon. Policy makers need to understand these technologies to determine whether and how policy frameworks need to adapt in response. The establishment of dedicated digital ministries, a trend likely to continue, can help in this respect. As the proliferation of digital policy initiatives continues, dedicated digital ministries can also provide the direction and needed support as countries work even harder to ensure their digital policies achieve their objectives.

Other major trends have widespread impacts on policy domains from a digital perspective and will, in turn, affect digital policy making. The COVID-19 pandemic, for example, was a one-time, extreme shock with impacts on telework (labour markets), e-commerce (trade) and telemedicine (health). In contrast, the green transition is a slower, ongoing shift, where costs and benefits are harder to quantify but which are nonetheless critical to address. For example, the green transition raises climate-related issues related to impacts from digital activities such as cryptocurrencies (finance) and data centres (connectivity infrastructures). These, in turn, will have implications for digital policy. Moreover, geopolitics – including the Russian war of aggression in Ukraine – will affect digital policy making. This is seen by the increasing focus on the spread of false and misleading content on line and the use of satellites for connectivity in crisis situations.

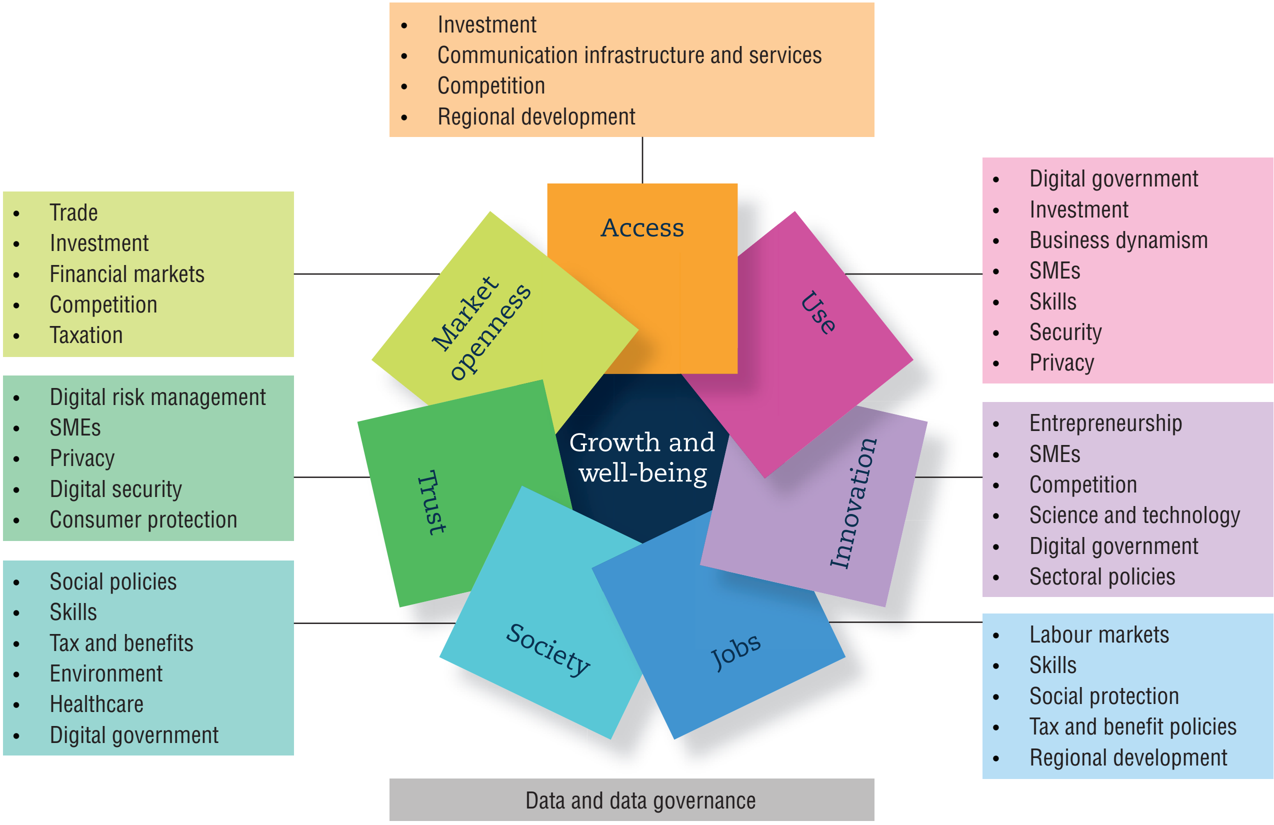
Thinking through the impacts of these major trends and others that will surely come requires flexibility and agility on the part of all actors in the digital policy landscape. As digital technologies become more powerful and their use more widespread, the stakes are higher than ever for governments. They must ensure a policy framework is flexible and co-ordinated enough to make the most of the opportunities of digital technologies while mitigating their risks. A robust evidence base is needed to make informed policy decisions. Given measurement is a medium- to long-term endeavour across a wide range of areas, it is critical to identify and prioritise activities and partnerships.

Annex 1.A. The Going Digital Integrated Policy Framework

Digital transformation affects almost all aspects of the economy and society, and designing effective digital policies requires a whole-of-government effort. While the effects of digital technologies and data differ depending on national context and culture, it is a global challenge to navigate the digital transition effectively and ensure it both protects and enhances well-being and growth. For this reason, the OECD developed the Framework (OECD, 2020[1]), which aims to help countries build a more inclusive and prosperous digital future with effective, impactful and evidence-based digital policies.

The Framework consists of seven interrelated policy dimensions (Access, Use, Innovation, Jobs, Society, Trust and Market openness), each of which contain several policy domains (Figure 1.A.1). Growth and well-being are at its heart, and several transversal domains (investment, digital government, skills, small and medium-sized enterprises, tax and benefits, regional development, privacy and security) cut across multiple dimensions. Some domains, such as data and data governance, as well as gender, are relevant for all of the Framework's dimensions.

Figure 1.A.1. The Going Digital Integrated Policy Framework and its constituent domains



Source: Gierten and Lesher (2022[2]).

Recognising the evolving nature of technology, the Framework has remained relatively flexible to accommodate changes in the digital technology landscape. It further provides guidance on the governance of digital policies to ensure coherence and co-ordination of policies across all domains and sectors that shape digital transformation, and how to involve all relevant stakeholders in the development and implementation of digital policies.

Annex 1.B. NDSC sources

Table 1.B.1. NDSC sources

National digital strategies and related strategies and policies used to construct the NDSC, 2024

Country	National digital strategy	Co-ordinated strategies or policies
Austria	Digital Austria, 2021, *www.digitalaustria.gv.at/*	BMLRT, 2019, Broadband Strategy 2030 – Austria's Path to the Gigabit Society, *https://data.breitbandbuero.gv.at/PUB_Breitbandstrategie-2030.pdf* Digital Austria Actionplan 1 – Ziele, Leitlinien & Prinzipien, *www.digitalaustria.gv.at/downloads.html* Digital Austria Actionplan 2 – Die große Daten-Chance, *www.digitalaustria.gv.at/downloads.html* Digital Austria Actionplan 3 – Digitalisierung nützen und krisenfest wachsen, *www.digitalaustria.gv.at/downloads.html* Digital Austria Actionplan 4 – Digitale Wirtschaftstransformation, *www.digitalaustria.gv.at/downloads.html*
Brazil	Estratégia Brasileira para a Transformação Digital (E-Digital) (ciclo 2022-2026), 2022 *www.gov.br/mcti/pt-br/acompanhe-o-mcti/transformacaodigital/arquivosestrategiadigital/e-digital_ciclo_2022-2026.pdf*	
Canada	Canada's Digital Charter, 2019 *https://ised-isde.canada.ca/site/innovation-better-canada/en/canadas-digital-charter-trust-digital-world*	National Cyber Security Strategy, 2018 *www.publicsafety.gc.ca/cnt/rsrcs/pblctns/ntnl-cbr-scrt-strtg/index-en.aspx#s1* National Cyber Security Action Plan (2019-2024), 2019 *www.publicsafety.gc.ca/cnt/rsrcs/pblctns/ntnl-cbr-scrt-strtg-2019/index-en.aspx* Pan-Canadian Artificial Intelligence Strategy, 2020 *https://ised-isde.canada.ca/site/ai-strategy/en*
Colombia	National Digital Strategy of Colombia 2023-2026, 2024 *https://colaboracion.dnp.gov.co/CDT/Desarrollo%20Digital/EVENTOS/END_Colombia_2023_2026.pdf*	National Science, Technology and Innovation Policy 2022-2031, 2021 *https://colaboracion.dnp.gov.co/CDT/Conpes/Econ%C3%B3micos/4069.pdf*
Croatia	Digital Croatia Strategy for the period until 2032, 2022 *https://rdd.gov.hr/UserDocsImages//SDURDD-dokumenti//Strategija_Digitalne_Hrvatske_final_v1_EN.pdf*	National plan for the development of broadband access in the Republic of Croatia in the period from 2021 to 2027, 2021 *https://mmpi.gov.hr/UserDocsImages/dokumenti/PROMET/Promet%203_21/MMPI-NPR-BB2021-2027-VRH%2015-3_21.pdf* National development strategy of the Republic of Croatia until 2030, 2020 *https://hrvatska2030.hr/wp-content/uploads/2021/02/Nacionalna-razvojna-strategija-RH-do-2030.-godine.pdf*
Czech Republic	Digital Czechia - Government Programme for the Digitalization of the Czech Republic 2018+ *https://digitalnicesko.gov.cz/vize* 1. Czechia in Digital Europe, 2023 2. Information concept of Czechia, 2023 3. Digital Economy and Society, 2023 4. Digital Education, 2023	National Plan for the Development of Very High Capacity Networks, 2021 *www.mpo.cz/assets/cz/e-komunikace-a-posta/elektronicke-komunikace/koncepce-a-strategie/narodni-plan-rozvoje-siti-nga/2021/3/149908-21_III_mat_VHCN_EN.pdf* National Cyber Security Strategy of the Czech Republic, 2021 *https://nukib.gov.cz/download/publications_en/strategy_action_plan/NSCS_2021_2025_ENG.pdf* Action Plan for the National Cybersecurity Strategy of the Czech Republic from 2021-2025, 2021 *https://nukib.gov.cz/download/publications_en/strategy_action_plan/NSKB-AP_ENG.pdf* Strategy to Support Small and Medium-sized Enterprises in the Czech Republic 2021-2027, 2021 *www.mpo.cz/assets/en/business/small-and-medium-sized-enterprises/studies-and-strategic-documents/2021/9/Strategy-to-support-SMEs-in-the-Czech-Republic-2021-2027.pdf* National Strategy of Artificial Intelligence in Czechia, 2019 *https://vlada.gov.cz/assets/evropske-zalezitosti/umela-inteligence/NAIS_kveten_2019.pdf*
Denmark	Denmark's Digitalisation Strategy, 2023 *https://digmin.dk/Media/638357207253210400/SVM%20regeringen_Danmarks%20digitaliseringsstrategi_2023_V9_Online_Final%20(1)-a.pdf*	Agreement on initiatives for digital inclusion, 2023 *https://digmin.dk/Media/638234538170844637/Aftale%20om%20indsatser%20for%20digital%20inklusion.pdf* The Joint Government Digital Strategy 2022-2025, 2022 *https://digst.dk/media/27689/digst_fods_webtilgaengelig.pdf* The Danish National Strategy for Cyber and Information Security 2022-2025, 2021 *https://en.digst.dk/media/27024/digst_ncis_2022-2024_uk.pdf*
Estonia	Estonia's Digital Agenda 2030, 2021 *https://mkm.ee/media/6970/download*	

Country	National digital strategy	Co-ordinated strategies or policies
Finland	Finland's Digital Compass, 2022 *https://julkaisut.valtioneuvosto.fi/bitstream/handle/10024/164472/VN_2022_72.pdf?sequence=1&isAllowed=y*	Digikompass implementation plan, 2023 *https://api.hankeikkuna.fi/asiakirjat/c13aac5c-1106-45be-9dd5-a47fa1217b34/a836d9ae-723c-4b4a-8f63-db690ca3ae1d/SUUNNITELMA_20231220135611.PDF*
Germany	Digitalstrategie der Bundesregierung (Digital Strategy of Germany), 2022 *https://digitalstrategie-deutschland.de/static/eb25ff71f36b8cf2d01418ded8ae3dc2/Digitalstrategie_EN.pdf*	Gigabitstrategie der Bundesregierung, 2022 *https://bmdv.bund.de/SharedDocs/DE/Anlage/K/gigabitstrategie.pdf?__blob=publicationFile*
Greece	Digital Transformation Bible 2020-2025, 2021 *https://digitalstrategy.gov.gr/vivlos_pdf*	
Hungary	Nemzeti Digitalizációs Stratégia 2022-2030, 2022 *https://kormany.hu/dokumentumtar/nemzeti-digitalizacios-strategia-2022-2030*	
Ireland	Harnessing Digital - The Digital Ireland Framework, 2021 *www.gov.ie/pdf/?file='https://assets.gov.ie/214584/fa3161da-aa9d-4b11-b160-9cac3a6f6148.pdf#page=null*	Impact 2030 - Ireland's Research and Innovation Strategy, 2022 *www.gov.ie/pdf/?file='https://assets.gov.ie/224616/5f34f71e-e13e-404b-8685-4113428b3390.pdf#page=null* AI - Here for Good A National Artificial Intelligence Strategy for Ireland, 2021 *www.gov.ie/pdf/?file='https://assets.gov.ie/215889/627544be-1d4d-4459-8df8-b7c6b2b15aa5.pdf#page=null* The Digital Connectivity Strategy for Ireland, 2022 *www.gov.ie/pdf/?file='https://assets.gov.ie/242271/96f1b6ad-b766-4ecb-95a1-bd3c9236f90b.pdf#page=null* National Broadband Plan, 2020 *www.gov.ie/en/publication/c1b0c9-national-broadband-plan/* National Cyber Security Strategy 2019-2024, 2019 *www.ncsc.gov.ie/pdfs/National_Cyber_Security_Strategy.pdf*
Italy	Italia digitale 2026, 2022 *https://assets.innovazione.gov.it/1665677773-italia-digitale-2026.pdf*	National Plan of Recovery and Resilience, 2022 *https://italiadomani.gov.it/en/home.html*
Japan	Priority Policy Program for Realizing Digital Society, 2023 *www.digital.go.jp/assets/contents/node/basic_page/field_ref_resources/5ecac8cc-50f1-4168-b989-2bcaabffe870/b24ac613/20230609_policies_priority_outline_05.pdf*	Startup Development Five-year Plan, 2022 *www.cas.go.jp/jp/seisaku/atarashii_sihonsyugi/pdf/sdfyplan2022en.pdf*
Jordan	The National Digital Transformation Strategy and Implementation Plan (2021-2025), 2021 *www.modee.gov.jo/ebv4.0/root_storage/en/eb_list_page/dts-2021-eng.pdf*	National Cyber Security Strategy 2018-2023, 2018 *https://modee.gov.jo/ebv4.0/root_storage/en/eb_list_page/national_cyber_security_strategy_2018_2023.pdf* Jordan AI national strategy and implementation plan 2023-2027, 2023 *www.modee.gov.jo/ebv4.0/root_storage/en/eb_list_page/40435648.pdf*
Latvia	Digital transformation guidelines 2021-2027, 2021 *https://likumi.lv/ta/id/324715-par-digitalas-transformacijas-pamatnostadnem-20212027-gadam*	Electronic connection industries development plan for 2021 - 2027, 2021 *www.sam.gov.lv/lv/media/1527/download?attachment*
Mexico	National Digital Strategy 2021-2024, 2021 *https://dof.gob.mx/nota_detalle.php?codigo=5628886&fecha='06'/09/2021#gsc.tab=0*	
Netherlands	Strategie Digitale Economie, 2022 *www.nederlanddigitaal.nl/binaries/nederlanddigitaal-nl/documenten/rapporten/2022/11/18/strategie-digitale-economie/Strategie+Digitale+Economie.pdf*	Value-Driven Digitalisation Work Agenda, 2022 *www.digitaleoverheid.nl/wp-content/uploads/sites/8/2023/01/Value-Driven-Digitalisation-Work-Agenda.pdf* Strategic agenda for the business climate in the Netherlands, 2022 *https://open.overheid.nl/documenten/ronl-177c07692be1e04fd57870be3e4880c42e2bc2a0/pdf* Netherlands Cybersecurity Strategy 2022-2028, 2022 *https://english.nctv.nl/binaries/nctv-en/documenten/publications/2022/12/06/the-netherlands-cybersecurity-strategy-2022-2028/The+Netherlands+Cybersecurity+Strategy+2022-2028.pdf* Action plan on green and digital jobs, 2023 *https://open.overheid.nl/documenten/ronl-a245a47c3d74e4bc8d2781bc835add45eb9efcd2/pdf*

Country	National digital strategy	Co-ordinated strategies or policies
New Zealand	The Digital Strategy for Aotearoa, 2022 *www.digital.govt.nz/assets/Digital-government/Strategy/Digital-Strategy-for-Aotearoa-English-PDF.pdf*	New Zealand's Cyber Security Strategy 2019, 2019 *www.dpmc.govt.nz/sites/default/files/2019-07/Cyber%20Security%20Strategy.pdf* Digital Technologies Industry Transformation Plan, 2023 *www.mbie.govt.nz/assets/digital-technologies-industry-transformation-plan.pdf* Government Data Strategy and Roadmap 2021, 2021 *www.data.govt.nz/docs/data-strategy-and-roadmap-for-new-zealand-2021* 2022–23 Action Plan for the Digital Strategy for Aotearoa, 2022 *www.digital.govt.nz/dmsdocument/238~202223-action-plan-for-the-digital-strategy-for-aotearoa/html*
Norway	Digital Agenda for Norway (2015-16), *www.regjeringen.no/no/dokumenter/meld.-st.-27-;20152016/id2483795/*	National Cyber Security Strategy, *www.regjeringen.no/contentassets/c57a0733652f47688294934ffd93fc53/national-cyber-securitystrategy-for-norway.pdf* Long-term plan for research and higher education 2019–2028, *www.regjeringen.no/contentassets/9aa4570407c34d4cb3744d7acd632654/engb/pdfs/stm201820190004000engpdfs.pdf* (updated version 2019-2028)
Portugal	Portugal Digital, Portugal's Action Plan for Digital Transition, 2020, *https://portugaldigital.gov.pt/wp-content/uploads/2022/01/Portugal_Action_Plan_for_Digital_Transition.pdf*	National Strategy for Cyberspace Security 2019-2023, 2019 *www.cyberwiser.eu/sites/default/files/portugal_-_ncss_2019_2023_en_2.pdf* AI Portugal 2030, 2019 *www.portugal.gov.pt/download-ficheiros/ficheiro.aspx?v=%3D%3DBAAAAB%2BLCAAAAAAABACzMDQxAQC3h%2ByrBAAAAA%3D%3D* Advanced Computing Portugal 2030, 2020 *https://rnca.fccn.pt/wp-content/uploads/2023/01/advanced-computing-portugal_2030-acp-2030-relatorio.pdf*
Slovak Republic	2030 Digital Transformation Strategy for Slovakia, 2019 *https://mirri.gov.sk/wp-content/uploads/2019/10/SDT-English-Version-FINAL.pdf*	The National Digital Skills Strategy of the Slovak Republic and the Action Plan for the years 2023-2026, 2023 *https://digitalnakoalicia.sk/wp-content/uploads/2023/08/THE-NATIONAL-DIGITAL-SKILLS-STRATEGY-OF-THE-SLOVAK-REPUBLIC-AND-THE-ACTION-PLAN-FOR-THE-YEARS-2023-2026.pdf* The Action Plan for the Digital Transformation of Slovakia for the years 2023-2026, 2023 *https://mirri.gov.sk/wp-content/uploads/2023/01/APDTS-2023-2026.pdf*
Slovenia	Digitalna Slovenija 2030, 2023 *https://nio.gov.si/nio/asset/strategija+digitalna+slovenija+2030?lang=en*	Strategy for the Digital Transformation of the Economy, 2021 *www.gov.si/assets/ministrstva/MGTS/Dokumenti/DIPT/Digitalizacija/Strategy-of-digital-transformation-of-the-economy.pdf* Digital Public Services Strategy 2030, 2023 *https://nio.gov.si/nio/asset/strategija+digitalnih+javnih+storitev?lang=en*
Spain	España digital 2026, 2021 *espanadigital.gob.es/sites/espanadigital/files/2022-08/Digital%20Spain%202026.pdf*	The Digital Infrastructure and Connectivity Plan for society, economy and the territories, 2020 *https://espanadigital.gob.es/sites/espanadigital/files/2022-10/Connectivity%20Plan.pdf*
Switzerland	Digital Switzerland Strategy 2023, 2023 *https://digital.swiss/*	
United Kingdom	UK Digital Strategy, 2022 *www.gov.uk/government/publications/uks-digital-strategy/uk-digital-strategy*	Levelling Up the United Kingdom, 2022 *https://assets.publishing.service.gov.uk/media/61fd3c71d3bf7f78df30b3c2/Levelling_Up_WP_HRES.pdf* Digital Regulation: Driving growth and unlocking innovation, 2021 *www.gov.uk/government/publications/digital-regulation-driving-growth-and-unlocking-innovation* National Cyber Strategy 2022, 2022 *https://assets.publishing.service.gov.uk/media/620131fdd3bf7f78e469ce00/national-cyber-strategy-amend.pdf*

Notes: The policies assessed from New Zealand were developed under a previous administration. As of June 2024, Norway's NDS is being revised.

References

Gierten, D. and M. Lesher (2022), “Assessing national digital strategies and their governance”, *OECD Digital Economy Papers*, No. 324, OECD Publishing, Paris, *https://doi.org/10.1787/baffceca-en*. [2]

OECD (2024), *Going Digital Toolkit*, *https://goingdigital.oecd.org* (accessed on 27 February 2024). [3]

OECD (2024), “National digital strategy comprehensiveness”, *OECD Going Digital Toolkit*, based on the OECD National Digital Strategy Database, *https://oe.cd/ndsc* (accessed on 18 November 2024). [5]

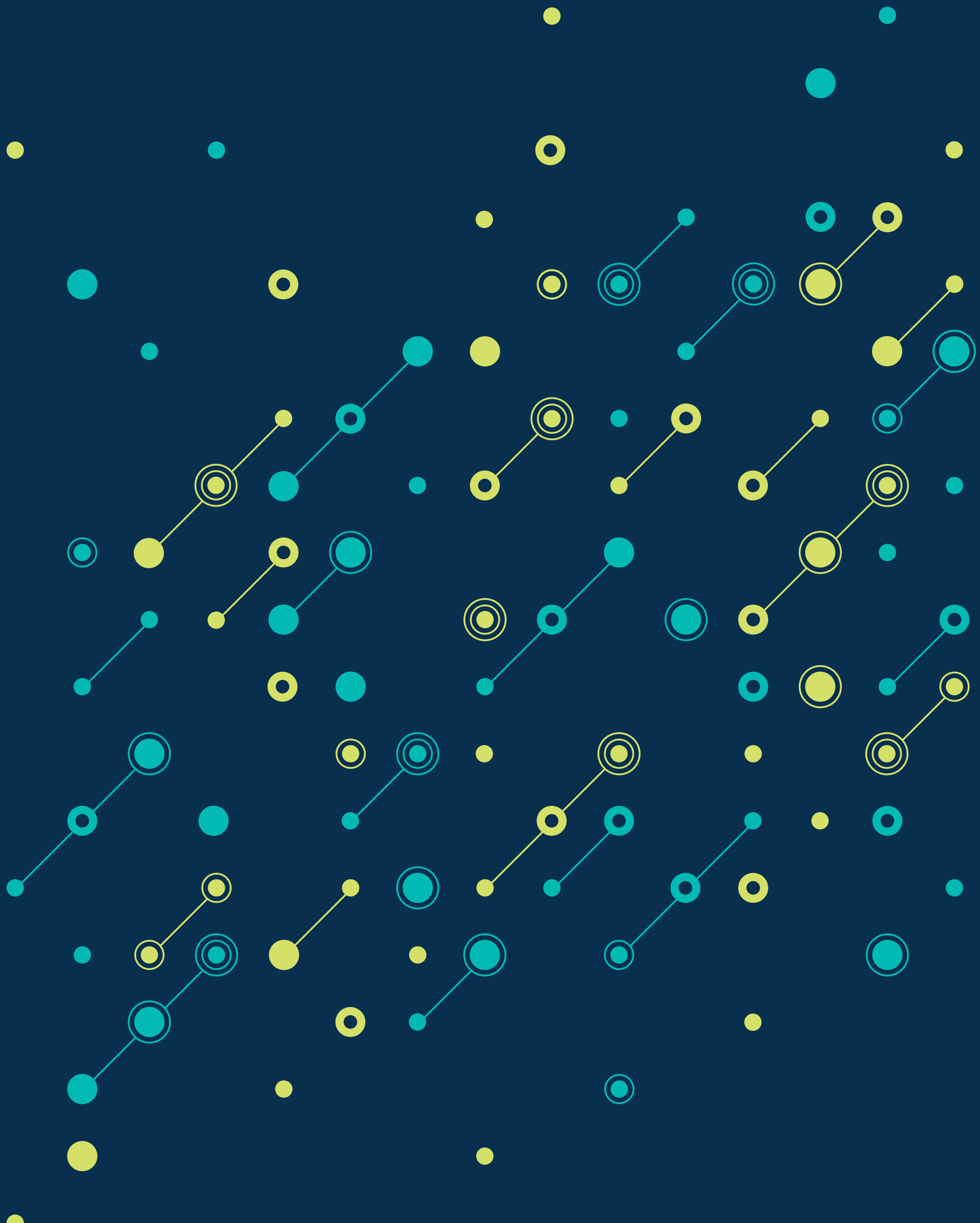
OECD (2020), “Going Digital integrated policy framework”, *OECD Digital Economy Papers*, No. 292, OECD Publishing, Paris, *https://doi.org/10.1787/dc930adc-en*. [1]

OECD (2020), *OECD Digital Economy Outlook 2020*, OECD Publishing, Paris, *https://doi.org/10.1787/bb167041-en*. [4]

Notes

1. OECD countries that responded to Part I of the questionnaire on digital policy priorities comprise: Austria, Belgium, Canada, Chile, Colombia, Costa Rica, the Czech Republic, Denmark, Estonia, Finland, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Korea, Latvia, Lithuania, Luxembourg, Mexico, the Netherlands, New Zealand, Norway, Poland, Portugal, the Slovak Republic, Slovenia, Spain, Sweden, Switzerland, Türkiye and the United Kingdom. Partner economies that responded comprise: Bulgaria, Brazil, Croatia, Jordan, Peru, Romania, Singapore and Thailand.
2. OECD countries that responded to Part I of the questionnaire on national digital strategies and their governance comprise: Austria, Belgium, Canada, Costa Rica, the Czech Republic, Denmark, Estonia, Finland, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Korea, Latvia, Lithuania, Luxembourg, Mexico, the Netherlands, New Zealand, Norway, Portugal, the Slovak Republic, Slovenia, Spain, Switzerland, Türkiye and the United Kingdom. Partner economies that responded comprise: Bulgaria, Brazil, Croatia, Jordan, Peru, Romania, Singapore and Thailand.
3. OECD countries that responded to Part II of the questionnaire on the digital policy landscape comprise: Austria, Belgium, Canada, Chile, Colombia, Costa Rica, the Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Israel, Italy, Japan, Korea, Latvia, Lithuania, Luxembourg, Mexico, the Netherlands, New Zealand, Norway, Poland, Portugal, the Slovak Republic, Slovenia, Spain, Sweden, Switzerland, Türkiye, the United Kingdom and the United States. Partner economies that responded comprise: Argentina, Bulgaria, Brazil, Croatia, Jordan, Peru, Romania, Singapore and Thailand.
4. OECD countries that responded to Part III of the questionnaire comprise: Austria, Belgium, Canada, Chile, Colombia, Costa Rica, the Czech Republic, Denmark, Finland, Germany, Hungary, Ireland, Iceland, Israel, Italy, Japan, Korea, Latvia, Lithuania, Luxembourg, Mexico, the Netherlands, Norway, Portugal, the Slovak Republic, Slovenia, Spain, Switzerland, Sweden, Türkiye and the United Kingdom. Partner economies that responded comprise: Bulgaria, Croatia, Jordan, Peru, Romania, Singapore and Thailand.
5. OECD countries that responded to the *DEO 2017* Questionnaire comprise: Austria, Belgium, Canada, Chile, the Czech Republic, Denmark, Estonia, Finland, France, Germany, Hungary, Ireland, Israel, Italy, Japan, Korea, Latvia, Lithuania, Luxembourg, Mexico, the Netherlands, New Zealand, Norway, Poland, Portugal, the Slovak Republic, Slovenia, Spain, Switzerland, Türkiye, the United Kingdom and the United States. Partner economies that responded comprise: Brazil, the People’s Republic of China, Costa Rica, Lithuania, the Russian Federation and Singapore.
6. OECD countries that responded to the *DEO 2020* on national digital strategies and policies comprise: Australia, Austria, Belgium, Canada, Chile, Colombia, the Czech Republic, Denmark, Estonia, Finland, Germany, Greece, Hungary, Iceland, Israel, Italy, Japan, Korea, Latvia, Lithuania, Luxembourg, Mexico, the Netherlands, Norway, Poland, Portugal, Slovenia, Spain, Sweden, Switzerland, Türkiye, the United Kingdom and the United States. Partner economies that responded comprise: Brazil, Costa Rica, the Russian Federation, Singapore and Thailand.

7. An NDS is considered to be fully comprehensive if either the NDS itself or a co-ordinated strategy or policy contains at least one policy measure in each of the Framework's 38 policy domains. To qualify as a co-ordinated policy or strategy, the respective document must be either initiated, discussed or referenced in a section of the NDS that addresses issues in the policy domain(s) for which the measure(s) from a co-ordinated document may be considered. Each dimension of the Framework is given an individual comprehensiveness score, which is calculated as the proportion of domains within the dimension containing at least one qualifying policy measure. Each policy measure can only be considered once within the assessment process. A full list of the documents considered for the assessment can be found in Annex 1.B.
8. Figure 2 includes the 22 countries with an NDS meeting the definition stated above, in addition to five countries whose previously assessed NDS remains valid.



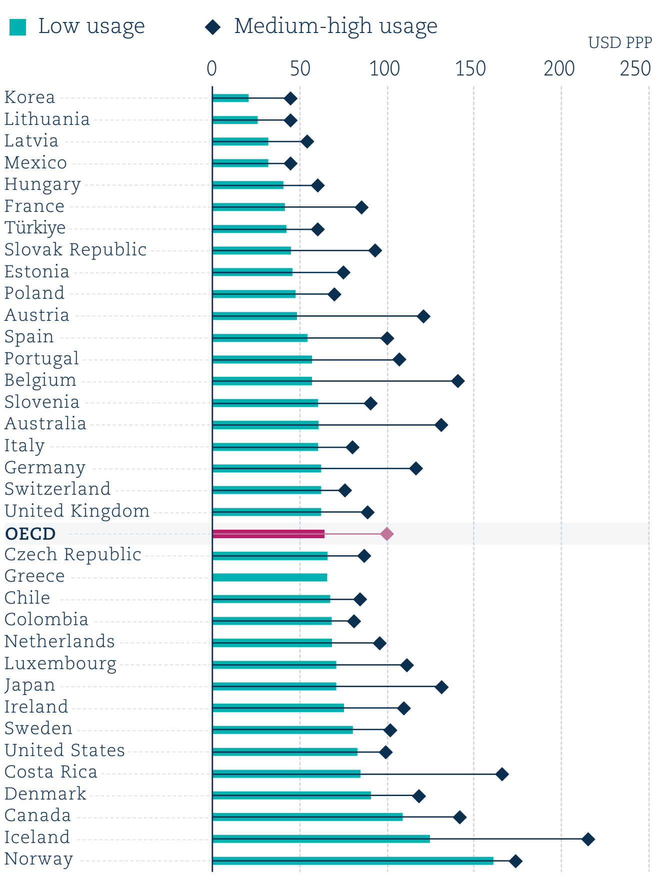
Chapter 2

Trends in access and connectivity

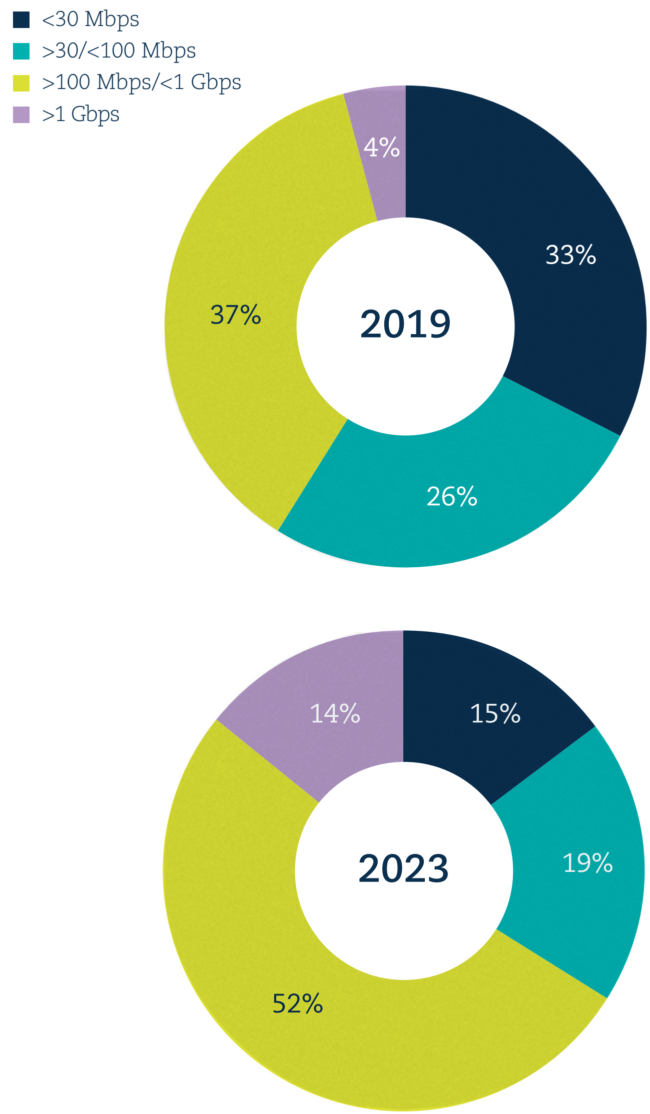
Our digital future relies on ubiquitous, high-quality and affordable connectivity. This chapter assesses progress towards this goal by exploring the status and main developments in broadband connectivity, subscription rates, access technologies and the quality of broadband connections. It looks at the state of digital divides through the lens of communication services affordability and spatial connectivity gaps, and identifies actions to close these gaps. The chapter concludes with trends shaping future connectivity and how communication policy and regulation must adapt to bring broadband connectivity to the next level of connecting people, businesses and things.

Our digital future relies on ubiquitous, high-quality and affordable connectivity

Affordability is one of the main barriers to broadband uptake in many countries.
There is a wide disparity in prices of triple-play bundled communication baskets (TV, Internet, voice) across the OECD.



The demand for high-quality connectivity is on the rise.
The share of gigabit fixed broadband subscriptions more than tripled from 2019 to 2023 in the OECD.



Since 2021, OECD communication regulators have expanded their mandate in broader digital issues including AI, IoT, cloud computing, streaming services as well as environmental sustainability.

Key findings

Developments in connectivity: Where do we stand?

- Without connectivity, there is simply no digital transformation. As the latter progresses, the demand for high-quality broadband services continues to increase in the OECD area. For example, the share of gigabit fixed broadband subscriptions more than tripled from 2019 to 2023, reaching 14% of total fixed broadband subscriptions by December 2023.
- Fibre-to-the-home connections that help "future-proof" networks have been the fastest growing fixed broadband access technology in OECD countries during the last decade accounting for 42% of all fixed subscriptions at the end of 2023.
- The rollout of 5G continues apace. As of June 2024, 5G was available in 37 of 38 OECD countries. The number of 5G connections per 100 inhabitants averaged 38.6 in 2023 up from 25 (per 100) a year earlier, according to GSMA Intelligence data.

Towards bridging connectivity divides

- Bridging connectivity divides (i.e. gaps in affordable access to high-quality broadband services) is at the heart of the policy agenda in OECD countries, more than half of which consider access to the Internet as a basic right for citizens.
- Affordability is one of the main barriers for broadband adoption and take-up. Mobile broadband prices have significantly decreased over 2013-23 in OECD countries. Prices of bundled communication services across the OECD area, however, remained relatively stable during 2020-23. The exception has been a 19.5% decrease in the price of the common triple-play (i.e. fixed broadband, fixed voice and television) medium-usage profile bundle.
- There are persistent and substantial territorial gaps to high-quality broadband access across and within countries. In OECD countries, people living in cities (metropolitan areas) experienced median fixed broadband download speeds that were 50% higher than those available to people living in regions far from metropolitan areas in Q4 2023 (based on OECD analysis of data provided by Ookla).

Main trends shaping the future of connectivity and related policy challenges

- Future policy priorities for OECD countries include transitioning to more future-proof networks; bridging connectivity divides; addressing changes to market structures in the connectivity ecosystem; and ensuring secure, resilient and environmentally sustainable communication networks.
- Policy makers and regulators have been active in furthering access to high-quality broadband networks and adapting regulatory frameworks. Several OECD countries are beginning to shut down legacy networks.
- Communication regulators increasingly play a role in broader digital policy issues. Since 2021, their partial or full responsibilities increased for topics related to over-the-top services; end-user devices; the Internet of Things (IoT); artificial intelligence (AI); environmental sustainability, and cloud computing.

Our digital future relies on ubiquitous high-quality and affordable connectivity. However, despite the remarkable progress in the deployment of fixed and mobile networks, there are still significant disparities between urban and rural areas in the use, quality and coverage of broadband connections. Access to high-quality and resilient networks and services is increasingly urgent to secure an inclusive digital future.

This chapter comprises three sections. First, it provides an overview of developments in connectivity. It then focuses on connectivity divides and key policy challenges in the pursuit of expanding high-quality connectivity for all. Finally, the chapter discusses the main trends shaping future networks and emerging communication policy issues raised by an evolving connectivity ecosystem.

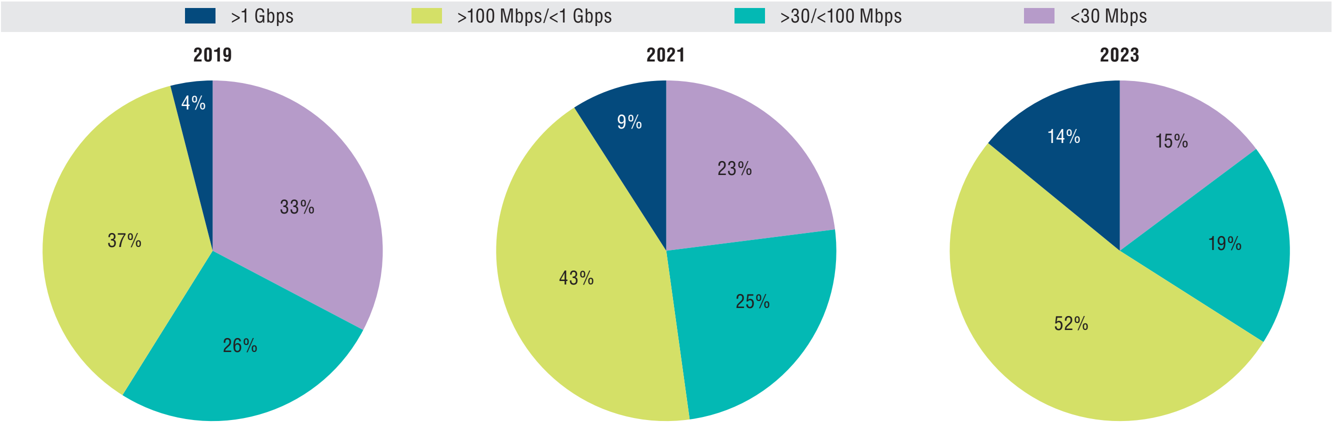
Developments in connectivity: Where do we stand?

Applications across all sectors of the economy, from smart factories and hospitals to automated vehicles, increase the overall demand on broadband networks. Consequently, to meet growing needs, networks evolve to offer higher speeds, greater reliability and improved network response times (i.e. low latency) (OECD, 2022[1]). Actions today to promote high-quality broadband networks will influence the implementation and diffusion of digital technologies transforming our society (e.g. the IoT, AI, augmented and virtual reality).

The demand for reliable and high-quality broadband connectivity is growing in OECD countries. In recent years, broadband users have been upgrading their connections to gigabit fixed broadband offers (i.e. subscriptions with advertised speeds above 1 gigabit per second [Gbps]), reflecting the rise of remote activities. Between 2019 and 2023, the share of gigabit offers over total fixed broadband subscriptions grew 250% across the OECD, reaching 14% of fixed broadband subscriptions in December 2023, up from 4% at the end of 2019. In December 2023, two thirds (66%) of all fixed broadband subscriptions had advertised speeds higher than 100 megabits per second (Mbps) (Figure 2.1). Following a similar trend, the volume of mobile data usage per subscription in OECD countries almost tripled over a five-year period, from 4.7 gigabytes (GB) per SIM card per month in 2018 to 13 GB in 2023. For some leading countries, such as Latvia, Finland and Austria, this average exceeds by a factor of three or four, with data usages of 48, 45 and 35 GB per month, respectively (OECD, 2024[2]). This trend will continue upwards with the increased adoption of 5G across OECD countries.

Figure 2.1. Take-up of gigabit fixed broadband offers grew strongly in the OECD from 2019 to 2023

Fixed broadband offers by speed tiers as a share of total fixed broadband subscriptions in the OECD area



Note: Data are for available OECD countries.

Source: OECD elaborated from the *CSI DEO 2024* Data Questionnaire.

StatLink https://stat.link/se710x

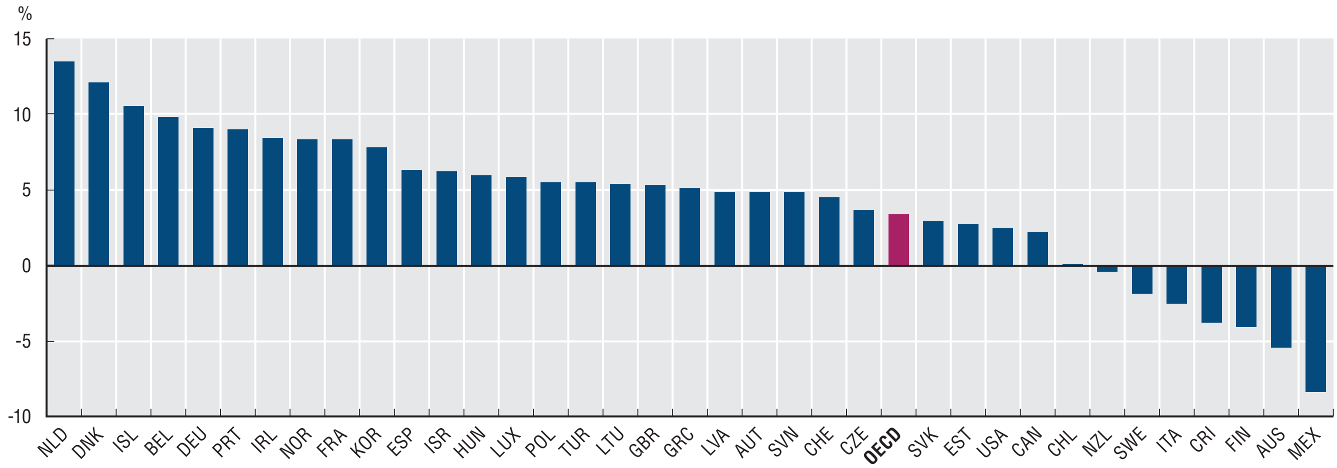
Given the trend towards a "remote economy", where business processes increasingly move on line, people adopt flexible working and learning approaches and data-intensive applications continue to grow, the demand on networks is only expected to increase (OECD, 2022[1]). This demand must be met with investments to expand and upgrade broadband networks. Over the past decade, investments in the communication sector in OECD countries grew by 39%, which translates to a compound annual growth rate (CAGR) of 3.3%. In five years (2018-23), the sector experienced a 18% investment increase (CAGR of 3.4%), reaching USD PPP (purchasing power parity) 290 billion at the end of 2023 (Figure 2.2).

Several OECD countries – Belgium, Denmark, Germany, Iceland, the Netherlands and Portugal – experienced investment growth higher than 50% (CAGR 9%) over 2018-23 (Figure 2.2). The three-year rolling OECD average investment per capita during 2021-23 in the communication sector amounted to USD PPP 207 (OECD, 2024[2]).

Revenues of communication service providers in OECD countries increased slightly during the 2018-23 period at a CAGR of 1.3% while the share of investment over communication sector revenues rose from 16.5% to 19%. Most OECD countries experienced an increase of this ratio over the last five years (i.e. 26 of 36 countries for which data were available). Investment by communication service providers was mainly driven by the expansion and upgrade of broadband networks, such as fibre and 5G, as well as the decommissioning of legacy networks (e.g. copper DSL and 2G/3G mobile networks). For more details on revenues and investments in the communication sector per country and per year, please refer to the Statistical Annex.

Figure 2.2. Investment in the communication sector has risen in most OECD countries over the 2018-23 period

Compound annual growth rate of investment in the communication sector in OECD countries, 2018-23



Notes: Data for 2022 have been used as estimates for the missing 2023 data. For Colombia, investment data are not available. Japan is not included in the graph because a change in the data collection methodology that occurred in 2021.

Source: OECD (2024[2]), *Broadband Statistics* (database), *https://www.oecd.org/en/topics/sub-issues/broadband-statistics.html*.

StatLink *https://stat.link/1sx3w5*

In recent years, the connectivity ecosystem has also diversified with other players besides "traditional" communication operators financing communication networks (e.g. private equity firms, fibre wholesale-only operators, tower companies). For example, tower companies invest in parts of the broadband infrastructure, a direct consequence of divestments by traditional communication operators. In addition, although not their core business, publicly listed technology companies often develop their own communication infrastructure and financial asset providers. Such providers, including private equity firms, hedge funds or pension funds, increasingly deliver capital to invest in the sector, namely in fibre wholesale access networks. The latter is changing both the structure of the connectivity ecosystem and traditional ownership structures of broadband networks, as explored in recent OECD work (OECD, 2024[3]).

Deployment status of future-proof technologies

The sharp rise in usage and demand for high-quality, ubiquitous connectivity is leading to a transition to "future-proof" broadband access technologies that can support digital transformation across all sectors of the economy. Scalable broadband access technologies that can provide symmetrical download and upload broadband speeds, such as fibre-to-the-home (FTTH), exemplify this trend. In addition, countries are at full speed in the deployment of next generation wireless networks, such as 5G.

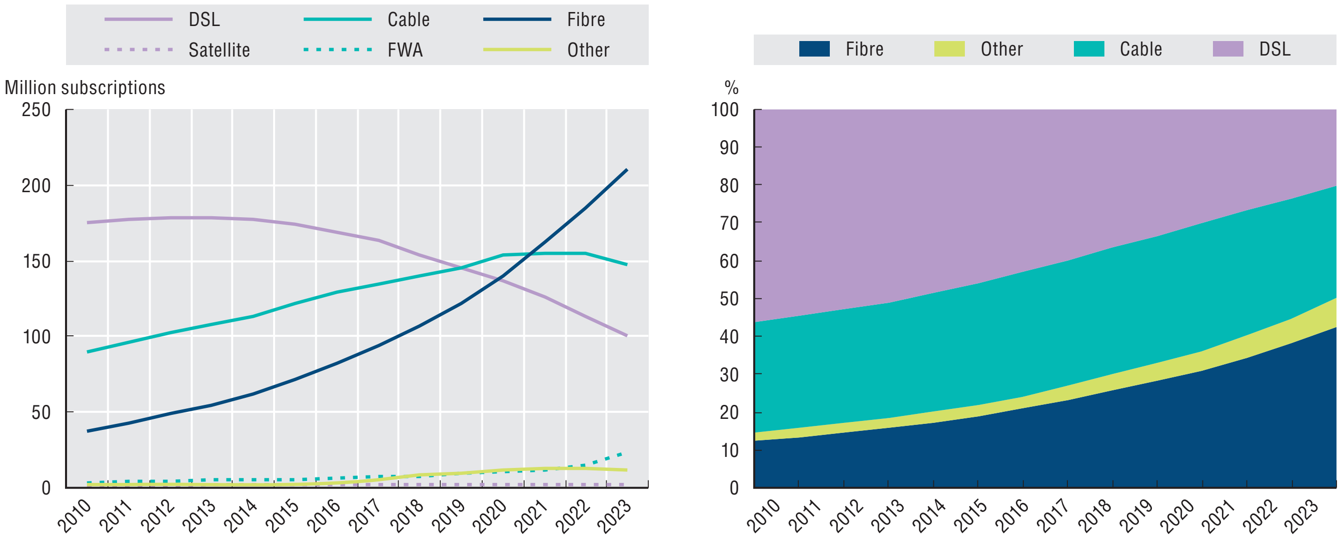
At a wholesale level, fibre needs to be deployed deeper into networks to increase broadband performance across all access technologies. Mobile networks are quickly becoming the extension of fixed networks as network densification progresses. This process brings mobile cells closer to users for increased performance, which requires access to backhaul connectivity to redirect mobile traffic via fixed networks (OECD, 2019[4]). This includes offloading indoor mobile traffic into wireless local area networks (WLANs, such as Wi-Fi). It also involves redirecting mobile access traffic in radio access networks (RANs) to the operator's fixed core networks (i.e. backhaul and backbone), mostly comprised of fibre.

The deployment and adoption of broadband has seen strong growth over the last decade (2013-23) in OECD countries. Total fixed and mobile broadband subscriptions increased by 42% and 100%, respectively, during the period. Moreover, in recent years, fixed broadband subscriptions were still growing in most OECD countries, reaching 496.5 million in December 2023 and averaging 36 subscriptions per 100 inhabitants. This compares to 433.4 million at the end of 2019, shortly before the start of the COVID-19 pandemic. The difference amounts to an increase of 63 million, or 15%, in four years. Fibre accounted for 42% of all fixed subscriptions at the end of 2023, up from 28% in December 2019 (Figure 2.3). During the same period, mobile broadband subscriptions continued to expand, despite high penetration rates, growing by 19% between 2019 and 2023.

Fibre has been the fastest growing fixed broadband technology in the last decade (Figure 2.3). During the 2013-23 period, and starting in 2014, legacy copper DSL has continued to decline. It is being replaced by fibre, which is now the dominant access technology for fixed broadband connections in OECD countries (Figure 2.3).

Figure 2.3. Fibre has become the dominant fixed broadband access technology in OECD countries

Evolution of total fixed broadband subscriptions by access technology in the OECD, 2010-23



Notes: Fibre subscriptions data include fibre-to-the-home (FTTH) also known as fibre-to-the-premises (FTTP), and fibre-to-the-building (FTTB); it excludes fibre-to-the-curb (FTTC) and fibre-to-the-node (FTTN). For the graph on the Percentage share of fixed broadband subscriptions, "Other" includes fixed wireless access (FWA), satellite and other technologies.

Source: OECD (2024[2]), *Broadband Statistics* (database), *www.oecd.org/sti/broadband/oecdbroadbandportal.htm*.

StatLink https://stat.link/31e8r2

Belgium, Greece, Israel, Mexico and United Kingdom increased their fibre subscriptions by more than 40% in one year (2022-23). At the end of 2023, the share of fibre in total fixed broadband subscriptions exceeded 80% in Iceland, Korea, Lithuania and Spain. In addition, it was greater than 50% in a further fourteen OECD countries (Chile, Denmark, Estonia, Finland, France, Japan, Latvia, Luxembourg, Mexico, New Zealand, Norway, Portugal, Slovenia and Sweden) (OECD, 2024[2]). The introduction of policies, incentives and public funding to support fibre rollout contributed to this growth (see Section on Main trends shaping the future of connectivity and related policy challenges).

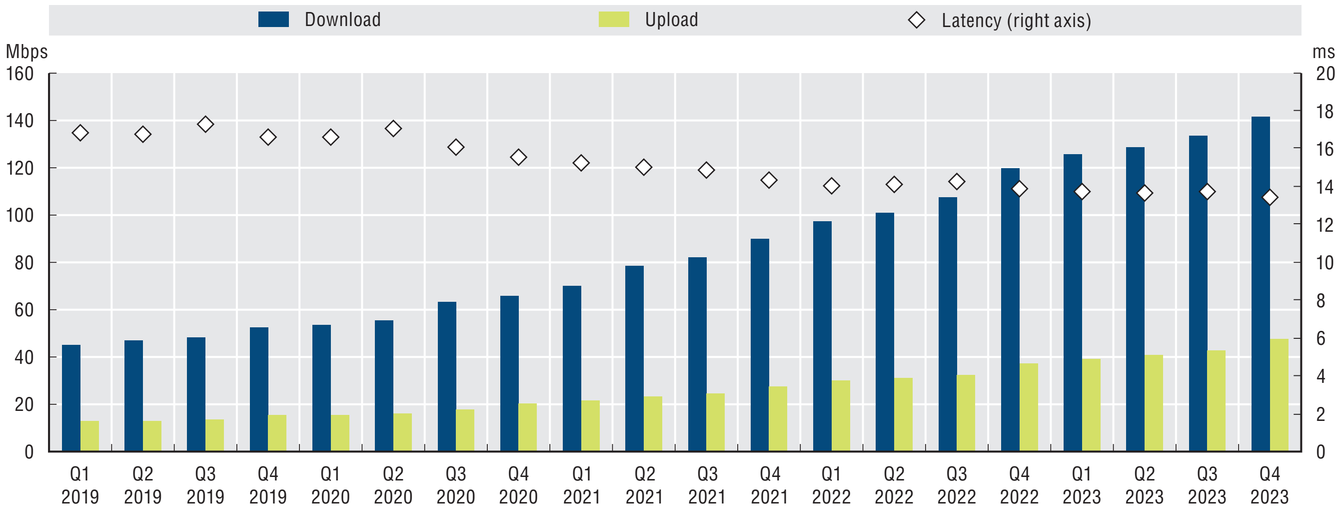
The take-up of cable remained relatively stable over 2013-23, with a slight rise from 8 to 10.6 subscriptions per 100 inhabitants in 2023. In some OECD countries, cable has high penetration rates (e.g. United States, Belgium, Canada and the Netherlands, with 24, 23, 20 and 19 subscriptions per 100 inhabitants, respectively) (OECD, 2024[2]). In December 2023, cable made up 30% of total fixed broadband subscriptions,[1] while fixed wireless access (FWA) and satellite broadband represented only 5% and 0.5% of total fixed broadband subscriptions across the OECD, respectively (Figure 2.3).

Broadband performance indicators are key to gauging the state of connectivity and are often correlated to the type of access technology pervasive in the market. Notwithstanding the increase in data traffic, networks are managing demand effectively. Across the OECD, fixed broadband download and upload speeds experienced by users increased in the 2019-23 period. According to data from Ookla, median download speeds in OECD countries, on average, rose 169% in four years (Q4 2019 – Q4 2023), while median upload speeds more than doubled (i.e. 207% growth). Meanwhile, median latency was reduced by 20% during the same period (Figure 2.4). An increase in upload speeds can have significant effects on people teleworking or using video conferencing applications that require upload throughput. A reduction in latency (i.e. network response time) is important for critical applications.

Total mobile broadband subscriptions more than doubled over the past decade in OECD countries. Between 2013 and 2023, mobile broadband subscriptions rose from 928 million to 1.86 billion, reaching a penetration of 134 subscriptions per 100 inhabitants (OECD, 2024[2]). One of the recent factors driving this demand is the introduction of 5G.

Figure 2.4. Across the OECD, download and upload speeds are steadily increasing, while latency declined in the 2019-23 period

Evolution of fixed broadband median speeds and latency experienced in OECD countries, Q1 2019 to Q4 2023



Notes: Mbps = Megabite per second. ms = milliseconds. OECD calculations are based on Speedtest by Ookla Fixed Network Performance Maps for Q1 2019 – Q4 2023. OECD average is of download median speed and latency tests experienced, weighted by the number of tests across 36 OECD countries (data for Costa Rica and Israel unavailable). Measurements are based on tests performed by users around the globe via the Speedtest platform. For a more comprehensive picture on broadband performance metrics, see OECD (2022[1]).

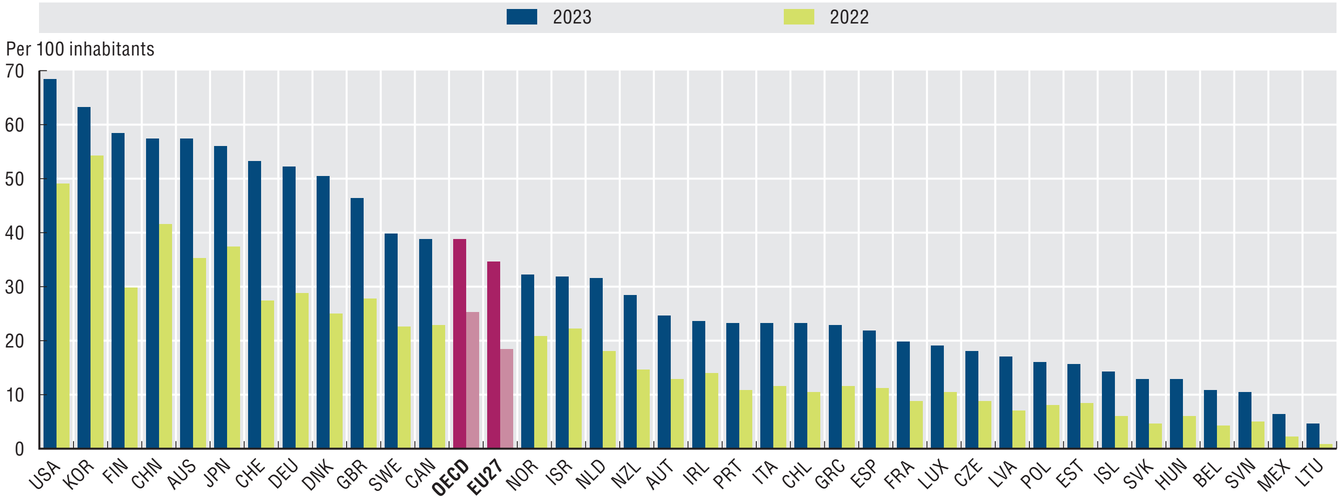
Source: Speedtest® by Ookla®.

StatLink https://stat.link/j8d7hf

The rollout of 5G continues apace. As of June 2024, 5G was available in some form in 37 of 38 OECD countries.[2] According to GSMA Intelligence, the number of 5G connections[3] per 100 inhabitants averaged 38.6 in 2023 up from 25 the prior year for the 35 OECD countries where data was available (Figure 2.5). The top-five leading OECD countries were the United States with 68.4 5G connections per 100 inhabitants, followed by Korea (63), Finland (58), Australia (57) and Japan (56) (Figure 2.5). Moreover, according to this same data source, the share of 5G connections in overall mobile connections in OECD countries was 31% in 2023 (GSMA Intelligence, 2024[5]).

Figure 2.5. In just one year, 5G connections have grown significantly

5G connections per 100 inhabitants, OECD, EU27 and People's Republic of China



Notes: GSMA Intelligence's definition of 5G connections: "5G unique SIM cards (or phone numbers, where SIM cards are not used) that have been registered on the mobile network at the end of the period. Connections differ from subscribers such that a unique subscriber can have multiple connections." See *https://data.gsmaintelligence.com/definitions*.

Sources: GSMA (2024[5]), ©GSMA Intelligence 2024, *OECD National Accounts Statistics* (database), *https://doi.org/10.1787/na-data-en* (accessed on 26 June 2024).

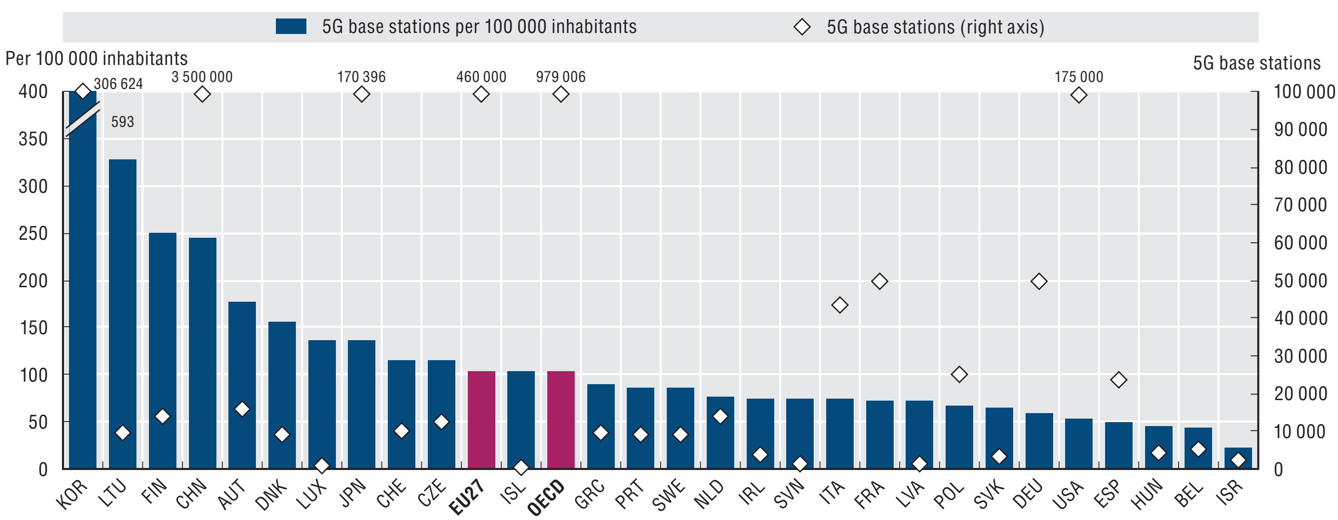
StatLink https://stat.link/ep2x96

The number of 5G base stations is an indicator on the level of deployment of commercial services within countries and can influence the availability and quality of these services. The number of 5G base stations is constantly increasing and reached 979 000 in 2023 for the 27 OECD countries where data were available. Korea has the highest number of 5G base stations relative to its population with 593 base stations per 100 000 inhabitants, followed by Lithuania (328) and Finland (251) (Figure 2.6).

Most 5G commercial networks to date are based on non-standalone (NSA)-5G (i.e. relying on 4G core network infrastructure and using NSA-5G standards in the radio interface). However, standalone (SA)-5G deployments are on the rise (OECD, 2022[1]). While NSA-5G is built using current 4G core networks, SA-5G requires deploying an entire new network end-to-end (OECD, 2022[1]).[4] SA-5G offers a number of advantages such as faster speeds, lower latency, support for massive numbers of devices, and programmable systems enabling faster and more agile creation of services and network slices. In all, 124 of 588 operators in 58 countries worldwide are investing in 5G-SA for public networks, with at least 49 operators in 29 countries having launched 5G-SA commercial networks by April 2024 (GSA, 2024[6]).

Figure 2.6. 5G base station deployment is on the rise but varies widely across OECD countries

5G base stations, 2022 OECD, EU27 and People's Republic of China, 2023



Notes: OECD total is for the 27 OECD countries where data were available. Data for Japan are for March 2023 and data for Korea are for August 2023.

Source: OECD elaborated from the *CSI DEO 2024 Data* Questionnaire. Japan: Data are from MIC (2024[7]), *Survey on Actual Radio Spectrum Usage*. Korea: Base stations data are from MIST (2024[8]) K-Network 2023 Strategy. Data for Austria, Hungary, Luxembourg, the People's Republic of China, the Slovak Republic and the United States are from European Commission (2024[9]).

StatLink *https://stat.link/limgkq*

Across the OECD, private networks have also been emerging in different sectors, e.g. industrial applications, health care and national defence. Private networks are usually local, non-public communication networks. They are typically dedicated to the owner of the network with unified connectivity and optimised services within a specific area (e.g. a factory or plant). Such networks can be operated by the entities owning the networks or by mobile network operators (MNOs). By June 2024, 78 countries had at least one private mobile network and more than 66 network operators were involved with private mobile network deployments, according to a GSA report (GSA, 2024[10]).

A major hurdle for the development of private networks is providing access to appropriate and affordable spectrum. Local private networks can access spectrum resources either through direct local licences assigned to non-communication service providers (i.e. industrial firms, public entities) or via mobile operators offering such capabilities (OECD, 2022[11]). In Korea, spectrum for private 5G networks is shared in specific zones (e.g. lot, building) to provide services tailored to the demand in the area – from manufacturing, education and ship building to logistics and health. To allow customised private 5G services in diverse areas, Korea has provided 50 branches of 29 companies with private 5G spectrum as of 13 December 2023. In Portugal, ANACOM approved changes to the spectrum access model in the 400 MHz band for providers interested in delivering private mobile services to third parties.

Developments in wireless indoor connectivity are increasingly important and complement other connectivity solutions. WLANs are a particularly important use case that benefit from unlicensed spectrum to support connectivity, primarily indoors, for residential home networks, as well as local area networks for enterprises. They also serve to offload data from mobile networks (OECD, 2022[11]). Several developments can be noted concerning Wi-Fi[5] standard, a type of WLAN. Wi-Fi 6 and Wi-Fi 6E, for example, aim to improve performance particularly for large outdoor deployments, increase throughput in dense deployments and reduce device power consumption (Intel, 2024[12]). Wi-Fi 7 was expected to be released in mid-2024 (Koziol, 2023[13]).[6]

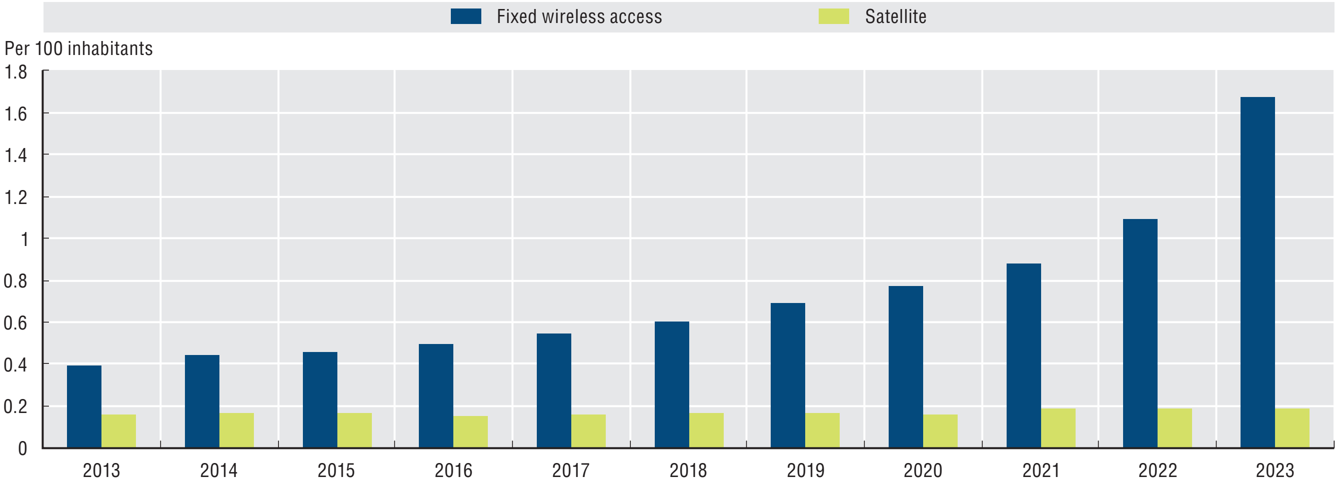
Other broadband access technologies: Fixed wireless access and satellite broadband

The ambition to connect the entire population, and therefore people living in remote areas, has led operators and local players to find innovative connectivity solutions. While FWA and satellite broadband access have existed for a while, recent technological developments promise to allow these technologies to bridge spatial connectivity divides.

In recent years, FWA has grown steadily in OECD countries. Despite the low level of adoption (i.e. 1.7 subscriptions per 100 inhabitants in December 2023), the number of FWA subscriptions reached 23 million in 2023 (OECD, 2024[2]) (Figure 2.7). In December 2023, FWA penetration was higher than the OECD average in certain countries, such as the Czech Republic (15 subscriptions per 100 inhabitants), the Slovak Republic (7.7), New Zealand (7) and Estonia (6.7) (OECD, 2024[2]).

Figure 2.7. FWA and satellite subscriptions continue to grow in OECD countries and may help bridge spatial connectivity divides

Fixed wireless access (FWA) and satellite subscriptions per 100 inhabitants, OECD



Note: OECD average is for available countries. The FWA definition was revised in 2023.

Source: OECD (2024[2]), *Broadband Statistics* (database), *OECD Telecommunications and Internet Statistics* (database), *https://www.oecd.org/en/topics/sub-issues/broadband-statistics.html*. StatLink contains more data.

StatLink https://stat.link/etcjzb

Satellite broadband, meanwhile, has remained at a low level, averaging around 0.2 subscriptions per 100 inhabitants over the 2013-23 period in OECD countries (Figure 2.7). In December 2023, New Zealand, the United States and Australia had the highest satellite penetration with 0.9, 0.6 and 0.3 subscriptions per 100 inhabitants, respectively (OECD, 2024[2]). More details on advances in satellite technology, including recent developments in low Earth orbit (LEO) satellite constellations, can be found in *DEO Volume 1*, Spotlight "Next generation networks and the evolving connectivity ecosystem" (OECD, 2024[14]).

Operators are expanding FWA solutions in several OECD countries (e.g. Australia, Italy, New Zealand, Switzerland and the United States). For example, in Australia, Nokia will supply FWA services using millimetre wave spectrum for the National Broadband Network (NBN) (Majithia, 2022[15]). In the United States, T-Mobile and Verizon have been leading with FWA offers. T-Mobile expects to serve 7-8 million FWA customers by 2025, and Verizon's Home Internet" service expects to serve 4-5 million subscribers by the end of 2025 (Alleven, 2022[16]; Fletcher, 2022[17]). In India, Reliance Industries announced an "AirFiber" service in 2022, an FWA offer leveraging on Reliance Jio's 5G network with a device that acts as a Wi-Fi hotspot at home or in a business (Hardesty, 2022[19]). The company launched the service in eight Indian cities in September 2023 and plans to reach 100 million FWA customers (Wood, 2023[20]).

FWA may provide advantages in terms of reaching remote residential locations with high-speed as a complementary solution for last mile connectivity. At the same time, FWA drawbacks include bandwidth limitations depending on spectrum availability. The specific benefits often depend on the technology used (e.g. 4G-LTE, 5G, WiMax) and how operators manage traffic from FWA connections.

While technologies like FWA and satellite broadband are proposed as possible options to provide communication services in rural and remote areas, they can come with drawbacks. For example, satellite broadband may have restricted bandwidth (e.g. data caps), a lower advertised speed or be of lower quality at a higher price (OECD, 2022[21]). Acknowledging the potential role of satellites in bridging connectivity divides, as well as the associated costs, some countries have previously opted to incorporate subsidies for satellite services in rural areas (OECD, 2018[22]; 2017[23]).

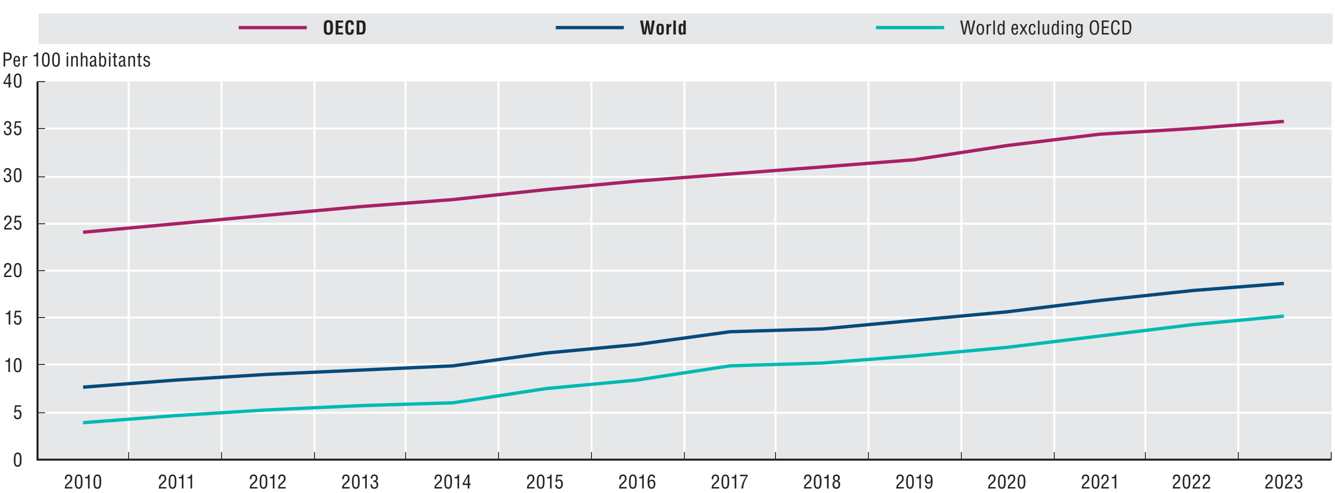
Towards bridging connectivity divides

Without connectivity, there is simply no digital transformation. Therefore, closing gaps in affordable access to high-quality broadband services (i.e. bridging connectivity divides[7]) is at the forefront of digital policy agendas. As such, Phase IV of the OECD's horizontal project "Going Digital" (2023-24) aims to shed light on such divides through the "Digital Divides: Improving connectivity" pillar.

Connectivity divides vary across and within countries. For example, OECD countries had more than twice the level of fixed broadband penetration (35.8 subscribers per 100 inhabitants) than the world average (excluding OECD countries) of 15 per 100 in December 2023 (Figure 2.8).

Figure 2.8. While fixed broadband penetration is growing around the world, there are persistent connectivity divides across countries

Evolution of fixed broadband subscriptions per 100 inhabitants, OECD and world



Note: Data for World average based on ITU data.

Source: OECD (2024[2]), *Broadband Statistics* (database); (ITU, 2024[24]), *World Telecommunication/ICT Indicators* (database), *www.itu.int/pub/D-IND-WTID.OL.*

StatLink *https://stat.link/but9le*

On many dimensions, great progress has been made to increase the number of connected people and start closing connectivity divides. However, persistent and substantial territorial gaps to affordable and high-quality broadband remain. Therefore, assessing the affordability of communication services and spatial connectivity divides are important indicators to guide policy makers in their pursuit of achieving connectivity for all.

Affordable access to communication services

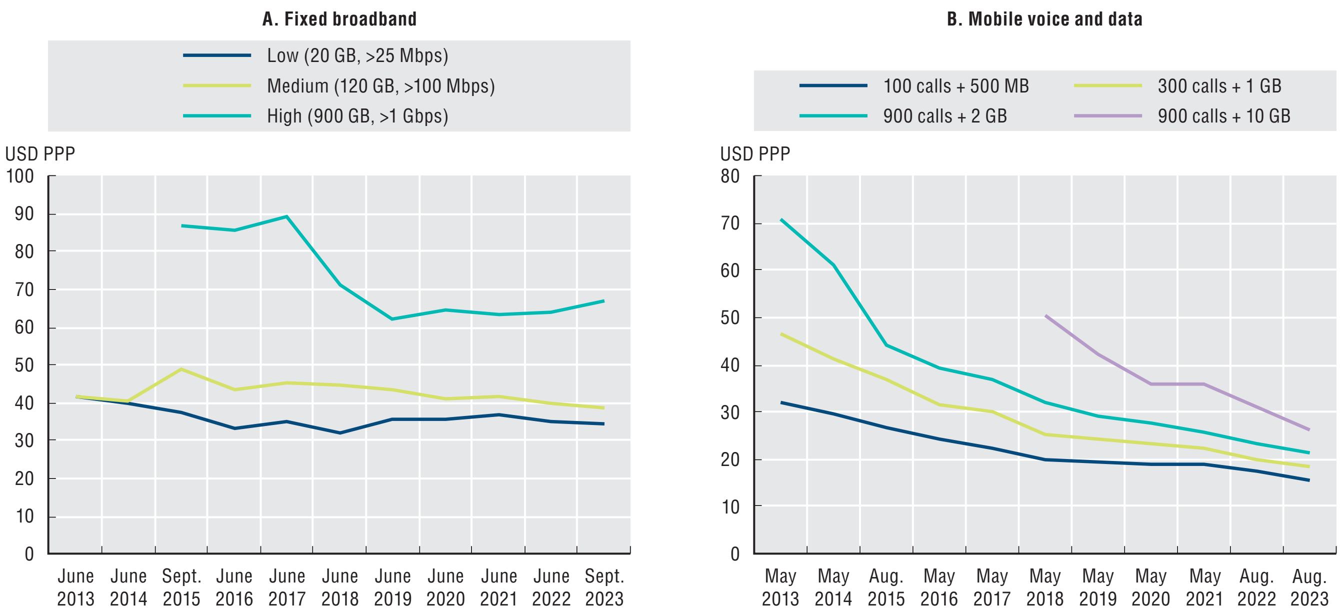
Affordable access to communication services leads to increased adoption and more inclusive participation in digital transformation. Affordability is one of the main barriers to broadband uptake by households and business in many OECD countries. It leads to accentuated digital divides and can disproportionally affect low-income households and/or populations living in rural areas.

Assessing the prices of communication services is a way to gauge their affordability and an important factor in understanding competition dynamics. Several factors influence the price of communication services. Policy and regulatory frameworks directly affect investment incentives, barriers to entry and network deployment costs (including spectrum licensing rights). Competition levels in communication markets also affect price. The OECD's communication baskets provide detailed information on price trends for fixed, mobile and bundled communication services. The new OECD price methodology for bundled communication services includes different combinations of fixed broadband, fixed voice, mobile voice and data (i.e. mobile broadband), as well as television services and usage profiles.[8]

Over the last decade, fixed and mobile broadband prices across the OECD have declined. Between 2013 and 2023, the OECD average prices for four different mobile broadband baskets (i.e. mobile voice and data baskets) experienced a sharp decrease. The price for the low-usage basket of 100 calls and 500 Megabytes (MB) of data allowance declined by 54% – from 32 USD PPP to 14.6 USD PPP. Price declines for the medium-usage basket are at a similar level (-63%). The high-usage basket (900 calls and 2 Gigabytes [GB] of data allowance) saw the sharpest drop in prices – from 71 USD PPP to 20 USD PPP, a 72% decline from the original average OECD price. The highest-usage profile (i.e. 900 calls with 10 GB), for which the time series is shorter, dropped 50% in price from 2018 to 2023. The decrease in mobile prices has undoubtedly helped address one source of inequality in access to communication services in OECD countries (Figure 2.9).

Figure 2.9. Over the past decade, fixed and mobile broadband prices across the OECD have declined

Evolution of price baskets for fixed broadband and mobile voice and data in USD PPP



Note: PPP = purchasing power parity; GB = Gigabyte; MB = Megabyte. The basket methodology consists of selecting, for every OECD country, the cheapest offer in the market meeting all criteria for a given user profile (i.e. low, medium, high and highest usage profiles).

Source: OECD calculations based on (Teligen/TechInsights, 2024[25]), "Teligen tariff & benchmarking market data using the OECD methodology".

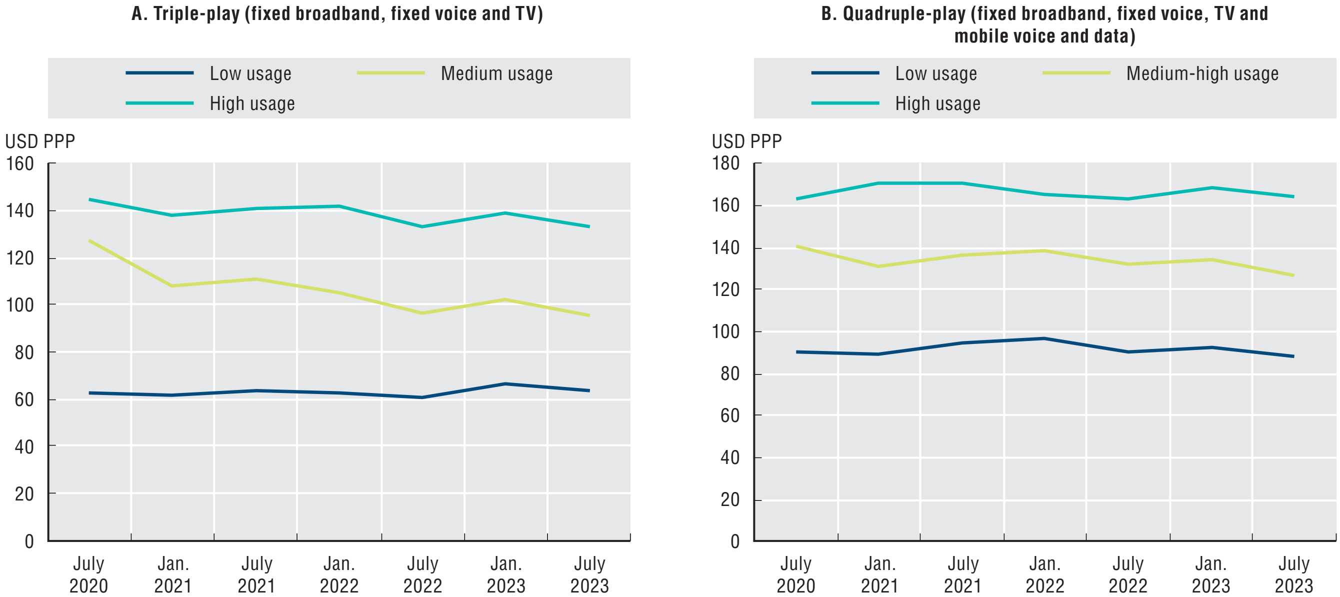
StatLink https://stat.link/o8k7fc

For fixed broadband baskets in the OECD area, the declining trend is more pronounced in high-usage profiles (i.e. 900 GB data allowance and speeds higher than 1 Gbps), which decreased by 22.5% between 2015 and 2023. Between 2013 and 2023, the price for the low-usage (20 GB data allowance) fixed broadband basket decreased by 17%. Meanwhile, prices of the medium-usage baskets (120 GB) remained relatively stable (i.e. -7.4%) during 2013-23 (Figure 2.9).

Bundles of communication services are becoming more prevalent across the OECD. In 2023, bundled communication services accounted for 69% of total fixed broadband offers across the OECD (OECD, 2024[2]). More than one-quarter (26%) of these offers were triple-play (i.e. fixed broadband, fixed voice and television), while 15% were quadruple-play (fixed broadband, fixed voice, television and mobile broadband) (OECD, 2024[2]). In about three years (July 2020-January 2023), prices of triple-play bundles have, on average, decreased by around 19.5% for the medium-usage profile in the OECD area. Most prices for triple- and quadruple-play bundles have remained relatively stable (Figure 2.10).

Figure 2.10. Prices of bundled communication services across OECD have remained relatively stable during 2020-23, with the exception of triple-play medium-usage profile bundle

Price evolution of triple- and quadruple-play bundles, OECD average, 2020-23, in USD PPP



Note: Prices calculations are for the average of the three cheapest offers meeting all criteria for a given user profile.

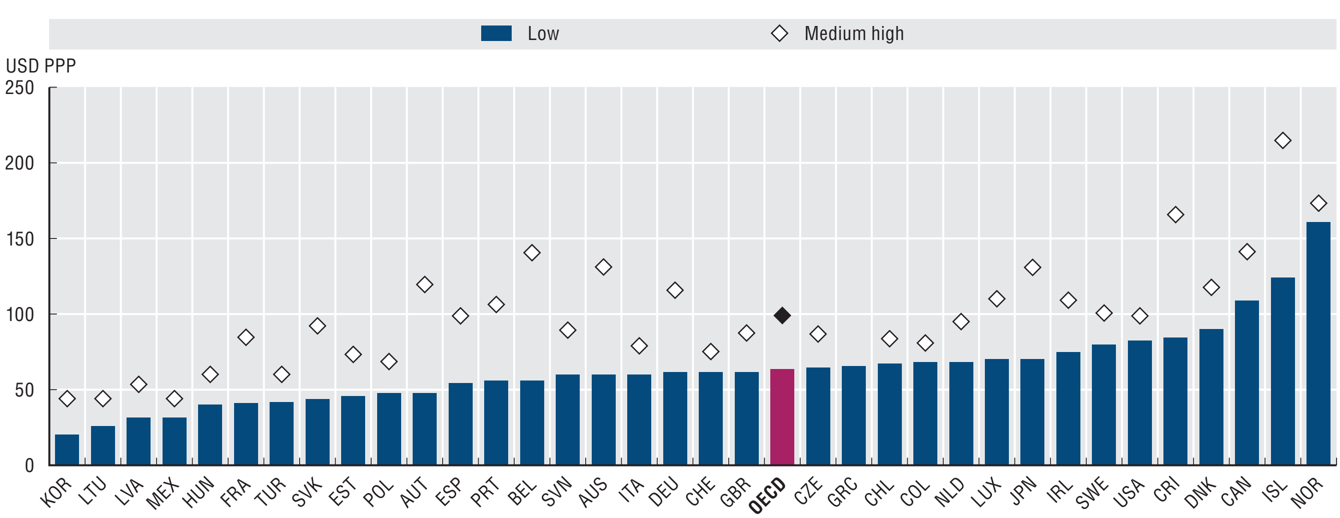
Source: OECD calculations based on (Teligen/TechInsights, 2024[25]), "Teligen tariff & benchmarking market data using the OECD methodology", *www.strategyanalytics.com/access-services/service-providers/tariffs---mobile-and-fixed*.

StatLink https://stat.link/j3a9fk

Disparities in broadband bundle prices exist between countries. For example, for the low-usage basket of triple-play bundles, prices in USD PPP terms vary by a factor of eight when comparing the country with the lowest priced bundle to the highest. In January 2023, the OECD average price for the low-usage and medium-high usage profile of triple-play bundles was 64 USD PPP and 100 USD PPP, respectively (Figure 2.11).

Figure 2.11. There is a wide disparity in prices of triple-play bundled communication baskets across OECD countries

Prices across OECD countries of triple-play bundled communication baskets (fixed broadband, fixed voice and pay television), low and medium-high usage profile, January 2023



Note: Price calculations are for the average of the three cheapest offers meeting all criteria for a given user profile. Triple-play bundles=fixed broadband, fixed voice and pay-TV.

Source: OECD calculations based on (Teligen/TechInsights, 2024[25]), "Teligen tariff & benchmarking market data using the OECD methodology", *www.strategyanalytics.com/access-services/service-providers/tariffs---mobile-and-fixed/U*.

StatLink https://stat.link/losntm

In countries where the prices of communication services are high, these services can be unaffordable for parts of the population (ITU, 2023[26]). In countries with high income disparities, the average household may be able to afford high-priced communication services, but other households may find them out of reach. Without access to communication services, some disadvantaged groups risk further marginalisation if they cannot access the digital tools needed for essential services (e.g. education, employment, health care, transportation) and running businesses (OECD, 2022[21]). (For more details on the different price baskets, see the Statistical Annex containing all tables of prices of communication services).

Geographical broadband connectivity divides

Communication regulators across the OECD highlight the need to bridge spatial connectivity divides as one of the main policy challenges. The measurement of broadband quality and coverage across regions is essential to track the evolution of urban-rural access divides and inform policy making. These indicators will contribute to the pillar on digital divides of the ongoing horizontal project Going Digital Phase IV.

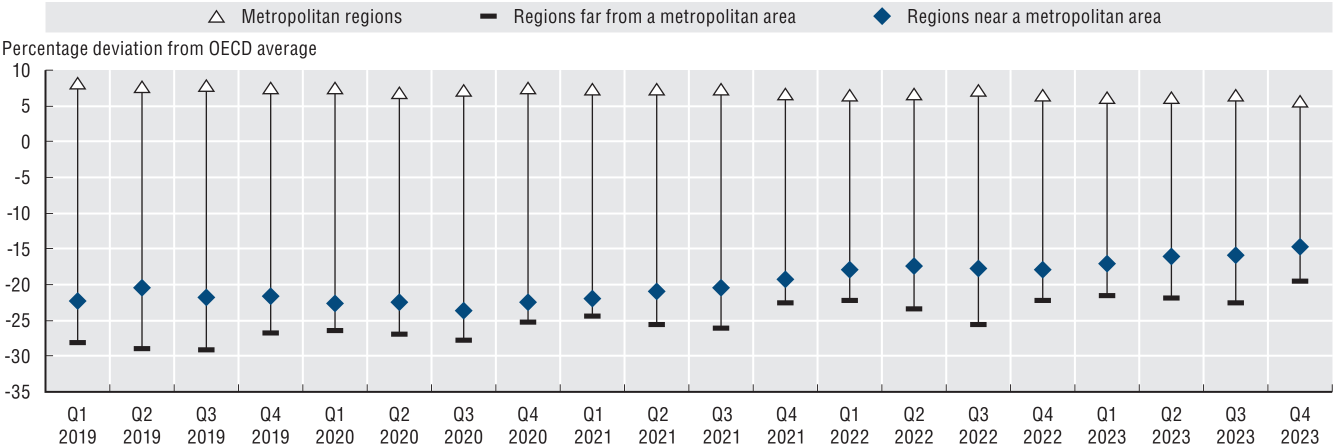
Within and across OECD countries, there are persistent and substantial spatial divides. This is true both in terms of the availability of high-speed broadband offers in rural areas, as well as disparities in broadband performance across regions. The share of overall households reporting basic Internet access (above 256 Kbps)[9] increased considerably over the last decade in OECD countries, rising from 75.7% in 2013 to 91.5% in 2023. However, there are substantial gaps in household adoption of Internet services in rural areas compared to urban areas. In 2023, 89.2% of OECD households in rural areas reported having Internet access, albeit at minimal speeds, compared to 91.5% of households overall (OECD, 2024[27]).

High-speed broadband coverage in rural areas remains a major challenge for many OECD countries. This challenge is often linked to the cost differences to deploy infrastructure in rural areas compared to more populous centres (OECD, 2021[28]). For example, only 45% of European rural households lived in areas with high-speed broadband network coverage (i.e. FTTH or DOCSIS 3.1)[10] in 2022 compared to 73% of households in overall areas (European Commission, 2024[29]).

Territorial differences in connectivity also translate into user experiences that vary substantially depending on where people live and work. This is evidenced by the differences in actual download speeds in metropolitan regions compared to other areas (either remote or close to a small/medium city). Over 2019- 23, connectivity data from the self-administered tests by Ookla (Speedtest) shows persistent gaps in speeds experienced between users living in metropolitan areas (cities) compared to regions far from metropolitan areas (i.e. either remote areas or close to a small/medium city) in the OECD area (Figure 2.12).

Figure 2.12. Over time, gaps in speeds experienced by users living outside metropolitan regions compared to those living in metropolitan areas (cities) persist

Evolution of gaps in mean fixed broadband download speeds experienced by users (Ookla) by TL3 (small regions) classification, OECD average, Q1 2019-Q4 2023, percentage deviation from the OECD average



Notes: OECD calculations based on Speedtest by Ookla for Q1 2019 to Q4 2023. Average of mean download speeds experienced, weighted by the number of tests, as the percentage deviation from the OECD average across 34 OECD countries (data for Costa Rica, Iceland and Israel unavailable and Luxembourg only had metropolitan areas). Measurements are based on tests performed by users around the globe via the Speedtest platform. For a more comprehensive picture on broadband performance metrics, see OECD (2022[1]). Within small regions (TL3), the OECD has three main classifications: “Metropolitan regions”, “Regions near a metropolitan area”, and “Regions far from a metropolitan area”. The last category has two further subcategories: “Regions close to small/medium city” and “Remote regions” (see *https://doi.org/10.1787/20737009*).

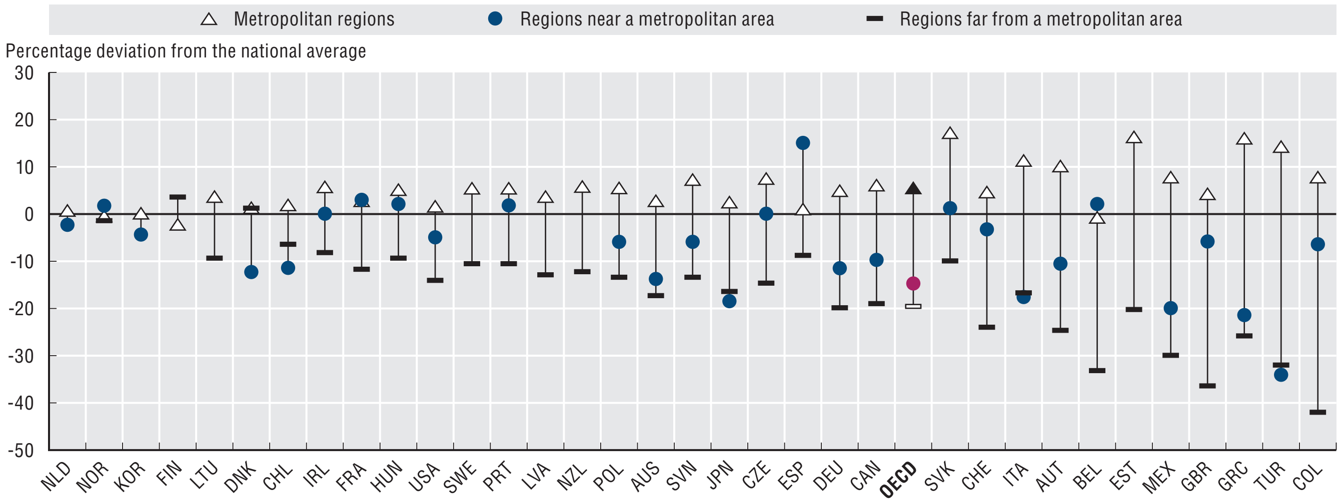
Source: Speedtest by Ookla Global, Fixed and Mobile Network Performance Maps.

StatLink *https://stat.link/tesodi*

For OECD countries, mean download speeds over fixed networks in regions located far from metropolitan areas were on average 19.6 percentage points below the national average, while mean download speeds in metropolitan (urban) areas were on average 6 percentage points above the national average in the fourth quarter of 2023 (Figure 2.13). Moreover, for OECD countries for which data were available, people in cities experienced median fixed broadband download speeds 50% higher than people living in regions far from metropolitan areas in Q4 2023 (Figure 2.14). While some countries have a narrower gap between regions, a persistent divide remains between urban and remote regions.

Figure 2.13. For OECD countries, mean download speeds over fixed networks in regions located far from metropolitan areas were almost 20% percentage points below the national average

Gaps in mean fixed broadband download speeds experienced by users, by TL3 (small regions) classification in OECD countries, Q4 2023



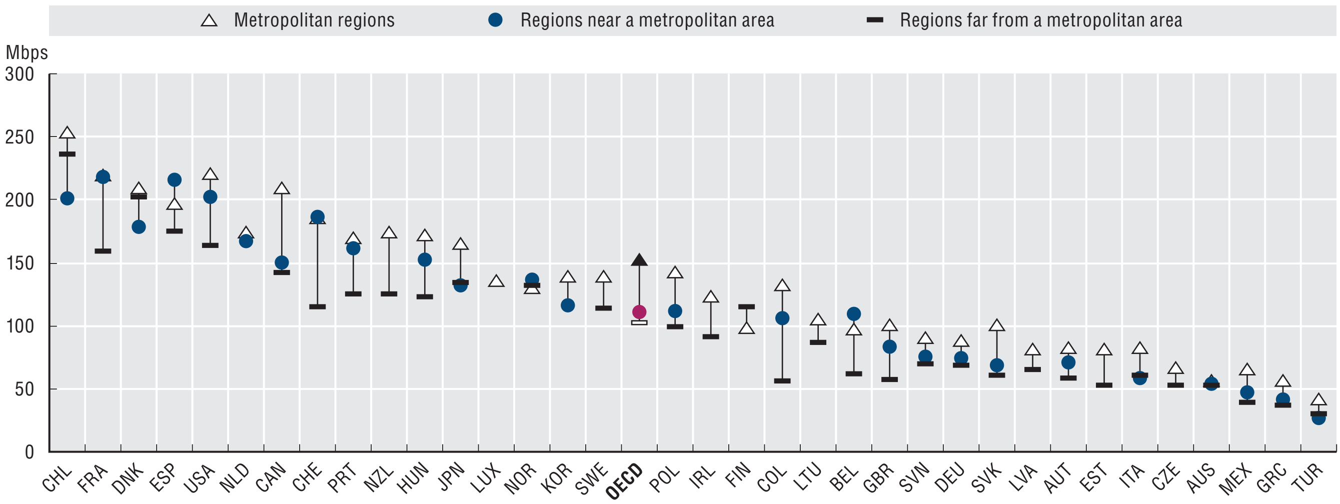
Notes: OECD calculations based on Speedtest by Ookla for Q4 2023. Average of mean download speeds experienced, weighted by the number of tests, as the percentage deviation from the national average across 34 OECD countries (data for Costa Rica, Iceland and Israel unavailable and Luxembourg only had metropolitan areas). See more notes in Figure 2.12.

Source: Speedtest by Ookla Global, Fixed and Mobile Network Performance Maps.

StatLink https://stat.link/xrfymc

Figure 2.14. People living in cities in the OECD experienced median fixed broadband download speeds 50% higher than those available to people living in regions far from metropolitan areas in Q4 2023

Median fixed broadband download speeds in OECD countries by TL3 (small regions) classification



Notes: Mbps = Megabits per second. OECD calculations based on Speedtest by Ookla for Q4 2023. Average of median download speeds experienced, weighted by the number of tests across 35 OECD countries (data for Costa Rica, Iceland and Israel unavailable).

Source: Speedtest by Ookla Global, Fixed and Mobile Network Performance Maps.

StatLink https://stat.link/zkqaxv

Download/upload speeds are only one aspect of broadband quality. Other metrics indicating network performance include latency (the time it takes for information to travel between two points e.g. from when a command is sent and a response is received), reliability and quality of experience (OECD, 2022[1]). Improved network response times (i.e. lower latency) supports many applications across different sectors (e.g. fully automated vehicles, remote surgery). Differences in quality dimensions other than speeds also exist between rural and urban areas, which can cause a lower overall quality of experience for rural users. Based on OECD calculations using Ookla data (Ookla, 2024[30]), people in cities across the OECD experienced, on average, 23% lower median latency compared to people living in regions far from metropolitan areas in Q4 2023.

Bridging connectivity divides, a top policy priority for countries

Increasingly, countries view an individual's right to connectivity as being just as important as the right to electricity or fresh water. For example, more than half of OECD countries consider access to the Internet as a basic right for citizens (i.e. 19 of 36 countries where data were available). Furthermore, most have changed their legal frameworks to include broadband as part of their universal service framework (30 of 36 OECD countries). Political recognition of connectivity as a fundamental right is a step towards bridging digital divides.

In light of the broadband coverage and quality spatial gaps within and across countries, action is needed to ensure ubiquitous, affordable and high-quality connectivity. Affordability and high-quality broadband services usually derive from competition in communication markets and investment in networks.

Overarching policies that foster competition, promote investment and facilitate infrastructure deployment are key tools to spur expansion of high-quality communication networks, including in rural and remote areas that are often underserved or completely unserved. Combining market forces with alternative approaches is key to expand connectivity (OECD, 2021[31]). As such, the regulatory, legal and institutional framework plays a fundamental role to bridge connectivity divides. This is especially the case for the communication sector, which is characterised by high fixed costs and barriers to entry (see Section on Communication policy and regulatory frameworks).

Connectivity targets and public programmes to expand high-quality broadband

Most OECD countries (36 of 38) have established connectivity targets either through a Digital Agenda or a National Broadband Plan. These set specific coverage and quality objectives to be achieved within a certain timeframe. However, many countries increasingly aim for higher speeds (e.g. "gigabit" speeds).

The majority of OECD countries (31 of 38) have allocated public funds to expand deployment of high-quality connectivity (e.g. 5G and fibre) with the aim of bridging divides. These public funds (or state aid) have been either part of economic recovery packages, elements of national digital or broadband strategies, or tailored funds to expand broadband in rural areas.

Given that countries are diverse in territorial features, regulatory frameworks, market dynamics and historical context, the amount of public funds required to complement private sector investment varies. Some countries have invested more than USD 1 billion in public funds to expand broadband since 2018 (e.g. Australia, Austria, Canada, Czech Republic, Germany, Ireland, Italy, New Zealand, Poland, Spain, the United Kingdom and the United States):

- In Canada, the Universal Broadband Fund (CAD 3.225 billion; USD 2.5 billion)[11] – part of the government of Canada's Connectivity Strategy – supports high-speed broadband projects across the country (Government of Canada, 2022[32]).
- In New Zealand, a government-funded programme (NZD 1.785 billion; USD 1.115 billion)[12] aims to provide fibre to more than 410 cities and towns and key institutions by 2023 (Ministry of Business, Innovation & Employment, 2022[33]).
- In the United States, the Infrastructure Investment and Jobs Act of 2021 allocates USD 65 billion to bridge digital divides by expanding broadband infrastructure and funding digital equity and inclusion programmes (The White House, 2021[34]).
- The United Kingdom allocated GBP 5 billion (USD 6.25 billion)[13] to subsidise the rollout of gigabit-broadband in areas that will not be reached by private investment (20% of the country) (DIST, 2023[35]).

Several public funding programmes include a focus on fibre (e.g. Australia, Austria, Chile, Colombia, New Zealand, Portugal and Türkiye). For example, Chile included the National Fibre Optic Project (FON) as part of the infrastructure subsidy programme of the Telecommunication Development Fund in 2021. Colombia funded the National Optical Fibre Project to expand the infrastructure of fibre networks. In December 2023, Portugal launched an international tender for fibre networks to cover the entire mainland territory by 2026/27 (Government of Portugal, 2023[36]). Türkiye allocated public funds to support the expansion of high-capacity broadband infrastructure, including fibre networks and mobile broadband networks, particularly to underserved regions.

Examples are emerging of innovative forms of public funding to expand broadband in extremely remote areas. In Brazil, the Connected North Programme, partially funded by the proceeds of the 5G spectrum auction held in 2021 (BRL 1.3 billion; USD 250 million),[14] will extend 12 000 km of sub-fluvial fibre to connect broadband to 59 municipalities (10 million people) in the Amazon region. The investment includes an open consortium of operators that will ensure the project is environmentally sustainable. To that end, they will preserve around 68 million trees compared to a communication network requiring inland deployment with ducts and posts. As of November 2023, about three of eight segments have been deployed, bringing high-quality connectivity across Brazil's Amazon region (Ministério das Comunicações, 2023[37]). OECD (2024[3]) includes further detail in its annex about different methods of financing public funds across OECD countries.

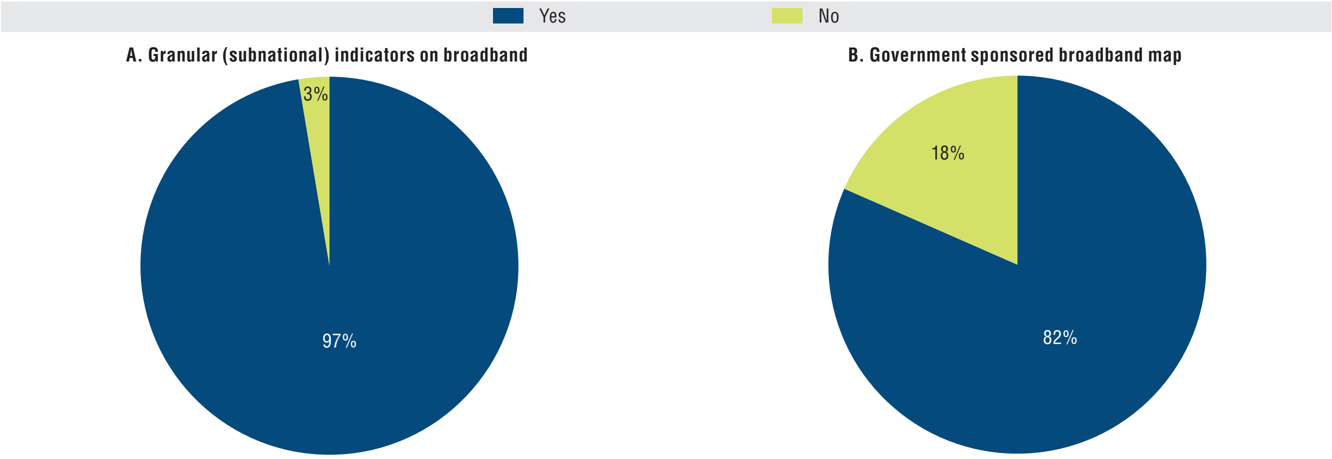
Granular indicators on connectivity to foster broadband development

Assessing connectivity divides is a prerequisite to tailor policies and regulatory measures aimed at maximising the benefits of access to and use of broadband services. As such, OECD countries are increasingly collecting and publishing granular indicators on broadband (Figure 2.15).

Most OECD countries (97%) collect subnational indicators on broadband coverage, subscriptions and/or quality. The vast majority (31 of 38) have national broadband maps sponsored by the government to increase transparency of broadband availability (e.g. France's "Ma connexion internet", Mexico's Microsite, Portugal's Geographical Platform, Sweden's "bredbandskartan"). Moreover, almost half of OECD countries (18 of 38 countries) use approaches such as "crowdsourcing" and open data to measure broadband quality and coverage. The United Kingdom, for example, publishes the "Ofcom Connected Nations Report" (Ofcom, 2022[38]). Some countries, such as Canada, Mexico and the United States, also publish data on coverage for particular populations or geography such as Indigenous persons or land (FCC, 2021[39]; CRTC, 2024[40]; IFT, 2024[41]).

Figure 2.15. Nearly all OECD countries produce subnational indicators on broadband availability and quality, and a large majority produce broadband maps

Granular approaches to broadband measurement in OECD countries



Note: Sample size is 38 OECD countries (i.e. 37/38 have subnational indicators on broadband and 31/38 have broadband maps).

Source: OECD elaboration based on the *CSI DEO 2024 Regulatory* Questionnaire.

StatLink https://stat.link/4wa1sr

Improving the accuracy of broadband data at a granular level is crucial to providing end-user transparency and increasing the effectiveness of broadband policy measures. Broadband maps, for example, can influence the allocation of funds to close connectivity gaps in unserved and underserved areas. As such, OECD countries are constantly trying to improve these maps. In the United States, for example, the Federal Communications Commission (FCC) released a draft of its new National Broadband Map in 2022, inviting the public to submit challenges to improve its accuracy (FCC, 2022[42]). In addition, releasing the underlying information for the maps as open data can enable third parties to contribute with further analysis. Countries including Canada, France and the United States provide data for their maps in open format (ISED, 2022[43]; Arcep, 2022[44]; FCC, 2024[45]).

Countries also sponsor the provision of tools that facilitate drawing comparisons in terms of both broadband availability and prices, given that affordability is a key concern. Access to this information empowers consumers, provides useful insights about the level of competition in the market and complements other metrics used to assess the sector's overall efficiency and performance.

Bottom-up approaches: Municipal and community networks

Some OECD countries use municipal networks to promote fibre deployment in cities, smaller towns and surrounding regions. These networks are typically high-speed networks that have been fully or partially facilitated, built, operated or financed by local governments, public bodies, utilities, organisations, or co-operatives with some type of public involvement (OECD, 2015[46]).

In addition to municipal networks, community networks are often bottom-up approaches in rural and remote areas that build on local knowledge and initiatives, and can play a complementary role with respect to national service providers in bridging connectivity divides (Redes, 2020[47]). Institutional framework conditions can help foster bottom-up initiatives to expand connectivity in rural and/or remote areas. In 2013, for example, telecommunication reform in Mexico provided for social use spectrum licences, including community and Indigenous networks with non-profit purposes. These changes helped spark the rise of community networks in rural areas (OECD, 2017[48]). Mexico has granted local spectrum licences to facilitate Wireless Internet Service Providers (WISPs), mainly in rural areas (OECD, 2022[11]). It reported more than 660 WISP licences in 2022 (IFT, 2022[49]). In Brazil, the communication regulator (Anatel) explicitly recognised community networks as an option for Internet access (Anatel, 2020[50]).

Some measures that help reduce barriers to entry for local operators include: access to spectrum at a local level (see Section below), streamlining licensing requirements for small service providers, enhancing access to backhaul connectivity and updating universal service provisions so that alternative operators can access such funds (Redes, 2020[47]).

Tailored programmes to bridge connectivity divides

Some OECD countries have both overarching and targeted policies to bridge connectivity gaps. Overarching policies in some OECD countries aim to increase competition and investment in broadband markets that directly influence affordability and access of communication services. At the same time, they may also tailor approaches to bridging connectivity divides in rural and remote regions. These include programmes targeted to low-income populations (i.e. demand-side initiatives) to promote uptake of broadband services. For example, residential Internet providers in Portugal must offer social Internet tariffs where infrastructure permits (ANACOM, 2022[51]). For its part, the United States launched the Affordable Connectivity Program, discussed in more detail in OECD (2023[52]).

Demand aggregation models in the market can help increase certainty for investors and operators. In Germany, for example, demand aggregation[15] extends connectivity in rural and remote areas; some 30-40% of households are expected to commit before FTTH networks are deployed (Deutsche Glasfaser, 2020[53]; FiberConnect Council MENA, 2022[54]).

As a complement, some countries are also implementing public broadband access solutions (e.g. in the form of public Wi-Fi hotspots). For example, in Colombia, the project "Universal Access to Rural Areas: Digital Centres", aims to provide public Wi-Fi connectivity solutions in 14 750 "Digital Centres" throughout all Colombian departments until 2031 (OECD, 2022[55]). In Mexico, the state-owned programme named "CFE (Comisión Federal de Electricidad) Telecomunicaciones e Internet Para Todos" (Federal Electricity Commission Telecommunications and Internet for All) provides 91 000 free Wi-Fi hotspots across the country (Government of Mexico, 2024[56]). However, these hotspots are no substitute for household and business broadband subscriptions. For more details on tailored approaches to bridge connectivity divides, refer to OECD (2021[28]).

Main trends shaping the future of connectivity and related policy challenges

Accelerating the deployment of ubiquitous high-quality, secure and resilient broadband networks is a strategic challenge for all countries. It supports both their competitiveness across the digital ecosystem and participation in the digital and green transitions. A new wave of digital innovation driven by emerging technologies requires networks to continue evolving.

Broadband networks are responding to the surging demand of digital transformation. With the need for more flexible network design and more cost-effective, high-quality communication services, the communication industry is moving towards disaggregation of network elements, virtualisation, integration of cloud services into networks, more private networks and more use of AI systems in networks, among other measures (OECD, 2022[1]). Operators are using AI and machine learning to improve and optimise network management, do predictive maintenance and reduce energy consumption of broadband networks. Moreover, as virtualisation progresses, networks are also integrating cloud and edge computing solutions. As such, partnerships between communication service providers and major cloud providers (Microsoft Azure, Amazon Web Services and Google Cloud) have increased in recent years (OECD, 2022[1]).

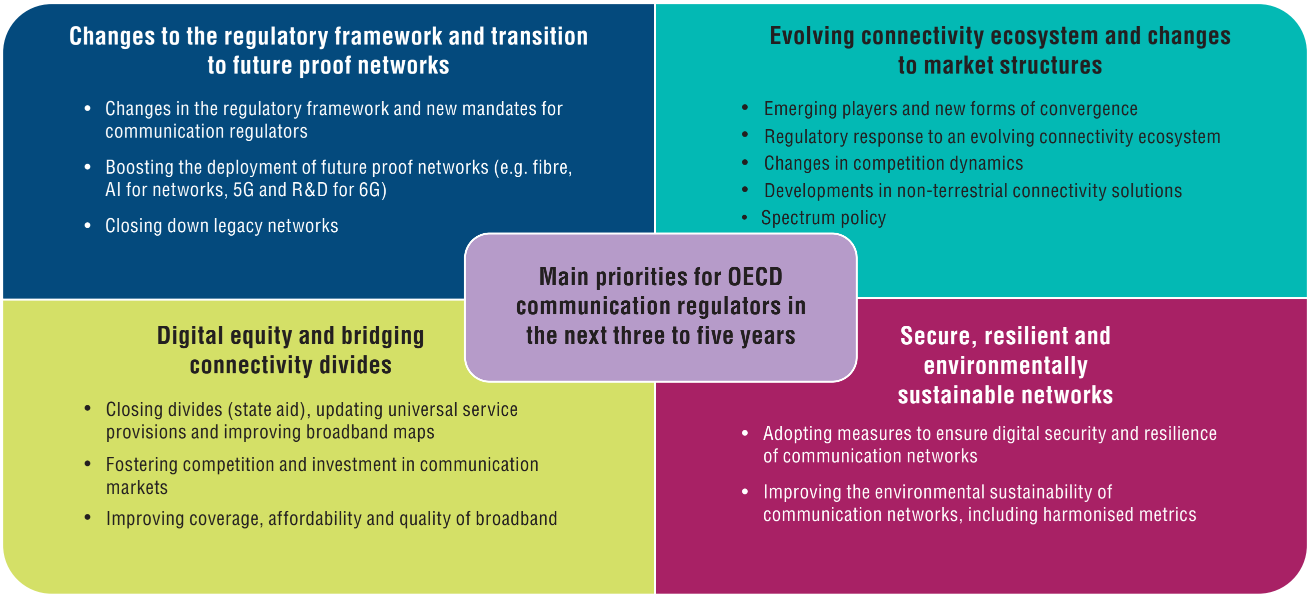
Against this backdrop of technological trends shaping networks, the connectivity landscape is also changing. Both emerging and existing players are gaining more prominent roles in connectivity. Tower companies, cloud providers, satellite companies and over-the-top players, for example, are redefining their engagement in business models.

A broad array of connectivity solutions, many complementary, are needed to face the demands placed on future broadband networks and to ensure seamless connectivity to users (OECD, 2022[1]). Developments touch on satellite broadband solutions (e.g. LEO satellite constellations); the road towards "beyond 5G" technologies; further advances in WLANs (such as Wi-Fi); and the next stage of network convergence with the development of hybrid wireless terrestrial and non-terrestrial networks. All these developments point towards a future where the co-integration of connectivity solutions will become increasingly important. At the same time, such developments will increase the complexity of communication regulatory and policy landscape. (See DEO Volume 1 Spotlight "Next generation networks and the evolving connectivity ecosystem" (OECD, 2024[57]).)

As networks and the connectivity ecosystem evolve, regulation and policies must also adapt. On the one hand, the regulatory environment must continue to foster innovation and investment to ensure optimum conditions for network rollout. On the other, policies must ensure competition and services meet user needs and continue to be affordable.

The main communication policy priorities or challenges reported by OECD communication regulators in 2023 for the upcoming three to five years can be grouped into four broad categories: i) changes to the regulatory framework and the transition to future-proof networks (e.g. boosting fibre deployment, AI for networks, 5G, research for 6G); ii) policies to bridge connectivity divides (as explored in the previous section); iii) the evolving connectivity ecosystem and changes to market structure; and iv) ensuring secure, resilient and environmentally sustainable broadband infrastructure (Figure 2.16).

Figure 2.16. Broad overview of top challenges in communication policy and regulation in the next three to five years



Note: The diagram was created for illustrative purposes. It is not intended to summarise most common listed priorities and is not exhaustive of all regulatory priorities in the area of connectivity as reported by OECD countries.

Source: OECD elaboration based on the *CSI DEO 2024 Regulatory Questionnaire*.

This section explores generally how OECD countries are adapting regulatory frameworks to meet the needs of the digital transformation and key policies to ensure that networks are fit for the future. The impact of digital transformation on the environment, including networks, is discussed in Chapter 3. The OECD is preparing reports on the environmental sustainability of communication networks and the resilience of communication networks.

Communication policy and regulatory frameworks are evolving to face the challenges stemming from digital transformation

Policy makers and regulators across the OECD area are actively adapting regulatory frameworks to spur competition, innovation and investment in communication markets. In 2023, 37 OECD countries reported making significant policy changes affecting the provision of communication services since 2021. These changes include reforms to sectoral legislation, national digital strategies, development plans or broadband plans, new regulations, amendments to universal service provisions, internal restructuring of the regulator, and new legislation on broader digital policy issues (e.g. on digital security, online harms) that expanded the mandate of communication regulators.

Several OECD countries have updated and/or amended their sectoral legislation in recent years (e.g. Canada in 2022, Chile in 2021, Colombia in 2021, Costa Rica in 2022, Iceland in 2022, Israel in 2022, Japan in 2023, Korea in 2023, New Zealand in 2018 and Switzerland in 2021).

For OECD countries within the EU area, changes in the regulatory framework mainly include the transposition of the European Electronic Communications Code (EECC) of 2018 (Directive (EU) 2018/1972), the transposition of European Directives such as the Broadband Cost Reduction Directive (2014/61/EU) and the alignment with Gigabit Society targets set by the European Commission. As such, reforms to sectoral legislation in many European countries have been observed (e.g. Austria, Belgium, Czech Republic, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, the Netherlands, Norway, Poland, Portugal, Slovak Republic, Slovenia, Spain and Sweden).

Some OECD countries within the EU area expect further amendments in sectoral legislation. These changes derive from implementation of the Digital Services Act (DSA), the Digital Markets Act (DMA), the Data Governance Act, the "Directive on measures for a high common level of cybersecurity across the Union" (the NIS2 Directive) and the European Artificial Intelligence Act. For example, some European countries highlighted potential changes to regulation on issues of convergence and regulatory treatment of audio-visual content provided over the Internet with the implementation of the DMA and DSA. European countries are also monitoring ongoing EU legislation and recommendations. The "Gigabit Infrastructure Act" entered into force in May 2024, replacing the Broadband Cost Reduction Directive of 2014 (European Commission, 2024[58]). Meanwhile, the "Recommendation on the regulatory promotion of gigabit connectivity" proposed in February 2023, was published in February 2024 (European Commission, 2024[59]).

Since 2021, OECD countries have been adapting regulations in different policy areas. For example, 28 OECD countries reported changes to wholesale access regulation, 14 countries reported changes to network interconnection regulation and 23 countries reported changes on the regulatory treatment of over-the-top providers or on bundling of communication services.[16]

The mandate of regulators in the communication sector continues to evolve

The mandate or responsibilities of communication regulators continue to evolve since 2021, with half of OECD countries reporting major changes. The changing nature of communication markets has driven modifications in the mandates and responsibilities of communication regulators in OECD countries. These include increased convergence, as well as how the evolution of the connectivity ecosystem blurs the boundaries between "traditional" communication markets and broader digital players (OECD, 2022[60]).

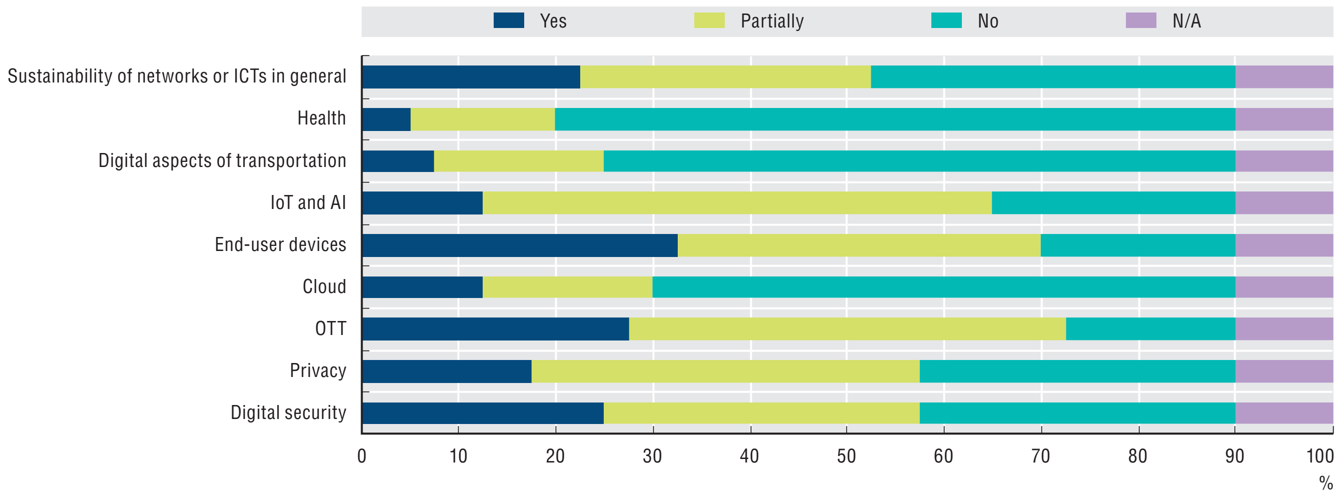
Communication regulators in OECD countries, Brazil and Singapore have increasingly at least partial responsibilities in broader digital policy issues either through their own mandates, regulatory co-operation or as part of a whole-of-government approach (Figure 2.17). Compared to 2021 (OECD, 2022[60]), partial or full responsibilities of communication regulators in 2023 have notably increased in the following domains: OTTs, end-user devices, IoT and AI, environmental sustainability and cloud computing (Table 2.1). In addition, almost half of OECD countries (47%) reported having a converged broadcasting and communication sector regulator in 2023.

Several examples highlight the role of communication regulators in broader digital policy issues. In January 2023, the Australian government announced it would introduce legislation to provide the communication regulator with new powers. The Australian Communications and Media Authority (ACMA) would now hold digital platforms to account for and improve efforts to combat false and misleading content on line (Australian Government, 2023[61]). In the

United Kingdom, the Online Safety Act introduces rules for sites and apps such as social media, search engines and messaging platforms to protect users from online harms. Ofcom, the UK communication regulator, has been tasked with new responsibilities by providing guidance and establishing codes of practice on how companies can comply with this legislation (United Kingdom, 2023[62]).

Figure 2.17. Communication regulators increasingly have a mandate in broader digital policy issues

Mandate of communication regulators by topic in OECD countries, Brazil and Singapore, 2023



Note: The sample size is 40 (i.e. 38 OECD countries, Brazil and Singapore). Four OECD countries did not reply to this question and are marked at N/A (i.e. 10%). Countries answered the following question (question 8): "Does your national regulatory authority, with responsibility for communication/telecommunication/broadcasting services have the mandate for the following areas?: Digital security, privacy, OTT services, issues related to cloud computing, issues related to end-user devices, issues in the area of the IoT and AI, issues related to the digital aspects of transportation, issues related to health, issues related to the sustainability of networks or digital technologies in general?"

Source: OECD elaboration based on the *CSI DEO 2024 Regulatory* Questionnaire. StatLink contains more data.

StatLink https://stat.link/35gcbd

Table 2.1. Evolving role of communication regulators, 2021 and 2023

Mandate and/or partial responsibilities on digital policy issues	2021	2023
Over-the-top (OTT) services	60%	72.5%
End-user devices	63%	70%
IoT and AI	60%	65%
Digital security	65%	57.5%
Privacy	55%	57.5%
Environmental sustainability of networks or broader ICTs	48%	52.5%
Cloud computing	22.5%	30%
Digital aspects of transportation	25%	25%
Digital aspects of health	18%	20%

Note: Green highlight=increase of mandate or responsibility since 2021.

Source: OECD elaboration based on the *CSI DEO 2024 Regulatory* Questionnaire.

With new players gaining prominence in communication markets, some countries are restructuring their national regulatory authority. In the United States, for example, given the increase in applications for new satellites that feature new commercial models, players and technologies, the FCC created the Office of International Affairs and Space Bureau to support the burgeoning satellite industry (FCC, 2023[63]). In the United Kingdom, Ofcom released a "Space spectrum strategy" and new licensing framework for Non-Geostationary Orbit satellites (Ofcom, 2022[64]). See DEO Volume 1, Spotlight "Next generation networks and the evolving connectivity ecosystem" (OECD, 2024[57]).

Communication regulators are also increasingly engaging in inter-agency co-operation to achieve digital policy objectives that require a whole-of-government approach, such as the environmental sustainability of digital technologies. For example, the French government tasked its communication regulator, Arcep, and its agency for ecological transition (Agence de la transition écologique, ADEME), to quantify the current and future environmental footprint of digital technologies. In January 2022, the two agencies delivered the first two volumes of the study that assessed the current impact of ICTs on the environment (Arcep, 2022[65]). In March 2023, they delivered the third volume providing a forward-looking assessment (2030-50) (Arcep, 2023[66]) (See Chapter 3).

The transition towards future-proof networks and shutting down legacy networks

As new generations of broadband networks are rapidly emerging, deploying fibre backhaul further into fixed networks to support increases in speed and capacity across all network technologies becomes critical. In response, OECD countries have worked on how to extend and improve broadband access through policies that reduce deployment costs. Moreover, to promote deployment of broadband networks of the future, OECD countries have been working to streamline rights of way, ensuring efficient spectrum management, and promoting access to backhaul and backbone connectivity.

Adapting the regulatory framework to the shutting down of legacy networks

Several OECD countries have begun the transition from legacy networks and services, adapting regulatory frameworks to accommodate this evolution. In 2023, 33 OECD countries observed plans by operators to shut down legacy networks. In 29 OECD countries, the plans concerned the closing down of mobile networks (e.g. 2G or 3G networks). In 23 countries, they related to the transition from copper fixed networks to future-proof technologies, such as fibre.

The closing down of legacy networks, such as copper, boosts the deployment of high-capacity networks as operators invest in the transition to new access technologies. Many OECD communication regulators face the common challenge of adapting the regulatory framework to provide incentives to boost the deployment of future-proof access technologies, such as fibre. Approaches to the decommissioning of copper networks vary by country. Regulators need to ensure the timeline for copper shutdown is properly co-ordinated with the transition to fibre and other future-proof access technologies. Namely, the remaining affected customers on copper networks to be shut down need ample advance notice to migrate to newer technologies. Legacy customers also need satisfactory service levels on the copper network until it is phased out.

In Slovenia, the incumbent is allowed to switch off parts of the copper network if there is a parallel fibre network deployed or another open access network available. In New Zealand, copper network infrastructure is being withdrawn in specified areas and being gradually replaced by fibre if operators (principally Chorus, the incumbent) have ensured comparable or better levels of service are available to customers. The withdrawal of copper is subject to compliance with the “Copper Withdrawal Code” (Commerce Commission New Zealand, 2023[67]; Chorus, 2024[68]). In Norway, shortly after a broadband market analysis decision by the Norwegian Communications Authority (Nkom), the historical incumbent (Telenor) unliterally decided in 2019 to launch a plan to close down its copper network by 2022. In 2020, Nkom decided that Telenor had to maintain its wholesale access products delivered over its copper until September 2025, unless the incumbent provided a migration plan that wholesale access seekers could accept (Nkom, 2020[69]). In some OECD countries, the copper PSTN shutdown of the incumbent network has been completed with a full transition to fibre (e.g. the Czech Republic).

Wholesale access remedies with the aim of providing incentives to upgrade networks

OECD countries have taken several approaches to promote broadband development and foster competition. Actions include the promotion of both infrastructure competition and common wholesale infrastructures with regulated[17] or non-regulated wholesale access to increase competition at the retail level (i.e. last mile or access part of the network). Insufficient infrastructure competition in some instances may require ongoing regulatory intervention or oversight. This explains why integrated incumbents in OECD countries were, and in many cases still are, subject to wholesale regulatory measures.

With the aim of fostering fibre deployment, regulators are both looking to safeguard competition while incentivising investments in networks. Some OECD countries are promoting infrastructure-based competition, including through physical infrastructure access, to boost fibre deployment. Some implement this through asymmetric wholesale access remedies. Others have applied symmetric regulation for fibre wholesale products based on geographical segmentation (OECD, 2022[1]).

Spain has emerged as a connectivity leader in Europe and in the OECD. The share of fibre in total fixed broadband connections in Spain grew from 35% to 86% between 2016 and 2023 (OECD, 2024[2]). The increase resulted from a combination of wholesale access regulation that spurred competition and targeted public funds. In 2016, after seven years of the initial regulatory forbearance for fibre deployments, Spain applied fibre wholesale access regulation based on geographical segmentation of competitive versus non-competitive areas (Godlovitch et al., 2019[70]). In 2021, the Spanish communication regulator relaxed the imposed obligations by deeming more geographical areas of the country "competitive markets". In addition, backed by funding from the European Regional Development Fund, Spain has delivered major programmes to subsidise connectivity investment in rural areas. In 2021, it expanded the next evolution of broadband networks to the whole country (Government of Spain, 2021[71]).

Easing network deployment and promoting infrastructure sharing

Infrastructure sharing

With the increasing need for high-quality networks, infrastructure-sharing agreements among operators are on the rise to mitigate the costs of deployment of the next evolution of broadband networks. Such agreements can permit the sharing of passive infrastructure (e.g. masts, towers, sites) or active mobile infrastructure (e.g. RAN sharing, roaming, software elements).

Most OECD countries encourage infrastructure sharing, provided the advantages outweigh the drawbacks, i.e. that sharing is not detrimental to competition (OECD, 2022[1]). Almost all OECD countries promote sharing of passive infrastructure. However, active infrastructure sharing is becoming increasingly common and allowed in most OECD countries.[18]

The nature of infrastructure-agreements is changing. They may sometimes relate to deeper forms of network and spectrum sharing (i.e. in the active layer of networks compared to only passive infrastructure). This approach raises new competition and regulatory challenges.

In many countries, operators themselves develop active infrastructure-sharing agreements and do not require regulatory approval; however, they must notify the authority. In some cases, all such agreements are subject to regulatory approval. Thirty-two OECD countries generally allow sharing agreements of the RAN (e.g. antennas, transceivers, power, base stations, backhaul networks also called "multi-operator radio access network"), with some subject to regulatory approval. In 27 OECD countries, sharing of RAN and spectrum resources is allowed (i.e. "multi-operator core network"), while secondary trading or sharing of spectrum resources may require regulatory approval. Finally, in 24 OECD countries there is core network sharing (i.e. sharing of core network functionalities and servers).

In Japan, the Ministry of Internal Affairs and Communications revised its guidelines on infrastructure sharing in August 2022. The guidelines clarified the application of relevant regulations and established rules between mobile operators and infrastructure-sharing operators (MIC, 2022[72]). In the Netherlands, the Authority for Consumers and Markets announced guidelines on mobile network sharing in April 2021 to answer questions about passive/active infrastructure sharing (ACM, 2021[73]).

Dig-once policies and single information points

Most OECD countries (71%, or 27 of 38) allow and encourage network operators to access available infrastructure at utilities and/or public administrations, including through "dig-once" policies that leverage non-broadband infrastructure projects (e.g. utilities, street light providers and highway/road construction) and reduce the costs of broadband network deployment. Moreover, 21 OECD countries have a single information point (SIP) on either the available infrastructure at utilities and public administrations for broadband network deployment or on planned civil engineering works for co-ordination purposes.

With respect to broadband deployment, several OECD countries have an "infrastructure atlas" for communication service providers. This acts as a SIP for the location of backbone and backhaul connectivity, as well as other types of wholesale infrastructure (OECD, 2022[1]). Such an approach enhances transparency for infrastructure-sharing and joint-deployment initiatives that bring deployment costs down:

- Finland has a Geographic Information System (GIS) portal with data of building plans to co-ordinate civil works. This tool also allows network owners to contact relevant authorities to access physical infrastructure in certain geographical areas.
- In Mexico, the communication regulator (IFT) has had a public portal for planned civil engineering works since 2020. Interested operators can render public their deployment plans for co-ordination purposes.

- In Portugal, the Adequate Infrastructure Information System (SIIA Portal) enables communication operators to access information on infrastructure suitable for hosting their networks and to co-ordinate civil works. Through SIIA, those who need to install communication networks can find out who owns the infrastructure that can host them. This increases transparency for infrastructure-sharing and joint-deployment initiatives that reduce deployment costs.
- In Slovenia, the communication regulator (AKOS) has taken steps to facilitate investment in broadband networks by providing maps of underlying wholesale infrastructure. This allows operators to plan their deployments (through the public portal "Geoportal AKOS" and the "Infrastructure Investment Portal").
- In Sweden, PTS collaborates with the Authority of the Land Survey (Lantmäteriet) and the Swedish National Heritage Board to continuously supply the SIP with an updated map (European Commission, 2022[74]).
- In Spain, the new General Telecommunication Law established that the Ministry of Economic Affairs and Digital Transformation will create a SIP.

Joint deployments or co-investment

An increasing number of OECD countries have implemented policies on co-investment, or joint deployment of broadband networks. In the European Union, for example, the EECC creates incentives for co-investment in new fibre networks. To that end, it provides for regulatory relief to operators entering into such agreements (see OECD (2022[1])). In Italy, TIM, FiberCop (a fibre joint investment company founded by TIM) and Open Fiber signed an agreement in October 2022 to share fixed services. The agreement will enable Open Fiber to use FibreCop's network infrastructure in so-called white areas; public funding has helped develop a TLC infrastructure under concession in these areas (Open Fiber, 2022[75]).

In the United Kingdom, MNOs, the government and the regulator (Ofcom) agreed to a programme called "Shared Rural Network" (SRN) in March 2020. Under this programme, EE, O2, Three and Vodafone have built and shared 222 mobile masts to enhance mobile broadband coverage in rural areas. The SRN is an advanced form of network and spectrum sharing to ensure population and geographic coverage. Operators agreed to invest to close connectivity gaps in areas where there is only coverage by one, but not all operators (i.e. "grey areas"). Meanwhile, government funding is complementing such investments to close connectivity gaps in areas where there is no coverage from any operator, also known as "white areas" (Shared Rural Network, 2020[76]).

Streamlining rights of way

Many OECD countries have issues around access to rights of way to deploy communication infrastructure. Ensuring access requires a high degree of collaboration between national, state/regional and local authorities. In Sweden, for example, the Broadband Forum brings together all three levels of government to ease broadband deployment (OECD, 2018[77]). Some OECD countries issue a code of "Good Practices" to streamline access to rights of way, while others monitor how municipalities adhere to the national communication law (e.g. Spain). Colombia publishes an index of municipalities to measure the degree that capital cities "ease infrastructure deployment". This aims to provide incentives for municipal authorities to reduce barriers for network rollout (CRC, 2022[78]; OECD, 2022[55]).

Streamlining rights of way can help reduce the cost of network deployment. Austria issued a new Telecommunications Act in 2021, which grants rights of way for broadband infrastructure on private and publicly owned properties. As part of the Austrian Broadband Strategy 2030, the ministry installed the "Platform Internet-Infrastructure Austria (PIA 2030)". This platform enables responsible stakeholders to discuss ways to accelerate and streamline deployment (European Commission, 2022[74]).

Germany announced the Gigabit Strategy in July 2022 that calls for fibre coverage of at least half of households and full mobile coverage by the end of 2025. To achieve these goals, the strategy set out to simplify approval processes for communication infrastructure deployment by the end of 2022 (Bundesministerium für Digitales und Verkehr, 2022[79]).

Promoting efficient spectrum management

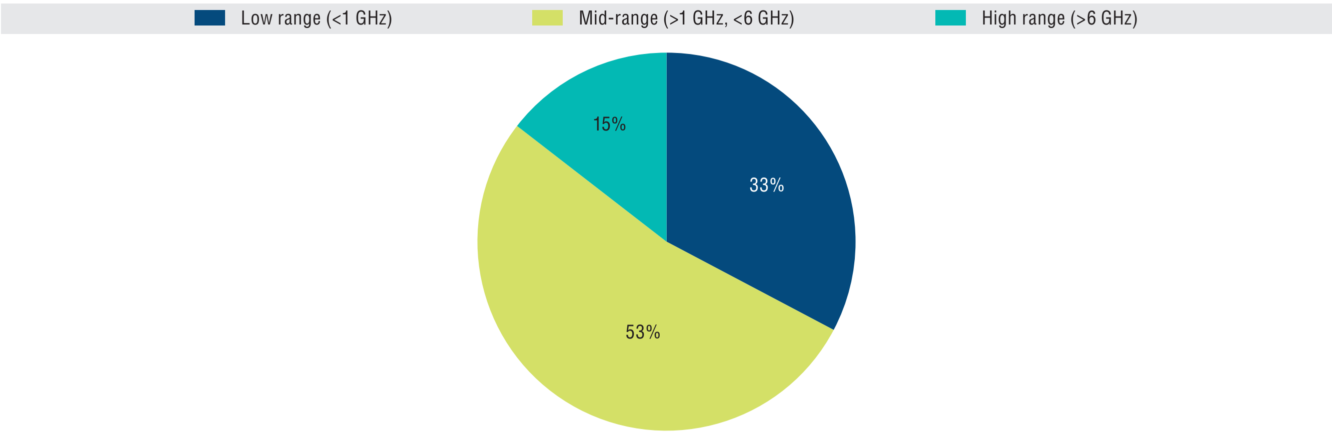
Spectrum is a scarce essential input, in the form of invisible airwaves, that is required to provide wireless communication services, including mobile connectivity. Its timely availability is key to foster a vast array of critical applications and to enable connectivity for mass consumer and business communications. Therefore, efficient spectrum management can help expand overall economic and social welfare. As the demands for spectrum increase, many OECD countries are considering how to enable shared access to spectrum to increase its efficient use (OECD, 2022[11]).

Spectrum assignments for mobile services have been prominent in 30 OECD countries and in Brazil since 2021. Between 2021 and 2023, 55 spectrum assignments via auctions in different frequency ranges for mobile communications took place in OECD countries and in Brazil. Many of these auctions targeted licences in multiple bands (i.e. "multi-band auctions"). The most common frequency range was mid-band spectrum (i.e. above 1 GHz and below 6 GHz) (Figure 2.18). Eight countries licensed millimetre wave (mmWave) spectrum through auctions (Australia, Brazil, Denmark, Estonia, Hungary, Korea, Slovenia and Spain). Other countries such as Chile, Denmark, Germany and Iceland opted for different assignment procedures for mmWave spectrum (e.g. comparative selection, administrative selection or other).

Spectrum licensing plays a key role to close connectivity gaps, imposing build-out requirements in licences or allowing access to unused spectrum to expand connectivity in underserved areas (OECD, 2022[11]). Coverage obligations in spectrum assignment procedures, such as auctions, along with competitive communication markets, have proven to be an effective tool to extend mobile broadband coverage in rural and remote areas (OECD, 2022[11]).

Figure 2.18. Spectrum assignments for mobile services have been prominent in most OECD countries and in Brazil since 2021

Share of spectrum assignments according to frequency ranges auctioned during 2021-23 in OECD countries and Brazil



Note: A total of 55 spectrum assignments were auctioned, often in a multi-band setting.

Source: OECD elaboration based on *the CSI DEO 2024* Regulatory Questionnaire.

StatLink https://stat.link/4uach2

Spectrum licensing can also be used as a tool to promote wireless local community broadband networks. In several OECD countries, spectrum licensing frameworks can cater to local networks to address rural connectivity needs, including via low-cost licences to extend coverage in rural and remote areas (Australia, Finland, Japan, Mexico, New Zealand, Sweden, the United Kingdom and the United States) (OECD, 2022[11]). In Mexico, social purpose spectrum licences can be used to provide not-for-profit communication services, and commercial licences (i.e. for-profit) have been granted to local WISPs (OECD, 2022[11]). In the United States, the FCC established a "Tribe Priority Window" to allow tribes in rural areas to directly access unassigned 2.5 GHz spectrum to expand broadband in their lands (FCC, 2021[80]). (More details can be found in OECD (2022[11]).)

References

ACM (2021), "Guidelines for sharing of mobile networks", webpage, *https://www.acm.nl/en/publications/guidelines-sharing-mobile-networks* (accessed on 28 October 2022). [73]

Alleven, M. (2022), "T-Mobile's 5G Home Internet footprint is getting a lot bigger with a data capped version", 9 August, Fierce Wireless, *http://tps://www.fiercewireless.com/wireless/t-mobiles-5g-home-internet-footprint-getting-lot-bigger-light-version*. [16]

ANACOM (2022), "Social Internet tariff now open to subscriptions", webpage, *https://www.anacom.pt/render.jsp?contentId=1717706&languageId=1* (accessed on 22 January 2024). [51]

Anatel (2020), "Redes Comunitárias" [Community Networks], 17 May, News Release, Agência Nacional de Telecomunicações, Brasilia, *https://www.gov.br/anatel/pt-br/regulado/universalizacao/redes-comunitarias*. [50]

Arcep (2023), "Christophe Bechu, Agnès Pannier-Runacher and Jean-Noël Barrot receive the forward-looking assessment of the digital environmental footprint in 2030 and 2050, from ADEME and Arcep", 6 March, Press Release, Arcep, Paris, *https://en.arcep.fr/news/press-releases/view/n/environment-060323.html*. [66]

Arcep (2022), *Maps & Data – Open Data* (database), *https://en.arcep.fr/maps-data/open-data.html* (accessed on 18 January 2024). [44]

Arcep (2022), "The digital environmental footprint in France: ADEME and Arcep submit their first report to the government", 19 January, Press Release, Arcep, Paris, *https://en.arcep.fr/news/press-releases/view/n/the-environment-190122.html*. [65]

Australian Government (2023), "New ACMA powers to combat misinformation and disinformation", webpage, *https://www.infrastructure.gov.au/have-your-say/new-acma-powers-combat-misinformation-and-disinformation* (accessed on 17 February 2024). [61]

Bundesministerium für Digitales und Verkehr (2022), "Gigabitstrategie der Bundesregierung verabschiedet", [Federal government's gigabit strategy adopted], webpage, *https://www.bmdv.bund.de/SharedDocs/DE/Pressemitteilungen/2022/050-wissing-gigabitstrategie-der-bundesregierung-verabschiedet.html* (accessed on 1 December 2022). [79]

Chorus (2024), "Phone and broadband options are changing in some areas", webpage, *https://www.chorus.co.nz/copper-withdrawal* (accessed on 22 February 2024). [68]

Commerce Commission New Zealand (2023), "Development of the Copper Withdrawal Code", webpage, *https://comcom.govt.nz/regulated-industries/telecommunications/projects/development-of-the-copper-withdrawal-code* (accessed on 19 March 2024). [67]

CRC (2022), *Índice de favorabilidad al despliegue de infraestructura de telecomunicaciones en las capitales del país*, [Favourability index for the deployment of telecommunications infrastructure in the country's capital cities], Comisión de Regulación de Comunicaciones, Colombia, *https://www.crcom.gov.co/es/micrositios/indice* (accessed on 28 July 2022). [78]

CRTC (2024), *Current Trends - High-speed Broadband* (database), *https://crtc.gc.ca/eng/publications/reports/PolicyMonitoring/ban.htm* (accessed on 22 January 2024). [40]

De Nil, M. (2023), "The emergence of Wi-Fi HaLow for IoT adoption and innovation", 17 May, Forbes, *https://www.forbes.com/sites/forbestechcouncil/2023/05/17/the-emergence-of-wi-fi-halow-for-iot-adoption-and-innovation*. [84]

Deutsche Glasfaser (2020), "Deutsche Glasfaser: Netzausbau", [Deutsche Glasfaser: Network expansion], webpage, *https://www.deutsche-glasfaser.de/netzausbau* (accessed on 12 August 2020). [53]

DIST (2023), "Project Gigabit progress update, June 2023", *Policy Paper*, 30 June, Department of Science, Innovation and Technology, London, *https://www.gov.uk/government/publications/project-gigabit-progress-update-june-2023/project-gigabit-progress-update-june-2023* (accessed on 28 August 2023). [35]

European Commission (2024), *5G Observatory, Biannual Report, June 2024*, European 5G Observatory, *https://5gobservatory.eu/report-20-june-2024*. [9]

European Commission (2024), "DESI 2023 indicators: Digital Infrastructure", *DESI 2023 Dashboard for the Digital Decade* (database), *https://digital-decade-desi.digital-strategy.ec.europa.eu/datasets/desi/indicators#desi2023-2* (accessed on 22 February 2024). [29]

European Commission (2024), "Recommendation on the regulatory promotion of gigabit connectivity", 6 February 2024, European Commission, Brussels, *https://digital-strategy.ec.europa.eu/en/library/recommendation-regulatory-promotion-gigabit-connectivity*. [59]

European Commission (2024), "Regulation (EU) 2024/1309 of the European Parliament and of the Council of 29 April 2024 on measures to reduce the cost of deploying gigabit electronic communications networks, amending Regulation (EU) 2015/2120 and repealing Directive 2014/61/EU Gigabit", 8 May 2024, European Commission, Brussels, *https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32024R1309*. [58]

European Commission (2022), “Connectivity toolbox: Member States’ implementation reports”, Report/Study, 19 May, European Commission, Brussels, *https://digital-strategy.ec.europa.eu/en/library/connectivity-toolbox-member-states-implementation-reports*. [74]

FCC (2024), *FCC National Broadband Map* (database), *https://broadbandmap.fcc.gov/data-download* (accessed on 18 January 2024). [45]

FCC (2023), “FCC Space Bureau & Office of International Affairs to launch April 11”, 11 April, Press Release, Federal Communications Commission, Washington, D.C., *https://www.fcc.gov/document/fcc-space-bureau-office-international-affairs-launches-april-11*. [63]

FCC (2022), “FCC releases new national broadband maps”, 18 November, Press Release, Federal Communications Commission, Washington, D.C., *https://www.fcc.gov/document/fcc-releases-new-national-broadband-maps*. [42]

FCC (2021), “Broadband radio service & education broadband service”, webpage, *https://www.fcc.gov/broadband-radio-service-education-broadband-service* (accessed on 4 May 2022). [80]

FCC (2021), *Fourteenth Broadband Deployment Report*, Federal Communications Commission, Washington, D.C., *https://www.fcc.gov/reports-research/reports/broadband-progress-reports/fourteenth-broadband-deployment-report*. [39]

FiberConnect Council MENA (2022), “The business models that are attracting FTTH investment now”, 24 August, Fibre Connect Council, *https://fiberconnectmena.org/index.php?option=com_content&view=article&id=1795:the-business-models-that-are-attracting-ftth-investment-now&catid=100&lang=en&Itemid=259*. [54]

Fletcher, B. (2022), “Verizon expects 4-5M fixed wireless customers by the end of 2025”, 4 March, Fierce Wireless, *https://www.fiercewireless.com/wireless/verizon-expects-4-5m-fixed-wireless-customers-end-2025*. [17]

Godlovitch, I. et al. (2019), “Prospective competition and deregulation: An analysis of European approaches to regulating full fibre for BT”, report commissioned by Ofcom, WIK-Consult, February. [70]

Government of Canada (2022), “Universal Broadband Fund”, webpage, *https://ised-isde.canada.ca/site/high-speed-internet-canada/en/universal-broadband-fund* (accessed on 28 August 2023). [32]

Government of Mexico (2024), *CFE Telecomunicaciones e Internet Para Todos*, [CFE Telecommunications and Internet For All], website, *https://mapa.internetparatodos.cfe.mx/?entidad=&municipio=&t4g=true&tsatelital=true&tadsl=true* (accessed on 16 February 2024). [56]

Government of Portugal (2023), “Tender to take fibreoptics to the entire country is launched”, 12 December, Press Release, Government of Portugal, *https://www.portugal.gov.pt/en/gc23/communication/news-item?i=tender-to-take-fibre-optics-to-the-entire-country-is-launched*. [36]

Government of Spain (2021), “Recovery plan is most ambitious economic plan in Spain’s recent history“, says Pedro Sánchez”, 13 April, President’s News, La Moncla, Government of Spain, *https://www.lamoncloa.gob.es/lang/en/presidente/news/Paginas/2021/20210413recovery-plan.aspx*. [71]

GSA (2024), “5G - 5G-Standalone April 2024 Summary”, webpage, *https://gsacom.com/paper/5g-standalone-april-2024-summary* (accessed on 30 June 2024). [6]

GSA (2024), “Private Mobile Networks June 2024 Summary”, webpage, *https://gsacom.com/technology/private-mobile-networks* (accessed on 30 June 2024). [10]

GSMA (2019), “Infrastructure sharing: An overview”, webpage, *https://www.gsma.com/futurenetworks/wiki/infrastructure-sharing-an-overview* (accessed on 28 October 2022). [85]

GSMA Intelligence (2024), *GSMA Intelligence* (database), *https://www.gsmaintelligence.com* (accessed on 18 September 2023). [5]

Hardesty, L. (2022), “Reliance Jio to launch a different kind of fixed wireless access”, 6 September, Fierce Wireless, *https://www.fiercewireless.com/5g/reliance-jio-launch-different-kind-fixed-wireless-access?utm_source=email&utm_medium=email&utm_campaign=FT-NL-FierceWireless&oly_enc_id=2115D4525489H3G*. [19]

IFT (2024), “Diagnostics of Mobile service coverage among indigenous peoples”, webpage, *https://www.ift.org.mx/usuarios-y-audiencias/diagnosticos-de-cobertura-del-servicio-movil-en-los-pueblos-indigenas* (accessed on 22 January 2024). [41]

IFT (2022), *Análisis de las iniciativas públicas y privadas para proveer servicios de telecomunicaciones y radiodifusión en zonas rurales y/o marinadas*, [Analysis of public and private initiatives to provide telecommunications and broadcasting services in rural and/or marginalised areas], Federal Telecommunications Institute, Mexico City, *https://centrodeestudios.ift.org.mx/admin/files/estudios/1669919717.pdf*. [49]

Intel (2024), “What is Wi-Fi 6?”, webpage, *https://www.intel.com/content/www/us/en/gaming/resources/wifi-6.html* (accessed on 22 February 2024). [12]

ISED (2022), “National broadband data information”, webpage, *https://ised-isde.canada.ca/site/high-speed-internet-canada/en/universal-broadband-fund/national-broadband-data-information* (accessed on 18 January 2024). [43]

ITU (2024), *World Telecommunication/ICT Indicators* (database), *http://www.itu.int/pub/D-IND-WTID.OL* (accessed on 19 September 2023). [24]

ITU (2023), "The affordability of ICT services 2022", *Policy Brief*, International Telecommunication Union, Geneva, *https://www.itu.int/dms_pub/itu-d/opb/ind/D-IND-POL_BRIEF.02-2023-PDF-E.pdf*. [26]

Koziol, M. (2023), "Wi-Fi 7 signals the industry's new priority: Stability", 29 December, IEEE Spectrum, *https://spectrum.ieee.org/wi-fi-7* (accessed on 10 March 2024). [13]

Lennighan, M. (2023), "AT&T to maintain 5G spend and push FWA in 2023", 26 January, Telecoms.com, *https://telecoms.com/519601/att-to-maintain-5g-spend-and-push-fwa-in-2023*. [18]

Majithia, K. (2022), "Nokia to deploy FWA mmWave on Australian NBN", 18 October, Mobile World Live, *https://www.mobileworldlive.com/featured-content/home-banner/nokia-to-deploy-fwa-mmwave-on-australian-nbn/?ID=a6g1r000000xNauAAE&JobID=1270899&utm_source=sfmc&utm_medium=email&utm_campaign=MWL_20221018&utm_content=https%3a%2f%2fwww.mobileworldlive.com%2ff*. [15]

MIC (2024), *Survey on Actual Radio Spectrum Usage*, *https://www.soumu.go.jp/main_content/000917561.pdf*. [7]

MIC (2022), "Results of solicitation of opinions on draft revisions to the guidelines on application relationships of the Telecommunications Business Act and the Radio Act", 29 March, Press Release, Ministry of Internal Affairs and Communications, Toyko, *https://www.soumu.go.jp/main_sosiki/joho_tsusin/eng/pressrelease/2024/3/29_2.html*. [72]

Ministério das Comunicações (2023), "Norte Conectado", [Connected North], Brazilian Ministry of Communications, Brasilia, *https://www.gov.br/mcom/pt-br/acesso-a-informacao/acoes-e-programas/programas-projetos-acoes-obras-e-atividades/norte-conectado*. [37]

Ministry of Business, Innovation & Employment (2022), *Lifting Connectivity in Aotearoa New Zealand*, Ministry of Business Innovation and Employment, Wellington, *https://www.mbie.govt.nz/assets/lifting-connectivity-in-aotearoa-new-zealand-december-22.pdf*. [33]

MSIT (2024), "K-Network 2030 Strategy", Press Release, Ministry of Science and ICT, Seoul, *https://www.msit.go.kr/bbs/view.do?mId=113&mPid=238&bbsSeqNo=94&nttSeqNo=3182740*. [8]

Nkom (2020), "Decision to amend the decisions in Markets 3a and 3b - obligation to maintain access to copper-based access networks", Norwegian Communications Authority, Fornebu, *https://nkom.no/ekom-markedet/markeder/marked-3a-og-3b-lokal-og-sentral-tilgang-til-faste-aksessnett/_/attachment/download/9ab67684-1bda-4df8-a091-a6256cdd9b9b:56396f4462c29e3222055780475048 31d4a75c2d/Vedtak%20om%20endring%20av%20vedtakene%20i%20Marked%20*. [69]

OECD (2024), *Broadband Statistics* (database), *https://www.oecd.org/en/topics/sub-issues/broadband-statistics.html* (accessed on 14 March 2024). [2]

OECD (2024), "Financing broadband networks of the future", *OECD Digital Economy Papers*, No. 365, OECD Publishing, Paris, *https://doi.org/10.1787/eafc728b-en*. [3]

OECD (2024), "Internet access", (indicator), *https://doi.org/10.1787/69c2b997-en* (accessed on 29 September 2023). [27]

OECD (2024), "Next generation wireless networks and the connectivity ecosystem", in *OECD Digital Economy Outlook 2024 (Volume 1): Embracing the Technology Frontier*, OECD Publishing, Paris, *https://doi.org/10.1787/45ba765d-en*. [57]

OECD (2024), *OECD Digital Economy Outlook 2024 (Volume 1): Embracing the Technology Frontier*, OECD Publishing, Paris, *https://doi.org/10.1787/a1689dc5-en*. [14]

OECD (2023), *Enhancing Rural Innovation in the United States*, OECD Rural Studies, OECD Publishing, Paris, *https://doi.org/10.1787/22a8261b-en*. [52]

OECD (2022), "Broadband networks of the future", *OECD Digital Economy Papers*, No. 327, OECD Publishing, Paris, *https://doi.org/10.1787/755e2d0c-en*. [1]

OECD (2022), "Building better societies through digital policy: Background paper for the CDEP Ministerial meeting", *OECD Digital Economy Papers*, No. 338, OECD Publishing, Paris, *https://doi.org/10.1787/07c3eb90-en*. [21]

OECD (2022), "Communication regulators of the future", *OECD Digital Economy Papers*, No. 333, OECD Publishing, Paris, *https://doi.org/10.1787/f02209e6-en*. [60]

OECD (2022), "Developments in spectrum management for communication services", *OECD Digital Economy Papers*, No. 332, OECD Publishing, Paris, *https://doi.org/10.1787/175e7ce5-en*. [11]

OECD (2022), *Rural Policy Review of Colombia 2022*, OECD Rural Studies, OECD Publishing, Paris, *https://doi.org/10.1787/c26abeb4-en*. [55]

OECD (2021), "Bridging connectivity divides", *OECD Digital Economy Papers*, No. 315, OECD Publishing, Paris, *https://doi.org/10.1787/e38f5db7-en*. [28]

OECD (2021), *Bridging digital divides in G20 countries*, OECD Publishing, Paris, *https://doi.org/10.1787/35c1d850-en*. [31]

OECD (2020), "OECD bundled communication price baskets", *OECD Digital Economy Papers*, No. 300, OECD Publishing, Paris, *https://doi.org/10.1787/64e4c18a-en*. [82]

OECD (2019), "The road to 5G networks: Experience to date and future developments", *OECD Digital Economy Papers*, No. 284, OECD Publishing, Paris, *https://doi.org/10.1787/2f880843-en*. [4]

OECD (2018), "Bridging the rural digital divide", *OECD Digital Economy Papers*, No. 265, OECD Publishing, Paris, *https://doi.org/10.1787/852bd3b9-en*. [22]

OECD (2018), *OECD Reviews of Digital Transformation: Going Digital in Sweden*, OECD Reviews of Digital Transformation, OECD Publishing, Paris, *https://doi.org/10.1787/9789264302259-en*. [77]

OECD (2017), *OECD Telecommunication and Broadcasting Review of Mexico 2017*, OECD Publishing, Paris, *https://doi.org/10.1787/9789264278011-en*. [48]

OECD (2017), *Revised Telecommunication Price Baskets*, Working Party on Communication Infrastructures and Services Policy, OECD, Paris, *https://one.oecd.org/document/DSTI/CDEP/CISP(2017)4/FINAL/En/pdf*. [81]

OECD (2017), "The evolving role of satellite networks in rural and remote broadband access", *OECD Digital Economy Papers*, No. 264, OECD Publishing, Paris, *https://doi.org/10.1787/7610090d-en*. [23]

OECD (2015), "Development of High-speed Networks and the Role of Municipal Networks", *OECD Science, Technology and Industry Policy Papers*, No. 26, OECD Publishing, Paris, *https://doi.org/10.1787/5jrqdl7rvns3-en*. [46]

Ofcom (2022), *Connected Nations 2022*, Ofcom, London, *https://www.ofcom.org.uk/research-and-data/multi-sector-research/infrastructure-research/connected-nations-2022*. [38]

Ofcom (2022), *Space Spectrum Strategy*, 10 November, Ofcom, London, *https://www.ofcom.org.uk/__data/assets/pdf_file/0023/247181/statement-space-spectrum-strategy.pdf*. [64]

Ookla (2024), "Global, fixed and mobile network performance maps", *Speedtest® by Ookla®*, 4Q 2023, Registry of Open Data on AWS, *https://registry.opendata.aws/speedtest-globalperformance*. [30]

Open Fiber (2022), "TIM, FiberCop and Open Fiber sign a commercial agreement to speed up digitalisation of the country", 13 May, Press Release, Open Fiber, *https://openfiber.it/en/open-fiber-world/press-releases/partnership-open-fiber-tim-fibercop/#:~:text=Rome%2C%2013%20May%202022,been%20financed%20by%20public%20funding*. [75]

Redes, A. (2020), "Expanding the telecommunications operators ecosystem: Policy and regulatory guidelines to enable local operators", webpage, *https://www.apc.org/en/pubs/expanding-telecommunications-operators-ecosystem-policy-and-regulatory-guidelines-enable-local* (accessed on 9 March 2022). [47]

Shared Rural Network (2020), "About the shared rural network", webpage, *https://srn.org.uk/about* (accessed on 28 October 2022). [76]

Teligen/TechInsights (2024), "Teligen tariff & benchmarking market data using the OECD methodology", Teligen/TechInsights. [25]

The White House (2021), "President Biden's bipartisan infrastructure law", November, Press Release, The White House, Washington, D.C., *https://www.whitehouse.gov/bipartisan-infrastructure-law* (accessed on 28 July 2022). [34]

United Kingdom (2023), *Online Safety Act*, Government of the United Kingdom, *https://www.legislation.gov.uk/ukpga/2023/50/enacted* (accessed on 22 January 2024). [62]

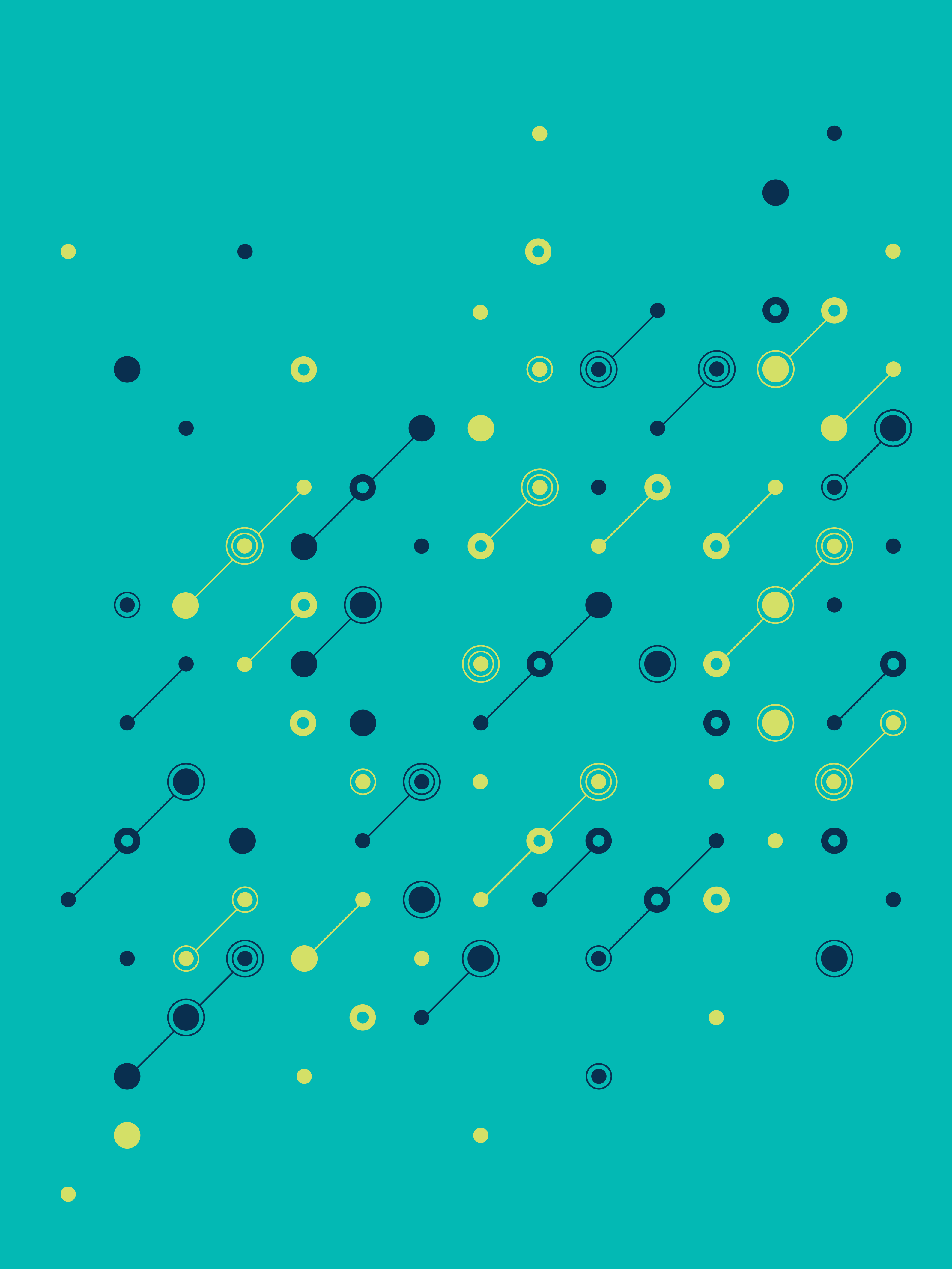
Wi-Fi Alliance (2024), "Discover Wi-Fi CERTIFIED HaLow: Long Range, Low Power Wi-Fi for IoT", webpage, *https://www.wi-fi.org/discover-wi-fi/wi-fi-certified-halow* (accessed on 20 May 2024). [83]

Wood, N. (2023), "Jio's FWA service goes live in eight cities", 21 September, Telecoms.com, *https://telecoms.com/523838/jios-fwa-service-goes-live-in-eight-cities*. [20]

Notes

1. Data Over Cable Service Interface Specification (DOCSIS) is a standard that allows delivery of broadband on an existing Hybrid Fibre-Coaxial (HFC) cable technology. The standard has evolved to its current version DOCSIS 3.1. While DOCSIS 3.1 may provide a viable alternative to FTTH in terms of download speeds, it does not achieve symmetrical upload speeds. The scalability of these cable networks depends on the evolution of the DOCSIS standard. DOCSIS 4.0 envisions to achieve 10 Gbps symmetrical speeds.
2. In most countries, rollouts concerned mobile services except for Colombia where one provider (DirectTV) is delivering 5G FWA services in the capital.

3. The definitions of the GSMA Intelligence database are the following: "5G connections: 5G unique SIM cards (or phone numbers, where SIM cards are not used) that have been registered on the mobile network at the end of the period. Connections differ from subscribers such that a unique subscriber can have multiple connections. Total mobile connections: Total unique SIM cards (or phone numbers, where SIM cards are not used), excluding licensed cellular IoT connections, that have been registered on the mobile network at the end of the period."
4. Namely, SA-5G uses both the 3rd Generation Partnership Project (3GPP) core network architecture for 5G (i.e. 5G Core, 5GC), as well as the 5G radio interface (i.e. New Radio, NR) (OECD, 2022[1]).
5. Wireless networking protocols that are based on the IEEE 802.11 network standard.
6. Moreover, WLAN developments are also seeking to improve IoT use cases. For example, the Wi-Fi HaLow standard enables low power and long-range connectivity necessary for applications, including sensor networks and wearables (De Nil, 2023[84]; Wi-Fi Alliance, 2024[83]).
7. Connectivity divides are defined as gaps in access and uptake of high-quality broadband services at affordable prices in areas with low population densities and for disadvantaged groups compared to the overall population (OECD, 2021[28]).
8. The OECD has been collecting prices of communication services for 30 years and has developed a unique methodology to compare the prices of communication services with different features across countries. The price baskets have been revised over the years to keep pace with service offerings and technological developments. In 2020, the OECD adopted a new basket methodology for bundled communication services. The revised version of price baskets for mobile broadband services (called "mobile voice and data") and fixed broadband services were adopted in 2017 (OECD, 2017[81]). With increased convergence and the prevalence of communication bundles in most OECD countries, a new methodology for prices baskets was approved in 2020, allowing to compare prices of bundled communication services (dual-play, triple-play and quadruple-play bundles) (OECD, 2020[82]). The features of different offers of communication services are evaluated and compared, including the number of calls, download speed, data allowance, and number of TV channels and premium channels in the case of bundles. The basket methodology consists of selecting, for every OECD country, the cheapest offers in the market meeting all criteria for a given user profile (i.e. low, medium, high usage profiles).
9. "Internet access is defined as the percentage of households who reported that they had access to the Internet. In almost all cases this access is via a personal computer either using a dial-up, ADSL or cable broadband access. This indicator is measured in percentage of all households."
10. Percentage of households covered by any fixed very-high-capacity network (VHCN) according to the European Commission definition. The technologies considered are FTTH and FTTB for 2017-18 and FTTH, FTTB and Cable DOCSIS 3.1 for 2019 onwards.
11. Using an exchange rate of CAD 1.302/USD in 2022 according to OECD.stat.
12. Using an exchange rate of NZD 1.6/USD in 2022 according to OECD.stat.
13. Using an exchange rate of GBP 0.8/USD in 2022 according to OECD.stat.
14. Using an exchange rate of BRL 5.2/USD in 2022 according to OECD.stat
15. Demand aggregation models help investors by essentially signing up customers in advance, co-ordinating and bundling demand to increase the potential profitability, economies of scale and/or the certainty of the business case for network expansion.
16. Note: Sample size is 37 of 38 OECD countries. Source: OECD elaboration based on CSI Regulatory Questionnaire responses in 2023.
17. "Wholesale access regulation" is defined as the mandatory offering by network operators of specific wholesale elements of their network to other operators, on terms approved by a regulator or sanctioned by a court. It requires the incumbent to allow rivals to lease or grant access to certain individual building blocks that make up a communication network (network segments or layers). This concept is distinct from the concept of "network sharing", which refers to an agreement between operators for the shared use of network elements, which may be subject to regulatory measures (OECD, 2022[60]).
18. Active infrastructure can be categorised into three types from a technical point of view: i) Multi-Operator Radio Access Network (MORAN), in which operators share the RAN but use their own dedicated spectrum and core network; ii) MOCN (Multi-Operator Core Network), in which operators share RAN and spectrum, but do not share their core network; and iii) Core Network Sharing, where operators share RAN, spectrum and their core network (GSMA, 2019[85]).



Spotlight

Skills for the digital age

Digital transformation affects economies and societies in complex and interrelated ways. A solid mix of foundational, information communication technology (ICT) and complementary skills help empower individuals to navigate an increasingly digital world, participate in the global economy and compete in job markets. With the breathtaking technological progress in automation, robotics and artificial intelligence combined with the power of data, businesses rely more than ever on ICT specialists to develop applications and manage networks. There is also a rising premium placed on skills such as communication, emotional intelligence and problem solving in today's job markets. Staying updated with future skills needs is an ongoing process and requires engagement of individuals and businesses in up- and re-skilling activities. Governments have a key role in helping them to develop and use skills effectively to thrive in an increasingly interconnected and rapidly changing world.

Individuals need a wide range of skills to thrive in the digital world

Foundational skills

- Science
- Reading
- Mathematics

Foundational skills are a prerequisite for the effective use of digital technologies.

ICT skills

Basic skills

- Basic office software use
- Information search
- Social media use

Specialist skills

- Artificial intelligence
- Software programming

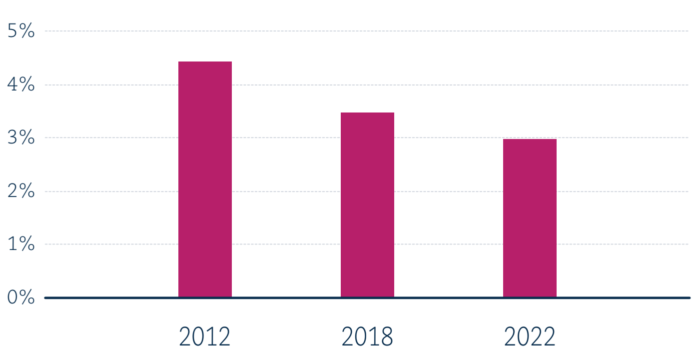
There is a growing demand in the labour market for these skills.

Complementary skills

- Critical thinking
- Empathy
- Teamwork

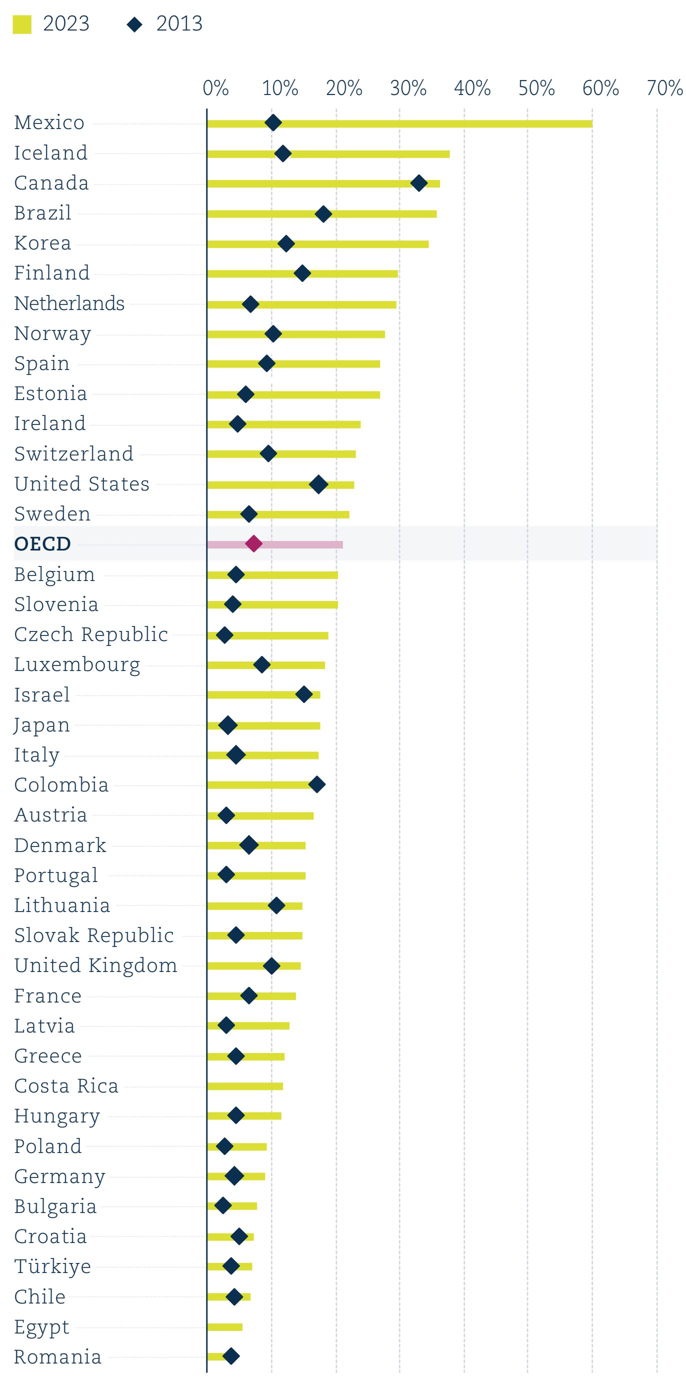
Complementary skills are as essential as ICT skills.

The share of top-performing students in the OECD with foundational skills is decreasing.



Up- and re-skilling will be essential to meet future skill needs.

Individuals have increasingly engaged in online training activities over the past decade.



The effective use of digital technologies and data requires a wide range of skills that need to be acquired, maintained and upgraded throughout a person's lifetime. Individuals of all ages need to be well equipped to make the most of digital technologies The young need to be able to use digital technologies effectively to learn and prepare for the world of work. The middle-aged must continually up- and re-skill as the demand for skills changes. Finally, older populations must learn how to live in a highly digital economy and society or risk being left behind.

The acquisition of skills needed in the digital age takes place through multiple channels, at various places and at different times. Digital technologies play an increasingly prominent role in education and training. The use of generative artificial intelligence (AI) might revolutionise teaching and learning, changing the ways in which students explore topics, ask questions and develop understanding. Stronger connectivity facilitates "flipped" classrooms where students are introduced to content at home and practise working through it at school. Meanwhile, teachers rely on different mobile applications to communicate with parents. As learning goes digital across the globe – a phenomena accelerated by the COVID-19 pandemic – an enormous innovation potential that had been dormant in education systems has come to the fore in many countries (OECD, 2021[1]).

The pandemic further accelerated the pace of digital transformation, shifting an increasing number of activities and services from the physical world on line. In the labour market, teleworking became a common feature in many workplaces. While the base is relatively small, online platform workers (OECD, 2019[2]) represent an increasing share in the overall workforce in many OECD countries (Urzì Brancati, Pesole and Fernández-Macías, 2020[3]; Kim, 2021[4]; Anderson et al., 2021[5]).

Trends such as globalisation and advances in AI are also changing the demands of the labour market and the skills needed for workers to thrive (Bakhshi et al., 2017[6]). Individuals rely even more on their uniquely (so far) human capacity for creativity, initiative and the ability to "learn to learn" throughout their life (OECD, 2019[7]; Samek, Squicciarini and Cammeraat, 2021[8]). In parallel, as individuals live and work longer, they also face more frequent job changes and the risk of skills obsolescence (OECD, 2019[9]).

Governments play an important role in fostering acquisition of skills at all ages, facilitating just transitions in the labour market and incentivising businesses to invest in their workers. Building on the OECD Skills Strategy (OECD, 2019[10]) and the OECD Jobs Strategy (OECD, 2018[11]), this spotlight presents trends and raises policy challenges that need to be addressed to prepare for the skills needs of tomorrow. It first sheds light on the range of skills needed to live and work in a highly digital economy and society. It also discusses changes in the demand for skills from the business perspective. Finally, it explores how individuals, businesses and governments can best respond to the changing skill needs raised by digital transformation, highlighting the need to closely monitor evolving AI capabilities. As the field of AI develops further in the years to come, possibly very rapidly, understanding what AI can and cannot do will be increasingly important to inform responsive policies (OECD, 2023[12]).

Individuals need a wide range of skills to thrive in a digital economy and society

In a fast-moving digital landscape, individuals need a wide range of skills to thrive. These skills can be considered as follows: first, foundational skills that enable all people to participate in a digital economy and society; second, basic skills level – such as basic computer skills, communication and information search skills and proficiency in using office productivity software; and advanced skills (e.g. AI skills, software programming). In addition, complementary skills such as teamwork, autonomy, problem solving, creative thinking, communication, collaboration and emotional intelligence enable high-performance work practices and a strong ability to continue learning.

Foundational skills are a prerequisite for the effective use of digital technologies

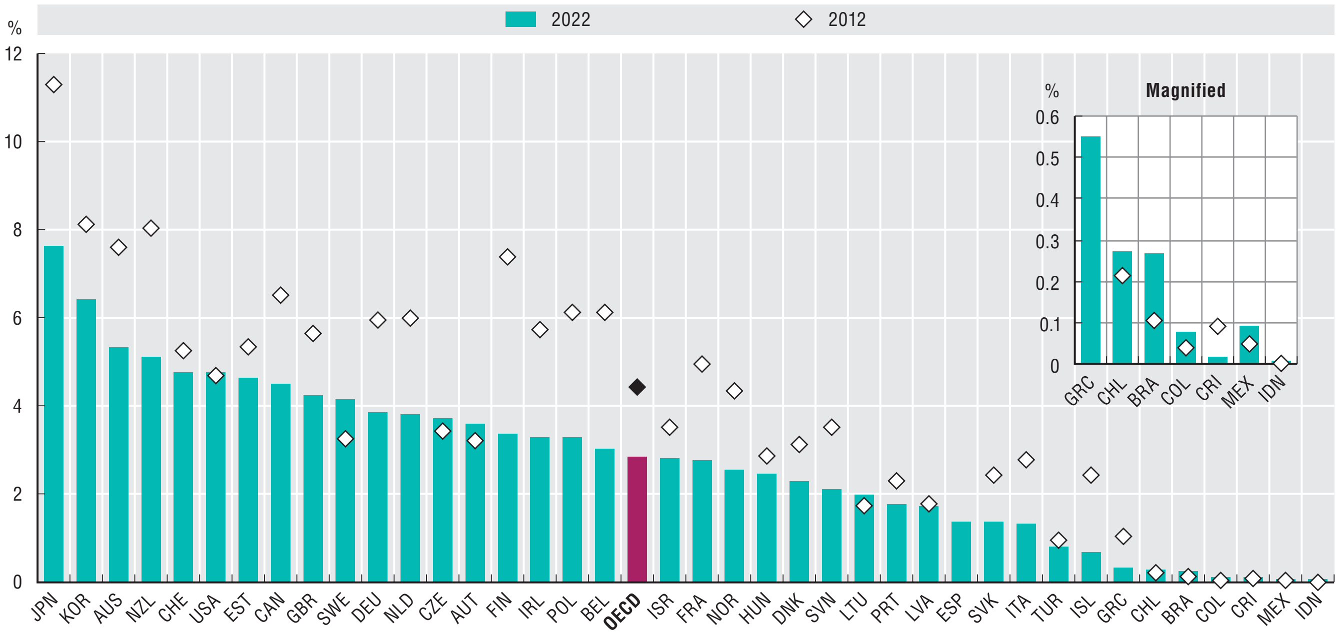
Foundational skills such as in science, numeracy and reading are essential for everyday activities (OECD, 2019[14]). Evidence from the first round of the OECD Programme for the International Assessment of Adult Competencies (PIAAC) shows that high levels of proficiency in literacy and numeracy, and in problem solving in digital environments, go hand in hand. On the other hand, low levels of proficiency in literacy, and particularly in numeracy, may be significant barriers to using ICT applications to manage information effectively (OECD, 2013[15]).

Figure 1.S.1 shows the share of top performers[1] in science, mathematics and reading in 2012 and 2022. These students can draw on and use information from multiple direct and indirect sources to solve complex problems, and can integrate knowledge from across different areas. Such exceptional skills can provide a significant advantage in a competitive, knowledge-based global economy as they allow adapting to the scale, speed and scope of digital transformations.

Between 2012 and 2022, the share of top performers in science, mathematics and reading decreased in most countries with available data. Despite a drop of about four percentage points in 2022, Japan remained the country with the highest share of top performers (7.6%), followed by Korea, Australia and New Zealand.

Figure 1.S.1. The share of academic all-rounders has been decreasing over time

Top performers in science, mathematics and reading, 2022



Source: Authors' calculations based on OECD (2024[16]) *PISA 2022 Database*, *https://www.oecd.org/pisa/data/2022database* (accessed on 11 March 2024).

StatLink *https://stat.link/ta13ps*

Recent OECD evidence also shows that individuals well equipped with strong foundational skills use digital technologies in a diverse and more complex way (OECD, 2019[17]), and also have a more positive attitude towards lifelong learning (OECD, 2021[18]). Experts emphasise the importance of deriving pleasure from reading at an early age as a marker for their adulthood (Sanacore, 2002[19]). Cross-country evidence from PISA survey shows that 15-year-old students with higher reading skills generally better distinguish facts from opinions on line, a critical skill to navigating the digital environment (OECD, 2021[20]).

As the share of academic all-rounders (i.e. top performers in science, mathematics and reading) has been decreasing over time, the performance of AI systems has been advancing quickly in tasks engaged by students across the board. This includes core reading, mathematical and scientific reasoning tasks commonly taught to 15-year-olds at school (OECD, 2023[21]; OECD, 2023[22]).

ICT skills strengthen the ability to cope with change and keep learning

In addition to foundational skills, individuals also need basic ICT skills to prosper in a digital economy and society. These include basic computer skills, communication and information search skills, as well as proficiency in using productivity software such as operational and information-navigation. Such skills enable access to information, facilitate communication, support civic participation and enhance employability and well-being (Burns and Gottschalk, 2019[23]; OECD, 2022[24]; OECD, 2019[17]). Yet, according to data from the first round of PIAAC, 25% of adults on average in OECD countries lacked the most basic digital skills and another 14% could only perform basic functions on a computer or other digital device (Verhagen, 2021[25]).

A more advanced level of ICT skills (e.g. software programming, AI skills) strengthens the ability to cope with change (e.g. in work organisation) and keep learning (e.g. new programming languages). It also allows people to leverage the wealth of open-source information available on line.

Programming skills are highly versatile and applicable in a wide range of fields. They enhance problem-solving abilities, promote creativity and innovation, and offer numerous career opportunities. Additionally, in today's technology-driven world, a basic understanding of programming is increasingly valuable for individuals in various aspects of life. The skill is useful for troubleshooting technical issues or changing the privacy settings of a personal device, building a customised website, analysing personal expenditures to make informed decisions about spending and saving, etc. According to the OECD ICT Usage by Households and Individuals data, only about 7% of 16-64 year-olds in OECD countries reported having written computer code in 2021.

More specifically, AI skills refer to the abilities and knowledge required to develop or undertake an advanced use of AI systems. Some key AI skills include programming, understanding and implementing machine-learning algorithms; data mining and data processing; deep learning; natural language processing; and understanding computer vision concepts, such as image processing and object detection (OECD, 2024[26]).

Complementary skills are becoming as essential as cognitive skills

When combined with a minimum level of ICT skills, complementary skills can significantly enhance an individuals' effectiveness and productivity in digital environments. Complementary skills include teamwork, autonomy, problem solving, creative thinking, communication, collaboration, emotional intelligence and a strong ability to continue learning. These are valuable assets across sectors and increasingly sought in today's technology-driven world that enables high-performance work practices in the digital age. The OECD' Skills for 2030 project identifies two types of complementary skills. "Meta-cognitive skills" include critical thinking, creative thinking, learning-to-learn and self-regulation, while "social and emotional skills" include empathy, self-efficacy, responsibility and collaboration (OECD, 2019[7]).

Demographic and societal changes such as ageing populations increase the demand for a variety of occupations related to health care. These require both scientific skills, and social and emotional skills, such as caring, sociability and respect (OECD, 2021[27]). In addition, social and emotional skills, such as empathy, self-awareness, respect for others and the ability to communicate, are becoming essential as classrooms, workplaces and societies become more ethnically, culturally and linguistically diverse.

In parallel, increasing reliance on AI and sophisticated machines may lead people to devalue the work of others. Indeed, some researchers are convinced this devaluation is already occurring (Turkle, 2017[28]). If this observation is generalised, then it will be increasingly important for people to learn how to recognise the value of their own humanity and that of others (Putnam, 2000[29]). Valuing the contributions of people to society is necessary not only for individual and societal well-being, but also for the health and relevance of institutions (Berkowitz and Miller, 2018[30]).

Finally, achievement at school also depends on social and emotional skills, such as perseverance, self-control, responsibility, curiosity and emotional stability. Some social and emotional skills are a prerequisite for successful participation and performance in academic settings. In other words, poor social and emotional skills can impede the development and use of cognitive skills (OECD, 2019[7]).

The increasing digitalisation of businesses is driving changes in skills demand

The introduction of new digital technologies in businesses changes the nature of work by reducing the demand for routine jobs and increasing the demand for ICT specialists in the labour market. Strong foundational skills are needed for the digital economy, including basic skills to live and work in increasingly digitalised environments. These complement advanced digital competencies, such as software programming and skills related to the design and deployment of AI systems.

This section discusses the shortage of ICT specialists through labour market indicators on occupations, job vacancies and wages. It draws on official statistics but also some private-sector data to provide a more complete picture with timely metrics. It then focuses on small and medium-sized enterprises (SMEs) for which investments in skills are a longstanding challenge. Finally, the section discusses the potential impact of digitalisation on skill demand by considering evidence on evolving AI capabilities and the exposure of different job tasks to automation.

The demand for ICT specialists is growing

The introduction of new digital technologies in businesses is changing the nature of work. Digital technologies are reducing the demand for routine jobs and increasing the demand for ICT specialists needed to programme, develop applications and manage networks. A high number of job vacancies for ICT specialists have made them among the most dynamic occupations in recent years. Yet shortages of ICT specialists also persist in several sectors (Censorii, 2021[31]). In 2021, more than 60% of EU enterprises that recruited or tried to recruit ICT specialists struggled to fill vacancies. In response, the European Commission announced an ambitious target for 20 million IT specialists within the European workforce by 2030 (European Commission, 2023[32]).

Spiezia, Koksal-Oudot and Montagnier (2016[33]) propose several proxy indicators based on occupations, job vacancies, vacancy duration and wages to assess potential shortages in a given occupation on the demand for ICT specialists. Based on labour force statistics, the OECD's Going Digital Toolkit shows that ICT specialists in 2021-22 accounted for 8% of all jobs in Sweden and Israel, about 4% in EU27 and only 1.4% in Türkiye.

Table 1.S.1 displays the most in-demand jobs on LinkedIn™ where "Salesperson" ranked first in Q2 2024. More broadly, customer service and sales roles dominate this list, especially in retail, which accounts for four of the top ten jobs. For recruiters, this shift underscores the rising premium placed on complementary skills such as communication, emotional intelligence and problem solving in today's job markets. It also suggests a need for talent professionals to focus on defining, assessing and evaluating these skills, as service-oriented jobs continue to attract higher demand (Lewis, 2024[34]). Interestingly, the only ICT specialist occupations on this list are software engineers but they rank third at a stable place as compared to the previous quarter.

Table 1.S.1. "Salesperson" is the job most in demand on LinkedIn

Roles with the greatest number of paid LinkedIn job posts, Q2 2024

Raking	Occupation	Position compared to the previous quarter
1	Salesperson	No change
2	Retail salesperson	No change
3	Software engineer	No change
4	Registered nurse	No change
5	Project manager	No change
6	Sales manager	No change
7	Customer service representative	No change
8	Full stack engineer	No change
9	Driver	+13
10	Cashier	+8

Note: The results are based on global LinkedIn data on all premium job posts from January 2024 up to June 2024 (inclusive). The analysis excludes roles with fewer than 1 000 job posts in either quarter and roles for which most job posts come from a single company. The most in-demand jobs are those with the highest number of job posts in the most recent quarter (1 April - 30 June 2024).

Source: (Lewis, 2024[34]).

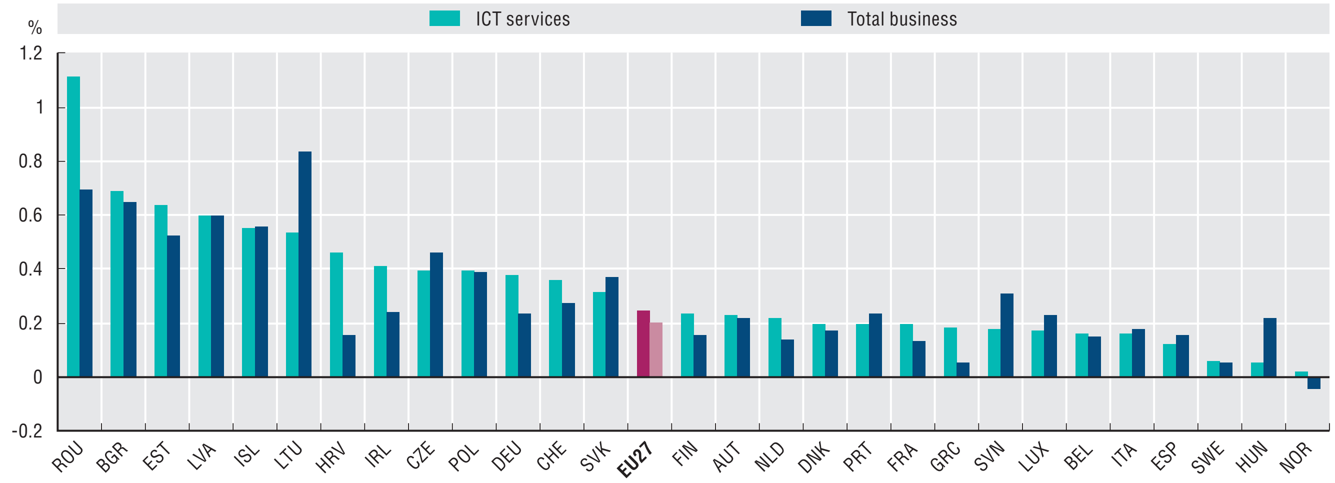
Alternative sources of information can be leveraged to provide timely information about trends in international labour demand, in particular for rapidly evolving fields like AI (OECD, 2024[35]). Based on Lightcast™ data on online job vacancies, AI-related online vacancies represent a small but growing share of all vacancies posted on line (Borgonovi et al., 2023[36]; Green and Lamby, 2023[37]; OECD, 2023[38]). Workers with AI skills are particularly in demand due to the growing influence of AI in various industries such as health care, finance, manufacturing, automotive, and entertainment (Borgonovi et al., 2023[36]) and they earn relatively high wages (OECD, 2023[39]).

Increases in real wages for the occupations using these skills intensively represent another indicator of labour shortage of specific skills. If ICT skills are scarce in the labour market, firms have to pay higher real wages to attract workers with such skills. Changes in real wages, however, are not always a good measure for skills shortage. On the one hand, skill shortages may not translate immediately to higher wages due to adjustment lags (e.g. collective wage bargaining). On the other, wages may increase as a result of both industry-specific and economy-wide productivity shocks. Therefore, an increase in real wages may be regarded as a sign of skills shortage only if: i) it is persistent over time; ii) it exceeds the increase in labour productivity; and iii) it is larger than in the other sectors of the economy (Spiezia, Koksal-Oudot and Montagnier, 2016[33]).

Figure 1.S.2 compares the average growth rates of wages – relative to average labour productivity – in ICT services and the total business sector[2] over 2013-22. In about two-thirds of the 28 countries for which data are available, wages grew more in ICT services than in the total business sector. In the remaining countries, differences in wages growth were limited, i.e. less than 1% a year. These trends confirm that the demand for ICT specialists is growing faster than supply in European countries.

Figure 1.S.2. Wages in ICT services grew more than in the total business sector

Changes in wages relative to labour productivity 2013-22, annual averages



Source: Authors' calculations based on (Eurostat, 2023[40]) *Annual National Accounts Statistics*, *https://ec.europa.eu/eurostat/web/national-accounts* (accessed on 5 March 2024).

StatLink *https://stat.link/4ls2pk*

For SMEs in particular, investments in ICT skills are a longstanding challenge (OECD, 2021[41]). In Europe, the percentage of large enterprises employing ICT specialists (76%) was more than five times higher in 2020 than that of SMEs employing ICT specialists (14%) (Censorii, 2021[31]). This gap can be explained by examining the broader challenges faced by small firms that struggle to offer competitive salaries and benefit packages that can attract experienced ICT professionals.

Furthermore, SMEs often lack brand recognition or visibility in the job market compared with larger companies. This can make it harder for them to attract talent in competitive areas like ICT skills. In the case of niche skill requirements like cybersecurity, AI or specific programming languages, finding candidates with the right combination of skills and experience can be even more challenging.

As a result, SMEs often outsource ICT functions to larger organisations that often offer well-established career paths, mentorship programmes and opportunities for professional growth. SMEs, especially very small ones, may struggle to provide the same level of career advancement prospects, which can limit their attractiveness. Finally, lack of formal training programmes and uncertain job security may explain part of the difficulties to attract ICT talents.

Technological progress in AI and robotics will further transform skills demand

Digital transformation will have further implications for skills demand as the capabilities of AI and robotics continue to advance and transform many tasks performed by humans. Several recent studies explored the potential of AI to automate work tasks across jobs and occupations. Based on evaluations from computer scientists, these studies identify tasks that machines are unlikely to perform within a sample of occupations or jobs. The studies then develop a model of automatability and predict how susceptible jobs across the entire economy are to automation. According to one study, nearly 14% of jobs in OECD countries were likely to be automated in 2019, while 32% were at high risk of being partially automated (Nedelkoska and Quintini, 2018[42]).

More recently, based on data across 21 OECD countries over 2012-21 (Georgieff and Milanez, 2021[43]), all countries experienced employment growth over the past decade with no evidence for net job destruction at the broad country level. Within countries, however, employment growth was much lower in jobs at high risk of automation (6%) than in jobs at low risk (18%).

Low-educated workers, already more concentrated in high-risk occupations in 2012, have become even more prominent in these occupations. Yet, the low growth in jobs in high-risk occupations has not led to a drop in the employment rate of low-educated workers relative to that of other education groups. This is largely because the number of low-educated workers has fallen in parallel with the demand for these workers.

Looking ahead, the risk of automation will increasingly fall on low-educated workers. Moreover, the COVID-19 crisis may have accelerated automation, as companies reduce reliance on human labour and contact between workers, or re-shore some production (Georgieff and Milanez, 2021[43]). Importantly, these findings highlight that jobs requiring lower skill levels face the greatest automation risk, implying a decrease in automation vulnerability with higher educational attainment.

Other studies have investigated the potential impact of AI by focusing on skills rather than job tasks. For instance, Lassébie and Quintini (2022[44]) exploited an original dataset on the potential automatability of approximately 100 skills and abilities gathered through a survey of AI experts. Their findings show that skills related to complex problem solving, high-level management and social interaction remain hard to automate given the state of technological developments. However, the study also shows that some skills and abilities previously identified as "bottlenecks" to automation are more susceptible to automation with recent advances in AI. These skills include knowledge of fine arts and some psychomotor abilities such as the ability to work in cramped workspace and awkward positions, finger dexterity and manual dexterity.

In parallel, the authors also show that recent advances in AI increase the demand for several skills required in high-skilled jobs susceptible to automation. These include reading comprehension, deductive and inductive reasoning, fluency of ideas and scheduling skills typically associated with high-skilled occupations.

As a result, most jobs at highest risk of automation are not at risk of being entirely automated. This is because they involve bottleneck tasks and even jobs preserved from the risk of disappearing involve a small set of automatable tasks. For example, only about 18-27% of skills and abilities required by the most at risk occupations are highly automatable and these occupations still require around 5% of bottleneck skills. In other words, even the occupations at highest risk of automation are not likely to be entirely substituted by automated solutions. Instead, the work organisation will have to be adapted and workers in these jobs may need up- and re-skilling as technologies replace workers for several tasks (Lassébie and Quintini, 2022[44]).

In parallel, a survey of workers and employers in the manufacturing and financial sectors in Austria, Canada, France, Germany, Ireland, the United Kingdom and the United States aimed to capture perceptions of the current and future impact of AI on the workplace (Lane, Williams and Broecke, 2023[45]). It showed that as the AI becomes more pervasive, individuals may need a broader range of (social) skills to work with such technologies. This finding is consistent with previous literature, which also suggests the adoption of AI requires not just AI expertise but also (or rather) skills in creative and social intelligence, reasoning skills and critical thinking (OECD, 2019[7]; Samek, Squicciarini and Cammeraat, 2021[8]; Squicciarini and Nachtigall, 2021[46]).

Finally, using alternative data sources such as online job postings, Manca (2023[47]) explored the impact of AI on labour markets. It asked six questions, including those related to the impact of such technologies on the demand for "routine" (i.e. general administrative and clerical tasks) and "non-routine cognitive" skills (i.e. creativity, problem solving). The analysis suggests that AI and routine skills are not complementary. AI is adopted more widely, more demand for AI skills is likely to be associated with less demand for routine skills, all else being equal. On the contrary, the relationship between AI skills and high-level cognitive skills appears to be positive.

Individuals, businesses and governments all need to prepare for the skills requirements of tomorrow

To thrive in an increasingly digital economy and society, and a rapidly evolving business environment, individuals need to continually acquire new skills. This requires flexibility, openness towards lifelong learning and curiosity. This section shows how individuals, businesses and governments can address these challenges through joint action.

Individuals must be aware of their skill needs and engage in learning activities throughout their life

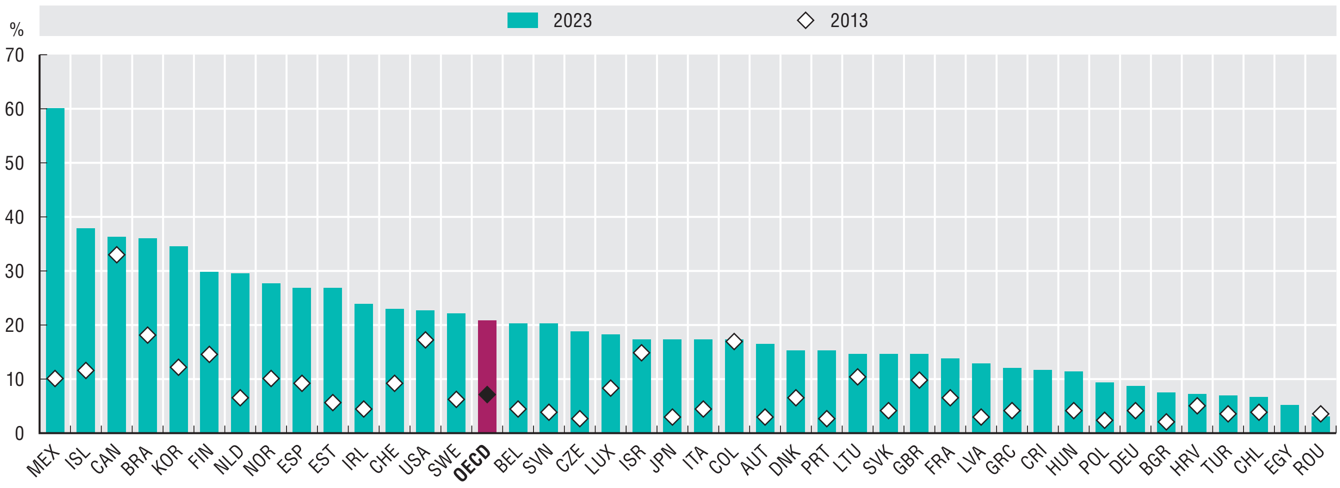
In an increasingly digital economy and society, the business environment is rapidly evolving. To adapt and thrive in this environment, individuals first need awareness of the associated risks and opportunities. Digital transformation can empower individuals to seize new opportunities, stay connected with loved ones and lead more fulfilling lives. On the other hand, a more digital world brings potential risks in terms of well-being and mental health, mis- and disinformation, and privacy and security incidents. In 2020, 52% of European citizens reported they felt fairly or very well informed about cybercrime compared to 46% in 2017. However, confidence in their ability to protect themselves sufficiently from this type of crime went down from 71% in 2017 to 59% in 2020 (European Commission, 2020[48]).

Awareness increases with knowledge. In 2023, two-thirds of individuals in the European Union (67%) asked for more education and training to develop their digital skills (European Commission, 2023[49]). In this respect, lifelong learning appears as a key tool for individuals to tackle skill challenges. However, it also requires a change in mindset. Learning is no longer compartmentalised in different phases of life. Rather, it evolves over the lifecycle (OECD, 2021[18]). Lifelong learning involves formal learning in official settings like schools or training centres, but also informal and non-formal learning (such as learning from co-workers and workplace training). In addition, spontaneous social interactions creates opportunities for unintentional learning.

Today, digital technologies revolutionise traditional learning mechanisms. OECD (2021[1]) shows that smart technologies improve education systems and education delivery in different ways. They enhance access to education, improve its quality for learners and enhance its cost efficiency for societies. Advances in large language models could unlock a future of increasingly personalised learning for students in all disciplines and age groups. As education and training go digital, learning takes place everywhere, and becomes less costly and more accessible for individuals. In this respect, Figure 1.S.3 shows the percentage of Internet users that followed an online course in OECD countries has more than doubled over the past decade[3] in almost all countries.

Figure 1.S.3. Individuals have increasingly engaged in online training activities over the past decade

Individuals using the Internet for an online course as a percentage of all individuals, 2023



Source: Authors' calculations based on (OECD, 2024[50]) *ICT Access and Usage Database*, *https://oe.cd/dx/ict-access-usage* (accessed on 31 January 2024).

StatLink *https://stat.link/8fqapt*

In the EU27 more specifically, 16.4% of individuals followed an online course in 2022; 20.7% used online learning material other than a complete course such as video tutorials, webinars, electronic textbooks, learning apps or platforms; and 18.1% communicated with educators or learners using audio or video online tools like Zoom, MS Teams and Google Classroom.

This said, research findings show a number of personal and professional characteristics affects adults' engagement in learning activities. These include age, gender, educational attainment or type of professional contract, tenure etc. Importantly, the self-directed nature of many online learning opportunities becomes a barrier for learners lacking the skills and dispositions to engage independently and fruitfully. OECD (2021[18]) argues that educational attainment is one of the strongest predictors of the willingness to continue learning. On average, tertiary-educated adults were less likely to be disengaged from adult learning than workers with lower-secondary education or below.

Containment and mitigation strategies related to the COVID-19 pandemic have also had direct and indirect effects on participation in adult learning among those willing to participate. Non-formal learning opportunities may have decreased by an average of 18% and informal learning opportunities by 25% in OECD countries (OECD, 2021[18]). Other factors, such as the availability of high-quality services, high training costs and personal constraints (e.g. lack of time or childcare responsibilities) also affect the decision of individual to engage in training.

Businesses should continuously engage in up- and re-skilling of employees

From a business perspective, digital technologies allow the automation of many routine tasks, give employees access to real-time data, provide them with the ability to telework, facilitate collaboration and communication, improve customer service, create a more engaging and personalised work experience and provide employees with mobile and social tools (Franke, 2022[51]). These changes cannot take place without a skilled workforce. Therefore, businesses should create a conducive environment for continuous learning and skill development, empowering their employees to thrive in the digital era. This not only benefits individual employees but also contributes to the overall success and competitiveness of the organisation in a rapidly evolving digital landscape.

To this end, employers need to invest in employees to help them gain and maintain the skills needed in the workplace (OECD, 2019[7]); some skills relevant today will be obsolete tomorrow. Yet, many adults do not participate – or wish to participate – in workplace learning. The pandemic also further reduced their opportunities to do so. This is especially true for low-skilled individuals lacking skills to engage in remote learning. In 2021, only 11.2% of EU enterprises provided their ICT specialists with professional training and 19.7% provided ICT training for other staff.

In addition to regular age- and skill-inclusive training programmes, businesses need to provide employees with access to online learning platforms, and subsidise or cover the costs of relevant courses. They must also foster a culture of continuous learning and skill development by inviting employees to take ownership of their own learning and providing resources to support them. Employees should be encouraged and supported to try out new digital tools and technologies in their work and benefit from a safe environment for experimentation and learning from failures.

Such work practices may sound disruptive or not affordable in all firms, in particular within an SME context which often needs specific skills. SMEs typically face a longstanding challenge in accessing and developing talent. They have limited connections to networks that may give access to qualified workers. They also lack formalised human resource management strategies to identify skills gaps and retain trained and skilled staff. In addition, SMEs may not be able to use the numerous financial incentives available to cover training costs, either because they are unaware of them, or because they are not eligible (OECD, 2023[52]).

To overcome such barriers, OECD (2023[52]) underlines the relevance of "skills ecosystems".[4] Facilitators can access bundles of skills, including transversal ones, without internalising them and fully bearing the related costs. Instead, skills can be accessed through the specialised labour pool or in the form of knowledge services. These positive externalities can enable SMEs to tap more easily into relevant expertise and respond to the need for "non-core" skills in a sustainable manner.

SMEs can also consider creative recruitment strategies, such as offering flexible work arrangements. These can showcase opportunities for growth and skill development, as well as emphasising the unique benefits of a smaller, close-knit team. Additionally, SMEs can look for candidates with a strong willingness to learn and adapt, as they may be more open to a broader range of responsibilities.

Co-operative coaching and learning sessions can consider each firm's history and context, making them especially effective in improving the take-up of digital technologies in SMEs (OECD, 2021[41]). However, firms also require continuous and operational support to implement solutions. Consequently, measures that combine peer learning and individual support services – through subsidised consulting/coaching services, for example – seem best placed to help SMEs invest in the key competences for digital transformation.

Well-designed policies will help individuals and businesses to best prepare for future skill needs

Given the abovementioned challenges, governments need to co-ordinate their action. On the one hand, they must adopt an agile approach to national up-skilling initiatives by working with businesses, non-profit organisations and the education sector. They also need to engage in social dialogue with trade unions to continually monitor and improve the effective functioning of skill ecosystems. On the other, governments need to facilitate labour market transitions to ensure no one is left behind.

Today, several OECD countries (e.g. Australia, Ireland, Luxembourg, Sweden) and key partners (e.g. India, South Africa) have one or more national skills strategies. These aim to design and deliver in a cross-government approach and accompany the twin transitions. In addition, they seek to align efforts across a range of policies and with strong stakeholder involvement. These include social partners; civil society and labour market actors; and the education and training sector. The European Union has its own Skills Agenda that sets out five-year targets for all its member states (European Commission, 2020[53]).

In addition to skill strategies, governments also put in place policies to address various challenges discussed in this Spotlight. For example, most national AI strategies include significant education and labour market elements (OECD, 2024[54]). Policies in this regard can be grouped as follows:

- **Investing in the quality, equity and labour market relevance of education and training systems** by allocating funding programmes that focus on in-demand skills and technologies and supporting vocational training, apprenticeships and on-the-job training opportunities and providing the relevant training to teachers (e.g. Education 4.0. CARNET Strategy 2022-2025 in Croatia, "Future Skills for Future Society" in Latvia).
- **Promoting lifelong learning** by advocating for a culture of continuous learning and development among workers and employers, and encouraging individuals to take advantage of online courses, workshops and other learning resources (e.g. "Digital Competences in Education program" in Croatia, "The Strategy for Lifelong Guidance 2020-2023" in Finland, "Digital throughout Life Strategy" in Norway).
- **Facilitating of access to training resources** by providing access to affordable or free training programmes and scholarships, especially for people on low income, and support initiatives such as public libraries, community centres and online platforms that offer educational resources (e.g. "Digitize for Work Program" in Chile, Digital learning platform for basic skills "vhs-Lernportal.de" in Germany, "Digital Literacy Program" in Mexico).
- **Recognising and certifying new skills** by establishing mechanisms for recognition of non-traditional forms of learning, such as micro-credentials, badges or competency-based assessments and encouraging development of certifications recognised by the industry (e.g. "National Digital Education Policy (PNED)" in Brazil, "Pix" platform in France).
- **Attracting talents through specific visa programmes and scholarships** to foster knowledge spill-over effects (e.g. "National AI Strategy" in the United Kingdom).
- **Engaging in public-private partnerships** to identify current and future skill needs and encourage companies to participate in training programmes and offer internships or apprenticeships (e.g. "Personal Training Account of a Private Sector Employee" in France).
- **Providing tax incentives and subsidies** by providing tax returns or subsidies to companies that invest in employee training and development, and creating incentives for individuals to pursue further education or training.
- **Promoting digital inclusion and diversity** by ensuring that up- and re-skilling initiatives are accessible to all segments of the age pyramid and implementing targeted programmes to support diversity (e.g. "Fondo Repubblica Digitale" in Italy).
- **Evaluating and measuring policy impact** by regularly assessing the effectiveness of programmes in terms of employment outcomes, wage growth and industry relevance, and using data-driven insights to refine and improve such initiatives over time.

Ensuring these policy measures remain relevant in a context of rapid technological development calls for closely monitoring how AI systems evolve. Anticipating shifts in skill demand caused by technology will be key for education and training systems to respond to the changing needs of individuals and businesses. Robust measurements of AI capabilities will hence be increasingly helpful to inform responsive social policies in the years to come (OECD, 2023[22]).

References

Anderson, M. et al. (2021), "The state of gig work in 2021", *Report*, 8 December, Pew Research Center, Washington, D.C., *https://www.pewresearch.org/internet/2021/12/08/the-state-of-gig-work-in-2021*. [5]

Bakhshi, H. et al. (2017), *The Future of Skills: Employment in 2030*, Pearson and Nesta, London, *https://media.nesta.org.uk/documents/the_future_of_skills_employment_in_2030_0.pdf*. [6]

Berkowitz, M. and K. Miller (2018), "Education and AI: Preparing for the future & AI, attitudes and values", *Future of Education and Skills 2030: Conceptual Learning Framework*, 8th Informal Working Group Meeting, 28-31 October, OECD, Paris, *https://www.oecd.org/education/2030-project/about/documents/Education-and-AI-preparing-for-the-future-AI-Attitudes-and-Values.pdf*. [30]

Borgonovi, F. et al. (2023), "Emerging trends in AI skill demand across 14 OECD countries", *OECD Artificial Intelligence Papers*, No. 2, OECD Publishing, Paris, *https://doi.org/10.1787/7c691b9a-en*. [36]

Burns, T. and F. Gottschalk (eds.) (2019), *Educating 21st Century Children: Emotional Well-being in the Digital Age*, Educational Research and Innovation, OECD Publishing, Paris, *https://doi.org/10.1787/b7f33425-en*. [23]

Censorii, E. (2021), "ICT specialists: The skills gap hinders growth in the EU countries", 31 August, Digital Skills and Jobs Platform, European Union, Brussels, *https://digital-skills-jobs.europa.eu/en/latest/news/ict-specialists-skills-gap-hinders-growth-eu-countries*. [31]

European Commission (2023), "Europe's digital decade: Digital targets for 2030", webpage, *https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/europe-fit-digital-age/europes-digital-decade-digital-targets-2030_en* (accessed on 31 March 2024). [32]

European Commission (2023), "The digital decade", *Special Barometer*, No. 532, European Commission, Brussels, *https://europa.eu/eurobarometer/surveys/detail/2959*. [49]

European Commission (2020), "European skills agenda for sustainable competitiveness, social fairness and resiliance", 1 July, Press Release, European Commission, Brussels, *https://ec.europa.eu/commission/presscorner/detail/en/ip_20_1196*. [53]

European Commission (2020), "Europeans' attitudes towards cyber security", January, Eurobarometer, European Commission, Brussels, *https://europa.eu/eurobarometer/surveys/detail/2249*. [48]

Eurostat (2023), *Annual National Accounts Statistics*, *https://ec.europa.eu/eurostat/web/national-accounts* (accessed on 5 March 2024). [40]

Franke, R. (2022), "Digital transformation: Empowering employees for success", 29 August, LinkedIn, *https://www.linkedin.com/pulse/digital-transformation-empowering-employees-success-roy-franke*. [51]

Georgieff, A. and A. Milanez (2021), "What happened to jobs at high risk of automation?", *OECD Social, Employment and Migration Working Papers*, No. 255, OECD Publishing, Paris, *https://doi.org/10.1787/10bc97f4-en*. [43]

Green, A. and L. Lamby (2023), "The supply, demand and characteristics of the AI workforce across OECD countries", *OECD Social, Employment and Migration Working Papers*, No. 287, OECD Publishing, Paris, *https://doi.org/10.1787/bb17314a-en*. [37]

Kim, J. (2021), "Digital platform work in South Korea", *Issue Paper Series Labour and Society*, No. 4, Friedrich-Ebert-Stiftung, Seoul, *https://library.fes.de/pdf-files/bueros/seoul/18646.pdf*. [4]

Lane, M., M. Williams and S. Broecke (2023), "The impact of AI on the workplace: Main findings from the OECD AI surveys of employers and workers", *OECD Social, Employment and Migration Working Papers*, No. 288, OECD Publishing, Paris, *https://doi.org/10.1787/ea0a0fe1-en*. [45]

Lassébie, J. and G. Quintini (2022), "What skills and abilities can automation technologies replicate and what does it mean for workers?: New evidence", *OECD Social, Employment and Migration Working Papers*, No. 282, OECD Publishing, Paris, *https://doi.org/10.1787/646aad77-en*. [44]

Lewis, G. (18 July 2024), "The most In-demand jobs on LinkedIn right now", LinkedIn Talent blog, *https://www.linkedin.com/business/talent/blog/talent-strategy/most-in-demand-jobs*. [34]

Manca, F. (2023), "Six questions about the demand for artificial intelligence skills in labour markets", *OECD Social, Employment and Migration Working Papers*, No. 286, OECD Publishing, Paris, *https://doi.org/10.1787/ac1bebf0-en*. [47]

Nedelkoska, L. and G. Quintini (2018), "Automation, skills use and training", *OECD Social, Employment and Migration Working Papers*, No. 202, OECD Publishing, Paris, *https://doi.org/10.1787/2e2f4eea-en*. [42]

OECD (2024), *ICT Access and Usage Database*, *https://oe.cd/dx/ict-access-usage* (accessed on 31 January 2024). [50]

OECD (2024), "National AI policies & strategies", *OECD.AI Policy Observatory*, *https://oecd.ai/en/dashboards/overview* (accessed on 23 January 2024). [54]

OECD (2024), *PISA 2022 Database*, *https://www.oecd.org/pisa/data/2022database* (accessed on 11 March 2024). [16]

OECD (2024), "Relative international AI skill demand", *OECD.AI Policy Observatory*, *https://oecd.ai/en/data?selectedArea=ai-jobs-and-skills&selectedVisualization=relative-international-ai-skill-demand* (accessed on 23 January 2024). [35]

OECD (2024), "Top AI skills worldwide", *OECD.AI Policy Observatory*, *https://oecd.ai/en/data?selectedArea=ai-jobs-and-skills&selectedVisualization=top-ai-skills-worldwide* (accessed on 20 February 2024). [26]

OECD (2023), *AI and the Future of Skills, Volume 2: Methods for Evaluating AI Capabilities*, Educational Research and Innovation, OECD Publishing, Paris, *https://doi.org/10.1787/a9fe53cb-en*. [22]

OECD (2023), *Is Education Losing the Race with Technology?: AI's Progress in Maths and Reading*, Educational Research and Innovation, OECD Publishing, Paris, *https://doi.org/10.1787/73105f99-en*. [21]

OECD (2023), *OECD Employment Outlook 2023: Artificial Intelligence and the Labour Market*, OECD Publishing, Paris, *https://doi.org/10.1787/08785bba-en*. [39]

OECD (2023), *OECD Skills Outlook 2023: Skills for a Resilient Green and Digital Transition*, OECD Publishing, Paris, *https://doi.org/10.1787/27452f29-en*. [38]

OECD (2023), *OECD SME and Entrepreneurship Outlook 2023*, OECD Publishing, Paris, *https://doi.org/10.1787/342b8564-en*. [52]

OECD (2023), "Putting AI to the test: How does the performance of GPT and 15-year-old students in PISA compare?", *OECD Education Spotlights*, No. 6, OECD Publishing, Paris, *https://doi.org/10.1787/2c297e0b-en*. [12]

OECD (2022), "The broader social outcomes of education: Educating for thriving individuals and societies", in *Value for Money in School Education: Smart Investments, Quality Outcomes, Equal Opportunities*, OECD Publishing, Paris, *https://doi.org/10.1787/20abef3a-en*. [24]

OECD (2021), *21st-Century Readers: Developing Literacy Skills in a Digital World*, PISA, OECD Publishing, Paris, *https://doi.org/10.1787/a83d84cb-en*. [20]

OECD (2021), *Beyond Academic Learning: First Results from the Survey of Social and Emotional Skills*, OECD Publishing, Paris, *https://doi.org/10.1787/92a11084-en*. [27]

OECD (2021), *Incentives for SMEs to Invest in Skills: Lessons from European Good Practices*, Getting Skills Right, OECD Publishing, Paris, *https://doi.org/10.1787/1eb16dc7-en*. [41]

OECD (2021), *OECD Digital Education Outlook 2021: Pushing the Frontiers with Artificial Intelligence, Blockchain and Robots*, OECD Publishing, Paris, *https://doi.org/10.1787/589b283f-en*. [1]

OECD (2021), *OECD Skills Outlook 2021: Learning for Life*, OECD Publishing, Paris, *https://doi.org/10.1787/0ae365b4-en*. [18]

OECD (2019), "Conceptional learning framework: Skills for 2030", *Future of Education and Skills 2030*, OECD, Paris, *https://www.oecd.org/education/2030-project/teaching-and-learning/learning/skills/Skills_for_2030_concept_note.pdf*. [7]

OECD (2019), *Going Digital: Shaping Policies, Improving Lives*, OECD Publishing, Paris, *https://doi.org/10.1787/9789264312012-en*. [14]

OECD (2019), "Measuring platform mediated workers", *OECD Digital Economy Papers*, No. 282, OECD Publishing, Paris, *https://doi.org/10.1787/170a14d9-en*. [2]

OECD (2019), *OECD Employment Outlook 2019: The Future of Work*, OECD Publishing, Paris, *https://doi.org/10.1787/9ee00155-en*. [9]

OECD (2019), *OECD Skills Outlook 2019: Thriving in a Digital World*, OECD Publishing, Paris, *https://doi.org/10.1787/df80bc12-en*. [17]

OECD (2019), *OECD Skills Strategy 2019: Skills to Shape a Better Future*, OECD Publishing, Paris, *https://doi.org/10.1787/9789264313835-en*. [10]

OECD (2018), *Good Jobs for All in a Changing World of Work: The OECD Jobs Strategy*, OECD Publishing, Paris, *https://doi.org/10.1787/9789264308817-en*. [11]

OECD (2013), *OECD Skills Outlook 2013: First Results from the Survey of Adult Skills*, OECD Publishing, Paris, *https://doi.org/10.1787/9789264204256-en*. [15]

Putnam, R. (2000), *Bowling Alone: The Collapse and Revival of American Community*, Simon and Schuster, New York. [29]

Samek, L., M. Squicciarini and E. Cammeraat (2021), "The human capital behind AI: Jobs and skills demand from online job postings", *OECD Science, Technology and Industry Policy Papers*, No. 120, OECD Publishing, Paris, *https://doi.org/10.1787/2e278150-en*. [8]

Sanacore, J. (2002), "Struggling literacy learners benefit from lifetime literacy efforts", *Reading Psychology*, Vol. 23/2, pp. 67-86. [19]

Spiezia, V., E. Koksal-Oudot and P. Montagnier (2016), "New skills for the digital economy: Measuring the demand and supply of ICT skills at work", *OECD Digital Economy Papers*, No. 258, OECD Publishing, Paris, *https://doi.org/10.1787/5jlwnkm2fc9x-en*. [33]

Squicciarini, M. and H. Nachtigall (2021), "Demand for AI skills in jobs: Evidence from online job postings", *OECD Science, Technology and Industry Working Papers*, No. 2021/03, OECD Publishing, Paris, *https://doi.org/10.1787/3ed32d94-en*. [46]

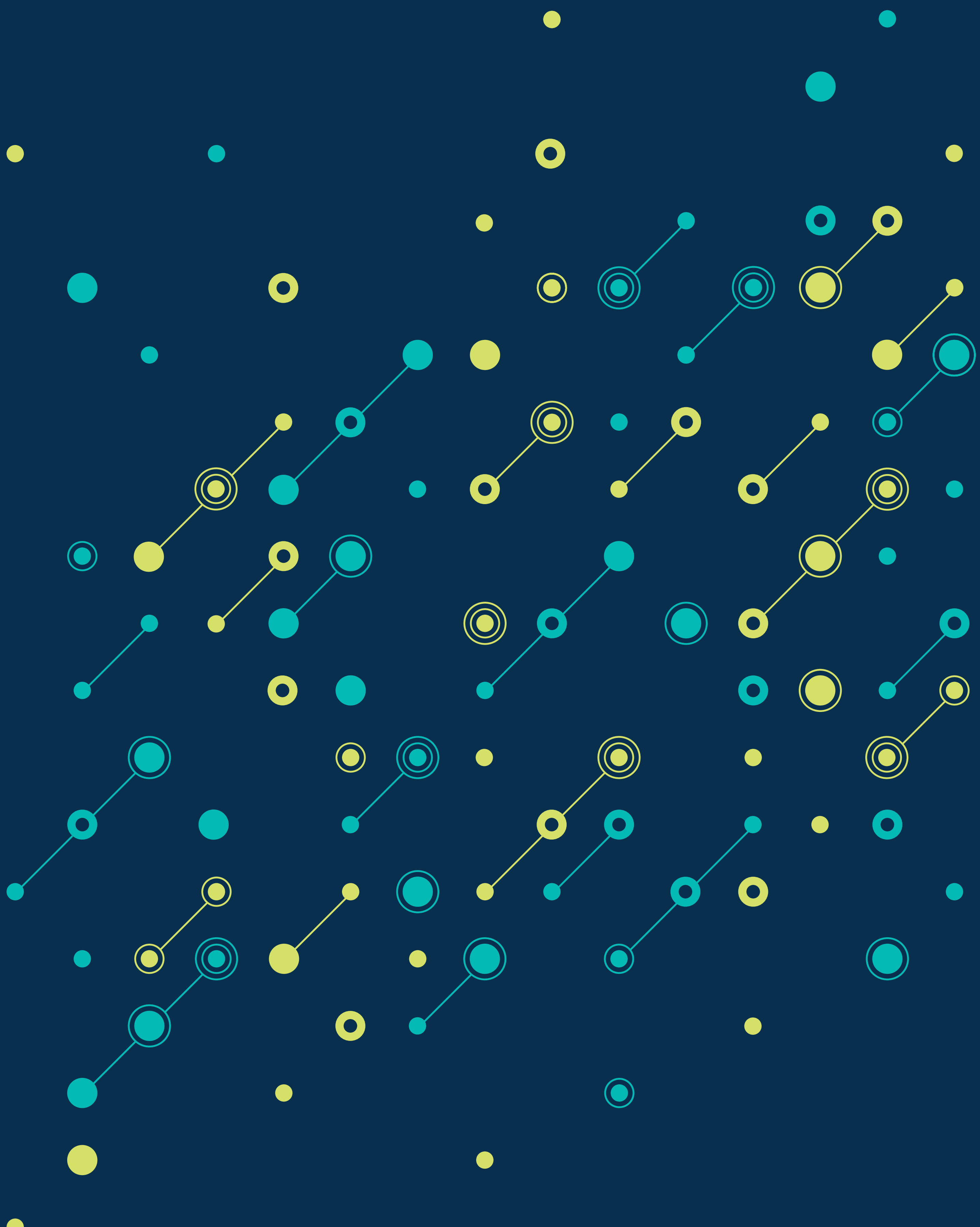
Turkle, S. (2017), *Alone Together: Why We Expect More from Technology and Less from Each Other*, Basic Books, New York, NY. [28]

Urzì Brancati, M., A. Pesole and E. Fernández-Macías (2020), "New evidence on platform workers in Europe: Results from the second COLLEEM survey", *Science for Policy*, Joint Research Centre, Publications Office of the European Union, Luxembourg, *https://publications.jrc.ec.europa.eu/repository/bitstream/JRC118570/jrc118570_jrc118570_final.pdf*. [3]

Verhagen, A. (2021), "Opportunities and drawbacks of using artificial intelligence for training", *OECD Social, Employment and Migration Working Papers*, No. 266, OECD Publishing, Paris, *https://doi.org/10.1787/22729bd6-en*. [25]

Notes

1. Top performers (also called "academic all-rounders") are defined as students who have the highest level of proficiency in PISA as they achieved Level 5 or 6 in science, reading and mathematics concomitantly.
2. Due to data availability, business sector is defined as the aggregation of the following NACE Rev.2 activity classes:
   - [B-E]: Industry (except construction)
   - F: Construction
   - [G-I]: Wholesale and retail trade, transport, accommodation, and food service activities
   - J: Information and communication
   - K: Financial and insurance activities
   - L: Real estate activities
   - [M-N]: Professional, scientific and technical activities; administrative and support service activities
   - [R-U]: Arts, entertainment and recreation; other service activities; activities of household and extra-territorial organizations and bodies.
3. For Canada and Japan, data refer to 2012 and 2022. For Chile, data refer to 2012 and 2017. For Colombia and Iceland, data refer to 2013 and 2021. For Costa Rica, data refer to 2018. For Israel, data refer to 2020 and 2021. For Egypt, data refer to 2022. For Colombia and Korea, data refer to 2013 and 2022. For Mexico, data refer to 2013 and 2022, and include "conducting job training", "taking courses to supplement education", "taking tutorials on any topics of interest", and "other types of training". For Poland, data refer to 2011 and 2023. For Switzerland, data refer to 2017 and 2023. For the United Kingdom, data refer to 2013 and 2020. For the United States, data refer to 2015 and 2021.
4. A skill ecosystem can be defined as a community (businesses, industry/sector, education and training providers, non-governmental organisations, local or regional stakeholders, etc.) in which individuals and organisations connect and interact to address skill needs and develop, use and transmit, in an autonomous way, knowledge, abilities and competences.



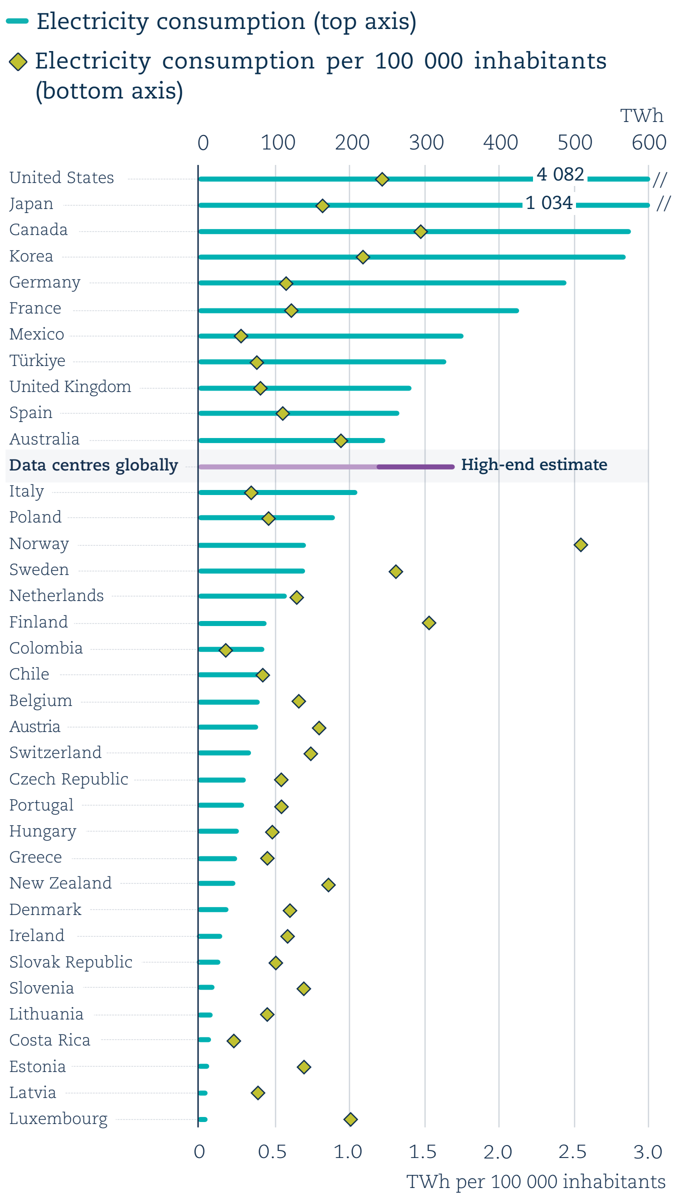
Chapter 3

Digital technologies and the environment

The green and digital "twin transitions" offer the promise of leveraging digital technologies to reach environmental sustainability goals. Digital technologies and their underlying connectivity can significantly accelerate green transformation across economic sectors, but their environmental footprint must also be considered. This chapter focuses on key sectors where policy makers and technology providers can harness digital technologies to help meet environmental sustainability goals and describes ways to mitigate the negative environmental impact from digital technologies. It concludes by outlining policy priorities and the challenges of aligning the green and digital twin transitions to accelerate action for the good of the planet.

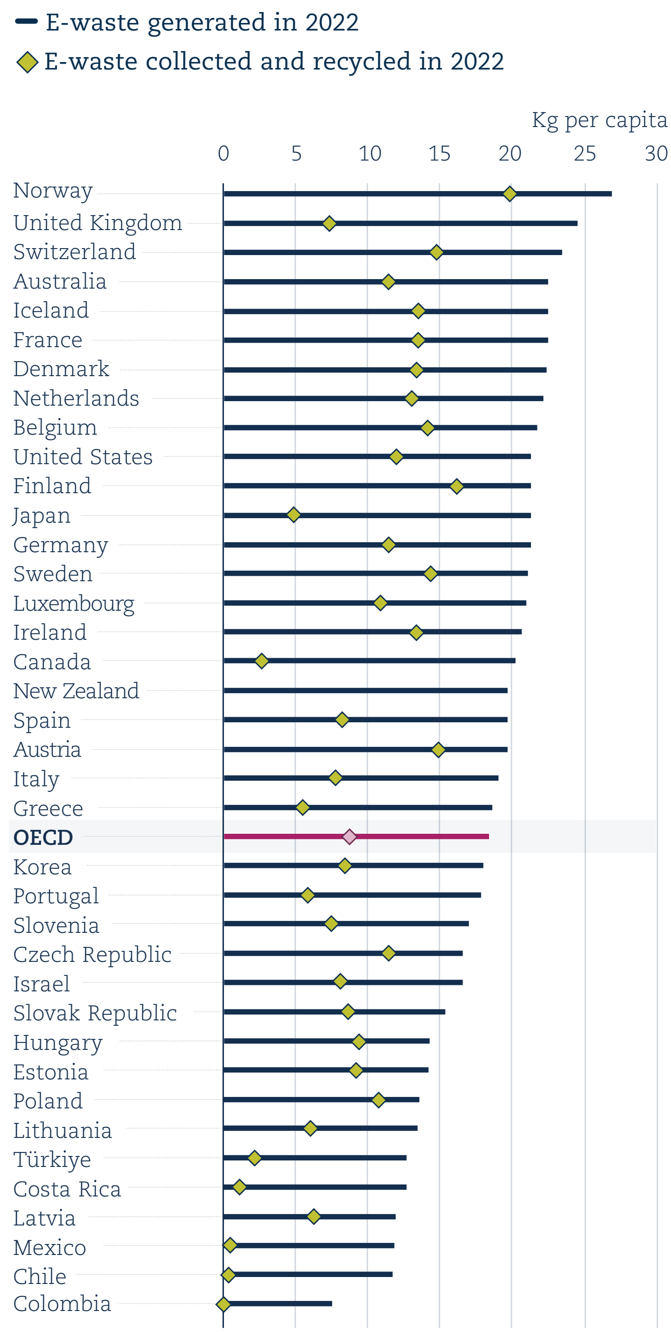
A life cycle approach is needed for a green, digital future

In 2022, data centres globally consumed more electricity than the total electricity consumption in some OECD countries.



Source: OECD elaboration based on data from the IEA, Enerdata and Ember.

Managing e-waste remains a significant challenge in OECD countries.



Digital technologies like **AI** and **IoT** can **accelerate the green transition** in sectors such as energy and transport.

Key findings

The world is facing a climate emergency: Will digital technologies help or hinder the green transition?

- As the time window for successful climate action narrows, it is increasingly clear that the digital and green "twin transitions" must be harnessed to rapidly decarbonise economies and to achieve the Sustainable Development Goals (SDGs).
- However, digital technologies themselves have an environmental footprint along their life cycle, with information and communication technologies (ICTs) making up between 1.5% and 4% of global greenhouse gas (GHG) emissions in 2020 (Bieser et al., 2023[1]).
- About 90% of electricity used by data centres is estimated to be lost as waste heat, representing a largely untapped opportunity to apply circular economy models through applications like district heating (Luo et al., 2019[2]).

Digital technologies offer a viable pathway to decarbonisation across sectors

- Digital technologies are major building blocks to help achieve the deep cuts in emissions needed for a net-zero emissions world. Technologies like the Internet of Things (IoT) and digital twins enabled by artificial intelligence (AI) can improve energy efficiency, reduce costs, and accelerate innovation across energy grids and product supply chains.
- Communication infrastructures and services are fundamental to a sustainable and resilient digital transformation. For example, they are needed to deploy technologies like smart electrical grids to IoT-based precision agriculture, which support decarbonisation of many sectors of the economy. At the same time, they have their own environmental footprint to be minimised.
- Sectors including global transportation systems stand to benefit from digital technologies that support reducing environmental impacts through fuel efficiency gains, predictive maintenance and shared mobility, as well as by enabling low-carbon transport systems and multimodal mobility services.

Towards policies for a green and resilient digital future

- Digitalisation and environmental sustainability are increasingly being considered together on the agendas of policy makers, including in national strategies and recovery plans, as well as in dedicated strategies for digital technologies and the environment.
- The road to a green digital world includes difficult policy questions. For example, as digital technologies increase the demand for computing power and data centres, questions arise around whether local energy grids are ready to support increased green digital transformation.

Countries are amid two fundamental transformations in the 21st century: the transition towards an environmentally sustainable and carbon-neutral economy, and the proliferation of digital technologies in almost all areas of public and private life. Ongoing digital transformation of economies and societies holds many promises to spur innovation; improve productivity and services; connect billions of people worldwide, including in emerging economies; and to generate efficiencies (OECD, 2019[3]), such as resources and productivity. Increasingly, these "green" and "digital" transitions are inter-linked by policy makers and stakeholders. They recognise the importance of ensuring the "twin transitions" are aligned and leveraged for a sustainable future. Adopted over a decade ago, the OECD Recommendation on Information and Communication Technologies and the Environment pioneered work in examining the relationship between digital technologies and the green transition (OECD, 2010[4]). The Recommendation is undergoing a review of relevance to reflect rapid technological changes and the exacerbating climate crisis.[1]

Avoiding the most severe impacts of climate change and environmental degradation in the next decades is a global challenge that requires urgent action. At the heart of the twin transitions are digital technologies, such as AI and IoT, along with the underlying connectivity enabling them. Digital technologies can significantly accelerate the sustainable transformation of global energy grids, transportation networks and communication infrastructure. At the same time, digital devices and infrastructure have their own environmental footprint – from the extraction of raw materials to greenhouse gas (GHG) emissions derived from energy consumption.

This chapter examines how countries are aligning the green and digital twin transitions.[2] It explores how embracing digital technologies in key sectors supports environmental sustainability goals, and how to mitigate the environmental footprint of digital technologies. It concludes with policy considerations on the road towards achieving a digital and environmentally sustainable future.

Achieving climate and economic resilience in a digital world by aligning the green and digital "twin transitions"

As the window for successful climate action narrows, digital technologies offer solutions to reach net-zero targets

Digital transformation offers a multitude of social and economic opportunities for people as citizens, consumers and workers (OECD, 2022[5]). Digital technologies play an increasingly important role in modern human societies – from smartphones and wearable technology to fully automated manufacturing sites and logistical networks. Globalisation and digital transformation have been key forces of productivity gains and innovation in the past decades, spurred in large part by the advent of the Internet and decreasing hardware costs. With smart devices widely embedded across economies, digital technologies define today's markets, and will likely continue to be foundational to the markets of tomorrow.

However, amid an increasingly digital world, countries globally are also feeling the impacts of the mounting climate crisis. The year 2023 was the warmest year ever recorded, with Antarctic Sea ice coverage hitting a record low (NOAA, 2024[6]). OECD work found that during the 2017-21 period, population exposure to heat stress has been high in many countries across the world. Latin America, the Mediterranean Basin, Australia and the United States have been particularly affected. Costa Rica and Israel, for example, experienced more than 140 days of heat stress per year during the same period (Maes et al., 2022[7]).[3] The World Meteorological Organisation (WMO) (2023[8]) estimates that between 2023 and 2027 there is a "66% likelihood that the annual average near-surface global temperature will be more than 1.5°C above pre-industrial levels for at least one year".

These trends sound the alarm for a world that will likely exceed the 1.5°C temperature target of the Paris Agreement. A growing number of extreme weather events, together with ever more grave scientific reports from the expert community, conclude that the world is in a state of climate emergency. This calls for mobilisation of all stakeholders towards swift and concrete actions to ensure the planet's environmental sustainability.

As the time window for successful climate action narrows, it is increasingly clear to policy makers that the transformative forces of digital transformation must be leveraged for the rapid decarbonisation of the global economy and to achieve the Sustainable Development Goals. OECD countries have called for leveraging digital technologies in the fight against climate change and aligning digital and green policies (OECD, 2022[9]). The Coalition for Digital Environmental Sustainability (CODES), led by the United Nations Environment Programme, envisions a sustainable planet in the digital age. This would foster a "global movement for digital environmental sustainability" to align, mitigate and accelerate the twin transitions (CODES, 2022[10]). At the European level, the European Union (EU) Green Deal follows an integrative approach for the green and digital twin transitions to reinforce each other and accelerate the achievement of ambitious climate goals by 2050 (Muench et al., 2022[11]).

Increased ICT diffusion creates both positive and negative environmental effects

ICTs form the backbone of digital transformation, providing connectivity, storage, memory, data processing and more. They enable applications like Industry 4.0 and a variety of smart consumer products – from automated vehicles to smart meters (OECD, 2018[12]). ICTs have become pervasive over the past decade, underscoring the importance of aligning the digital and green twin transitions. Between 2011 and 2021, the ICT sector[4] grew three times faster than the economy as a whole in OECD countries (OECD, 2024[13]).

Between 2010 and 2023, Internet users globally increased by 160% from 2 billion to 5.3 billion (ITU, 2023[14]). In the OECD area, fixed broadband penetration increased from 24 to 35.8 subscriptions per 100 inhabitants between 2010 and 2023. Meanwhile, mobile broadband penetration tripled during the same period (from 43.3 to 134 per 100 inhabitants) (OECD, 2024[15]). Internet adoption and the increase in broadband availability (measured by subscriptions) are some of the indicators that can be used as proxy measures for mass digitalisation.

While such trends point to increased ICT diffusion throughout economies, they also raise questions. Have environmental impacts of digital adoption also increased? Will positive enabling and systemic effects resulting from digitalisation offset any increases? (OECD, forthcoming[16]). Some examples of the enabling effects of ICTs include the use of IoT and AI to reduce household energy consumption; smart (precision) agriculture to improve crop yields and increase resource efficiency; smart energy grids; and the reduction in congestion through remote working, connected vehicles and smart cities.

Today, more than ever, advances in digital technologies enable development of tools that can assist countries in their journeys towards environmental sustainability (OECD, 2022[5]). From more efficient hardware to smart products that help consumers make greener choices, digital technologies offer one answer to how quickly global economies can achieve net-zero targets. A holistic policy approach to leverage the benefits of the twin transitions requires accurate measurements to understand both the positive and negative environmental impacts of digital technologies.

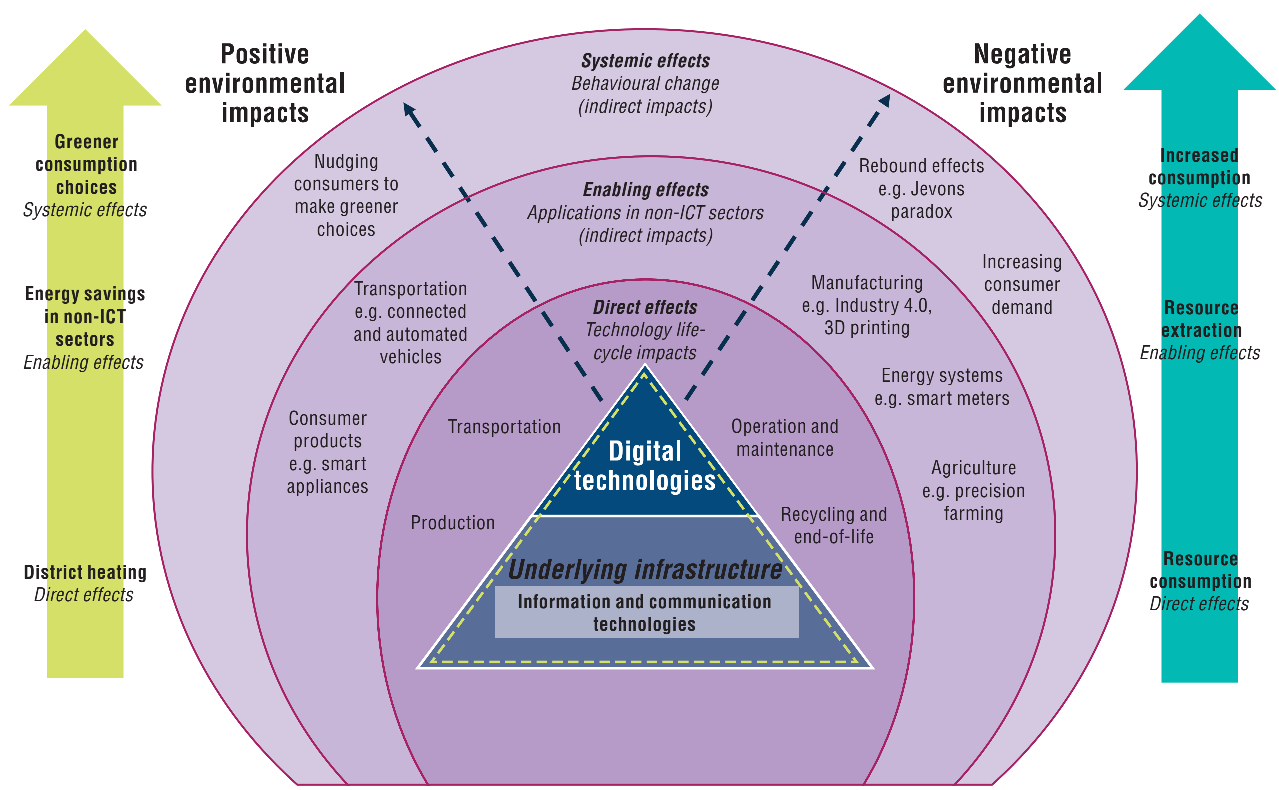
On the one hand, digital technologies can aid countries to achieve climate goals by creating significant efficiency gains through enabling effects across economic sectors. For example, they can help manage energy systems and achieve emissions cuts needed to meet climate targets. Technologies like AI and IoT can provide the necessary speed and scale to reduce emissions and accelerate innovations in key areas. These include planetary digital twins,[5] circular economic models and sustainable consumption habits (CODES, 2022[10]).

On the other hand, digital technologies and their supply chains also have negative environmental impacts along their life cycle, such as raw material extraction, energy and water use (IEA, 2023[17]). Although the ICT sector produces lower GHG emissions than other sectors, their environmental footprint must be thoughtfully managed. Gauging future opportunities and risks around the twin transitions first requires an in-depth understanding of several technologies today, such as IoT, AI and their underlying connectivity infrastructure, which carry great potential to accelerate the green transition.

Broadband connectivity, the Internet of Things and artificial intelligence can provide the speed and scale to rapidly green economies

Digital technologies, or ICTs,[6] can be referred to as "both different types of communication networks and the technologies used in them" (OECD, 2007[18]).[7] The digital technology ecosystem itself combines cloud computing, big data analytics, AI, blockchain and computing power, among others (OECD, 2019[3]). According to the OECD Recommendation on Information and Communication Technologies and the Environment (OECD, 2010[4]), ICTs can have: i) *direct effects* on the environment (e.g. through their life cycle of production, transportation, operation, and end-of-life); ii) *enabling effects* in other sectors (e.g. Industry 4.0, smart energy grids, smart agriculture, electric vehicles, etc.); and iii) *systemic effects* such as behavioural change (e.g. nudging consumers to make greener choices, rebound effects) (Figure 3.1).

Figure 3.1. Direct, enabling and systemic effects of digital technologies on the environment



Notes: Examples given are for illustrative purposes and are not exhaustive.

Source: OECD based on Hilty and Aebischer (2014)[19]; OECD (2022)[20]; OECD (2017)[21]; European Commission (2023)[22]; IEA (2023)[23].

Several key digital technologies are expected to be crucial for a green future. Technologies like IoT, AI and their underlying connectivity, are expected to advance in their capabilities and sectoral applications. They will likely have direct, enabling and systemic effects on environmental sustainability.

- **Broadband connectivity.** Communication networks are a key enabler of digital transformation. High-quality, resilient and affordable broadband connectivity is a prerequisite for several other digital technologies such as AI and the IoT. The communication sector is characterised by fast-paced developments such as new network infrastructure and architecture, the convergence of fixed and mobile networks, and a continuous integration of connectivity into other economic sectors. Communication networks can be a key enabler of environmental sustainability in many fields, while the environmental impact of the infrastructure itself will need to be minimised (OECD, 2022[20]).
- **Internet of Things.** The OECD defines IoT as "all devices and objects whose state can be altered via the Internet, with or without the active involvement of individuals" (OECD, 2018[12]). Connected objects may require the involvement of devices considered part of the "traditional Internet". However, this definition excludes laptops, tablets and smartphones already accounted for in OECD broadband metrics. IoT falls into two categories. In Wide Area IoT, devices are connected through cellular technology and through Low Power Wide Area Networks. In Short Area IoT, devices use unlicensed spectrum with a typical range up to 100 metres. IoT has several environmental applications such as sensors for agricultural sustainability, smart energy grids and smart home applications (OECD, 2018[12]).
- **Artificial Intelligence.** AI[8] underpins some of the most promising technological solutions to today's global challenges, including addressing climate change. AI applications are enabling efficiency gains across sectors and for both computer hardware and software. However, there are concerns around the energy intensity required to train and use some AI systems, especially the most advanced (OECD, 2022[20]). Today's advanced AI systems have scaled significantly in size, number of parameters and breadth of training datasets used (OECD, 2024[13]), making them energy intensive to train. Research also notes that compute demands for AI systems, such as processing power, has grown faster than hardware performance. This is especially the case for deep-learning applications such as machine translation, object detection and image classification (Thompson et al., 2020[24]). The rise of generative AI systems at the end of 2022 has also emphasised AI inference (e.g. using AI systems once they have been trained), raising questions around their environmental impact as AI diffusion grows.

What is the environmental footprint of digital technologies?

Measuring the direct effects of digital technologies involves assessing environmental impacts along their life cycle. These impacts are typically measured using a multicriteria life-cycle assessment, often in compliance with internationally recognised standards, such as the International Organization for Standardization (ISO) 14040:2006 and ISO 14044:2006 (Benqassem et al., 2021[25]). Life-cycle assessments usually differentiate between several distinct stages, such as production, transport, operations and end-of-life. This approach is advocated by the OECD Recommendation on Information and Communication Technologies and the Environment (OECD, 2010[4]; OECD, forthcoming[16]).

Although life-cycle categories can vary, the general methodology is widely used by researchers (Hertin and Berkhout, 2001[26]). Examples include "Methodologies for the assessment of the environmental impact of the information and communication technology sector" of 2018 (ITU-T, 2018[27]) and the OECD Recommendation on Information and Communication Technologies and the Environment (OECD, 2010[4]). Environmental impacts can be quantified using impact categories articulated in ISO environmental management life-cycle assessment standards. These include global warming (e.g. GHG concentration causing polar warming and ice melt), toxicity (e.g. causing smog and acid rain) and biodiversity loss (ISO, 2006[28]; ISO, 2006[29]; Mickoleit, 2010[30]).

In a handful of cases, operating digital technologies can produce positive environmental impacts (e.g. re-using excess heat produced by data centres). However, in most cases, their direct impacts have negative environmental impacts along their life cycle (e.g. natural resources consumed while operating digital technologies).

Positive enabling and systemic effects of digital technologies (e.g. indirect impacts such as energy-saving sectoral applications or nudging consumers to make greener choices) can sometimes outweigh the negative direct impacts on the environment from manufacturing, transporting, operating and disposing of ICTs along their life cycle. This makes the measurement of "net" environmental impacts complex. Nevertheless, several measurement frameworks aim to establish common indicators and facilitate a comprehensive environmental impact assessment: the Greenhouse Gas Protocol (2004[31]); first, second and third order effects (Hertin and Berkhout, 2001[26]; EITO, 2002[32]); ISO Environmental management – Life-cycle assessment (ISO, 2006[28]; 2006[29]); ITU-T Rec. L.1450 (09/2018) (ITU-T, 2018[27]), among others.

The operation and production of digital technologies have an environmental footprint

While research typically focuses on measuring GHG emissions from digital technologies, environmental impacts from their production could become a significant sustainability challenge, raising both environmental and human rights concerns. Such upstream supply chain measures are typically called "embodied emissions" or "Scope 3" emissions. They remain mostly voluntary in industry reporting frameworks like the Greenhouse Gas Protocol (WBCSD and WRI, 2004[31]) and the Science Based Targets Initiative, which publishes detailed Scope 3 guidance for the ICT sector (Science Based Targets, 2020[33]). Upstream supply chain impacts for digital technologies include the mining of critical minerals that can be environmentally damaging to extract and that carry supply chain and human rights risks.

Global population growth and rising wealth is projected to nearly double consumption of raw materials by 2060 (Livingstone et al., 2022[34]). Growing demand for digital technologies will play a role in driving this increase. Hardware, such as semiconductors, terminal devices and electric vehicle batteries, require mining of critical minerals at larger quantities than ever before. This may point to future resource constraints as demand grows, yet quantities of natural resources remain largely fixed (OECD, 2019[35]).

The production of ICT products requires a variety of materials, such as iron, steel, plastics, glass and various metals. For most of these materials, ICT products account for less than 1% of global annual usage (Malmodin, Bergmark and Matinfar, 2018[36]; Gupta et al., 2020[37]). However, the sector is a primary user of some critical minerals, for which the demand is expected to sharply increase in the future, as batteries become even more central to economic activities.

Demand is growing for key minerals to feed ICT products, raising concerns about their depletion

Demand for ICT products is contributing to a depletion of key minerals, raising concerns about their sustainability. The manufacturing of electrical and electronic equipment relies on the supply of inputs such as cobalt, gallium, indium, palladium and rare earth elements (REE), as well as tantalum, tin, gold and silver (Chancerel et al., 2015[38]). Compared to global use across sectors, the ICT sector was estimated to use over 80% of the world's indium, gallium and germanium in 2018. This contributed significantly to the material resource depletion potential of these critical minerals, raising questions around sustainability as demand for ICT products further increases (Malmodin, Bergmark and Matinfar, 2018[36]).

The focus of critical minerals has often been on high-volume categories like battery metals and copper. However, smaller critical minerals like gallium and germanium are characterised by high supply concentration. Consequently, these niche minerals could significantly disrupt supply chains for digital technologies despite their small volumes (IEA, 2023[39]).

Forecasting demand for niche minerals remains challenging due in part to lack of transparency in supply chains. The deployment of clean energy technologies such as photovoltaics – a key technology in solar panels – and batteries is "propelling unprecedented growth in the critical mineral market" (IEA, 2023[39]). In all scenarios, the IEA forecasts demand for critical minerals doubling or more than tripling by 2030 alone (IEA, 2023[39]).

However, projecting the impact of growing demand for digital technologies on the availability of key elements such as REEs, gallium or magnesium remains challenging. Many minerals are required in an extremely pure form for ICT uses, with producers of such pure elements often geographically concentrated. For example, the People's Republic of China produces 90% of global gallium and germanium output, as well as 70% of most REEs. The small volumes of production and opaque supply chains make it difficult to find production data to better forecast and plan supply and demand needs (UNCTAD, 2020[40]).

Market pressure and competition for critical minerals are expected to intensify as these minerals are essential inputs for green and digital strategies. As a result, jurisdictions like the European Union aim to diversify supply chains. They seek to increase secondary supply through circular economic models and substitute scarce materials where possible (European Commission, 2023[41]).

More investment in recycling, recovery and innovative technologies may help offset The impact of increased demand for rare earth elements

The market outlook for critical minerals points towards significant benefits of policies and programmes to encourage recycling and recovery of REEs and other key minerals used in digital technologies, as well as resource efficiency and circularity (European Commission, 2023[41]). This is especially important as most electronic waste is not collected and only about 1% of REEs are recycled. The recycling of elements such as neodymium – magnets used in hard disc drives, mobile phones, and video and audio systems – often takes less than half of the energy needed compared to their extraction (Geng, Sarkis and Bleischwitz, 2023[42]). Research points to high savings potential related to the recovery of

REEs from e-waste products through a circular economy approach. However, data protection and safety regulations can sometimes limit such practices. This can require the destruction and disposal of hardware in ways that do not allow recycling (Willenbacher and Wohlgemuth, 2022[43]).

Innovation has reduced the need for infrastructure to produce digital technologies, but demand for ICTs continues to exert pressure on critical minerals. Digital technologies have experienced a profound "dematerialisation" in recent years. Thanks to hardware and software innovation, these technologies require less physical infrastructure for more efficiency (Wäger, Hischier and Widmer, 2015[44]). However, demand growth for ICTs continues to place pressure on securing a steady supply of hardware inputs, including critical minerals.

When digital technologies are used, their operation produce GHG emissions through energy consumption, depending on the local energy mix of renewable energy and fossil fuels, and often requires large amounts of water, for example, for cooling data centres and other ICT equipment (Li et al., 2023[45]).

While ICT use has grown across sectors, its proportion of global emissions has remained flat largely due to hardware efficiency gains and the dynamics of energy markets (IEA, 2021[46]; 2023[17]). Estimates vary due to different scopes and definitions of the ICT sector. However, the global ICT industry (including terminal device hardware such as televisions) was estimated to make up 1.5% to 4% of global GHG emissions in 2020[9] (Bieser et al., 2023[1]). While this may point to hardware efficiency gains, dynamics in energy markets may also help explain this trend. Some research indicates that around 70% of all ICT GHG emissions can be attributed to electricity, as opposed to embodied emissions from hardware production early in the life cycle (Freitag et al., 2021[47]).

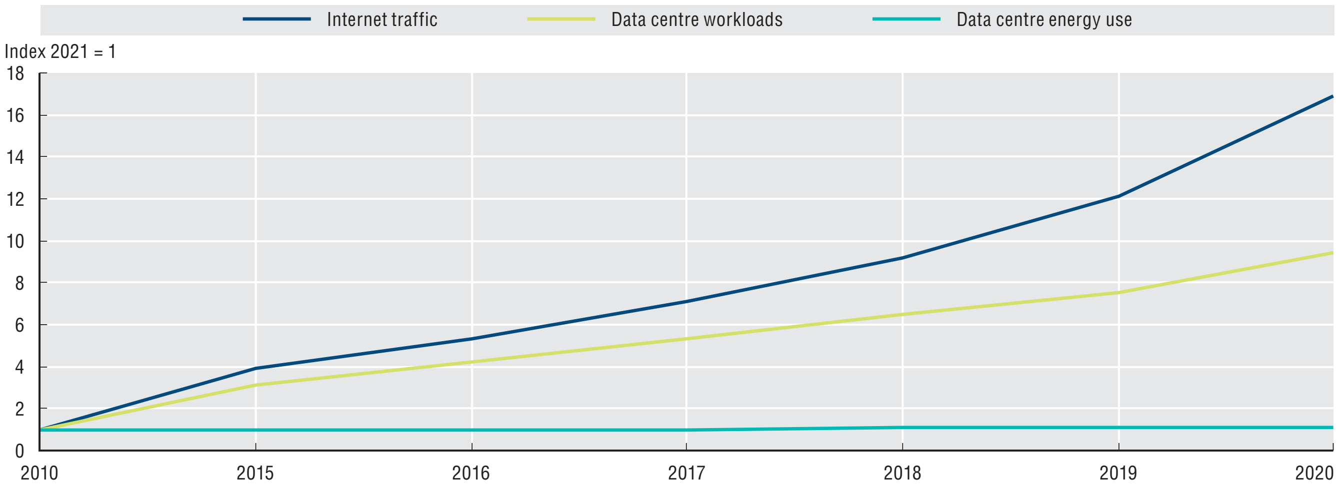
Such findings suggest that investment in renewable energy production and increasing uptake by the ICT sector could facilitate its rapid decarbonisation of the energy sector. This, in turn, would shift the focus on environmental sustainability concerns further up the ICT supply chain (e.g. to Scope 3 emissions) (Bieser et al., 2023[1]).

Data centres have more workload, but their energy use has remained stable

Despite major increases in the workloads of data centres, their use of energy has remained remarkably consistent. Data centres are a key underlying technology enabling digitalisation. According to the IEA, data centres used about 194 Terawatt hours (TWh) in 2014 or 1% of global energy demand (Figure 3.2). By 2020, they still accounted for this same percentage of global energy demand (IEA, 2021[46]).

Figure 3.2. Global data centre energy use has remained flat from 2010 to 2020

Global trends in Internet traffic, data centre workloads and data centre energy use



Notes: Updated November 2021. IEA provides a range for data centre electricity consumption: 240-340 TWh for 2022.

Source: IEA (2021[46]), "Global trends in Internet traffic, data centre workloads and data centre energy use, 2010-2020" based on data from Cisco Global Cloud Index and TeleGeography.

StatLink https://stat.link/q4ayvu

This consistency is striking for two reasons. First, the workload in data centres and Internet traffic have significantly increased. Second, data centres consume significant amounts of electricity, higher even than the electricity consumed by some OECD countries (Figure 3.3). Data centre efficiency improvements and the shift to large hyperscale data centres could help explain why data centre energy use has remained constant.

It is difficult to predict the growth in electricity demand for data centres on a global level. The IEA estimates that data centres consumed between 240-340 TWh globally in 2022, a notable increase from prior years. It also expects global electricity demand for data centres to increase significantly in the next decade – in some scenarios, up to twice current demand. However, such projections remain highly uncertain. They depend on the "pace of deployment, range of efficiency improvements" and other technological trends (IEA, 2024[48]).

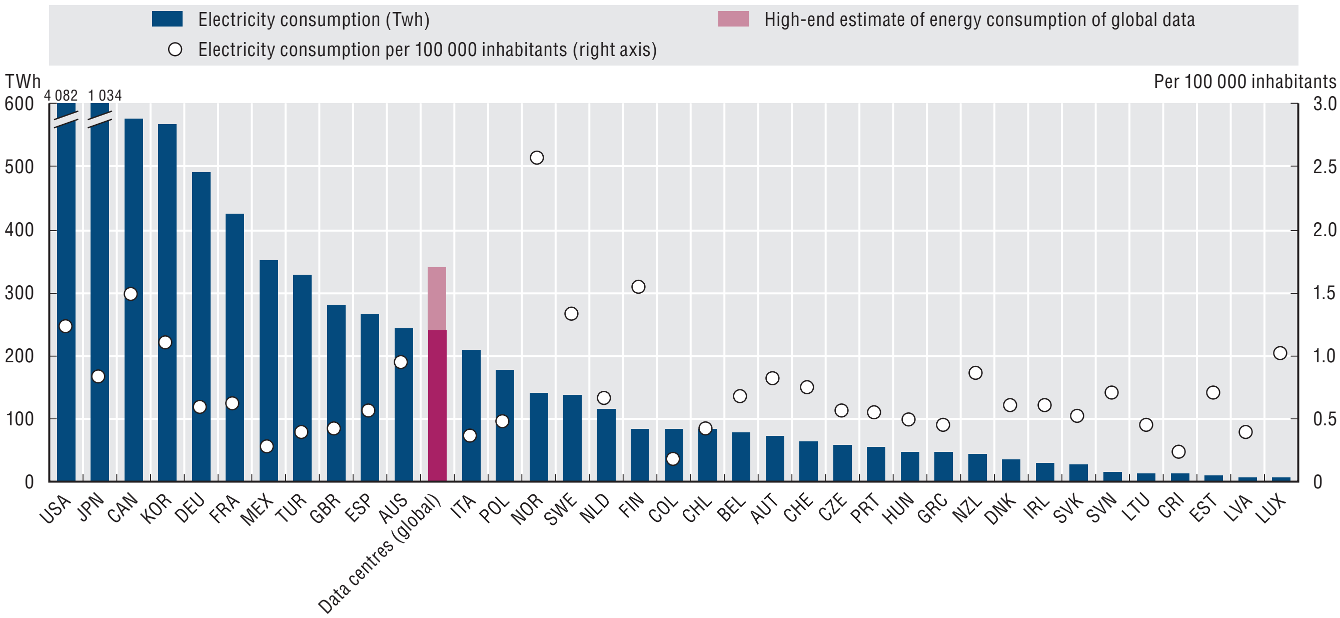
At the national level, some governments track energy consumption and projected demand for data centres within their borders. In Denmark, annual data centre energy demand is expected to grow from near-zero in 2020 to 5 TWh by 2025 and 7.5 TWh by 2030 (Danish Energy Agency, 2020[49]). In Ireland, a European hub for data centre operators, data centre energy consumption increased by 144% between 2015 and 2020, accounting for 11% of metered electricity consumed in the country in 2021 (Central Statistics Office, 2023[50]). Median-demand scenarios estimate that this figure could rise as much as 23% by 2030 (EirGrid, 2021[51]).

As data centre workloads and Internet traffic grow, energy grids and water supplies may have limited capacity to meet the growing demand for operating digital technologies. Some countries, including the United Kingdom and Denmark, are considering or imposing moratoria on new data centre construction due to strained national power supplies and rising energy costs (Swindhoe, 2022[52]; Fitri, 2023[53]). Climate change, causing more frequent heatwaves and droughts, can also add stress to power grids and data centres themselves, leading to power outages and concerns around water management (Google Cloud, 2022[54]).

Technologies like AI could further increase the demand for ICT infrastructure, as certain models become larger and more energy intensive to train. Beginning in about 2010, the prominence of an AI method called deep learning dramatically increased the size of machine-learning systems and their compute demands. Recent advances in generative AI systems, such as chatbots, are further raising questions about the energy intensity of AI training and the sustainability of underlying ICT infrastructure.

Figure 3.3. In 2022, data centres globally consumed more electricity than total electricity consumption in some OECD countries

Electricity consumption in TWh in OECD countries compared to global data centre consumption (left axis) and data centre electricity consumption in TWh per 100 000 inhabitants in OECD countries (right axis), 2022



Notes: IEA provides a range for estimated global data centre electricity consumption: 240-340 TWh for 2022 (light pink stacked bar). This excludes energy used for cryptocurrency mining. No electricity consumption data were found for Iceland and Israel.

Source: Authors' elaboration based on (IEA, 2023[17]; Enerdata, 2023[55]; Ember, 2023[56]; OECD, 2023[57]).

StatLink https://stat.link/b4m7el

The IEA expects AI to significantly increase the electricity demand of dedicated AI data centres, which could consume "at least ten times its demand in 2023" by 2026 (IEA, 2024[48]). Satisfying the demand for larger models was partially enabled by transitioning from general-purpose processors, such as Central Processing Units. More specialised processors support more efficient compute execution for certain operations (i.e. requiring less energy, less water for cooling and more computations per unit time).

Today, machine-learning systems are predominantly trained on specialised processors optimised for certain types of operations, such as Graphics Processing Units. In recent years, both governments and private sector companies have shown increasing interest in securing the supply of future generations of chips. These would be designed specifically for AI and promise more energy efficiency (OECD, 2023[58]).

Transporting ICT infrastructure relies on a global network of distribution, freight transportation, handling and storage, with associated environmental impacts

The manufacturing and assembly of ICT infrastructure has a significant environmental impact. The process of enabling digital technologies is embedded into highly globalised and complex supply chains. This global network of distribution comprises freight transportation from manufacturing sites to points of assembly and use, and includes handling and storage.

Such a process generates environmental impacts such as air pollution, oil spills, toxic-waste discharges and acoustic pollution, among others (Crawford, 2021[59]; OECD, 2022[20]). In 2022, energy-related GHG emissions resulting from the transport sector accounted for around a quarter of global emissions (IEA, 2023[60]).

While manufacturing and operations are responsible for most life-cycle emissions, it is unclear whether transport-related emissions will increase or decrease in the future. The life-cycle analysis of various types of hardware, such as computers and data centre infrastructure, often attributes a small percentage of GHG emissions from transport. In many cases, it is measured at below 5% of overall life-cycle emissions.

The manufacturing and operations stages often make up the bulk of life-cycle emissions (Gupta et al., 2020[37]; Kaack et al., 2022[61]). On the one hand, as more business and consumer activities take place on line and teleworking trends persist, the share of environmental impacts from the transportation of digital technologies may decrease. On the other, increased digitalisation could also drive-up market demand for the latest digital products and upgrades. This could, in turn, increase transportation requirements for digital technologies.

Water consumption is an often overlooked environmental impact of digital technologies

The impact of water use to support digital technologies is not well understood due to lack of data. During their operation, digital technologies consume water primarily for cooling systems in data centres. Producing digital technology hardware, such as semiconductor fabrication, can also use large amounts of water. Compared to energy use and GHG emissions, the water resource impacts of digital technologies are poorly understood (OECD, 2022[20]). For example, some researchers estimated that only 33-50% of data centre operators compiled and reported water-use metrics in 2021 (Mytton, 2021[62]; Uptime Institute, 2021[63]).

Taking stock of the water consumed by operating digital technologies is critical for resource management and future sustainability. Climate change and the associated growing incidence of extreme droughts stress global water ecosystems. Indeed, more than 2 billion people worldwide already experience water shortages (United Nations, 2022[64]). While availability of renewable freshwater resources varies considerably, water scarcity is a growing problem in many parts of the world. This results in groundwater depletion and more stress on water availability and quality (United Nations, 2022[64]).

With respect to the ICT sector, water usage is significantly harder to estimate than energy consumption and GHG emissions due to lack of reporting, standards and awareness in the industry. One of the few available evaluations puts the water consumption of United States data centres at less than 1% of total water consumption (Mytton, 2021[62]). However, digital infrastructure such as data centres often compete locally with large water users such as hospitals and the agricultural production. For example, the US data centre industry is a top ten water-consuming industry and often clusters in geographic areas that rely on scarce water supplies (Siddik, Shehabi and Marston, 2021[65]).

Severe weather events like droughts are also creating risks to the stability of upstream digital technology infrastructure production. For example, droughts in Chinese Taipei reportedly affected semiconductor production. This was due to the short supply of highly pure water needed to clean factories and chip components during manufacturing (The New York Times, 2021[66]).

Some research indicates that advanced digital technology applications like generative AI have considerable water footprints. One estimate for training OpenAI's GPT-3 AI model puts its water usage at between 700 000 and 2.1 million litres of freshwater. This is the equivalent of almost one full Olympic-sized swimming pool depending on the data centre location (Li et al., 2023[45]). According to one estimate, water cooling in data centres uses between 0.2 and 0.8 litres of water per kilowatt-hour used. This amounted to about 120 000 Olympic swimming pools per year for the global data centre industry (Andrews et al., 2021[67]).

Semiconductor and end-user device manufacturing also requires large amounts of water. By some estimates, a typical large chip fab uses up to 37 million litres of water a day (Johnson, 2022[68]). As digital technologies diffuse across sectors and uses, and demands for underlying infrastructure grows, careful water resource management will be needed to minimise the sector's use of potable water and ease local water stress.

Measurement challenges due to complexity of environmental impacts and rapid technological change

The expected growth in demand for digital services and products requires policy makers to understand and measure their impacts on national and local energy systems, power grids and GHG emission targets. Rapid improvements in energy efficiency and the shift to renewable sources of power have largely limited growth in overall ICT energy demand and GHG emissions. However, the IEA asserts that "strong government and industry efforts on energy efficiency, renewables procurement and research and development (R&D) will be essential to curb energy demand and emissions growth over the next decade" (IEA, 2022[69]).

Methodological challenges for estimating future GHG emissions include a lack of consistency in system boundaries and taxonomies, challenges in data availability and quality, and complexities with measuring enabling and systemic environmental impacts (Bremer et al., 2023[70]). Such challenges are reflected in the divergence of both past estimates and future predictions of the life-cycle GHG emissions of digital technologies. Published estimates for the ICT sector for 2015 "differ by a factor of 2", while "projections for 2025 diverge up to 25 times" (Bremer et al., 2023[70]).

While operating digital technologies consumes natural resources, their operation (direct effects) can sometimes contribute positively to environmental sustainability. Such "positive" cases have become more technologically viable in recent years, but scaling and commercialisation challenges remain. For example, data centres produce large amounts of excess heat, typically considered "low-grade energy". This energy usually cannot be directly repurposed for other activities as the temperatures are too low, typically below 35°C, often causing excess heat to be directed into cooling towers.

Several methods have been proposed to recover excess heat from data centre operations. These include combining the operation of a data centre and an onsite greenhouse or transferring it to local energy networks (ReUseHeat, 2017[71]; Karnama, Haghighi and Vinuesa, 2019[72]). This is known as "district heating" (Box 3.1). While such applications seem promising, they will typically require longer-term planning and co-ordination with urban development. They must overcome challenges around transporting such heat to the end-user effectively and related business models.

Box 3.1. Is waste heat from data centres a largely untapped opportunity?

Re-using waste heat from data centres can enable energy savings and support a circular economy

About 90% of the electricity used by data centres is converted into low-grade waste heat, which is typically lost and released into the atmosphere or discharged into local waterways (Luo et al., 2019[2]). This offers an opportunity to tap into a scarcely used source of energy and support circular economy and local decarbonisation efforts by providing heat to nearby commercial and residential buildings (IEA, 2023[17]). On a small scale, some data centre providers have already started to distribute waste heat to municipal district heating networks.

In Finland, one data centre operator – Elisa – provides heat to 1 000 homes through Helsinki Energy, while QTS Data Centres in the Netherlands heats more than 5 000 homes (Fisher, 2023[73]). District heating works well for urban areas, but there are often limitations to its use in rural areas due to a lack of a critical mass of customers. Nevertheless, even such challenges can be overcome. For example, heated wastewater from the data centre has the optimal temperature for lobsters to grow. With this in mind, a data centre operator in Norway has pioneered heat re-use for land-based lobster and trout farming (Green Mountain, 2021[74]). Countries like Germany have also proposed legislation to make it mandatory for data centre operators to provide waste heat to local suppliers (McGovan, 2023[75]). The IEA recommends policy makers work with data centre operators, utility companies and district heating suppliers to overcome barriers to scale-up and adoption, such as contractual and regulatory challenges, or achieving the required temperature for heating (IEA, 2023[17]).

In addition, while increased hyperscale operations have correlated with increased energy demand overall, such centralisation has also enabled large efficiency gains in energy use. New forms of cooling data centres are emerging but require scaling through substantial upgrades to infrastructure. Data centres based on liquid cooling could also recover the excess heat on-site to heat nearby buildings, in what some call an Organic Data Centre approach (Karnama, Haghighi and Vinuesa, 2019[72]). In addition to energy used directly by data centres, energy is also used to supply treated water to the data centres and treat the wastewater released from them (Siddik, Shehabi and Marston, 2021[65]). However, this wastewater often must be treated after use, which also consumes electricity and produces emissions, rendering the net sustainability impacts unclear (OECD, 2022[20]).

Recycling and end-of-life for digital technologies will need to be further improved to support climate and economic resilience

The ICT sector generates large amounts of electronic waste, which is expected to grow as demand for digital products rise. Waste from electrical and electronic equipment (WEEE or e-waste) refers to discarded electrical or electronic items without the intent of re-use (OECD, 2019[76]). The Global E-waste Statistical Partnership, led by the United Nations and the International Telecommunication Union, estimates that global e-waste amounted to 57.4 million metric tonnes in 2021, up almost 30% from 2014 (Forti et al., 2020[77]). This is further projected to grow to 82 million metric tonnes by 2030 (Baldé et al., 2024[78]). This makes e-waste "one of the world's fastest growing waste streams": its growth rate is estimated to be over three times higher than other prominent waste streams (Kumar, Holuszko and Espinosa, 2017[79]).

The Global E-waste Statistical Partnership estimates that only 22.3% of global e-waste was formally collected and recycled in 2022 (Baldé et al., 2024[78]). This leads to environmental concerns as large amounts of e-waste are incinerated or dumped in landfills, leading to environmental and social impacts such as air pollution, acidic and radioactive waste, and groundwater pollution (Crawford, 2021[59]). E-waste can contain more than 100 metals and materials such as lead and other toxic materials such as mercury, lithium and nickel. Consequently, it makes up around 70% of global surface-level toxic pollution (Vishwakarma et al., 2022[80]).

Digital technologies are not directly responsible for the largest amounts of global e-waste. The definition of e-waste is broad and generally comprises six categories: temperature exchange equipment (such as refrigerators and heat pumps), screens and monitors, lamps, large equipment (such as washing machines), small equipment (such as vacuum cleaners and toasters), and small IT and telecommunication equipment (OECD, 2019[76]). In 2019, the largest categories of global e-waste, such as small equipment and temperature exchange equipment, could not be directly attributed to digital technologies. Small IT and telecommunication equipment grew only moderately compared to 2015. Meanwhile, screens even declined by 1%. This was because light-emitting flat panel displays or screens (including light-emitting diodes [LEDs]) led to a decrease in total weight, even as the total number of screens increased (Forti et al., 2020[77]).

There are also significant regional differences in both generation and recycling of e-waste. In 2022, Europe generated 17.6 kg per capita, and recycled 7.53 kg per capita (42.8%). Meanwhile, the Americas[10] generated 14.1 kg per capita but recycled only 4.2 kg per capita (30%) (Baldé et al., 2024[78]).

Increasing re-use and recycling rates for ICT infrastructure can help meet the projected increase in demand for critical minerals. The economic value of raw materials contained in e-waste was estimated at USD 57 billion in 2019 (Forti et al., 2020[77]) and rose to USD 91 billion in 2022 (Baldé et al., 2024[78]). A lack of repairs, software support and planned obsolescence strategies for older digital technology products, coupled with low collection and recycling rates, led to high rates of e-waste worldwide. (Forti et al., 2020[77]). The export of significant amounts e-waste for informal disposal in emerging economies also risks creating a 'leakage effect' that may have serious consequences.

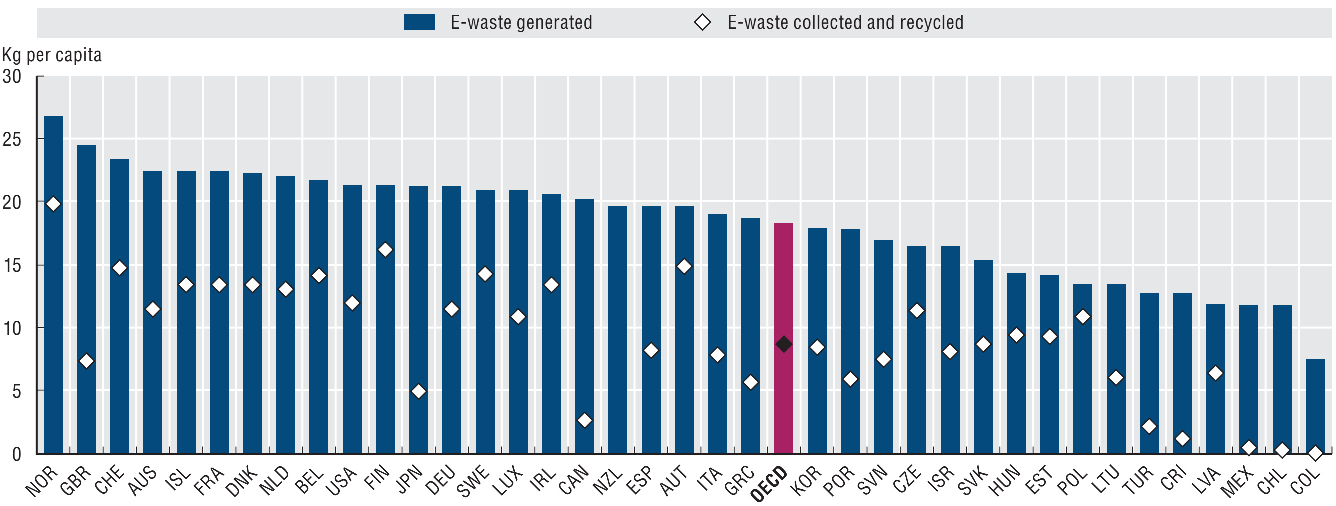
In terms of recycling, there remains a significant gap across OECD countries between e-waste generated and e-waste that is formally collected and recycled (Figure 3.4) (OECD, 2019[76]). The Global E-Waste Monitor notes that "recycling activities are not keeping pace with the global growth of e-waste"; since 2010, the growth of e-waste generation "(has been) outpacing the formal collection and recycling by almost a factor of five" (Baldé et al., 2024[78]). Even countries in the European Union, after two decades of e-waste legislation and the "highest documented formal e-waste collection and recycling rate of 42.5%", must increase collection rates further to meet EU targets (Forti et al., 2020[77]).

This objective of increasing formal e-waste collection and recycling is reflected in growing attention to reducing downstream environmental impacts of digital technologies. New policies are emerging to tackle e-waste and recycling. The EU WEEE Directive, for example, promotes re-use, recycling and other forms of recovery of WEEE. This aims to reduce the quantity of such waste to be disposed and to improve the environmental performance of the economic operators involved WEEE treatment (Directive 2012/19/EU, 2012) (EUR-Lex, 2012[81]).

Implementing circular economy solutions and "sustainability by design" could significantly decrease the e-waste related environmental impacts of digital technologies. Digital technologies, such as AI and IoT, can be applied to rethink product design and manufacturing, and extend the lifespan of products and their parts through predictive maintenance. They can also contribute to effective re-use of material through more efficient recycling and product recovery methods (One Planet Network, 2023[82]).

Figure 3.4. There remains a significant gap between generated and formally collected and recycled e-waste in OECD countries

E-waste generated, and formally collected and recycled (kg per capita) in OECD countries, 2022



Notes: The indicator measures e-waste generated in a given year per inhabitant and the amount of e-waste that has been collected and recycled (not all e-waste that is collected is necessarily recycled). E-waste, as defined in the Global E-Waste Monitor, refers to all items of electrical and electronic equipment that have been discarded as waste without the intent of re-use. It includes cooling and freezing equipment, screens and monitors, lamps, large equipment (e.g. washing machines and solar panels), small equipment (e.g. vacuum cleaners, microwaves and electronic toys), and small IT and telecommunications equipment (e.g. mobile phones, personal computers and printers). The Global E-Waste Monitor estimates stocks of e-products for each country and the amounts being discarded in each year. Due to a lack of direct data on sales of e-products, new additions to the stock are estimated based on imports less exports. Domestic production is also included for EU countries and Norway. National authorities provide recycling and re-use figures to Eurostat under the Waste Electrical and Electronic Equipment (WEEE) Directive, based on surveys and administrative data from waste collectors and treatment facilities.

Source: The OECD Going Digital Toolkit, based on the Global E-waste Monitor and the OECD Annual National Accounts Database (OECD, 2019[76]; Forti et al., 2020[77]; Eurostat, 2023[83]), *https://goingdigital.oecd.org/indicator/53*.

StatLink *https://stat.link/wxbq8p*

Embracing digital technology solutions offers a viable pathway to achieving climate and economic resilience across sectors

Digital technologies are expected to significantly affect the transformation of several sectors central to achieving climate and economic resilience. Applying digital technologies to energy systems and networks, greening communication infrastructure and services, and improving the efficiency of the transport sector through digital adoption, offer great promise for accelerated climate action. Harnessing digital technologies to decarbonise these and other sectors will significantly increase humanity's chance to reach net zero by 2050 (IEA, 2023[23]). Some scholars anticipate future years to bring a convergence of digitised broadband communication networks, electricity grids, the Internet, and mobility and logistics networks into increasingly integrated, digital and data-driven systems (Rifkin, 2022[84]).

Digital technologies have significant potential to bring positive sustainability impacts to nearly every sector of the economy. Key sectors that could become more sustainable from adoption of digital technologies include buildings and cities, heavy manufacturing like shipbuilding and steel production, farming and forestry, and green financing (Rolnick et al., 2022[85]). The OECD-FAO Agricultural Outlook 2021-2030 highlights that necessary improvements in productivity to feed the global population sustainably will not happen "without an important acceleration in digitalisation, technology, better data, and human capital" (OECD-FAO, 2021[86]).

Crucially, digital technologies are increasingly applied to climate predictions, forecasts and environmental modelling. Through its GreenData4All and Destination Earth projects, the European Union funds the development of a digital twin of the entire Earth system. It will be used to analyse the socio-economic impact of climate change and to develop strategies for climate mitigation and adaptation (Bauer et al., 2021[87]). While concrete evidence and macroeconomic projections have yet to materialise, digitalisation could contribute to "decouple economic activity from natural resource use and its environmental impacts". This, in turn, would support the transition towards a resilient and circular global economy (Barteková and Börkey, 2022[88]).

A new green and digital energy paradigm: Digital technologies can enable the clean energy systems of the future

The creation of smart energy systems and networks is one of the most promising applications for digital technologies. In the wake of a global energy crisis with soaring electricity prices and mounting energy demands, the IEA anticipates a "historic turning point towards a cleaner and more secure energy system". As clean technologies become cost competitive, a new clean energy paradigm is emerging in favour of a digitalised, decentralised and resilient clean energy grid (IEA, 2022[69]). Digital technologies play a fundamental role in enabling this transition. Technologies like AI, IoT and digital networks improve energy efficiency, reduce costs and accelerate clean technology innovation and diffusion across supply chains (IEA, 2023[23]).

The transformation of global energy systems from a centralised and fossil fuel-based system to a decentralised and renewable energy system requires significant flexibility. Such a system needs to integrate energy supply and demand from an increasing number of renewable energy sources as part of a resilient sustainable energy portfolio. Their flexible and decentralised nature make energy systems much more complex.

For these reasons, global energy systems will increasingly rely on digital technologies, especially those able to handle high levels of complexity and large amounts of data, to anticipate, manage and automate energy flows and prices. For example, smart energy storage can enable power-to-carrier (i.e. "power-to-X") procedures, which refers to the conversion of surplus renewable electricity into various other carriers that can store energy, such as synthetic fuels or hydrogen (Lange and Santarius, 2020[89]).

Digital technologies can also support energy efficiency and innovation across clean energy supply chains themselves. They can do this, for instance, through innovation and clean technology discovery, development and deployment, natural resources materials extraction and processing, manufacturing and installation, operations, and end-of-life (IEA, 2023[23]).

According to the IEA's 2023 Technology perspectives report, global energy flows are expected to become even more complex as more renewable energy sources come online. Electricity is set to become the largest energy vector, more than doubling in demand between 2021 and 2050 (IEA, 2023[23]). In addition, vast amounts of additional electrical loads are expected to be added to the electricity grid – from heat pumps to electric vehicles.

Tools like AI are optimal for analysing vast amounts of data to decipher patterns from complex data sets with many weights and parameters. They could play a significant role in managing and optimising future energy grids characterised by intermittent energy sources (IEA, 2023[23]). In a world where intermittent energy sources are predominant, connectivity is essential to co-ordinate the dispatch, transmission and distribution of electricity. As such, many of the environmental benefits of digital technologies and their underlying infrastructure derive from supporting the management of smart energy networks.

Deploying technologies such as fibre, 5G and AI systems can also optimise network management and reduce energy consumption. Applications such as "sleep mode" (enabled by machine learning) can help reduce energy consumption costs in mobile networks. Meanwhile, IoT and fibre-connected sensors can help optimise network energy management in buildings, cities and other critical infrastructure. Moreover, supporting the transition to fibre from legacy broadband access technologies could help achieve environmental sustainability goals for fixed broadband networks.

Re-imagining the electrical grid through a green lens

Several reports suggest that fibre-to-the-home (FTTH) networks may prove to be more energy efficient than traditional copper connections (OECD, 2022[90]) (Box 3.3). Around the world, new products such as AI-powered "home energy stations" monitor the energy demands of consumers and sell unused energy from devices like home solar panels back to the electricity grid. However, connectivity is essential for this type of AI and IoT applications to flourish. Connectivity divides, in particular in rural and remote areas, are a major challenge to overcome.

Other notable technology use cases for green energy grids include the deployment of smart meters in distribution networks. Smart meters can increase service quality and enable the introduction of innovative demand-side response measures by allowing customers to manage their energy consumption. Around 1.1 billion smart meters had been installed globally at the end of 2021 – already almost 40% of all residential meters (IEA, 2023[23]). Digital remote control and advanced protection devices can also manage bidirectional energy flows and identify grid faults quickly. Virtual Power Plants, for example, can integrate energy supply and demand, leveraging AI and IoT sensors (Nafkha-Tayari. et al., 2022[91]).

Further digital solutions include advanced voltage regulation at the distribution-grid level. Voltage regulation can increase the hosting capacity of the grid and enable integration of the increasing number of decentralised and intermittent sources of renewable electricity. In 2021, digital infrastructure accounted for 19% of global investment in electricity grids, with 75% of this amount in the distribution grid (IEA, 2023[23]). The increasing use of digital technologies in the energy sector can improve energy security through higher quality of supply and distributed energy sources. However, cybersecurity concerns pose a long-term risk for critical infrastructure such as power utilities (Casanovas and Nghiem, 1 August 2023[92]). Given digital security challenges, energy providers may prefer full-fibre connectivity for the energy grids.

AI-enabled digital twins of entire energy systems are a key tool that leverages digital technologies, combining clean technology use cases into a holistic and reliable solution for energy providers. As power systems need to increase flexibility by a factor of four by 2050, the digitalisation of power system management plays a key role in the net-zero transition (OECD, 2023[93]).

Digital twins, which represent a real-world system digitally by mirroring physical objects and processes, can improve forecasting, scheduling and control of power grids. They can also create advanced electricity systems to accommodate for flexible demand (Rolnick et al., 2022[85]). Digital twins exist for a variety of applications, such as Digital Twin Singapore for a multi-temporal digital virtual city (Singapore Land Authority, 2024[94]). They promote power systems that are closed-loop digital power grids, combining large amounts of data, machine learning, IoT and intelligent sensing for a national or even transnational digital twin (Bai and Wang, 2023[95]).

With respect to training AI systems, advances in data science can lead to fewer training runs involving smaller data sets and less complex models. In so doing, they can bring efficiencies more quickly than updating and modernising physical infrastructure such as data centres. For example, researchers at the Massachusetts Institute of Technology and at start-up MosaicML are training neural networks up to seven times faster by configuring AI algorithms to learn more efficiently (Leavitt, 18 July 2022[96]). With recent advances in large language models (LLMs), new generative AI tools have also emerged that can help advance understanding and accessibility of climate data (Box 3.2). The G7 Hiroshima Process on Generative AI launched in 2023 highlights generative AI's potential role to help address pressing societal challenges, such as helping to solve the climate crisis and achieving the SDGs (OECD, 2023[97]).

Box 3.2. Will generative AI be useful for climate action?

Generative AI tools can help design greener products and make climate data more accessible

Generative AI systems are emerging as potential tools to support climate action across various domains. By leveraging advanced algorithms that learn from massive amounts of data, generative AI could be used to identify energy-saving options across sectors. This includes more efficient urban planning, greener product designs and manufacturing processes, better supply chain efficiency, and new ways of processing waste and optimising recycling. Large language models (LLMs) could also be leveraged to make climate data more accessible to a wider audience. For example, researchers trained an LLM on peer-reviewed climate papers and reports of the Intergovernmental Panel on Climate Change. In this way, they created an interactive chatbot that can make often complex climate science understandable and accessible to a wider audience (ChatClimate, 2023[98]). LLMs might also offer opportunities for climate and sustainability research. In biodiversity preservation, for example, generative AI has helped predict species coexistence patterns to promote biodiversity maintenance (Hirn et al., 2022[99]).

Further research is needed to assess in which areas of climate action LLMs could be most useful and to fully understand the environmental impacts of widely used generative AI tools. Some trends are already emerging. "Training" a machine-learning model (e.g. determining the weights, parameters and data to train a neural network, also referred to simply as "learning") uses more energy than a single "inference" (e.g. using an AI chatbot to generate a response to a question). However, the inference stage overall typically is more energy- and water-intensive over the AI system's life cycle. This is because such models are usually trained only a few times, whereas inference is executed repeatedly every time a system is used during its lifetime of deployment (OECD, 2023[58]).

The mass diffusion of generative AI tools across business and consumer products has placed heightened emphasis on the potential environmental impacts of "inference", in addition to "training". Initial research suggests that if generative AI systems include safeguards to manage energy use for training, they would provide net sustainability benefits to society (Larosa et al., 2023[100]).

Greening communication infrastructure and services is fundamental to sustainable and resilient digital transformation

Communication services and infrastructures have an impact on the climate both negatively (e.g. the high-energy consumption of data centres) and positively (e.g. through support for other parts of the economy). Apart from their direct impact on the environment, they have an indirect or catalyst effect on other sectors. According to the 2021 OECD Council Recommendation on Broadband Connectivity, the environmental sustainability of communication networks is critical for the future. It recommends minimising the negative environmental impacts of communication networks in two ways. First, policy makers should foster smart and sustainable networks and devices, such as the IoT. Second, they should encourage operators to periodically report on their environmental impacts and on the positive environmental effects of connectivity (OECD, 2021$_{[101]}$).

The Recommendation was a building block to the "G20 Guidelines for Financing and Fostering High-Quality Broadband Connectivity for a Digital World", developed with the support of the OECD (G20, 2021$_{[102]}$). The G20 Guidelines recommend incentivising "communication network operators and other sectors, such as the transportation and energy sectors, to co-operate in network development and financing activities in order to minimise costs, disruption and environmental impacts" (G20, 2021$_{[102]}$).

In recent years, the communication infrastructure and services industry has promoted the sustainability of communication networks to reach net-zero targets (Box 3.3). According to the IEA, several large network operators have improved their networks' energy efficiency through innovative technologies, significantly reducing energy use. For example, despite a growing demand for energy, the communication operator company Sprint reduced the energy intensity of its network by more than 80% between 2014 and 2019, keeping its total network energy consumption flat (IEA, 2023$_{[17]}$).

Box 3.3. Upgrading to "future-proof" broadband network technologies with sustainability considerations in mind

Beyond "future proofing" aspects of symmetrical broadband speeds and the scalability of networks, the transition to fibre can also promote environmental sustainability. Several reports suggest that FTTH networks may prove to be more energy efficient than traditional copper connections (OECD, 2022$_{[90]}$). According to one report, fixed fibre networks consumed on average 0.5 Watts (W) per line (Arcep, 2019$_{[103]}$). This translates into three times less energy consumption than an ADSL line (1.8 W) and four times less than a traditional Publicly Switched Telephone Network line (2.1 W). Another study found that energy efficiency gains achieved from 5G deployment will begin in 2023 and be clear by 2028 in the most densely populated areas. However, it will be far more modest in more sparsely populated areas (Arcep, 2022$_{[104]}$).[11]

In recent years, the communication industry has undertaken various efforts to promote the sustainability of networks. Three large operators in Europe, for example, have categorised fibre rollout as part of their environmental sustainability agenda. They have linked "green" credit funding to achieve this objective. KPN, a fixed and mobile operator in the Netherlands, refinanced its credit line by tying the new interest rates to the company's performance in its sustainability strategy, such as fibre deployment and reduction of energy consumption (Lenninghan, 2021$_{[105]}$). KPN plans to invest EUR 3.5 billion (USD 3.99 billion)[12] by 2024 as it aims for nationwide fibre deployment (Telecom Review, 2020$_{[106]}$). In a similar way, the Swedish operator Telia used two "Green Bonds" funds for fibre investments. This responded to the company's vision of fibre rollout as energy saving and a key enabler of IoT solutions that help reduce carbon emissions (Lenninghan, 2021$_{[105]}$). For example, fibre-connected street furniture may enable IoT sensors across cities to optimise energy consumption and traffic management, resulting in fewer CO_2 emissions. Meanwhile, Telefónica issued its first "sustainable perpetual hybrid" bond amounting to EUR 1 billion (USD 1.142 billion)[12] in February 2021. This will finance environmental projects in Spain, Germany and Brazil, focusing on the transformation of copper networks to more reliable and energy-efficient fibre (i.e. 85% more energy efficient) (Telefónica, 2021$_{[107]}$).

A WIK report assessed the environmental effects of changes in the fixed broadband technology mix in Europe. Assuming that power sources remain unchanged, a migration from fixed broadband technology in the European Union to 100% fibre would reduce CO_2 emissions from 15.5 million tonnes to 3.2 million tonnes per year (i.e. a 79% yearly reduction) as FTTH is more energy efficient (WIK-Consult, 2020$_{[108]}$).

Source: OECD (2022$_{[90]}$).

Many communication regulators across OECD countries actively support decarbonisation of the sector. They do this either through their mandates or through inter-agency co-operation to achieve digital policy objectives that require a whole-of-government approach (OECD, 2022[109]). For example, the government of France tasked the communication regulator, Arcep, and the agency for ecological transition (ADEME), to quantify the current and future environmental footprints of digital technologies. In 2022, the two agencies assessed the current impact of ICTs on the environment in two volumes (Arcep, 2022[110]). In 2023, the third volume provided a forward-looking assessment (2030-50) (Arcep, 2023[111]). Moreover, compared to 2021 (OECD, 2022[109]), partial or full responsibilities of communication regulators in 2023 increased notably with regards to the environmental sustainability of networks. In 2023, 52.5% of OECD communication regulators reported responsibilities in this area (see Chapter 2).

Environmentally responsible practices and objectives of communication networks include the following:

- Reduction of energy consumption of network operations and the usage of renewable energy sources;
- Reduction of pollution, radiation and other hazards of networks;
- Adoption of environmentally responsible policies for network construction such as land-use policies, cell tower construction and data processing centres;
- Reduction of environmental impacts of electronic equipment and terminals once discarded e-waste, by adopting proper recycling and safe disposal practices; and
- Creation of more sustainable products, using a minimum of hazardous materials and allowing for longer useful lives rather than planned obsolescence (OECD, 2022[90]).

Moreover, as explored in the DEO Volume 1 Spotlight "Next generation networks and the evolving connectivity ecosystem" (OECD, 2024[13]), policy makers are considering environmental sustainability as a key value for 6G technologies and use cases for the next decade. Some stakeholders even call it the "green G".

The large enabling effects of communication and broadband for climate action and environmental stewardship are equally important to minimise the negative environmental impacts of communication networks. Broadband is often regarded as the foundation of the SDGs. For instance, connectivity enables the IoT across sectors such as energy, transport and agriculture. Massive machine-to-machine communication services, a subset of IoT, comprise the vast amount of sensors used in cities (e.g. electrical grids and highways), in industry (e.g. sensors within machines) and in the agricultural sector (e.g. sensors measuring humidity levels to improve water efficiency or better predict crop yields), among others (OECD, 2018[12]).

Enabling adoption of smart devices, such as IoT, can have a positive impact on the environment through a wide range of applications. Such applications range from smart electrical grids, fleet automation and precision agriculture to predictive maintenance, connected forests and traffic management systems that reduce transport congestion in smart cities. Smart grids are one application being fostered in many countries. In 2019, the Irish communication regulator (ComReg) assigned its 400 megahertz (MHz) Band Spectrum Award for the use of smart grids. The award complemented the Irish government's climate policies, with smart grids described as "an efficient utility network system typically using digital automation technology for monitoring, control, and analysis within the supply chain" and a key enabler for the reduction of GHG emissions (OECD, 2018[12]). For its part, Germany awarded an exclusive licence in the 450 gigahertz (GHz) band for a smart electrical grid private network in February 2022 to "450connect", a consortium of German regional and municipal energy and water utilities along with energy companies (Jones, 2022[112]).

Communication policy and regulation play a key role with regards to Earth observation, which is important to support climate mitigation. For example, spectrum policy helps enable Earth observation satellites that support several use cases in agriculture, as well as disaster preparedness, and weather and climate monitoring. Data from such satellites are expected to play an even greater role as countries grapple with the impact of climate change (OECD, 2022[113]). In addition, the International Telecommunication Union is discussing the role that "smart" submarine cables (i.e. equipped with scientific sensors) could play in providing real-time data for ocean climate monitoring and disaster mitigation (e.g. tsunamis) (ITU-T, 2023[114]).

As a significant contributor to GHG emissions, global transport systems stand to benefit greatly from energy efficiency gains enabled by digital technologies

With demand for travel increasing, the global transportation sector has made only modest progress at lowering emissions. The sector, excluding the manufacturing of motor vehicles and other transport equipment, was responsible for around a quarter of global energy sector GHG emissions in 2022 (IEA, 2023[60]).

Following the COVID-19 pandemic, demand for passenger road transport, freight transport (road, shipping and air), and commercial aviation have rebounded. Consequently, the sector has not significantly reduced its emissions. Moreover, demand for transport is expected to increase by 2050. Further concerns arise from unregulated and often uncontrollable GHG emissions like methane and nitrous oxide, and a shift away from low-carbon collective transportation systems like public buses to individual mobility solutions (EEA, 2022[115]).

Digital technologies can help reduce the environmental impact of global transportation networks. Digital technologies can reduce overall demand for travel and transportation through, for example, videoconferencing and teleworking. They can also help increase fuel efficiency and infrastructure longevity through AI-enabled digital twins to forecast energy needs, and IoT sensors for predictive maintenance (EEA, 2022[115]).

Shared mobility such as on-demand ride services or vehicle sharing can also reduce overall passenger transport activity. Freight routing and consolidation, such as smart shipment bundling, can significantly reduce freight trips (Rolnick et al., 2022[85]). The International Transport Forum describes how smart transport systems can improve operational efficiency of non-urban freight movements such as long-haul trucking, decreasing GHG gas emissions and costs through increased asset sharing and the use of high-capacity vehicles (ITF, 2023[116]).

Global transportation networks can benefit from digital technologies

The carbon intensity of transportation can be further lowered through digital technologies that improve the performance of low-emission vehicles and batteries, resulting in less overall demand for electricity and critical minerals. They can also speed up clean technology discovery and deployment by accelerating the R&D of alternative fuels such as synthetic fuels or hydrogen. Such alternative fuels hold great potential for decarbonising sectors that are difficult to electrify, including aviation, long-distance trucking and maritime shipping (Lange and Santarius, 2020[89]).

Connected and fully automated vehicles may help reduce air pollution but are also expected to generate negative impacts on the environment. These vehicles, commonly called “self-driving” cars or “autonomous vehicles” (OECD/ITF, 2015[117]; OECD, 2018[12]), include truck platooning (i.e. linking of two or more trucks in convoy using connectivity). They may help reduce road congestion, and hence air pollution, by traffic management techniques or simply by wind breaking (in the case of platooning). This is particularly important due to the contribution of road congestion to GHG emissions. At the same time, fully automated vehicles, using advanced wireless networks, are expected to produce massive amounts of data (OECD, 2018[12]), which have their own environmental footprint.

Despite breakthroughs in efficiency for maritime transport and aviation, more progress is needed

Despite large efficiency increases in global transportation in the past decades, there is still huge potential for optimisations in sectors such as maritime transport and aviation. A research consortium from Google Research, American Airlines and Breakthrough Energy, for example, has demonstrated how to reduce the contrails of airplanes by up to 54% in test flights using AI to develop contrail forecast maps. Contrails, which are clouds formed when water freezes around aerosols in airplane exhausts, generate around 35% of the global warming impact of aviation.

Given these trends, AI-based predictions could significantly reduce GHG emissions from aviation in a highly cost-effective manner (Elkin and Sanekommu, 2023[118]). Another example is RASMUS, which combines AI with oceanographic models to calculate shipping routes that leverage small dynamic ocean currents and swirls. The optimised routes could result in GHG emissions savings of up to 10% for shipping operators (Christian-Albrechts-Universität zu Kiel, 2023[119]).

Many experts agree that a narrow focus on increasing the efficiency of the transport sector will be insufficient to meet the sector’s climate goals because of rebound effects. The adoption of digital technologies in transportation has significantly increased energy efficiency. However, in many cases they have not decreased overall emissions as efficiency gains were offset by an increase in transportation demand (Creutzig et al., 2015[120]; Lange and Santarius, 2020[89]).

Analysts have raised similar concerns about the development and deployment of fully automated vehicles. Such vehicles offer the prospect of reducing fuel consumption and increasing vehicle occupancy rates. However, any gains could be offset by an increase in overall vehicle usage and road traffic as vehicle transportation becomes even more accessible (Barcham, 2014[121]; Rolnick et al., 2022[85]; Silva et al., 2022[122]).

Experts also question the energy requirements stemming from the IoT, data sharing and computing needs demanded by fully automated vehicles to deploy accurately and safely. One study estimates that emissions produced from a global fleet of fully automated vehicles would match that of all global data centres today in a 95% adoption rate scenario (Sudhakar, Sze and Karaman, 2022[123]).

Policy makers could encourage a shift to more efficient travel modes to decarbonise transportation

One of the most important ways to decarbonise transportation systems is called "modal shift", which describes strategies to incentivise the shift from carbon-intensive to low-carbon modes of transportation. The International Transport Forum encourages policy makers to enable modal shift and demand management where they are most effective. This is typically in urban environments and short-distance intercity and international travel (ITF, 2023[116]). Digital technologies can enable such modal shift through more efficient transport planning options. For example, they can nudge passengers towards low-carbon transport options, and enable low-carbon transport modes like vehicle sharing (Rolnick et al., 2022[85]).

Future transport systems could make use of multimodal digital mobility services, enabled by technologies like AI, cloud computing, mixed reality and predictive analytics. Such systems can also integrate road, rail, water, and air transport at urban, interurban and rural scales. They help passengers compare travel options and facilitate access to low-carbon, multimodal modes of public transport. In so doing, they enable transport planners to design a public transportation network that is both environmentally beneficial, reliable and efficient, and highly attractive for passengers (EEA, 2022[115]).

Digital technologies drive greener consumption choices in economies and societies

Digital technologies can be used to nudge consumers towards greener choices (Sunstein and Reisch, 2013[124]) – from reducing energy consumption (OECD, 2017[125]; Rivers, 2018[126]) to more sustainable online shopping (Banerjee et al., 2022[127]; Michels et al., 2022[128]). A nudge is generally "any aspect of the choice architecture that alters people's behaviour predictably without forbidding any option or significantly changing their economic incentives" (Thaler and Sunstein, 2009[129]). Nudges include data and notifications about energy and other consumption and proposing options for more sustainable alternatives for online purchases.

Such digital nudges could play a significant role in the green transition given that household spending accounts for around 60% of gross domestic product across the OECD (OECD, 2024[130]). At the same time, the potential positive effects from nudging consumers towards greener choices can be difficult to quantify. This further underlines the need for data collection and net benefit analyses of digital technologies on the environment (République Française, 2021[131]).

Supported by digital technologies, the trend towards teleworking may support the green transition. The COVID-19 pandemic saw an acceleration of teleworking enabled by digital technology. This allowed many businesses to continue operating with personnel working from home and using tools such as videoconferencing, cloud services and virtual private networks to communicate and work together. Early evidence suggests that around one-third of employed persons would like to continue being able to telework. A higher share of businesses also anticipates offering teleworking than before the pandemic – with a greater proportion of employees expected to make use of the option to telework (Ker, Montagnier and Spiezia, 2021[132]).

At the same time, digital technologies can be used in a similar way to promote interests that run counter to environmental sustainability goals. For instance, through manipulatory nudging, choice architects can influence consumption choices towards less sustainable alternatives using the same methods described for more greener choices (Sunstein and Reisch, 2013[124]).

Figure 3.1 shows that digital technologies can have negative environmental impacts through the direct technological life cycle, as well as through enabling and systemic effects. This includes both intended and unintended consequences of the application of digital technologies, such as the acceleration of emissions-intensive activities through AI. It also comprises system-level impacts like rebound effects in autonomous driving or negative consumption lifestyle changes through digital advertising (Kaack et al., 2022[61]). This is why some scholars have proposed the concept of "digital sobriety" or "digital sufficiency", which calls for a new "Digital Green Deal" that puts digital technologies in the service of a deep sustainability transformation (D4S, 2022[133]).

Towards policies for a green and resilient digital future

Policy responses acknowledge the link between the green and digital twin transitions

Policy makers increasingly consider both digitalisation and environmental sustainability on their agendas. They may include them, for example, in national strategies and recovery plans; in dedicated strategies for digital technologies and the environment; or through standalone national strategies for digitalisation or for the environment. Elevating these priorities to a strategic level while adopting a whole-of-government perspective that integrates digital and environmental policies across domains contributes to their effectiveness (OECD, forthcoming[16]).

Recent declarations and commitments at the OECD and beyond also emphasise the importance and opportunity of leveraging digital technologies for climate and economic resilience. This section provides a selection of policy responses taken by countries broadly grouped along three notable trends: i) aligning the vision, values and objectives of the green and digital twin transitions; ii) measuring, minimising and mitigating negative environmental impacts of digital technologies; and iii) accelerating innovation and adoption of green digital technologies solutions.

Aligning the vision, values and objectives of the green and digital twin transitions

Although the green and digital twin transitions have emerged together as policy priorities, such transitions are not always automatically aligned. Digital technologies are often designed and deployed to achieve social and economic gains first and foremost. They do not necessarily consider whether such technologies are "sustainable by design" and advance sustainability goals.

In recent years, policy makers have begun to align the vision, values and objectives of the green and digital twin transitions. Policies fit for the future will no longer consider only how to achieve economic productivity gains; policies become inseparable and synonymous with actions that also protect the planet. Designing such policies starts with the fundamental alignment of vision, values and objectives.

Many key intergovernmental organisations recognise the importance of vision alignment:

- The OECD Recommendation on Information and Communication Technologies and the Environment (OECD 2010[4]), adopted over a decade ago, was pioneering in recognising the connection between digital technology and environmental sustainability. Its ten principles helped lay the groundwork for using ICTs to improve environmental performance, increase energy efficiency and combat climate change.
- The UNEP-led CODES network calls for aligning "the global practice and discourse around digital advancement with sustainable development". It introduced several initiatives around this goal, including a World Commission on Sustainability in the Digital Age to streamline the twin transitions across the United Nations and beyond (CODES, 2022[10]). CODES also stresses the importance of considering both Indigenous and modern understandings of sustainability and protecting Indigenous land and data rights (CODES, 2022[10]).
- The Institute of Electrical and Electronics Engineers underscores the need to align the development and use of technology with ethical and environmentally responsible practices in its principles for *Strong Sustainability by Design* (IEEE SA, 2023[134]).
- The European Union Recovery and Resilience Regulation and its implementation across EU member states offers another example of an integrated approach that accounts for digital and environmental priorities as part of overall post-COVID growth and recovery plans (European Union, 2021[135]). Research from the European Commission also emphasises the importance of aligning the twin transitions to ensure the term not only describes parallel green and digital transitions, but also aims to unite both into one (Muench et al., 2022[11]).

Some countries have recently adopted national plans targeting the digital-environment nexus. In 2023, the Korean government established a plan to promote carbon neutrality through digital transformation. The initiative aims to secure green digital transformation technologies and infrastructure, and to disseminate them for use across the public and private sectors. Specifically, the initiatives cover developing technologies to reduce carbon emissions by sector, developing and applying low-power and high-performance data centre technologies, developing core technologies for low-power networks, laying the foundation for using carbon-neutral data and establishing a carbon-neutral decision-making support system (Government of Korea, 2023[136]).

Similarly, Finland, France and Germany have adopted overarching national plans for digital technologies and the environment. These seek to leverage the potential of digitalisation for climate objectives, while ensuring a sustainable digital transformation (Germany Federal Ministry for the Environment, Nature Conservation and Nuclear Safety, 2020[137]; Finland Ministry of Transport and Communications, 2021[138]; Government of France, 2021[139]):

- France's Law No. 1485 of 2021 on reducing the digital footprint on the environment recognises the impact of digital technologies in an integrated approach to environmental sustainability, cutting across policy areas. The law introduced and modified specific legal provisions in a broad array of legislation, such as consumer, environmental, electronic communications, intellectual property and commercial law (République Française, 2021[131]).
- Germany's Digital Policy Agenda for Environment covers four types of measures, including measures both to reduce resource use by digital technologies and those targeted at using AI to tackle environmental challenges. Germany has also proposed the Energy Efficiency Act would be applicable to data centres. If implemented, it would require efficiency benchmarks and re-use of excess heat (Bundesregierung, 2023[140]).

Promoting policies to measure, minimise and mitigate negative environmental impacts of digital technologies

Ensuring that digital transformation is aligned with efforts to minimise the environmental impacts of digital technologies is at the core of country policies seeking to promote an environmentally sustainable future. Such policies help not only to align digital transformation with climate targets, but also to increase the benefits from their application across sectors.

Countries have started to introduce measures to gauge, minimise and mitigate the environmental impacts of digital technologies. These include monitoring and tracking of impacts, sustainable procurement of digital infrastructure and the introduction of digital product passports (Muench et al., 2022[11]). While efficiency improvements, durability and recycling will play a critical role, some researchers and government agencies have called for the principle of "digital sufficiency". This entails only using digital technologies where they are necessary and offer a clear advantage over *low-tech* or *no-tech* solutions (D4S, 2022[133]).

In many cases, initiatives focus on the end-of-life phase and extending the lifespan of digital products. France's Law No. 1485 of 2021 seeks to reduce the environmental footprint of digital technology through several measures. These include prohibiting the planned obsolescence of devices; requiring the distribution of information to consumers about how to optimise equipment performance to expand its lifespan; and promoting annual national campaigns for returning electronic equipment (République Française, 2021[131]). The German Digital Policy Agenda for the Environment advocates for binding requirements on hardware manufacturers to expand product lifespans. It also highlights the responsibility of both the private and public sectors in reducing e-waste (Germany Federal Ministry for the Environment, Nature Conservation and Nuclear Safety, 2020[137]). The United Kingdom's "Greening Government: ICT and Digital Services Strategy 2020-2025" similarly focuses on the end-of-life phase, seeking to "map and account for ICT at end of life" to increase transparency, as part of procurement processes, and to advance a circular economy (Defra, 2020[141]).

Policy makers are analysing indirect impacts from new technologies on the environment

In addition to life-cycle approaches, policy makers are factoring indirect environmental impacts into policy design, such as enabling and systemic effects (indirect impacts). Enabling and systemic effects may arise from the use of new technologies themselves or be scaled by policies aimed at promoting them. With rebound effects, policies may have unintended outcomes, such as increasing consumption by making products and services more efficient. Rebound effects may not be easily foreseeable or identifiable due to the complexity of environmental systems, value chains and social behaviour involved in the assessment of their impact.

At the national level, policy makers seek to address the complexity of indirect environmental impacts in dedicated strategies for digital policy for the environment. For example, both Finland and Germany underscore the importance of understanding and measuring rebound effects of digital solutions to environmental challenges (Germany Federal Ministry for the Environment, Nature Conservation and Nuclear Safety, 2020[137]; Finland Ministry of Transport and Communications, 2021[138]). A French observatory established in 2021 aims to quantify and analyse direct and indirect environmental impacts of digital technologies, notably AI (République Française, 2021[131]). In France, the communication regulator, Arcep, is conducting environmental assessments of the ICT sector. In 2021, the government of France strengthened Arcep's powers to provide clear environmental impact information-gathering authority. This covers not just network operators, but also online communication service providers, data centre operators, consumer device manufacturers, network equipment suppliers and operating system providers (République Française, 2021[142]).

At the European level, the proposed European Union AI Act would require high-risk AI systems to be designed to enable "the recording of energy consumption, the measurement or calculation of resource use and environmental impact". The draft AI Act also highlights the potential contribution of AI systems to environmental monitoring; conservation and restoration of biodiversity and ecosystems; and climate change mitigation and adaptation (European Parliament, 2023[143]).

Measuring the environmental impact of digital technologies remains a challenge

Although several policies target measurement issues, regarding both the impact of digital technologies on the environment and of related policies, this remains a challenging area due to the myriad of frameworks and factors involved (OECD, forthcoming[16]). According to OECD (2010[4]), governments are encouraged to measure the impact of digital technologies themselves on the environment (through comprehensive and comparable metrics) and to measure the impact-related policies. In both cases, digital technologies play a role in advancing the ability to track and measure impact. Moreover, in both cases, the OECD can support countries in developing and applying co-ordinated and comparable measurement frameworks.

There is a need to further explore circular economy models for digital transformation with an emphasis on the entire life cycle to assess the environmental impact of networks and devices (OECD, 2022[113]). Regarding mobile handset acquisition models, previous OECD work underscores the need to properly reflect the societal cost of extraction and waste disposal of the metals used in mobile handsets (OECD, 2013[144]).

The OECD report "Case Study on Critical Metals in Mobile Devices" provides valuable recommendations for the management of critical metals in mobile phones through their life cycle (OECD, 2012[145]).[13] Access to reliable data and harmonised methodologies is a prerequisite for the pursuit of the objectives identified. In many OECD countries, regulators and/or ministries lack a mandate to collect data on the environmental impact of ICTs.

Accelerating innovation and adoption of green digital technology solutions

Digital technology and innovation are major building blocks to reach environmental goals and achieve the deep cuts in emissions needed to transition to a net-zero carbon world. Innovation is crucial because it can help reach environmental sustainability objectives, and is also the main source of modern economic growth. This implies that technology and innovation may help enable a green, more resilient future that goes in hand in hand with new growth opportunities and strengthened productivity growth. However, after rapid progress in the early 2000s, low-carbon innovation efforts (e.g. as measured by patent filings and public spending on energy R&D) started to decline around 2012. This decline occurred despite the ambitious climate objectives set out in the 2015 Paris Agreement (Cervantes et al., 2023[146]).

Technological progress fuelled by public and private investments can reduce the costs of emissions reduction policies. This is demonstrated by sharp declines in the costs of batteries and solar, which have both experienced a 90% reduction over the past decade (Cervantes et al., 2023[146]). However, reaching net zero by 2050 requires not only the rapid deployment of currently available technologies. It also demands further innovation in breakthrough technologies not yet on the market (Cervantes et al., 2023[146]). Strengthening innovation, along with technology diffusion, around the green and digital twin transitions is therefore essential to reach carbon neutrality and other environmental goals. Much of this innovation to increase efficiency and resource productivity relates to adoption of digital technologies, as seen in previous sections.

Several jurisdictions are investing in innovation to advance research and development of digital technologies

At least half of global reductions in energy-related GHG emissions through 2050 will rely on technologies not yet fully available for commercial use as they are at the demonstration or prototype phase (IEA, 2021[147]). Costs, access and availability of technology required for such solutions all hamper the innovation and commercialisation of such technologies. To address these challenges, governments have incorporated a mission-oriented approach to drive technological breakthroughs (OECD, 2023[93]; OECD, 2023[148]).

Governments are stepping up direct investments and creating incentives for other stakeholders to do the same, to advance R&D and innovation in digital technologies in support of the transition to a green and circular economy. Denmark provides funding, subsidies and tax deductibility, among other measures, for green research on technologies to capture and store CO_2 (Ministry of Finance, 2021[149]). Finland invests in emerging technology for clean energy production, including by using AI to reduce energy consumption and emissions (Finnish Government, 2021[150]). Mexico's National Institute of Ecology and Climate Change oversees the co-ordination of technological and scientific research and projects in co-operation with research institutes (Government of Mexico, 2022[151]).

Several jurisdictions are strengthening the underlying role of data access to enable digital innovation. The "All Data 4 Green Deal", a consortium of 12 partners jointly funded by Switzerland, the United Kingdom and the European Union, seeks to co-design a "Green Deal" common data space. This will enable the interoperable combination and integration of data from a variety of sources to support innovation; access; and informed decision making related to climate change, pollution and biodiversity (AD4GD, 2023[152]). For its part, Austria's Mobility plan refers to the role of data to support better decision making and innovative, energy-efficient and sustainable solutions in the transportation sector (BMK, 2021[153]).

Countries are also implementing policy measures to develop the skills needed for harnessing digital technologies for environmental sustainability, while reducing negative impacts. For both the earliest school age and university entry level, France developed training in "digital sobriety" and the impact of digitalisation on the environment. This is one of several measures to reduce the environmental footprint of digital technologies (INSP, 2023[154]). In Switzerland, the Digital Strategy seeks to embed environmental concerns into the development of digital skills (Federal Chancellery of Switzerland, 2023[155]). For their part, Finland and Germany seek to include "green coding", or environmentally sound software design, as part of the training of computer programmers (Germany Federal Ministry for the Environment, Nature Conservation and Nuclear Safety, 2020[137]; Finland Ministry of Transport and Communications, 2021[138]).

The European Commission regards digital technologies as a cornerstone of the European Green Deal to make the European Union climate neutral by 2050. It expects technologies like AI and IoT to enable the green transition in the agricultural sector, buildings and construction, electricity systems, energy-intensive industries, and transport and mobility (Muench et al., 2022[11]). Through the NextGenerationEU fund, the European Union has committed over USD 842 billion (EUR 800 billion)[14] to build a "greener, more digital and more resilient future". By 2050, the European Union plans to be the first climate-neutral society, while embracing technology (European Commission, 2023[156]).

The United States has passed three laws in recent years to support connectivity, digital technologies and initiatives related to climate change. The Inflation Reduction Act (IRA), signed in August 2022, allocated USD 500 billion in funds and tax breaks for clean energy and climate resilience investment programmes in various sectors (Badlam et al., 2022[157]; White House, 2022[158]). The Infrastructure Investment and Jobs Act of 2021 allocated USD 65 billion to broadband infrastructure. Finally, the "CHIPS and Science Act" was passed in 2022. Together, the three laws commit USD 2 trillion in public funds to connectivity, digital technologies and the fight against climate change (Badlam et al., 2022[157]). The IRA incentivises private companies, including those working on ICTs, to invest in clean production and development practices, as well as to develop talent in the field of clean technology (Badlam et al., 2022[157]).

As digital technology development and innovation progress, some potential policy questions arise. Like any product or service, digital technologies have environmental footprints. The challenge is to balance between minimising such footprints and fostering the positive, enabling environmental impacts of digital technologies throughout economic sectors. Examples of policy questions at the intersection of digital technologies and the environment include the ones below.

Are local energy grids ready to support the green and digital twin transitions? As the world becomes increasingly digitalised, data centres and data transmission networks are emerging as an important source of energy demand. However, at a local and regional level, energy grids may have limited capacity to support future levels of digital adoption. Already, data centre providers face strained national power supplies and rising energy costs in some locations, depending on the local energy grid mix and grid capacity. The energy demands of large data centres have led some jurisdictions to consider or impose moratoria and zoning rules on new data centre construction. This aims to ensure sufficient energy is available for other purposes like residential housing. In designing policies for the energy grids of the future, further understanding is needed around how changing demand for digital technologies translates into overall energy demand (IEA, 2023[17]).

Will computing power need to be managed as a national resource, with data centres becoming a new utility? Countries have acknowledged the increasing importance of computing power to enable broad digital transformation throughout economies and to train newer innovations like frontier AI models. Computing power is increasingly being viewed as a national resource to be carefully managed through, for example, hardware trade restrictions. As the critical infrastructure behind digital transformation, data centres are set to play a key role in enabling future productivity gains from digital technologies. However, data centre energy use is placing pressure on energy grids and becoming a key driver of rising costs. Policy makers need to decide if data centres should be treated and regulated like utilities.

A window of opportunity: Policy alignment for a green and digital future

Policy alignment and harnessing the potential of the digital and green twin transitions are essential to securing a future that is innovative, inclusive and sustainable. With the timeframe narrowing to avoid the most catastrophic impacts of a changing climate, leaders across all stakeholder groups and countries must share policy good practices and work together in support of a resilient future.

Promoting national policies in support of the twin transitions. Environmental considerations have gained increasing importance on policy agendas globally. Many consider climate change as the major challenge in the years ahead. Countries have launched and implemented significant roadmaps, policies and legislation to fight climate change and preserve biodiversity across the United Nations, the OECD and on a national level. Many economic recovery packages emphasise structural reforms to reduce emissions by acknowledging that "digital" and "green" policies are intertwined, and together can achieve sustainable growth (OECD, 2022[90]). The concept of the twin transitions is a key framework for policy makers to understand as countries race to achieve their sustainability targets in the crucial few decades ahead (Muench et al., 2022[11]).

Standardising the measurement of environmental impacts of digital technologies. Measurement of the environmental impacts of digital technologies is limited by a lack of common terminology, recognised standards, and varying or optional reporting requirements. Specific standards and policies are underdeveloped compared to other environmental, social and governance reporting requirements (OECD, 2022[20]). Harmonised indicators across countries will need to reflect a holistic understanding of the environmental impacts of digital technologies throughout their life cycle and applications. For example, the IEA recommends data centre providers collect and report sustainability data beyond energy consumption to include "embodied" life-cycle emissions from raw material extraction or end-of-life-disposal (IEA, 2023[17]). Focusing on select indicators could have unintended consequences and the compliance of such metrics could also be considered. Moving beyond measurement, the concept of "sustainability by design" calls for embedding sustainability standards and practices into the design of technological solutions from the beginning (IEEE SA, 2023[134]). Computer scientists and engineers can also work to better understand how their products and services generate various sustainability impacts in the real world (CODES, 2022[10]).

Facilitating intergovernmental co-operation to achieve climate targets. OECD legal instruments have increasingly recognised the interlinkages between digital technologies and the environment. The 2010 OECD Recommendation on Information and Communication Technologies and the Environment encourages the development of comparable indicators for the environmental impacts of ICT goods, services and applications. The 2019 OECD Recommendation on Artificial Intelligence, updated in 2024, underlines that AI systems should support beneficial outcomes for people and the planet and explicitly references environmental sustainability as a key concern. OECD countries also consider it critical to analyse the environmental impact and sustainability of communication networks. This is demonstrated by the 2021 OECD Recommendation on Broadband Connectivity, which stresses the need to minimise the negative environmental impacts of communication networks. The OECD also has an ongoing horizontal project on Net Zero+ policies to achieve climate and economic resilience in a changing world (OECD, 2023[93]), as well as a Horizontal Project on Going Digital Phase IV with a pillar focusing on "twin transitions".

Conclusion: Towards a world where digital technologies help preserve and protect the planet

The digital transformation of global economies and societies is accelerating at a rapid pace with technologies like AI, broadband and IoT shaping how people live, work and think, bringing productivity gains and improving lives. At the same time, human activity is profoundly transforming the planet, with the climate crisis endangering the natural foundations on which humanity depends. This transformation has been profound and persistent, leading scientists to make ever starker warnings. In this complex interplay between technology and sustainability, the future lies in humanity's ability to promote innovation that aligns the digital and green twin transitions, and in crafting policies that usher in a world where digital technologies not only bring economic gains but also preserve and protect the planet.

References

AD4GD (2023), *All Data 4 Green Deal - An Integrated, FAIR Approach for the Common European Data Space*, website, *https://ad4gd.eu* (accessed on 19 January 2024). [152]

Andrews, D. et al. (2021), "A circular economy for the data centre industry: Using design methods to address the challenge of whole system sustainability in a unique industrial sector", *Sustainability*, Vol. 13/11, p. 6319, *https://doi.org/10.3390/su13116319*. [67]

Arcep (2023), "Christophe Bechu, Agnès Pannier-Runacher and Jean-Noël Barrot receive the forward-looking assessment of the digital environmental footprint in 2030 and 2050, from ADEME and ARCEP", 6 March, Press Release, Arcep, Paris, *https://en.arcep.fr/news/press-releases/view/n/environment-060323.html*. [111]

Arcep (2022), "The digital environmental footprint in France: ADEME and Arcep submit their first report to the government", 19 January, Press Release, Arcep, Paris, *https://en.arcep.fr/news/press-releases/view/n/the-environment-190122.html*. [110]

Arcep (2022), "The Environment: 5G and networks' environmental footprint: Arcep engages in new work to inform the debate and identify levers of action", 14 January, Press Release, Arcep, Paris, *https://en.arcep.fr/news/press-releases/view/n/the-environment-140122.html*. [104]

Arcep (2019), "Réseaux du futur: L'empreinte carbone du numérique", *Note*, No. 5, Arcep, France, *https://www.arcep.fr/uploads/tx_gspublication/reseaux-du-futur-empreinte-carbone-numerique-juillet2019.pdf*. [103]

Badlam, J. et al. (2022), "McKinsey: The Inflation Reduction Act: Here's what's in it", 24 October, McKinsey & Company, *https://www.mckinsey.com/industries/public-sector/our-insights/the-inflation-reduction-act-heres-whats-in-it*. [157]

Bai, H. and Y. Wang (2023), "Digital power grid based on digital twin: Definition, structure and key technologies", *Energy Reports*, Vol. 8/4, pp. 390-397, *https://doi.org/10.1016/j.egyr.2022.10.328*. [95]

Baldé, C. et al. (2024), *Global E-waste Monitor 2024*, International Telecommunication Union and United Nations Institute for Training and Research, Geneva/Bonn, *https://ewastemonitor.info/wp-content/uploads/2024/03/GEM_2024_18-03_web_page_per_page_web.pdf*. [78]

Banerjee, S. et al. (2022), "What works best in promoting climate citizenship? A randomised, systematic evaluation of nudge, think, boost and nudge+", *Research Square*, *https://doi.org/10.21203/rs.3.rs-1534312/v1*. [127]

Barcham, R. (2014), *Climate and Energy Impacts of Automated Vehicles*, Goldman School of Public Policy, University of California. [121]

Barteková, E. and P. Börkey (2022), "Digitalisation for the transition to a resource efficient and circular economy", *OECD Environment Working Papers*, No. 192, OECD Publishing, Paris, *https://doi.org/10.1787/6f6d18e7-en*. [88]

Bauer et al., P. (2021), "A digital twin of Earth for the green transition", *Nature Climate Change*, Vol. 11, pp. 80-83. [87]

Benqassem, S. et al. (2021), "Digital technologies in Europe: An environmental life cycle approach", study commissioned by the European Parliamentary Group of the Greens/EFA, GreenIT.fr, December, *https://www.greenit.fr/wp-content/uploads/2021/12/EU-Study-LCA-7-DEC-EN.pdf*. [25]

Bieser et al., J. (2023), "A review of assessments of the greenhouse gas footprint and abatement potential of information and communication technology", University of Zurich, *https://www.zora.uzh.ch/id/eprint/228892/1/2023_A%20review%20of%20assessments%20of%20the%20greenhouse%20gas%20footprint%20and%20abatement%20potential%20of%20information%20and%20c.pdf*. [1]

BMK (2021), *Austria's 2030 Mobility Master Plan*, Austria Federal Ministry for Climate Action, Environment, Energy, Mobility, Innovation and Technology, Vienna, *https://www.bmk.gv.at/en/topics/mobility/mobilitymasterplan2030.html*. [153]

Bremer et al., C. (2023), "Assessing energy and climate effects of digitalization: Methodological challenges and key recommendations", nDEE Framing Paper Series, SSRN, *https://papers.ssrn.com/sol3/papers.cfm?abstract_id=4459526*. [70]

Bundesregierung (2023), "The public sector set to become a role model", 19 April, Bundesregierung, Berlin, *https://www.bundesregierung.de/breg-en/federal-government/the-energy-efficiency-act-2184958*. [140]

Casanovas, M. and A. Nghiem (1 August 2023), "Cybersecurity – Is the power system lagging behind?", IEA Commentaries, *https://www.iea.org/commentaries/cybersecurity-is-the-power-system-lagging-behind*. [92]

Central Statistics Office (2023), *Data Centres Metered Electricity Consumption 2022*, 12 June, Central Statistics Office, Cork, *https://www.cso.ie/en/releasesandpublications/ep/p-dcmec/datacentresmeteredelectricityconsumption2022/keyfindings*. [50]

Cervantes, M. et al. (2023), "Driving low-carbon innovations for climate neutrality", *OECD Science, Technology and Industry Policy Papers*, No. 143, OECD Publishing, Paris, *https://doi.org/10.1787/8e6ae16b-en*. [146]

Chancerel, P. et al. (2015), "Estimating the quantities of critical metals embedded in ICT and consumer equipment", *Resources, Conservation & Recycling*, Vol. 98, pp. 9-18, *https://www.sciencedirect.com/science/article/abs/pii/S0921344915000488*. [38]

ChatClimate (2023), *ChatClimate*, website, *https://www.chatclimate.ai* (accessed on 6 February 2024). [98]

Christian-Albrechts-Universität zu Kiel (2023), "Rasmus: Cost-efficient Ship Routing utilizing Ocean Currents", webpage, *https://www.ai.informatik.uni-kiel.de/de/projects/current-projects-2/copy_of_rasmus-ship-routing* (accessed on 13 April 2024). [119]

CODES (2022), "Action Plan for a Sustainable Planet in the Digital Age", United Nations Environment Programme, Nairobi, *https://www.unep.org/resources/report/action-plan-sustainable-planet-digital-age*. [10]

Crawford, K. (2021), *Atlas of AI*, Yale University Press, New Haven, CT, *https://yalebooks.yale.edu/book/9780300264630/atlas-of-ai*. [59]

Creutzig, F. et al. (2015), "Transport: A roadblock to climate change mitigation?", *Science*, Vol. 350/6263, pp. 911-912, *https://doi.org/10.1126/science.aac8033*. [120]

D4S (2022), *Digital Reset: Redirecting Technologies for the Deep Sustainability Transformation*, Digitalisation for Sustainability, Berlin, *https://digitalization-for-sustainability.com/digital-reset*. [133]

Danish Energy Agency (2020), *Denmark's Climate and Energy Outlook*, Danish Energy Agency, Copenhagen, *https://ens.dk/sites/ens.dk/files/Basisfremskrivning/deco_2020_27082020.pdf*. [49]

Defra (2020), "Greening government: ICT and digital services strategy 2020-2025", *Policy Paper*, UK Department for Environment, Food & Rural Affairs, London, *https://www.gov.uk/government/publications/greening-government-ict-and-digital-services-strategy-2020-2025/greening-government-ict-and-digital-services-strategy-2020-2025*. [141]

EEA (2022), *Transport and Environment Report 2022*, European Environment Agency, Copenhagen, *https://www.eea.europa.eu/publications/transport-and-environment-report-2022*. [115]

EirGrid (2021), *All-Island Generation Capacity Statement 2021-2030*, EirGrid Plc, Dublin and SONI Ltd, Belfast, *https://www.eirgridgroup.com/site-files/library/EirGrid/208281-All-Island-Generation-Capacity-Statement-LR13A.pdf*. [51]

EITO (2002), *The Impact of ICT on Sustainable Development*, European Information Technology Observatory, Madrid. [32]

Elkin, C. and D. Sanekommu (8 August 2023), "How AI is helping airlines mitigate the climate impact of contrails", Google blog, *https://blog.google/technology/ai/ai-airlines-contrails-climate-change*. [118]

Ember (2023), *Global Electricity Review 2023*, Ember, London, *https://ember-climate.org/app/uploads/2023/04/Global-Electricity-Review-2023.pdf*. [56]

Enerdata (2023), "Electricity domestic consumption", *World Energy & Climate Statistics 2023*, Enerdata, *https://yearbook.enerdata.net/electricity/electricity-domestic-consumption-data.html*. [55]

EUR-Lex (2012), *Directive 2012/19/EU of the European Parliament and of the Council of 4 July 2012 on waste electrical and electronic equipment (WEEE) (recast) Text with EEA relevance*, Eur-Lex, *http://data.europa.eu/eli/dir/2012/19/oj*. [81]

European Commission (2023), *ICT Task Force Study – Final Report*, Publications Office of the European Union, Luxembourg, *https://data.europa.eu/doi/10.2760/486253*. [22]

European Commission (2023), "Study on the critical raw materials for the EU 2023", *Final Report*, Publications Office of the European Commission, Luxembourg, *https://op.europa.eu/en/publication-detail/-/publication/57318397-fdd4-11ed-a05c-01aa75ed71a1*. [41]

European Commission (2023), "Use of NextGenerationEU Proceeds", webpage, *https://commission.europa.eu/strategy-and-policy/eu-budget/eu-borrower-investor-relations/nextgenerationeu_en#:~:text=NextGenerationEU%20is%20the%20EU's%20%E2%82%AC,digital%20and%20more%20resilient%20future* (accessed on 31 March 2024). [156]

European Parliament (2023), *Artificial Intelligence Act: Amendments adopted by the European Parliament on 14 June 2023 on the proposal for a regulation of the European Parliament and of the Council on laying down harmonised rules on artificial intelligence*, European Parliament, Strasbourg, *https://www.europarl.europa.eu/doceo/document/TA-9-2023-0236_EN.html*. [143]

European Union (2021), *Regulation (EU) 2021/241 of the European Parliament and of the Council of 12 February 2021 establishing the Recovery and Resilience Facility*, Official Journal of the European Union, *https://eur-lex.europa.eu/eli/reg/2021/241/oj*. [135]

Eurostat (2023), "Waste Statistics – Electrical and Electronic Equipment", webpage, *https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Waste_statistics_-_electrical_and_electronic_equipment#Electrical_and_electronic_equipment_.28EEE.29_put_on_the_market_and_WEEE_processed_in_the_EU* (accessed on 31 March 2024). [83]

Federal Chancellery of Switzerland (2023), *Digital Switzerland Strategy*, Federal Chancellery of Switzerland, Geneva, *https://digital.swiss/en/strategy/strategie.html#download*. [155]

Finland Ministry of Transport and Communications (2021), *Climate and Environmental Strategy for the ICT Sector*, Finland Ministry of Transport and Communications, Helsinki, *https://julkaisut.valtioneuvosto.fi/bitstream/handle/10024/162912/LVM_2021_06.pdf?sequence=1&isAllowed=y*. [138]

Finnish Government (2021), *Sustainable Growth Programme for Finland: Recovery and Resilience Plan*, Publications of the Finnish Government 2021:69, Helsinki, *https://julkaisut.valtioneuvosto.fi/bitstream/handle/10024/163363/VN_2021_69.pdf?sequence=1&isAllowed=y*. [150]

Fisher, S. (2023), "Data centers leverage cooling to heat homes", 18 January, Data Center Knowledge, *https://www.datacenterknowledge.com/power-and-cooling/data-centers-leverage-cooling-heat-homes#close-modal*. [73]

Fitri, A. (2023), "Inside the data centre moratorium movement", 29 June, Tech Monitor, *https://techmonitor.ai/technology/cloud/inside-the-data-centre-moratorium-movement*. [53]

Forti, V. et al. (2020), *The Global E-waste Monitor 2020: Quantities, flows and the circular economy potential*, United Nations University (UNU)/United Nations Institute for Training and Research (UNITAR) – co-hosted SCYCLE ProgrammeInternational Telecommunication Union (ITU) & International Solid Waste Association (ISWA), Bonn/Geneva/Rotterdam, *https://ewastemonitor.info/wp-content/uploads/2020/11/GEM_2020_def_july1_low.pdf*. [77]

Freitag, C. et al. (2021), "The real climate and transformative impact of ICT: A critique of estimates, trends, and regulations", *Patterns*, Vol. 2/9, p. 100340, *https://doi.org/10.1016/j.patter.2021.100340*. [47]

G20 (2021), *G20 Guidelines for Financing and Fostering High-Quality Broadband Connectivity for a Digital World*, Italian G20 Presidency for the G20 Infrastructure Working Group, October 2021, *http://www.g20.utoronto.ca/2021/G20-Guidelines-for-Financing-and-Fostering-High-Quality-Broadband-Connectivity-for-a-Digital-World.pdf*. [102]

Gartner (2022), "Gartner Glossary: Digital Twin", webpage, *https://www.gartner.com/en/information-technology/glossary/digital-twin* (accessed on 19 January 2024). [160]

Geng, Y., J. Sarkis and R. Bleischwitz (2023), "How to build a circular economy for rare-earth elements", *Nature*, Vol. 619/7969, pp. 248-251, *https://www.nature.com/articles/d41586-023-02153-z*. [42]

Germany Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (2020), *Digital Policy Agenda for the Environment*, Germany Federal Ministry for the Environment, Nature Conservation and Nuclear Safety, Bonn, *https://www.bmuv.de/fileadmin/Daten_BMU/Download_PDF/Digitalisierung/digitalagenda_policy_paper_en_bf.pdf*. [137]

Google Cloud (2022), "Incident Report", webpage, *https://status.cloud.google.com/incidents/fmEL9i2fArADKawkZAa2* (accessed on 19 January 2024). [54]

Government of France (2021), *Feuille de route: Numérique et environnement – faisons converger les transitions*, Government of France, Paris, *https://www.economie.gouv.fr/files/files/PDF/2021/Feuille_de_route_Numerique_Environnement_vremerciement1802.pdf?v=1663683594*. [139]

Government of Korea (2023), "Korean New Deal", 28 July, Press Release, Ministry of Industry and Finance, Seoul, *https://english.moef.go.kr/pc/selectTbPressCenterDtl.do?boardCd=N0001&seq=4948#fn_download*. [136]

Government of Mexico (2022), *General Law on Climate Change*, Government of Mexico, Mexico City, *https://www.diputados.gob.mx/LeyesBiblio/pdf/LGCC.pdf*. [151]

Green Mountain (2021), "Land-based lobster farming will use waste heat from data center", 22 June, News Release, Green Mountain, Stavanger, Norway, *https://press.greenmountain.no/pressreleases/land-based-lobster-farming-will-use-waste-heat-from-data-center-3107932*. [74]

Gupta, U. et al. (2020), "Chasing carbon: The elusive environmental footprint of computing", arXiv 2011.02839, *https://arxiv.org/pdf/2011.02839.pdf*. [37]

Hertin, F. and J. Berkhout (2001), "Impacts of information and communication technologies on environmental sustainability: Speculations and evidence", report commissioned by the OECD Directorate for Science Technology and Industry, Paris. [26]

Hilty, L. and B. Aebischer (2014), "ICT for sustainability: An emerging research field", in *Advances in Intelligent Systems and Computing, ICT Innovations for Sustainability*, Springer International Publishing, Cham, *https://doi.org/10.1007/978-3-319-09228-7_1*. [19]

Hirn, J. et al. (2022), "A deep generative artificial intelligence system to predict species coexistence patterns", *Methods in Ecology and Evolution*, Vol. 13/5, pp. 1052-1061, *https://doi.org/10.1111/2041-210X.13827*. [99]

IEA (2024), *Electricity 2024*, IEA, Paris, *https://iea.blob.core.windows.net/assets/6b2fd954-2017-408e-bf08-952fdd62118a/Electricity2024-Analysisandforecastto2026.pdf*. [48]

IEA (2023), *Critical Minerals Market Review 2023*, IEA, Paris, *https://www.iea.org/reports/critical-minerals-market-review-2023*. [39]

IEA (2023), "Data Centres and Data Transmission Networks", webpage, *https://www.iea.org/energy-system/buildings/data-centres-and-data-transmission-networks* (accessed on 19 January 2024). [17]

IEA (2023), *Energy Technology Perspectives*, IEA, Paris, *https://www.iea.org/reports/energy-technology-perspectives-2023*. [23]

IEA (2023), "Global CO2 emissions by sector, 2019–2022", *Data and Statistics*, IEA, Paris, *https://www.iea.org/data-and-statistics/charts/global-co2-emissions-by-sector-2019-2022*. [60]

IEA (2022), *World Energy Outlook 2022*, IEA, Paris, *https://www.iea.org/reports/world-energy-outlook-2022*. [69]

IEA (2021), "Global trends in Internet traffic, data centre workloads and data centre energy use, 2010-2020", *Data and Statistics*, IEA, Paris, *https://www.iea.org/data-and-statistics/charts/global-trends-in-internet-traffic-data-centre-workloads-and-data-centre-energy-use-2010-2019*. [46]

IEA (2021), *Net Zero by 2050: A Roadmap for the Global Energy Sector*, OECD Publishing, Paris, *https://doi.org/10.1787/c8328405-en*. [147]

IEEE SA (2023), "Strong sustainability by besign", webpage, *https://sagroups.ieee.org/planetpositive2030/our-work* (accessed on 22 February 2024). [134]

INSP (2023), "Tronc commun aux écoles de service public", webpage, *https://insp.gouv.fr/tronc-commun-aux-ecoles-de-service-public* (accessed on 19 January 2024). [154]

ISO (2006), "ISO 14040:2006, Environmental management — Life cycle assessment — Principles and framework", webpage, *https://www.iso.org/standard/37456.html* (accessed on 19 January 2024). [28]

ISO (2006), "ISO 14044:2006, Environmental management — Life cycle assessment — Requirements and guidelines", webpage, *https://www.iso.org/standard/38498.html* (accessed on 19 January 2024). [29]

ITF (2023), *ITF Transport Outlook 2023*, OECD Publishing, Paris, *https://doi.org/10.1787/b6cc9ad5-en*. [116]

ITU (2023), *World Telecommunication/ICT Indicators Database*, International Telecommunications Union, Geneva, *https://www.itu.int/en/ITU-D/Statistics/Pages/publications/wtid.aspx*. [14]

ITU-T (2023), *ITU/WMO/UNESCO IOC Joint Task Force to investigate the use of submarine telecommunications cables for ocean and climate monitoring and disaster warning*, webpage, *https://www.itu.int/en/ITU-T/climatechange/task-force-sc/Pages/default.aspx* (accessed on 30 March 2024). [114]

ITU-T (2018), "L.1450 : Methodologies for the assessment of the environmental impact of the information and communication technology sector", webpage, *https://www.itu.int/rec/T-REC-L.1450-201809-I/en* (accessed on 19 January 2024). [27]

Johnson, D. (2022), "Scarcity drives fabs to wastewater recycling: Boosting water recycling at fabs by up to 98 percent keeps chip production on target", 25 January, IEEE Spectrum blog, *https://spectrum.ieee.org/fabs-cut-back-water-use*. [68]

Jones, J. (2022), "450MHz network to be built out for critical infrastructure in Germany", 15 February, Smart Energy International, *https://www.smart-energy.com/smart-grid/450mhz-network-to-be-built-out-for-critical-infrastructure-in-germany*. [112]

Kaack, L. et al. (2022), "Aligning artificial intelligence with climate change mitigation", *Nature Climate Change*, Vol. 12/6, pp. 518-527, *https://doi.org/10.1038/s41558-022-01377-7*. [61]

Karnama, A., E. Haghighi and R. Vinuesa (2019), "Organic data centers: A sustainable solution for computing facilities", *Results in Engineering*, Vol. 4, p. 100063, *https://doi.org/10.1016/j.rineng.2019.100063*. [72]

Ker, D., P. Montagnier and V. Spiezia (2021), "Measuring telework in the COVID-19 pandemic", *OECD Digital Economy Papers*, No. 314, OECD Publishing, Paris, *https://doi.org/10.1787/0a76109f-en*. [132]

Kumar, A., M. Holuszko and D. Espinosa (2017), "E-waste: an overview on generation, collection, legislation and recycling practices", *Resource Conservation and Recycling*, Vol. 122, pp. 32-42, *https://doi.org/10.1016/j.resconrec.2017.01.018*. [79]

Lange, S. and T. Santarius (2020), *Smart Green World? Making Digitalization Work for Sustainability*, Routledge, Milton Park, England. [89]

Larosa, F. et al. (2023), "Halting generative AI advancements may slow down progress in climate research", *Nature*, Vol. 13, pp. 497-499, *https://www.nature.com/articles/s41558-023-01686-5*. [100]

Leavitt, M. (18 July 2022), "MosaicML ResNet Part 2: Research Deep Dive", Databricks blog, *https://www.mosaicml.com/blog/mosaic-resnet-deep-dive*. [96]

Lenninghan, M. (2021), "KPN links €1 billion credit facility to sustainability goals", 5 August, Telecoms.com, *https://telecoms.com/510827/kpn-links-e1-billion-credit-facility-to-sustainability-goals*. [105]

Li, P. et al. (2023), "Making AI less 'thirsty': Uncovering and addressing the secret water footprint of AI models", arXiv 2304.03271, *https://doi.org/10.48550/arXiv.2304.03271*. [45]

Livingstone, L. et al. (2022), "Synergies and trade-offs in the transition to a resource-efficient and circular economy", *OECD Environment Policy Papers*, No. 34, OECD Publishing, Paris, *https://doi.org/10.1787/e8bb5c6e-en*. [34]

Luo, Y. et al. (2019), "A decision support system for waste heat recovery and energy efficiency improvement in data centres", *Applied Energy*, Vol. 250, pp. 1217-1224, *https://doi.org/10.1016/j.apenergy.2019.05.029*. [2]

Maes, M. et al. (2022), "Monitoring exposure to climate-related hazards: Indicator methodology and key results", *OECD Environment Working Papers*, No. 201, OECD Publishing, Paris, *https://doi.org/10.1787/da074cb6-en*. [7]

Malmodin, J., P. Bergmark and S. Matinfar (2018), "A high-level estimate of the material footprints of the ICT and E&M sector", *ICT for Sustainability, EPiC Series in Computing*, Vol. 52, pp. 168-186, *https://doi.org/10.29007/q5fw*. [36]

McGovan, J. (2023), "Germany sets binding 2030 target for energy consumption reduction", 22 September, Clean Energy Wire, *https://www.cleanenergywire.org/news/germany-sets-binding-2030-target-energy-consumption-reduction*. [75]

Michels, L. et al. (2022), "Empowering consumers to make environmentally sustainable online shopping decisions: A digital nudging approach", *Hawaii International Conference on System Sciences Proceedings*, 4-7 January, Maui, HI. [128]

Mickoleit, A. (2010), "Greener and Smarter: ICTs, the Environment and Climate Change", *OECD Green Growth Papers*, No. 2010/1, OECD Publishing, Paris, *https://doi.org/10.1787/5k9h3635kdbt-en*. [30]

Ministry of Finance (2021), *Denmark's Recovery and Reslience Plan: Accelerating the Green Transition*, Ministry of Finance, Copenhagen, *https://en.fm.dk/media/18774/denmarks-recovery-and-resilience-plan-accelerating-the-green-transition_web.pdf*. [149]

Muench, S. et al. (2022), "Towards a green and digital future", Publications Office of the European Union, Luxembourg, *https://publications.jrc.ec.europa.eu/repository/handle/JRC129319*. [11]

Mytton, D. (2021), "Data centre water consumption", *npj Clean Water*, Vol. 4/1, *https://doi.org/10.1038/s41545-021-00101-w*. [62]

Nafkha-Tayari., W. et al. (2022), "Virtual power plants optimization issue: A comprehensive review on methods, solutions, and prospects", *Energies*, Vol. 15/10, p. 3607, *https://doi.org/10.3390/en15103607*. [91]

NOAA (2024), "2023 was the world's warmest year on record, by far", 12 January, National Ocean and Atmospheric Administration, Washington, D.C., *https://www.noaa.gov/news/2023-was-worlds-warmest-year-on-record-by-far#:~:text=Earth's%20average%20land%20and%20ocean,0.15%20of%20a%20degree%20C)*. [6]

OECD (forthcoming), *Review of Relevance of the OECD Recommendation on Information and Communication Technologies and the Environment*, OECD Publishing, Paris. [16]

OECD (2024), *Broadband Statistics* (database), *https://www.oecd.org/en/topics/sub-issues/broadband-statistics.html* (accessed on 19 January 2024). [15]

OECD (2024), "Household spending", (indicator), *https://doi.org/10.1787/b5f46047-en* (accessed on 7 March 2024). [130]

OECD (2024), *OECD Digital Economy Outlook 2024 (Volume 1): Embracing the Technology Frontier*, OECD Publishing, Paris, *https://doi.org/10.1787/a1689dc5-en*. [13]

OECD (2023), "A blueprint for building national compute capacity for artificial intelligence", *OECD Digital Economy Papers*, No. 350, OECD Publishing, Paris, *https://doi.org/10.1787/876367e3-en*. [58]

OECD (2023), "Definition of an AI System", *OECD.AI Policy Observatory*, *https://oecd.ai/en/ai-principles* (accessed on 7 March 2024). [159]

OECD (2023), *G7 Hiroshima Process on Generative Artificial Intelligence (AI): Towards a G7 Common Understanding on Generative AI*, OECD Publishing, Paris, *https://doi.org/10.1787/bf3c0c60-en*. [97]

OECD (2023), *Net Zero+: Climate and Economic Resilience in a Changing World*, OECD Publishing, Paris, *https://doi.org/10.1787/da477dda-en*. [93]

OECD (2023), *OECD Science, Technology and Innovation Outlook 2023: Enabling Transitions in Times of Disruption*, OECD Publishing, Paris, *https://doi.org/10.1787/0b55736e-en*. [148]

OECD (2023), "Population", OECD data explorer (indicator), *https://data.oecd.org/pop/population.htm* (accessed on 23 April 2024). [57]

OECD (2022), "Broadband networks of the future", *OECD Digital Economy Papers*, No. 327, OECD Publishing, Paris, *https://doi.org/10.1787/755e2d0c-en*. [90]

OECD (2022), "Building better societies through digital policy: Background paper for the CDEP Ministerial meeting", *OECD Digital Economy Papers*, No. 338, OECD Publishing, Paris, *https://doi.org/10.1787/07c3eb90-en*. [5]

OECD (2022), "Communication regulators of the future", *OECD Digital Economy Papers*, No. 333, OECD Publishing, Paris, *https://doi.org/10.1787/f02209e6-en*. [109]

OECD (2022), "Developments in spectrum management for communication services", *OECD Digital Economy Papers*, No. 332, OECD Publishing, Paris, *https://doi.org/10.1787/175e7ce5-en*. [113]

OECD (2022), *Measuring the environmental impacts of artificial intelligence compute and applications: The AI footprint*, OECD Publishing, Paris, *https://doi.org/10.1787/7babf571-en*. [20]

OECD (2022), *Recommendation of the Council on Blockchain and Other Distributed Ledger Technologies, OECD Legal/0474*, Compendium of Legal Instruments, OECD, Paris, *https://legalinstruments.oecd.org/en/instruments/OECD-LEGAL-0470*. [9]

OECD (2021), *Recommendation of the Council on Broadband Connectivity, OECD/Legal 0322*, Compendium of Legal Instruments, OECD, Paris, *https://legalinstruments.oecd.org/en/instruments/OECD-LEGAL-0322*. [101]

OECD (2019), "E-waste generated per capita", *OECD Going Digital Toolkit*, *https://goingdigital.oecd.org/en/indicator/53* (accessed on 19 January 2024). [76]

OECD (2019), *Global Material Resources Outlook to 2060: Economic Drivers and Environmental Consequences*, OECD Publishing, Paris, *https://doi.org/10.1787/9789264307452-en*. [35]

OECD (2019), *Going Digital: Shaping Policies, Improving Lives*, OECD Publishing, Paris, *https://doi.org/10.1787/9789264312012-en*. [3]

OECD (2018), "IoT measurement and applications", *OECD Digital Economy Papers*, No. 271, OECD Publishing, Paris, *https://doi.org/10.1787/35209dbf-en*. [12]

OECD (2017), "Information and communication technology (ICT)", (indicator), *https://doi.org/10.1787/04df17c2-en* (accessed on 16 March 2024). [21]

OECD (2017), *OECD Digital Economy Outlook 2017*, OECD Publishing, Paris, *https://doi.org/10.1787/9789264276284-en*. [161]

OECD (2017), *Tackling Environmental Problems with the Help of Behavioural Insights*, OECD Publishing, Paris, *https://doi.org/10.1787/9789264273887-en*. [125]

OECD (2013), "Mobile handset acquisition models", *OECD Digital Economy Papers*, No. 224, OECD Publishing, Paris, *https://doi.org/10.1787/5k43n203mlbr-en*. [144]

OECD (2012), *Case Study on Critical Metals in Mobile Devices*, 19 September, Working Party on Resource Productivity and Waste, OECD, Paris, *https://one.oecd.org/document/ENV/EPOC/WPRPW(2012)4/FINAL/en/pdf*. [145]

OECD (2010), *Recommendation of the Council on Information and Communication Technologies and the Environment*, *OECD Legal/0380*, Compendium of Legal Instruments, OECD, Paris, *https://legalinstruments.oecd.org/en/instruments/OECD-LEGAL-0380*. [4]

OECD (2007), "Information Economy – Sector definitions based on the international standard industry classification (ISIC 4)", OECD, Paris, *https://portal.oecd.org/eshare/sti/pc/Pages/Project.aspx?ProjectID=84*. [18]

OECD/ITF (2015), *Automated and Autonomous Driving*, OECD/ITF, Paris, *https://www.itf-oecd.org/sites/default/files/docs/15cpb_autonomousdriving.pdf*. [117]

OECD-FAO (2021), *OECD-FAO Agricultural Outlook 2021-2030*, OECD Publishing, Paris, *https://doi.org/10.1787/19428846-en*. [86]

One Planet Network (2023), *Rethinking, Extending, Re-using. Harnessing Digital Technologies for the Circular Economy*, One Planet Network Secretariat, UN Environment, Paris, *https://www.oneplanetnetwork.org/sites/default/files/2023-11/RETHINKING%2C%20EXTENDING%2C%20REUSING-%20HARNESSING%20DIGITAL%20TECHNOLOGIES%20FOR%20THE%20CIRCULAR%20ECONOMY%20-%205%20%281%29.pdf*. [82]

République française (2021), "LOI n° 2021-1485 du 15 novembre 2021 visant à réduire l'empreinte environnementale du numérique en France", République française, Paris, *https://www.legifrance.gouv.fr/jorf/id/JORFTEXT000044327272*. [131]

République française (2021), "LOI n° 2021-1755 du 23 décembre 2021 visant à renforcer la régulation environnementale du numérique par l'Autorité de régulation des communications électroniques, des postes et de la distribution de la presse", République française, Paris, *https://www.legifrance.gouv.fr/jorf/id/JORFTEXT000044553569#:~:text=de%20r%C3%A9gulation%20...-,LOI%20n%C2%B0%202021%2D1755%20du%2023%20d%C3%A9cembre%202021%20visant,distribution%20de%20la%20presse%20(1)*. [142]

ReUseHeat (2017), "Demo Sites: Braunschweig", webpage, *https://www.reuseheat.eu/brunswick* (accessed on 24 March 2024). [71]

Rifkin, J. (2022), *The Age of Resilience: Reimagining Existence on a Rewilding Planet*, Swift Press, London. [84]

Rivers, N. (2018), "Leveraging the Smart Grid: The Effect of Real-Time Information on Consumer Decisions", *OECD Environment Working Papers*, No. 127, OECD Publishing, Paris, *https://doi.org/10.1787/6ad4d5e3-en*. [126]

Rolnick, D. et al. (2022), "Tackling climate change with machine learning", *ACM Computing Surveys*, Vol. 55/2, pp. 1-96, *https://doi.org/10.1145/3485128*. [85]

Science Based Targets (2020), "Information and Communication Technology", webpage, *https://sciencebasedtargets.org/sectors/ict* (accessed on 10 January 2024). [33]

Siddik, M., A. Shehabi and L. Marston (2021), "The environmental footprint of data centers in the United States", *Environmental Research Letters*, Vol. 16/6, p. 064017, *https://doi.org/10.1088/1748-9326/abfba1*. [65]

Silva, O. et al. (2022), "Environmental impacts of autonomous vehicles: A review of the scientific literature", *Science of the Total Environment*, Vol. 830, *https://doi.org/10.1016/j.scitotenv.2022.154615*. [122]

Singapore Land Authority (2024), *Singapore Geospatial Master Plan*, Singapore Land Authority, *https://geospatial.sla.gov.sg/initiatives/masterplan*. [94]

Sudhakar, S., V. Sze and S. Karaman (2022), "Data centers on wheels: Emissions from computing onboard autonomous vehicles", *IEEE Micro*, Vol. 43/1, pp. 29-39, *https://doi.org/10.1109/MM.2022.3219803*. [123]

Sunstein, C. and L. Reisch (2013), "Automatically green: Behavioral economics and environmental protection", *Harvard Environmental Law Review*, Vol. 38/1, *https://doi.org/10.2139/ssrn.2245657*. [124]

Swindhoe, D. (2022), "UK and European data center colo firms face energy price "turbulence," warns FTI", 27 May, Datacentre Dynamics, *https://www.datacenterdynamics.com/en/news/uk-and-european-colo-firm-faces-energy-price-turbulence-warns-fti*. [52]

Telecom Review (2020), "KPN plans €3.5 billion fiber rollout by 2024", 26 November, Telecom Review, *https://www.telecomreview.com/index.php/articles/wholesale-and-capacity/4321-kpn-plans-3-5-billion-fiber-rollout-by-2024*. [106]

Telefónica (2021), "Telefónica issues the first sustainable hybrid bond of the telco sector, amounting to 1 Billion euros", webpage, *https://www.telefonica.com/en/web/press-office/-/telefonica-issues-the-first-sustainable-hybrid-bond-of-the-telco-sector-amounting-to-1-billion-euros* (accessed on 4 November 2021). [107]

Thaler, R. and C. Sunstein (2009), *NUDGE: Improving Decisions about Health, Wealth, and Happiness*, Penguin, New York. [129]

The New York Times (2021), "Taiwan is facing a drought, and it has prioritized its computer chip business over farmers", 4 April, *The New York Times*, *https://www.nytimes.com/2021/04/08/business/taiwan-is-facing-a-drought-and-it-has-prioritized-its-computer-chip-business-over-farmers.html*. [66]

Thompson, N. et al. (2020), "The computational limits of deep learning", arXiv 2007.05558, *https://doi.org/10.48550/arXiv.2007.05558*. [24]

UNCTAD (2020), "Digital economy growth and mineral resources: Implications for developing countries", *UNCTAD Technical Notes on ICT for Development*, No. 16, United Nations Conference on Trade and Development, Geneva, *https://unctad.org/system/files/official-document/tn_unctad_ict4d16_en.pdf*. [40]

United Nations (2022), *The United Nations World Water Development Report 2023*, UNESCO, Paris, *https://www.unwater.org/publications/un-world-water-development-report-2023*. [64]

Uptime Institute (2021), *Global Data Center Survey 2021*, Uptime Institute, New York, *https://uptimeinstitute.com/uptime_assets/4d10650a2a92c06a10e2c70e320498710fed2ef3b402aa82fe7946fae3887055-2021-data-center-industry-survey.pdf*. [63]

Vishwakarma, S. et al. (2022), "E-waste in information and communication technology sector: Existing scenario, management schemes and initiatives", *Environmental Technology & Innovation*, Vol. 27/9, p. 102797, *https://doi.org/10.1016/j.eti.2022.102797*. [80]

Wäger, P., R. Hischier and R. Widmer (2015), "The material basis of ICT", in *ICT Innovations for Sustainability. Advances in Intelligent Systems and Computing*, Springer, Cham. [44]

WBCSD and WRI (2004), *GHG Protocol Revised*, World Business Council for Sustainable Development, Geneva, and World Resources Institute, Washington, D.C., *https://ghgprotocol.org/sites/default/files/standards/ghg-protocol-revised.pdf*. [31]

White House (2022), *Inflation Reduction Act Guidebook*, The White House, Washington, D.C., *https://www.whitehouse.gov/cleanenergy/inflation-reduction-act-guidebook*. [158]

WIK-Consult (2020), "Neutral fibre and the European Green Deal", report commissioned by Stokab, WIK-Consult, October, *https://stokab.se/download/18.15d457b6178eff38ee02ed/1619701526100/Neutral%20fibre%20and%20the%20European%20Green%20Deal%20,%20WIK-Consult.pdf*. [108]

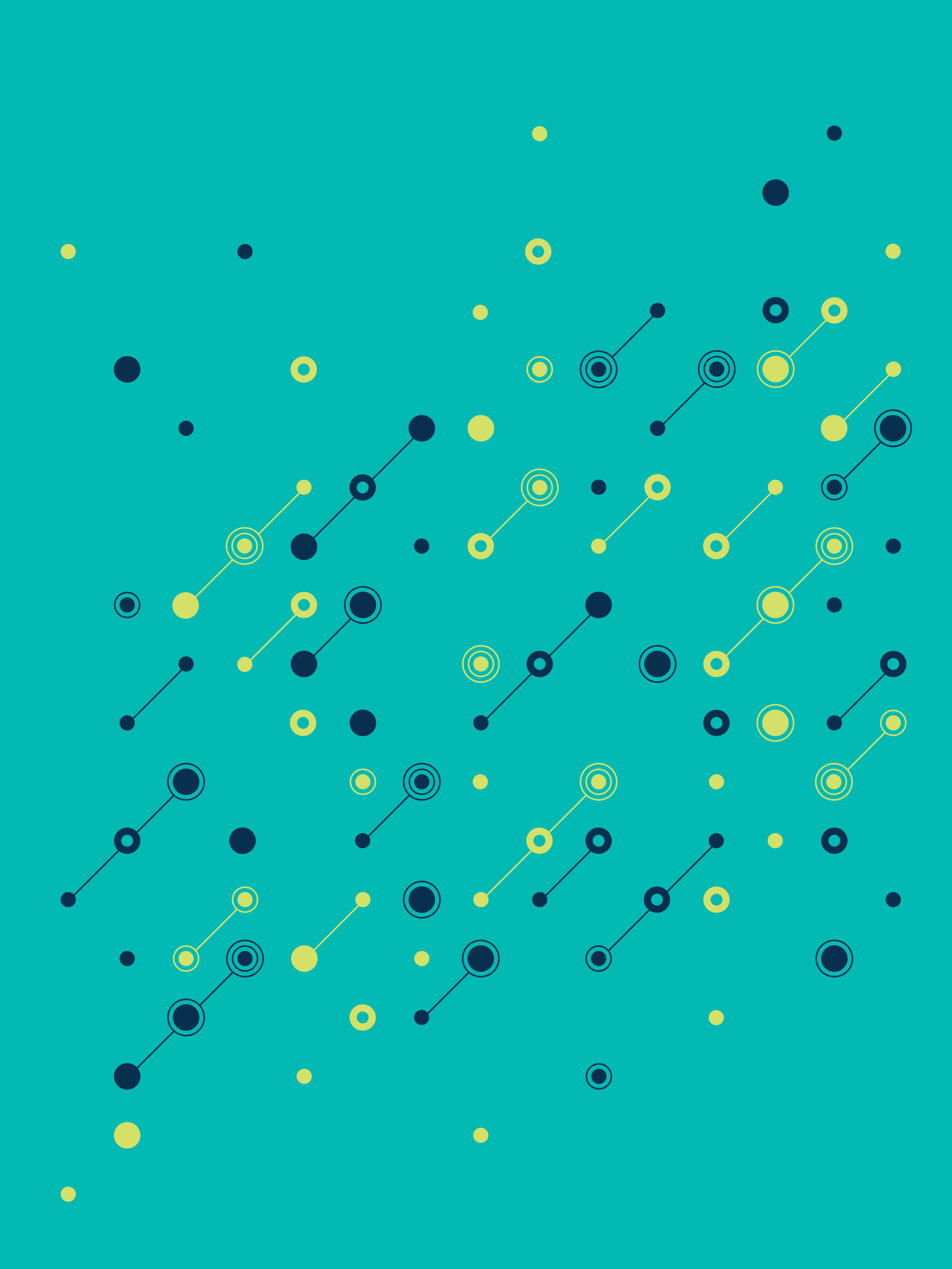
Willenbacher, M. and V. Wohlgemuth (2022), "Rebound effects in the use of rare earth metals in ICT", *International Journal of Environmental Sciences*, Vol. 30/1, p. 556277, *https://doi.org/10.19080/IJESNR.2022.30.556277*. [43]

WMO (2023), *WMO Global Annual to Decadal Climate Update – Target Years: 2022 and 2022-2026*, World Metereological Organization, Geneva, *https://library.wmo.int/idurl/4/56318*. [8]

Notes

1. Please refer to OECD ongoing work on the "Review of Relevance of the OECD Recommendation on Information and Communication Technologies and the Environment" (OECD, forthcoming[16]).
2. The OECD has an ongoing cross-directorate project on the twin "digital" and "green" transitions.
3. Indicators based on the Universal Thermal Climate Index (UTCI). The dataset provides a global assessment of changes in average temperature by providing the temperature anomaly, days with above-average temperatures and days with below-average temperatures. Extreme temperature indicators have been prepared jointly by the OECD and IEA, see the reference paper for a more complete description of the methods.
4. "The ICT sector combines manufacturing and services industries whose products primarily fulfil or enable the function of information processing and communication by electronic means, including transmission and display. The ICT sector contributes to technological progress, output and productivity growth. Its impact can be examined in several ways: directly, through its contribution to output, employment or productivity growth, or indirectly, as a source of technological change affecting other parts of the economy, for instance." (OECD, 2017[161]).

5. A digital twin is "a digital representation of a real-world entity or system. The implementation of a digital twin is an encapsulated software object or model that mirrors a unique physical object, process, organisation, person or other abstraction. Data from multiple digital twins can be aggregated for a composite view across a number of real-world entities, such as a power plant or a city, and their related processes" (Gartner, 2022[160]).
6. For the purpose of this chapter, "ICTs" and "digital technologies" are used interchangeably.
7. See OECD (2007[18]) for the full categorisation of ICT products and services. While ICTs have been a subject of measurement and study at the OECD for several decades, the terms "digital technologies" and "ICTs" are often used interchangeably as a precise definition of both terms has not been universally adopted. That said, the OECD's definition of ICTs has been instrumental in current measurement standards on the impact of ICTs and the environment, such as the efforts by the International Telecommunication Union Telecommunication Standardization Sector (ITU-T, 2018[27]). The lack of harmonised definitions can limit evidence-based analysis, especially when comparing statistics on the environmental impacts of digital technologies.
8. According to the OECD definition of an AI system, updated in late 2023, an AI system is "a machine-based system that, for explicit or implicit objectives, infers, from the input it receives, how to generate outputs such as predictions, content, recommendations, or decisions that can influence physical or virtual environments. Different AI systems vary in their levels of autonomy and adaptiveness after deployment" (OECD, 2023[159]).
9. The inclusion of certain device categories can lead to the upper bound estimates. For example, end-user devices such as smartphones and TVs make up a significant part of the ICT GHG footprint depending on methodologies and definitions used.
10. The authors refer to the continent Americas, including all countries in North, Central and South America.
11. The study identifies two scenarios based on identical traffic growth: a 4G-only network and a network that combines 4G and a 5G deployment. Initially, 5G will generate an increase in energy consumption – for a length of time that depends on different 5G rollout scenarios. After which 5G deployment will enable total energy savings of up to ten times 2020 consumption levels by 2028, compared to a scenario of 4G-only network densification, as well as a corresponding decrease of greenhouse gas (GHG) emissions of up to eight times 2020 GHG emissions. In less densely populated areas, however, where traffic density is lower, virtually non-existent gains will be seen until 2025 at the earliest, and by 2028 at the latest.
12. An exchange rate of EUR 0.876/USD for the year 2020 from OECD.stat has been used.
13. This report put forward a number of measures that decision makers should consider for achieving two main goals: i) to increase collection of mobile devices, instead of generating waste, and ii) to develop environmentally sound management (ESM) systems for waste in developing countries with large informal sectors (OECD, 2013[144]; OECD, 2012[145]).
14. An exchange rate of EUR 0.950/USD for the year 2022 from OECD.stat has been used.



Spotlight

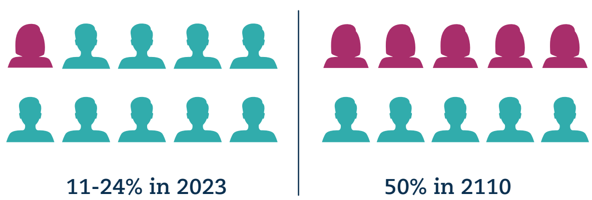
The potential of women for digital innovation

As digital transformation permeates more deeply into daily life, the equal participation of women in shaping digital transformation becomes more urgent. Women represent more than half of the global population, and an innovative and inclusive digital economy and society cannot be achieved if a significant share of society is excluded. Yet consistently and across OECD countries, women are underrepresented in information and communication technology (ICT) specialist jobs. They also contribute to significantly fewer ICT-related patents and start fewer ICT businesses. Action is needed to encourage women to develop the skills needed to work in ICT and digital-intensive sectors, nurture female entrepreneurship and help women to become ICT inventors. In so doing, policy makers can push out the digital innovation frontier, harnessing its important productivity-enhancing benefits.

Women are an untapped source of digital innovation

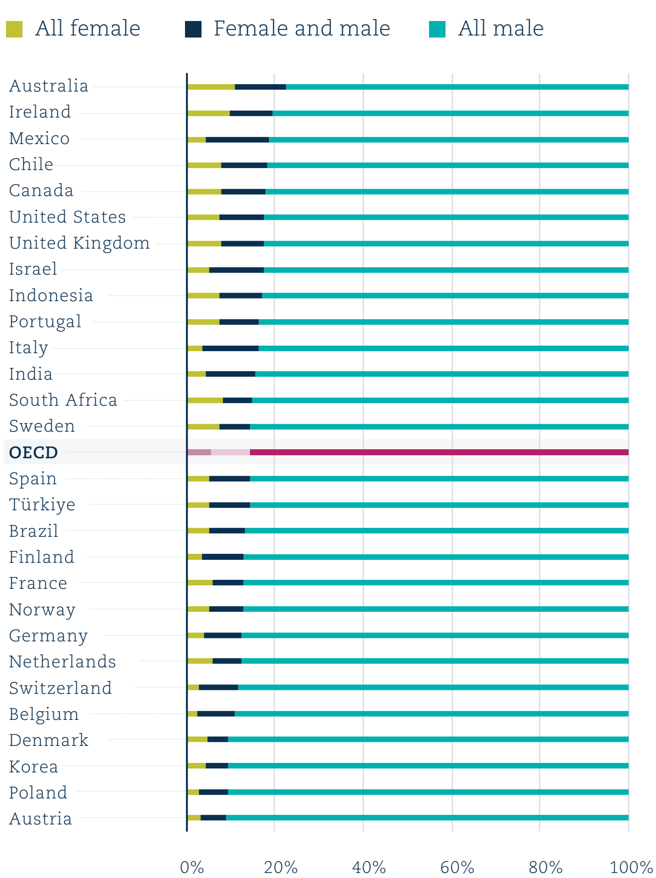
The growth of female ICT specialists outpaces men, but it will take a lifetime to reach parity.

Share of female ICT specialists in the OECD



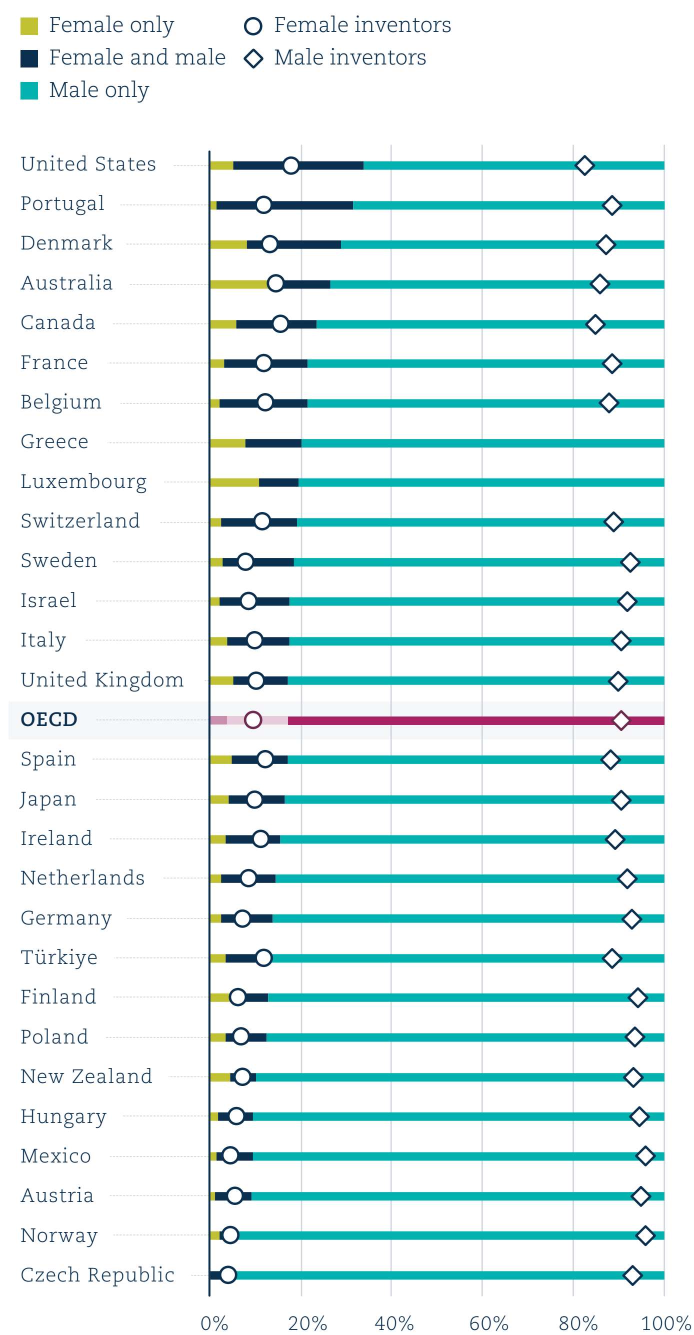
Women found fewer digital-related start-ups.

Share of VC-funded start-ups in digital-related activities with female and male founders, 2000-20



There are far more male ICT patent inventors than female ones.

Share of ICT-related IP5 patent families and inventors, by gender, 2018-21



Digital transformation provides new avenues for the empowerment of women and girls and can contribute to greater gender equality. The Internet, online platforms, mobile phones and digital financial services offer women and girls "leapfrog" opportunities to earn additional income, enhance employment prospects and access knowledge to help bridge gender divides. In turn, integrating more women and other underrepresented groups into ICT development will bring to bear the diverse perspectives needed to create a more inclusive digital future.

Significant progress has been made in the last decade in closing the gender gap in access to and use of the Internet across OECD countries (OECD, 2024[1]). The gender gap in Internet use is below 3 percentage points across almost all OECD countries. In many countries, the percentage of women using the Internet now exceeds that of men (OECD, 2024[1]). Many countries still have bigger gaps between men and women aged 55 to 74, but the differences have significantly narrowed (OECD, 2024[2]). Gender differences in the use of online activities such as interacting with the government, purchasing on line and using e-banking, among others, are also minimal.

While there is much to celebrate about the reduction of digital gender divides, the road to achieving gender equality is long. There is also always the risk that rather than helping close digital divides for women and girls, technological advances could exacerbate them. Women's participation in the development of ICT remains alarmingly low (OECD, 2024[3]). Fewer female professionals have artificial intelligence (AI) skills, and while, on average across the OECD, men contributed to about 90% of the scientific publications on AI, less than 40% were co-authored by women in 2023 (OECD, 2024[4]).

ICT skills offer opportunities for entrepreneurship and innovation, but men outnumber women among inventors and often female start-up founders receive less funding (OECD, 2023[5]; OECD, 2018[6]). Women's participation in shaping digital transformation is essential because powerful general-purpose technologies, such as AI, will have far reaching impacts. As a result, they may reinforce harmful stereotypes if women do not have a seat at the table (UNESCO/OECD/IDB, 2022[7]).

As digital transformation permeates more deeply into daily life, the equal participation of women in shaping it becomes more urgent. Women represent more than half of the global population, and an innovative and inclusive digital economy and society cannot be achieved if a significant share of society is excluded.

This Spotlight maps gender gaps and their potential causes throughout life to highlight areas of policy that might harness the full potential of women for digital innovation. In addition, it disentangles gender gaps in the digital innovation ecosystem to identify areas in which women lag, as well as opportunities for them to catch up. The Spotlight then explores how policy can support a more innovative and inclusive digital future.

Gender gaps in technical fields emerge early in life and persist throughout women's professional careers

Everyone needs a range of skills – foundational, ICT and complementary – to use digital technologies effectively in life and at work (OECD, 2019[8]). Yet gender gaps in skills are particularly troubling. Gender-based stereotypes in technical fields emerge as early as the age of six (Master, Meltzoff and Cheryan, 2021[9]) and influence education choices and career aspirations.

According to the 2022 OECD Programme for International Student Assessment (PISA) survey,[1] by the age of 15 less than 1.5% of girls on average across the OECD aspire to become ICT professionals, compared to almost 10% of boys (OECD, 2024[10]). Moreover, the percentage of girls expecting to work in the ICT sector exceeds 3% in only two countries. In contrast, the percentage of boys aiming to become ICT professionals exceeds 15% in several OECD countries. Even among the best performing students in mathematics or science in the OECD, boys are often more likely than girls to aspire to become an engineer or a scientist (OECD, 2024[10]).

Perhaps one reason for this difference is that high school boys tend to evaluate their math competences higher than girls with similar test scores (Wang and Degol, 2013[11]; Zander et al., 2020[12]). Their competency assessment is also less affected by lower grades in school (Rittmayer and Beier, 2008[13]; Zander et al., 2020[12]).

Girls' comparative advantage in reading is sometimes evoked as another potential explanation (Breda and Napp, 2019[14]). Indeed, data from the 2022 PISA survey show that 15-year-old girls significantly outperform boys in reading. Meanwhile, gender gaps in mathematics and science are on average relatively small. This small gap belies the argument that boys are biologically predisposed to mathematics and science. Girls who are competent in mathematics are likely to be even better in reading, leading to a possible diminished self-perception of numerical skills and an inclination to study humanities.

Parents have also traditionally played a role in students' educational choices and career aspirations. Responses to the 2022 PISA survey reveal that parents more frequently expect their sons rather than their daughters to pursue mathematics-related careers (OECD, 2024[10]).[2] At the same time, teachers can reinforce traditional gender stereotypes regarding the appropriate roles for men and women through conscious or unconscious biases, teaching methods, extracurricular activities or textbook choices (OECD, 2023[5]).

Gender stereotypes related to culture can also contribute to girls' belief in their inability to succeed in mathematics – so-called self-efficacy – despite comparable performance (Zander et al., 2020[12]). This belief has been shown to be a good predictor of future achievements and girls' field of study (Sakellariou and Fang, 2021[15]). Low self-confidence is reinforced by relatively better performance in other fields and the perception that such skills are innate rather than learnt. The perception of science, technology, engineering and mathematics (STEM) fields as inherently masculine is also a harmful stereotype that can become a self-fulfilling prophecy (Makarova, Aeschlimann and Herzog, 2019[16]). If girls do not choose engineering or computer science because they are perceived as "male" fields, there will be fewer female professionals. This, in turn, reinforces the image of these fields as masculine.

As girls continue their education, they are less likely to study STEM fields in tertiary education (OECD, 2024[17]). Across the OECD, on average only one-third of 2021 STEM graduates in tertiary education were women, although this headline figure masks some important differences. In almost all OECD countries, there are either more female graduates or a comparable number of men and women graduating in natural sciences, mathematics and statistics. Furthermore, nearly two-thirds of graduates in biological and related sciences are women (OECD, 2024[18]).[3] On the opposite end of the spectrum, only 22.7% of ICT degree holders in 2021 were women (OECD, 2024[17]).

Important disparities exist among OECD countries. Women represent one in three ICT graduates in Greece, Israel and Sweden, compared to one in eight in Belgium, Chile and Spain. In terms of ICT skills, more than twice as many young men than women aged 16-24 knew how to program across the European Union in 2023 (OECD, 2024[19]).[4]

Gender differences evident in education extend to the labour market. Researchers from the United States found that women's lower self-confidence contributes to lower salaries at workforce entry (Sterling et al., 2020[20]). As women leave education and enter the workforce, they tend to face higher expectations, harmful stereotypes and a toxic work culture more often than their male counterparts (OECD, 2018[6]; Paul, Sultana and Bosu, 2019[21]; Kenny and Donnelly, 2020[22]). A study run in Canada and the United States showed that men who had a strong implicit association of STEM with masculinity socialised with fewer female colleagues. Meanwhile, women with fewer male relationships reported greater career misfit and disengagement (Cyr et al., 2021[23]). Such stereotypes may have led some women to leave their STEM careers.

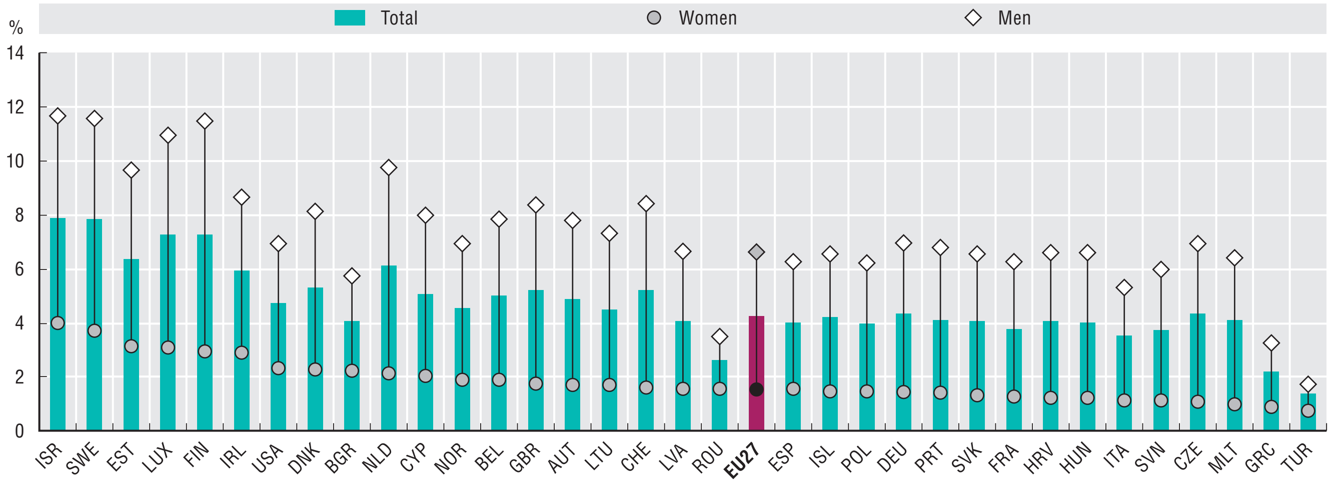
Across OECD countries, the percentage of men working as ICT specialists is three to seven times higher than the percentage of women working in such positions with the exception of Türkiye where the share is two times higher (Figure 2.S.1).[5] Gaps of a similar magnitude are evident among partner economies for which data are available (Croatia and Malta), with slightly smaller gaps in some others (Bulgaria and Romania). Countries with the highest share of ICT specialists in the total workforce, such as Israel, Estonia, Ireland and Sweden, also have the highest proportion of female ICT specialists. However, even these countries show a persistent and significant gap, with only 3-4% of women occupying those positions compared to 9-12% of men.

Overall, women represent between 11% (Czech Republic) and 24% (Israel and Estonia) of ICT specialists in the OECD countries for which data are available. Out of the entire ICT specialist workforce, 17% are women in the European Union and 23% in the United States. Women's low participation in ICT careers can be observed even in Nordic countries, which are known for higher gender equality (Corneliussen, 2021[24]). It also contributes to the gender wage gap as certain ICT specialist occupations, such as those related to artificial intelligence (AI), enjoy a substantial wage premium (OECD, 2023[25]).

The COVID-19 pandemic highlighted and accelerated the need for ICT skills across the economy; the growing number of jobs in the ICT sector could increase employment opportunities for women. In 2020, the number of female ICT specialists in the European Union increased by 12%, which is nearly twice the average annual growth in the last decade. In the same year, the growth rate of the male ICT workforce reached 4%, which corresponds to its average annual growth. The number of women working as ICT specialists is growing faster than the number of men. However, if average growth rates persist, it will take a lifetime (almost 90 years) to reach parity. Efforts to boost the number of women in the ICT sector are important, including by increasing transparency and reducing biases in recruitment.

Figure 2.S.1. Significantly more men than women are becoming ICT specialists

Proportion of ICT specialists in total employment, by gender, 2023



Note: ICT specialists correspond to International Standard Classification of Occupations 2008 (ISCO08): 133, 215, 251, 252, 351, 352 and 742.

Source: OECD (2024[3]), "Share of ICT task-intensive jobs", *OECD Going Digital Toolkit*, *https://goingdigital.oecd.org/indicator/40* (accessed on 2 July 2024).

StatLink *https://stat.link/rtxopq*

Box 2.S.1. How the (mis)perception of ICT-related jobs influences women's career paths

Goal congruity theory offers a compelling framework to help understand the origins of the relative lack of women in ICT careers (Diekman et al., 2016[26]). Goal congruity theory rests on the premise that people favour careers in alignment with their "communal goals" (e.g. altruism, helping the community and collaborating with others) and their "agentic goals" (e.g. self-fulfilment, recognition and high income). While people value both, women tend to value communal goals more and men tend to value agentic goals more (Diekman et al., 2016[26]).

ICT professionals are sometimes portrayed as antisocial, introverted and solitary (Jarreau et al., 2019[27]; Dou et al., 2020[28]). It is therefore not surprising that careers in those fields are perceived as not offering opportunities to support community projects and engage with others. The media often reinforce this stereotype, frequently portraying female scientists as lonely heroines (Kool, Azevedo and Avraamidou, 2022[29]). The misalignment between personal goals and the perception of ICT-related careers may discourage some women from STEM studies.

However, perceptions are changeable. Research shows that demonstrating the ways in which ICT-related jobs can serve communal goals could be a successful strategy to attract more women into STEM careers (Brown et al., 2015[30]). Harvey Mudd College is one of the leading undergraduate engineering programmes at non-doctorate granting institutions in the United States. It increased the number of computer science graduates from 12% to 40% in five years by emphasising real-life applications at early stages in the curriculum. This created a female community and enhanced the confidence of female students (Jivani, 2020[31]). Many non-profit organisations also attract women by promoting social challenges that can be solved with ICT-related skills, for example Girls Who Code or Engineers Without Borders (McCart, 31 August 2016[32]; Girls Who Code, 2024[33]).

Looking ahead, it is important to take steps to change the perception of ICT careers as inherently male, including by emphasising related "communal goals". For example, the ICT community could award grants for research focusing on societal challenges and foster mentorship programmes. In the workplace, connecting ICT specialists and scientists with the beneficiaries of their work could reinforce work engagement. Changing the perception of STEM fields could likewise have a positive impact on both female representation and on minorities (Davis et al., 2022[34]). Given the shortage of ICT professionals, reframing STEM fields could have a positive impact on the entire economy. Beyond scientists and engineers, recent data suggest that a similar approach emphasising societal aspects of the work could also improve representation of female entrepreneurs (Folberg et al., 2023[35]).

Women are markedly absent in the ICT innovation ecosystem

Innovation is a fundamental driver of digital transformation, pushing out the frontier of what is possible and driving job creation, productivity and sustainable growth. Digital innovation gives rise to new and novel products and services, and also creates opportunities for new business models and markets. In addition, it can drive efficiencies in the public sector and beyond.

In the digital innovation ecosystem, women represent a smaller share of researchers, inventors and entrepreneurs (OECD/European Union, 2017[36]). The total early-stage entrepreneurial activity rate varies between countries and regions. It reaches 30.2% for women in Chile (where job scarcity is the biggest driver for female entrepreneurs) compared to 2.4% in Poland (GEM, 2024[37]; GEM, 2022[38]). Women who do start businesses often face socio-cultural gender bias when raising capital (Breschi, Lassébie and Menon, 2018[39]; EIF and Invest Europe, 2023[40]).

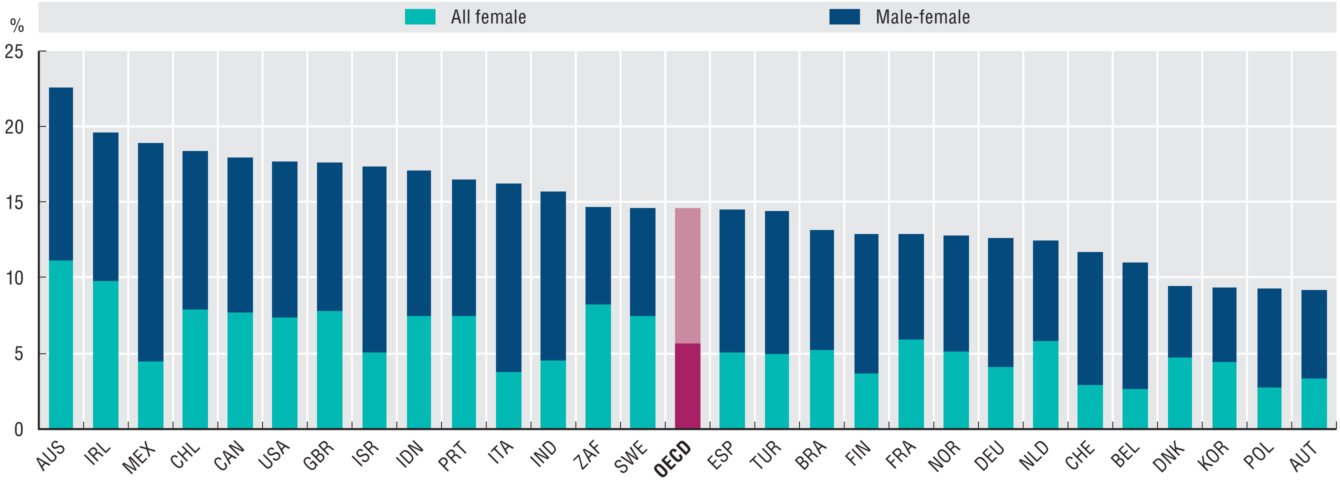
Innovation outcomes benefit from diversity through the inclusion of a variety of perspectives. Studies have shown positive effects from mixed teams on innovation performance (Dai, Byun and Ding, 2019[41]; Wikhamn and Wikhamn, 2020[42]). However, negative stereotypes, discrimination and difficulties in accessing financing, as well as weak connections to entrepreneurial networks, are key barriers to female entrepreneurship (Planes-Satorra and Paunov, 2017[43]; OECD, 2023[5]). Researchers estimate that greater participation of women and minorities in innovation could increase gross domestic product per capita in the United States by 0.6% to 4.4% (Cook, Gerson and Kuan, 2022[44]). Furthermore, closing the gender patent gap could lead to an increase of 2.5% of gross domestic product in the United States (Hunt et al., 2012[45]).

Gender differences exhibited by the fields of study of girls and boys are also evident in the entrepreneurial ecosystem. Women who start businesses are predominantly active in sectors such as education and retail. However, they are underrepresented in the ICT sector that benefits from significant venture capital (VC) interest. Data from Eurostat indicate that women across the European Union represent 18% of the self-employed in the ICT sector compared to 34% in the entire economy (Eurostat, 2024[46]). Among those self-employed with employees, the percentage of women drops to 12%. Generally, female entrepreneurs differ from their male counterparts in that they are less likely to have employees or expect their business to grow (Halabisky, 2018[47]).

VC investments are an important driver of digital innovation. However, in the last two decades, on average only 6% of VC-funded start-ups in digital-related activities were founded by women (only). Moreover, 15% were founded by at least one woman on average in OECD countries (Figure 2.S.2).[6] Australia stands out with over 11% of all-female founder teams; more than 23% of all VC-funded start-ups included at least one woman.

Figure 2.S.2. Women are founding fewer digital-related start-ups

Share of VC-funded start-ups in digital-related activities with female founders, 2000-20



Notes: The *OECD Start-up* Database combines data from Crunchbase and Dealroom, two commercial providers of firm-level data and VC deals. It contains information on start-ups founded between 2000 and 2020, their founders and investors. The database was developed following the methodology described in Greppi (2022[48]).

Source: OECD (2024[49]), "Share of VC-funded start-ups in digital-related activities with female founders", *OECD Going Digital Toolkit*, based on the OECD Start-up Database, *https://goingdigital.oecd.org/indicator/36* (accessed on 26 October 2023).

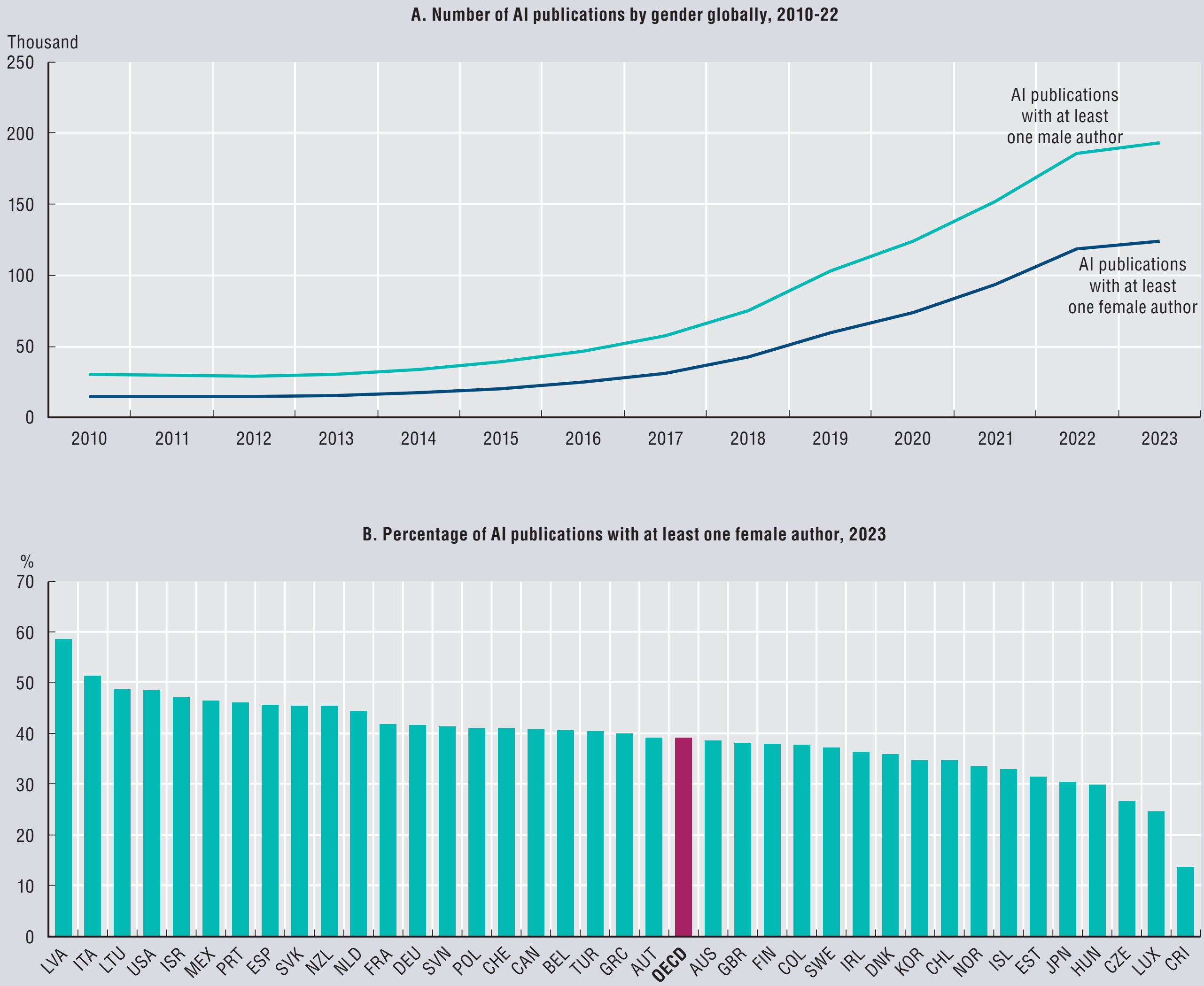
StatLink *https://stat.link/nzkdlh*

AI has been a key driver of digital innovation in recent years. AI-related start-ups have flourished in tandem, although female participation appears limited (Box 2.S.2). Researchers analysed VC investments in AI start-ups in the United Kingdom between 2012 and 2022 (Wajcman, Young and De Miguel Velazquez, 2023[50]). All-female start-ups accounted for 4.9% of all VC deals and companies with at least one female represented nearly a quarter of all deals. Of all AI start-up deals, 2.1% went to female-only start-ups and a fifth to companies with at least one female founder.

Box 2.S.2. The missing women in AI research and development

To reap the full benefits of AI, women and individuals from diverse groups must participate in its development and deployment. Although progress has been made towards greater diversity, men still dominate AI research and development. In 2023, just over one in four researchers publishing on AI worldwide was female (OECD, 2024[4]). While the number of publications in academic journals co-authored by at least one woman is increasing, in 2023, women contributed to 59% of AI publications worldwide, while over 90% listed at least one man as a co-author.

Figure 2.S.3. Women contribute to fewer AI publications than men do



Notes: Gender identification relies on name classifiers. To identify gender, Elsevier assigned a gender value only to those authors in the Scopus dataset for whom the algorithm returned a gender probability of >85%.

Source: OECD (2024[4]), "Live data: AI research", *OECD.AI Policy Observatory*, *https://oecd.ai/en/data?selectedArea=ai-research&selectedVisualization=number-of-research-publications-in-ai-by-gender-and-country* (accessed on 2 July 2024).

StatLink https://stat.link/j8dby7

Box 2.S.2. The missing women in AI research and development *(cont.)*

Even more strikingly, women are the sole authors of only 8% of AI publications, while 41% are penned by men alone worldwide. In OECD countries, women contribute to about half of all AI publications. Analysis at the country level also reveals disparities. In Latvia, 59% of AI publications are authored by at least one woman, followed by Italy, Lithuania and the United States. Conversely, in Costa Rica only 14% of AI publications are authored by at least one woman and in Luxembourg and the Czech Republic the share is only about one in four (Figure 2.S.3).[7]

AI developers who are women are an even smaller minority than AI researchers. A 2022 survey of Stack Overflow users (a popular platform for knowledge sharing among developers and computer programmers) shows that slightly over 4% of respondents are women. However, countries like Belgium, Denmark and Norway stand out for having a higher, but modest, share of female AI developers (OECD, 2024[51]).

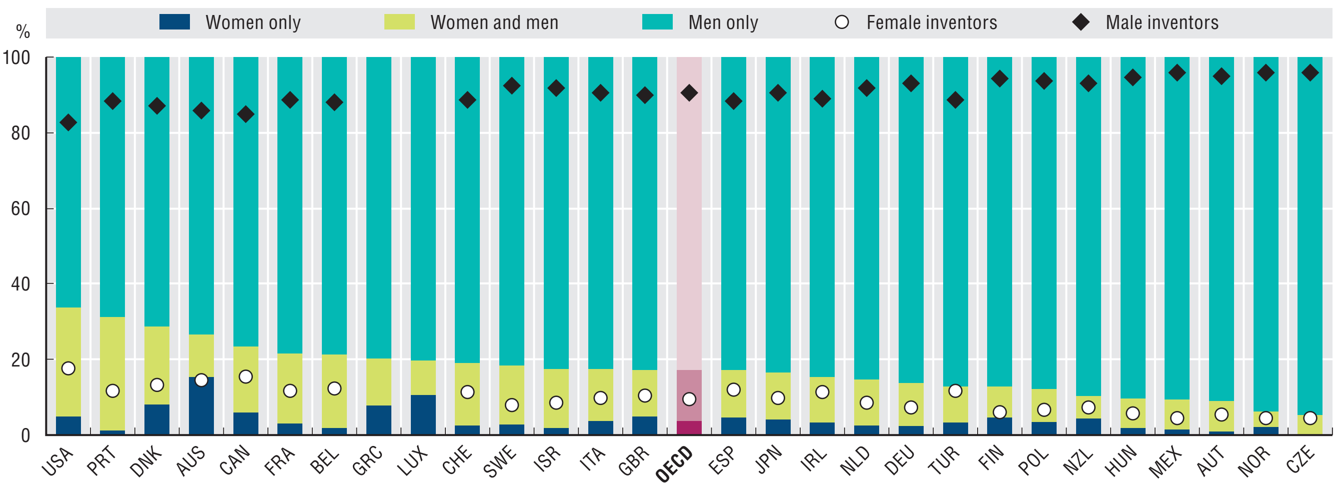
Access to finance is often an important barrier to female entrepreneurship. Findings from the United Kingdom show that AI firms with all-female founders raised on average six times less capital than firms with all-male founders. In comparison, female-founded start-ups across all fields received four times less capital. Overall, all-female teams received 0.4% of all capital invested in AI start-ups while all-male teams received nearly 80%.

Research also suggests the gender gap in VC funding could result from a quasi-absence of female investors (Balachandra, 2020[52]). Given that VC investors typically influence the culture and products of the companies in which they invest, this means relatively more male influence on new firms overall (Wajcman, Young and De Miguel Velazquez, 2023[50]). Moreover, decision makers in technology companies are mostly male, with women representing only 18% of C-suite leaders in AI companies and top start-ups worldwide in 2019 (UNU/UNU-CS/EQUALS, 2019[53]). In the United Kingdom, only 2% of VC firms and funds have a majority of female decision makers (Wajcman, Young and De Miguel Velazquez, 2023[50]).

Patents have been shown to increase the chances of VC investment and the amount of funding (Comino, Manenti and Thumm, 2019[54]). Yet women are also underrepresented among ICT inventors (Figure 2.S.4).[8] In 2021, the United States (18%) had the highest share of female ICT inventors, followed by Canada (15%). In contrast, the Czech Republic, Mexico and Norway had the lowest share of female ICT inventors (4%). For comparison, female inventors across OECD countries averaged 13%, ranging from 7% in Austria, Hungary and Slovakia to 23% in Portugal.

Figure 2.S.4. The share of male ICT patent inventors far exceeds that of their female counterparts

Share of ICT-related IP5 patent families and inventors, by gender, 2018-21



Notes: Data refer to the share of IP5 patent families in the ICT-related technologies, by earliest priority date, and to the share of woman in total inventors of IP5 patent families in the ICT-related technologies, weighted by the number of families, by earliest priority date, corrected using a three-year moving average.

Source: OECD (2024[55]), STI Micro-data Lab: Intellectual Property Statistics (database), *http://oe.cd/ipstats* (accessed on 28 June 2024).

StatLink https://stat.link/r49b2j

Between 2011 and 2021, the average percentage of female inventors in the ICT sector grew from 8% to 9%.[9] On average across the OECD, only 4% of ICT-related patent families were invented by women (only) and 20% were invented by a team including at least one woman in the period 2018-2021. In the Czech Republic, as many as 95% of patents were invented uniquely by men, while Australia had the highest share of all-female invented patents (15%).

Could discrimination be hindering female innovators? A study in the United States comparing patent grant rates of female inventors showed a lower success rate for female inventors with gender-specific names compared to female inventors with gender-neutral names. This suggested that some bias against women is introduced during patent examination (Schuster et al., 2020[56]). Moreover, female copyright registrations for machine-readable works or computer programs in the United States for 1978 to 2020 reveal that only about 13% listed female authors, one of the lowest shares of the categories analysed (United States Copyright Office, 2021[57]). In addition, research suggests that the women who succeed in receiving patents are less likely than men to reap financial rewards from intellectual property rights (Caviggioli, Colombelli and Ravetti, 2023[58]).

Towards a more innovative and inclusive digital future

National strategies, well-designed policy initiatives and targeted educational programmes can help encourage more women to pursue ICT careers and become ICT inventors. In this way, women can contribute to digital innovation and its important productivity-enhancing benefits. While a range of policies can support gender equality, this section outlines three key areas in which policy action can be particularly helpful in harnessing the potential of women for digital innovation: closing the ICT skills gap; promoting female entrepreneurship in ICT and related sectors; and catalysing female ICT innovators and inventions.

Closing the ICT skills gap

OECD countries have been successful in removing barriers to connectivity for women, and they can also empower women and girls by providing opportunities to obtain the range of skills needed to thrive in a digital world (i.e. foundational, ICT and complementary skills). In the early years, curricula must overcome gender biases and stereotypes regarding math and science. In the middle years, girls and young women should be actively encouraged to undertake STEM studies, including through publicly funded career guidance services. In later years, women should have equal access to retraining and reskilling services. Given that women often cite family responsibilities and cost as barriers to participation in adult education and training, more can be done to cover the direct and indirect costs of training, as well as ensuring the availability of flexible learning opportunities (OECD, 2023[5]). Countries are engaging in a range of innovative initiatives to boost ICT and related skills development for women and girls (Box 2.S.3).

Box 2.S.3. Innovative practices aimed at closing the ICT skills gap

Digital Pioneers in Austria

Digital Pioneers, co-funded by the Chamber of Labor Vienna and the Federation of Austrian Industries, offers women interested in STEM professions the opportunity to complete a "digital year" (Digital Pioneers, 2024[59]). The programme starts with eight weeks of basic training, where young women aged 17 to 27 acquire skills needed for a successful start in ICT and related jobs. Afterwards, these women work on projects in a partner company for at least eight months to apply what they have learnt. Graduates from the Digital Pioneers programme receive a national diploma from the respective partner company and the educational institution (e.g. Digital Campus Vorarlberg, BFI Upper Austria, BFI Tyrol) after successfully presenting their final project.

Women in Tech initiative in Luxembourg

Some countries take a whole-of-government approach to encouraging skills development for the digital age. For example, Luxembourg's Women in Tech initiative encourages a broad awareness about computer programming. In addition to promoting STEM skills for girls via the Gender4Stem, it supports the WIDE non-profit to encourage more girls and women to learn programming through girls-only coding classes. It also raises awareness among both teachers and companies. To that end, it encourages teachers to motivate girls and boys for STEM equally. With support from Digital Luxembourg, the initiative also holds workshops for companies and employers such as "How to recruit and retain women in ICT" (Digital Luxembourg, 2023[60]).

Box 2.S.3. Innovative practices aimed at closing the ICT skills gap *(cont.)*

Digital Skills for Mexican Women in the 21st Century

The *Habilidades digitales para las Mexicanas del siglo XXI* (Digital Skills for Mexican Women of the 21st Century) is a collaboration between the private sector (CISCO Networking Academy) and the Mexican Ministry of Labour and Social Provision. It aims to train Mexican women over 16 years of age in ICT and related skills (Gobierno de México, 2024[61]). It seeks to reduce the digital gender divide by promoting literacy and technological specialisation. The programme, now in its second phase, comprises eight courses that are free of charge, on line and self-study. These courses focus on basic skills (e.g. how to use a computer) to more specialised skills (e.g. how to program in Python and JavaScript).

Source: OECD *DEO 2024* Questionnaire and national sources.

Promoting female entrepreneurship in ICT and related sectors

Targeted policies can help promote female entrepreneurship, such as facilitating access to finance for new business in the ICT and other digital-intensive sectors. Other approaches include dedicated entrepreneurship centres and mentoring programmes that offer business development support tailored to female entrepreneurs. Tax incentives, grants and other forms of support can also help women start and grow businesses in ICT and digital-intensive sectors. At the same time, paid leave and flexible work arrangements are important components of supporting female entrepreneurs. However, their implementation needs to be carefully designed. For example, entitlements should not discriminate against the self-employed (Neergaard and Thrane, 2011[62]). Evidence shows that uptake of paternity leave is positively associated with female entrepreneurship (Naldi et al., 2021[63]). Countries are engaging in a range of initiatives aimed at increasing female ICT entrepreneurship and ICT innovators (Box 2.S.4).

Box 2.S.4. Innovative practices to promote female entrepreneurship in ICT and related sectors

ENISA Emprendedoras Digitales in Spain

ENISA *Emprendedoras Digitales* is dedicated to funding female digital entrepreneurship projects, with the end goal of reducing the gender gap in entrepreneurship (Enisa, 2024[64]). The initiative aims to reach the European Union's goal of facilitating the growth of scale-ups and their access to funding. It also seeks to mobilise EUR 51 million for projects managed by women entrepreneurs. Participative loans may be obtained by small and medium-sized emerging or growing companies in which one or more women hold a relevant position of leadership or power within society: in the shareholding, in the management body or as part of the management team. The loans are for a minimum of EUR 25 000 up to a maximum of EUR 1 500 000 for each beneficiary company.

Tech Undivided in Canada

As a part of Canada's Women's Entrepreneurship Strategy, Tech Undivided helps female founders of technology companies that concentrate on hardware and/or enterprise software technologies in southern Ontario to grow and scale their businesses (ventureLAB, 2024[65]). For six months, women engage in mentoring meetings and skills workshops aimed at learning how to raise capital effectively; commercialise new technology and intellectual property; attract talent; and identify (and win) new customers by "practising your pitch" at a dedicated "Investor Café". Beyond technology and business support, Tech Undivided aims to reduce unconscious bias and create an inclusive tech ecosystem that increases representation and access to capital.

Women Entrepreneurship programme in Egypt

Egypt's Women Entrepreneurship Program is designed by the Technology Innovation and Entrepreneurship Center (TIEC) to support early-stage women entrepreneurs operating in the ICT sector. This includes creating technology products or using technology to commercialise their products, such as websites, mobile applications, software programs or Internet of Things-powered platforms (Egypt, 2024[66]; MCIT, 2024[67]). The free programme seeks to train Egyptian female entrepreneurs on start-up methodologies and concepts across 27 governorates. Established in 2010, TIEC aims to drive innovation and entrepreneurship in the local ICT industry through building the capacity of enterprises and individuals, providing innovation assessment and certification services, and participating in national innovation initiatives.

Source: OECD, *DEO 2024* Questionnaire and national sources.

Catalysing female ICT inventors and inventions

ICT specialists are shaping the future with new technologies, and intangible assets (e.g. patents, organisational capital and software) play a role in promoting digital innovation. Integrating more women and other underrepresented groups into ICT development will bring to bear the diverse perspectives needed to create a more inclusive digital future. In parallel, inclusive innovation policies not only contribute to social well-being but can also lead to economic growth and job creation (Planes-Satorra and Paunov, 2017[43]). Data on patents over the lifespan of their careers show that persistent work-life inequalities introduce more barriers to women than to men in the innovation ecosystem. Countries are working to increase the number of female ICT innovators and inventions (Box 2.S.5).

Box 2.S.5. Innovative practices aimed at catalysing female inventors and inventions

European Prize for Women Innovators

The European Prize for Women Innovators is a joint initiative from the European Innovation Council and the European Institute for Innovation & Technology to promote female role models in innovation (European Innovation Council, 2024[68]). In total, nine prizes ranging from EUR 20 000 to EUR 100 000 are awarded to female founders of enterprises at least two years old from the European Union and associated countries. A specific category is dedicated to women under 35. The prize elevates breakthrough innovations that benefit people and the planet.

Empowering Women's Entrepreneurship in the United States

Empowering Women's Entrepreneurship is a community-based initiative in the United States to increase women's equity, job creation and economic prosperity through their ideas, insights and innovations under the auspices of the U.S. Patent and Trademark Office (USPTO, 2024[69]). It focuses on positive use cases from women who have achieved success, as well as resources to help women protect their intellectual property, fund their ideas and expand their professional network. It also concentrates on areas related to the ICT sector, such as AI (Larrimore, 2024[70]).

Women Scientist Scheme in India

The Department of Science and Technology in India established the Women Scientist Scheme to provide opportunities for women to re-enter the profession after a career break (Department of Science & Technology, 2024[71]). The programme is organised around three initiatives: fellowships for research in science and engineering, support for tech projects addressing societal challenges, and training in intellectual property rights with hands-on experience.

Source: National and other sources.

Gender divides exist in a range of areas – from labour markets to politics to childcare. Seen through a digital lens, gender divides are among the most marked in digital innovation. The consequences of inaction are clear – lower productivity, slower growth and increasing inequality. Action is urgently needed to close the ICT skills gap, promote female entrepreneurship, and catalyse female ICT innovators and inventions. In this way, policy makers can harness the potential of women for digital innovation.

References

Balachandra, L. (2020), "How gender biases drive venture capital decision-making: Exploring the gender funding gap", *Gender in Management: An International Journal*, Vol. 35/3, pp. 261-273, *http://dx.doi.org/10.1108/GM-11-2019-0222*. [52]

Breda, T. and C. Napp (2019), "Girls' comparative advantage in reading can largely explain the gender gap in math-related fields", *Proceedings of the National Academy of Sciences*, Vol. 116/31, pp. 15435-15440, *https://doi.org/10.1073/pnas.1905779116*. [14]

Breschi, S., J. Lassébie and C. Menon (2018), "A portrait of innovative start-ups across countries", *OECD Science, Technology and Industry Working Papers*, No. 2018/2, OECD Publishing, Paris, *https://doi.org/10.1787/f9ff02f4-en*. [39]

Brown, E. et al. (2015), "Closing the communal gap: The importance of communal affordances in science career motivation", *Journal of Applied Social Psychology*, Vol. 45/12, pp. 662-673, *https://doi.org/10.1111%2Fjasp.12327*. [30]

Caviggioli, F., A. Colombelli and C. Ravetti (2023), "Gender differences among innovators: A patent analysis of stars", *Economics of Innovation and New Technology*, Vol. 32/7, pp. 1000-1018, *https://doi.org/10.1080/10438599.2022.2065634*. [58]

Comino, S., F. Manenti and N. Thumm (2019), "The role of patents in information and communication technologies: A survey of the literature", *Journal of Economic Surveys*, Vol. 33/2, pp. 404-430, *https://doi.org/10.1111/joes.12277*. [54]

Cook, L., J. Gerson and J. Kuan (2022), "Closing the innovation gap in pink and black", *Entrepreneurship and Innovation Policy and the Economy*, Vol. 1/1, pp. 43-66, *https://www.journals.uchicago.edu/doi/pdf/10.1086/719250*. [44]

Corneliussen, H. (2021), "Unpacking the Nordic gender equality paradox in ICT research and innovation", *Feminist Encounters: A Journal of Critical Studies in Culture and Politics*, Vol. 25/5 (2), *https://www.lectitopublishing.nl/download/unpacking-the-nordic-gender-equality-paradox-in-ict-research-and-innovation-11162.pdf*. [24]

Cyr, E. et al. (2021), "Mapping social exclusion in STEM to men's implicit bias and women's career costs", *Proceedings of the National Academy of Sciences*, Vol. 118/40, *https://doi.org/10.1073/pnas.2026308118*. [23]

Dai, Y., G. Byun and F. Ding (2019), "The direct and indirect impact of gender diversity in new venture teams on innovation performance", *Entrepreneurship Theory and Practice*, Vol. 43/3, pp. 505-528, *https://journals.sagepub.com/doi/pdf/10.1177/1042258718807696*. [41]

Davis, V. et al. (2022), "Framing engineering as community activism for values-driven engineering: RFE design and development (Years 3-4)", 2022 ASEE Annual Conference & Exposition, 26-29 June, Minneapolis, MN, *https://peer.asee.org/41959*. [34]

Department of Science & Technology (2024), "Women in Science and Engineering-Kiran (WISE-Kiran)", webpage, *https://dst.gov.in/scientific-programmes/wise-kiran* (accessed on 5 March 2024). [71]

Diekman, A. et al. (2016), "A goal congruity model of role entry, engagement, and exit: Understanding communal goal processes in STEM gender gaps", *Personality and Social Psychology Review*, Vol. 21/2, pp. 142-175, *https://doi.org/10.1177/1088868316642141*. [26]

Digital Luxembourg (2023), "Women in Tech", webpage, *https://innovative-initiatives.public.lu/initiatives/women-tech* (accessed on 1 March 2024). [60]

Digital Pioneers (2024), *Digital Pioneers*, website, *https://digitalpioneers.at* (accessed on 5 March 2024). [59]

Dou, R. et al. (2020), "The effects of computer science stereotypes and interest on middle school boys' career intentions", *ACM Transactions on Computing Education (TOCE)*, Vol. 20/3, pp. 1-15, *https://doi.org/10.1145/3394964*. [28]

Egypt (2024), "ITIDA organizes new round of women entrepreneurship program", 19 August, Press Release, Information Technology Industry Development Agency, Cairo, *https://itida.gov.eg/English/PressReleases/Pages/ITIDA-Organizes-New-Round-of-Women-Entrepreneurship-Program.aspx*. [66]

EIF and Invest Europe (2023), *The VC Factor – Gender Lens*, 24 October, EIF and Invest Europe, *https://www.investeurope.eu/news/newsroom/new-invest-europe-and-eif-report-maps-european-vc-ecosystem-and-tracks-gender-diversity-in-greater-detail-than-ever/*. [40]

Enisa (2024), "Emprendedoras digitales", [Digital women entrepreneurs], webpage, *https://www.enisa.es/es/financia-tu-empresa/lineas-de-financiacion/d/emprendedoras-digitales* (accessed on 5 March 2024). [64]

European Innovation Council (2024), "European Prize for Women Innovators", webpage, *https://eic.ec.europa.eu/eic-prizes/european-prize-women-innovators-powered-eic-eit_en* (accessed on 5 March 2024). [68]

Eurostat (2024), “Self-employment by sex, age and occupation (1 000)”, *Employment and unemployment (LFS) Database*, *https://ec.europa.eu/eurostat/databrowser/view/lfsa_esgan2__custom_7960655/default/table?lang=en* (accessed on 5 March 2024). [46]

Folberg, A. et al. (2023), “Viewing entrepreneurship through a goal congruity lens: The roles of dominance and communal goal orientations in women’s and men’s venture interests”, *Frontiers in Psychology*, Vol. 14, *https://doi.org/10.3389/fpsyg.2023.1105550*. [35]

GEM (2024), *GEM 2023/2024 Global Report: 25 Years and Growing*, Global Entrepreneurship Monitor, London, *https://www.gemconsortium.org/reports/latest-global-report*. [37]

GEM (2022), *Global Entrepreneurship Monitor 2021/22 Women’s Entrepreneurship Report: From Crisis to Opportunity.*, Global Entrepreneurship Monitor, London, *https://www.gemconsortium.org/reports/womens-entrepreneurship*. [38]

Girls Who Code (2024), “What Do I Need to Know About the 2023-2024 GWC Challenge?”, webpage, *https://girlswhocode.zendesk.com/hc/en-us/articles/8783684973595-What-do-I-need-to-know-about-the-2023-2024-GWC-Challenge-* (accessed on 5 March 2024). [33]

Gobierno de México (2024), “Habilidades Digitales Para las Mexicanas del Siglo XXI”, [Digital skills for Mexican women of the 21st century], webpage, *https://www.mexicanasdigitales.mx/2aFase* (accessed on 5 March 2024). [61]

Greppi, A. (2022), “Essay in empirical economics: Intangible economy, innovative firms and institution of innovation”, Thesis, Università di Bologna, *https://amsdottorato.unibo.it/10116/1/Thesis_Greppi_final.pdf*. [48]

Grundke, R. et al. (2017), “Skills and global value chains: A characterisation”, *OECD Science, Technology and Industry Working Papers*, No. 2017, OECD Publishing, Paris, *https://doi.org/10.1787/cdb5de9b-en*. [73]

Halabisky, D. (2018), “Policy brief on women’s entrepreneurship”, *OECD SME and Entrepreneurship Papers,* No. 8, OECD Publishing, Paris, *https://doi.org/10.1787/dd2d79e7-en*. [47]

Hunt, J. et al. (2012), “Why don’t women patent?”*, Working Paper*, No. 17888, National Bureau of Economic Research, Cambridge, MA. [45]

Jarreau, P. et al. (2019), “Using selfies to challenge public stereotypes of scientists”, *PloS one*, Vol. 14/5, *https://doi.org/10.1371/journal.pone.0216625*. [27]

Jivani, A. (2020), “Gender lens to the future of work”, *Daedalus*, Vol. 149/1, pp. 134-143, *https://doi.org/10.1162/DAED_a_01778*. [31]

Kenny, E. and R. Donnelly (2020), “Navigating the gender structure in information technology: How does this affect the experiences and behaviours of women?”, *Human Relations*, Vol. 73/3, pp. 326-350, *https://journals.sagepub.com/doi/pdf/10.1177/0018726719828449*. [22]

Kool, D., N. Azevedo and L. Avraamidou (2022), “The lonely heroine: Portrayal of women scientists in films”, *Educational Media International*, Vol. 59/2, pp. 150-171, *https://doi.org/10.1080/09523987.2022.2101205*. [29]

Larrimore, L. (2024), *Artificial intelligence for all*, United States Patent and Trademark Office, Alexandria, VA, *https://www.uspto.gov/learning-and-resources/journeys-innovation/field-stories/artificial-intelligence-all* (accessed on 5 March 2024). [70]

Lax-Martinez, G., J. Raffo and K. Saito (2016), “Identifying the gender of PCT inventors”*, Economic Research Working Paper Series*, No. 33, World Intellectual Property Organization, Geneva, *https://www.wipo.int/publications/en/details.jsp?id=4125*. [74]

Makarova, E., B. Aeschlimann and W. Herzog (2019), “The gender gap in STEM fields: The impact of the gender stereotype of math and science on secondary students’ career aspirations”, *Frontiers in Education*, *https://doi.org/10.3389/feduc.2019.00060*. [16]

Master, A., A. Meltzoff and S. Cheryan (2021), “Gender stereotypes about interests start early and cause gender disparities in computer science and engineering”, *Proceedings of the National Academy of Sciences*, Vol. 118/48, *https://doi.org/10.1073/pnas.2100030118*. [9]

McCart, A. (31 August 2016), “Creating gender equality through humanitarian design”, EWB blog, *https://ewb.org.au/blog/2016/08/31/creating-gender-equality-through-humanitarian-design*. [32]

MCIT (2024), “Women Entrepreneurship Program”, webpage, *https://mcit.gov.eg/en/Innovation/Get_Inspired/Women_Entrepreneurship_Program* (accessed on 5 March 2024). [67]

Naldi, L. et al. (2021), “Gender (in)equality within the household and business start-up among mothers”, *Small Business Economics*, Vol. 56, pp. 903-918, *https://doi.org/10.1007/s11187-019-00275-1*. [63]

Neergaard, H. and C. Thrane (2011), “The Nordic welfare model: Barrier or facilitator of women’s entrepreneurship in Denmark?”, *International Journal of Gender and Entrepreneurship*, Vol. 3/2, pp. 88-104, *https://www.emerald.com/insight/content/doi/10.1108/17566261111140189/full/html*. [62]

OECD (2024), “Disparity in Internet use between men and women”, *OECD Going Digital Toolkit*, *https://goingdigital.oecd.org/indicator/57* (accessed on 5 March 2024). [1]

OECD (2024), *ICT Access and Usage Database*, *https://oe.cd/dx/ict-access-usage* (accessed on 5 March 2024). [2]

OECD (2024), *Live data: AI demographics*, *https://oecd.ai/en/data?selectedArea=ai-demographics&selectedVisualization=ai-demographics-by-gender* (accessed on 2 July 2024). [51]

OECD (2024), "Live data: AI research", *OECD.AI Policy Observatory*, *https://oecd.ai/en/data?selectedArea=ai-research&selectedVisualization=number-of-research-publications-in-ai-by-gender-and-country* (accessed on 2 July 2024). [4]

OECD (2024), "New tertiary graduates in science, technology, engineering and mathematics as a share of new graduates", *OECD Going Digital Toolkit*, *https://goingdigital.oecd.org/indicator/43* (accessed on 5 March 2024). [17]

OECD (2024), *Online Education Database*, *https://www.oecd.org/education/database.htm* (accessed on 5 March 2024). [18]

OECD (2024), *PISA 2022 Database*, *https://www.oecd.org/pisa/data/2022database* (accessed on 5 March 2024). [10]

OECD (2024), "Share of ICT task-intensive jobs", *OECD Going Digital Toolkit*, *https://goingdigital.oecd.org/indicator/40* (accessed on 2 July 2024). [3]

OECD (2024), "Share of VC-funded start-ups in digital-related activities with female founders", *OECD Going Digital Toolkit*, *https://goingdigital.oecd.org/indicator/36* (accessed on 18 November 2024). [49]

OECD (2024), *STI Micro-data Lab: Intellectual Property Statistics (database)*, *http://oe.cd/ipstats* (accessed on 27 June 2024). [55]

OECD (2024), "Women as a share of all 16-24 year-olds who can program", *OECD Going Digital Toolkit*, *https://goingdigital.oecd.org/indicator/54* (accessed on 5 March 2024). [19]

OECD (2023), *Joining Forces for Gender Equality: What is Holding us Back?*, OECD Publishing, Paris, *https://doi.org/10.1787/67d48024-en*. [5]

OECD (2023), *OECD Employment Outlook 2023: Artificial Intelligence and the Labour Market*, OECD Publishing, Paris, *https://doi.org/10.1787/08785bba-en*. [25]

OECD (2019), *Going Digital: Shaping Policies, Improving Lives*, OECD Publishing, Paris, *https://doi.org/10.1787/9789264312012-en*. [8]

OECD (2018), *Bridging the Digital Gender Divide: Include, Upskill, Innovate*, OECD, Paris, *https://www.oecd.org/digital/bridging-the-digital-gender-divide.pdf*. [6]

OECD/European Union (2017), *The Missing Entrepreneurs 2017: Policies for Inclusive Entrepreneurship*, OECD Publishing, Paris, *https://doi.org/10.1787/9789264283602-en*. [36]

Paul, R., K. Sultana and A. Bosu (2019), "Expressions of sentiments during code reviews: Male vs. female", arXiv 1812.05560, *https://arxiv.org/pdf/1812.05560.pdf*. [21]

Planes-Satorra, S. and C. Paunov (2017), "Inclusive innovation policies: Lessons from international case studies", *OECD Science, Technology and Industry Working Papers*, No. 2017/2, OECD Publishing, Paris, *https://doi.org/10.1787/a09a3a5d-en*. [43]

Rittmayer, A. and M. Beier (2008), "Overview: Self-efficacy in STEM", *SWE-AWE CASEE Overviews*, Vol. 1/3, *http://aweonline.org/arp_selfefficacy_overview_122208_002.pdf*. [13]

Sakellariou, C. and Z. Fang (2021), "Self-efficacy and interest in STEM subjects as predictors of the STEM gender gap in the US: The role of unobserved heterogeneity", *International Journal of Educational Research*, Vol. 109, *https://doi.org/10.1016/j.ijer.2021.101821*. [15]

Schleicher, A. (2019), *PISA 2018: Insights and Interpretations*, OECD Publishing, Paris, *https://www.oecd.org/pisa/PISA%202018%20Insights%20and%20Interpretations%20FINAL%20PDF.pdf*. [72]

Schuster, M. et al. (2020), "An empirical study of patent grant rates as a function of race and gender", *American Business Law Journal*, Vol. 57/2, pp. 281-319, *https://doi.org/10.1111/ablj.12159*. [56]

Sterling, A. et al. (2020), "The confidence gap predicts the gender pay gap among STEM graduates", *Proceedings of the National Academy of Sciences*, Vol. 117/48, pp. 30303-30308, *https://doi.org/10.1073/pnas.2010269117*. [20]

UNESCO/OECD/IDB (2022), *The Effects of AI on the Working Lives of Women*, UNESCO, Paris, *https://doi.org/10.1787/14e9b92c-en*. [7]

United States Copyright Office (2021), *Women in the Copyright System: An Analysis of Women Authors in Copyright Registrations from 1978 to 2020*, United States Copyright Office, Washington, D.C., *https://www.copyright.gov/policy/women-in-copyright-system/Women-in-the-Copyright-System.pdf*. [57]

UNU/UNU-CS/EQUALS (2019), *Taking Stock: Data and Evidence on Gender Equality in Digital Access, Skills and Leadership*, United Nations University, United Nations University Institute on Computer and Society/Intenational Telecommunication Union, Macao, *https://i.unu.edu/media/cs.unu.edu/attachment/4040/EQUALS-Research-Report-2019.pdf*. [53]

USPTO (2024), "Learn about WE", webpage, *https://www.uspto.gov/initiatives/we/learn-about-we* (accessed on 5 March 2024). [69]

ventureLAB (2024), "Introducing the New Tech Undivided cohort", 22 June, ventureLAB, Markham, Canada, *https://www.venturelab.ca/news/introducing-the-new-tech-undivided-cohort* (accessed on 5 March 2024). [65]

Wajcman, J., E. Young and J. De Miguel Velazquez (2023), *Rebalancing Innovation: Women, AI and Venture Capital in the UK*, The Alan Turing Institute, London, United Kingdom, *https://www.turing.ac.uk/sites/default/files/2023-10/rebalancing_innovation_-_women_ai_and_venture_capital_in_the_uk.pdf*. [50]

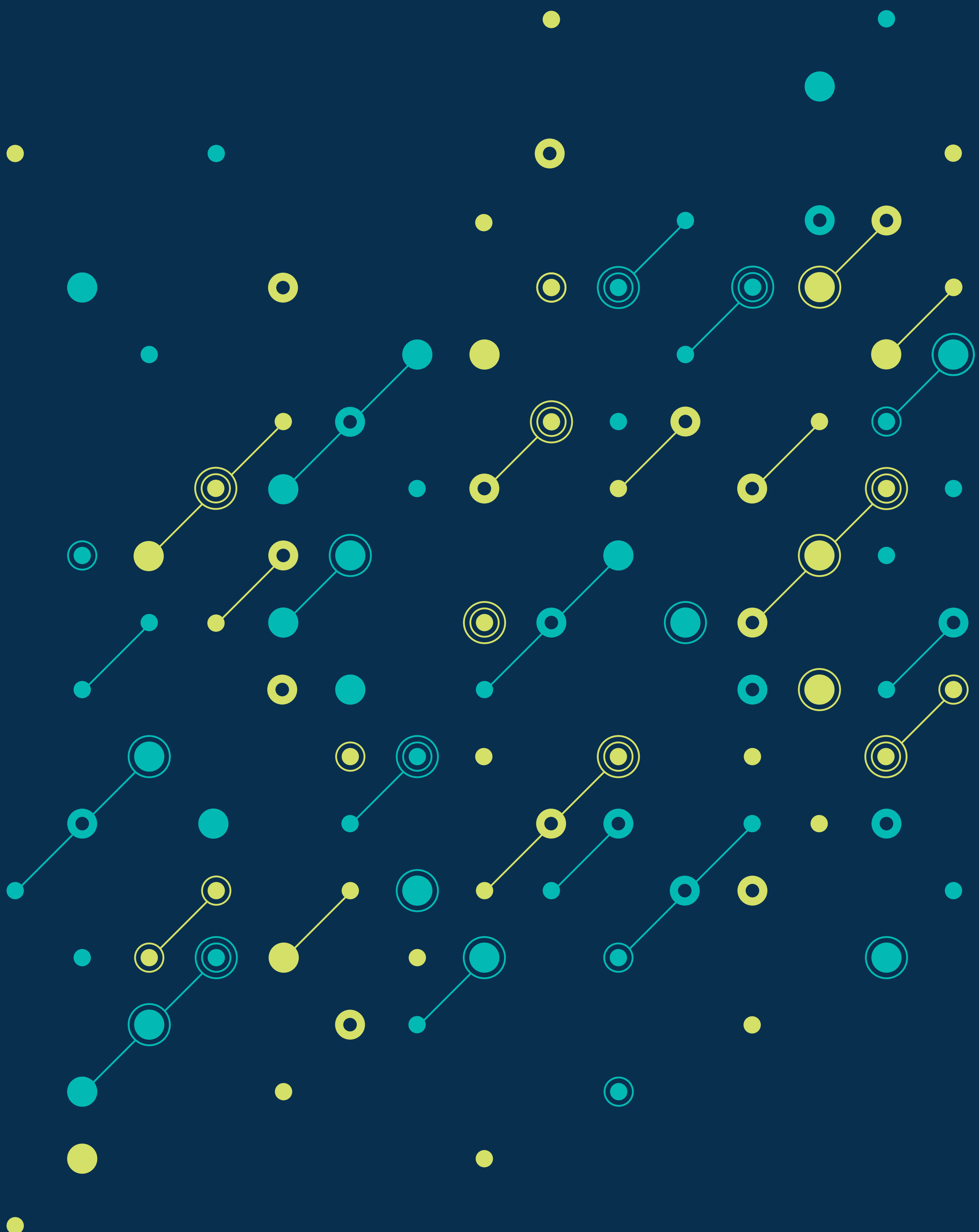
Wang, M. and J. Degol (2013), "Motivational pathways to STEM career choices: Using expectancy–value perspective to understand individual and gender differences in STEM fields", *Developmental Review*, Vol. 33/4, pp. 304-340, *https://doi.org/10.1016/j.dr.2013.08.001*. [11]

Wikhamn, W. and B. Wikhamn (2020), "Gender diversity and innovation performance: Evidence from R&D workforce in Sweden", *International Journal of Innovation Management*, Vol. 24/07, *https://biopen.bi.no/bi-xmlui/bitstream/handle/11250/2719034/Wikhamn_Wikhamn_2019.pdf*. [42]

Zander, L. et al. (2020), "When grades are high but self-efficacy is low: Unpacking the confidence gap between girls and boys in mathematics", *Frontiers in Psychology*, Vol. 11, *https://doi.org/10.3389/fpsyg.2020.552355*. [12]

Notes

1. The 2022 PISA survey covers 81 countries and economies.
2. Only 17 countries and economies administered a Parent Questionnaire to the parents of the students participating in PISA 2022.
3. Data are unavailable for Estonia, Greece, Japan, Lithuania and Mexico.
4. These data come from a perception survey, and as such may partially reflect low self-confidence among the young women surveyed.
5. ICT specialists correspond to International Standard Classification of Occupations 2008 (ISCO08): 133, 215, 251, 252, 351, 352 and 742. The occupations are identified using factor analysis of the frequency of ICT tasks in different occupations based on data from the OECD Survey of Adult Skills, see (Grundke et al., 2017[73]). This survey is representative of the population aged between 16 and 65 in participating countries, see: *www.oecd.org/skills/piaac*. For Israel, data are from 2022. For the United Kingdom, data are from 2019.
6. The digital-related activities regroup start-ups classified in apps, AI, data and analytics, information technology, Internet services, messaging and telecommunications, platforms, software, enterprise software, fintech, robotics and semiconductors. The following threshold has been applied to select countries: more than 100 VC-funded start-ups with information of founders' gender and at least 40% of VC-funded start-ups with information on gender. The OECD average does not include Colombia, Costa Rica, the Czech Republic, Estonia, Greece, Hungary, Iceland, Japan, Latvia, Lithuania, Luxembourg, New Zealand, the Slovak Republic and Slovenia.
7. Publications with both male and female co-authors are double counted.
8. Inventors' gender was identified using a gender-name dictionary (first names by country), following the methodology described in (Lax-Martinez, Raffo and Saito, 2016[74]). IP5 patent families are patents filed in at least two offices worldwide, one of which being any of the five largest IP offices: the European Patent Office, the Japan Patent Office, the Korean Intellectual Property Office, the US Patent and Trademark Office and the National Intellectual Property Administration of the People's Republic of China. Data for 2020 and 2021 are estimates based on available data for those years. The following threshold has been applied to select countries for the share of inventors: more than 50 inventors per year and more than 60% of inventors' names are matched to gender. The following threshold has been applied to select countries for the share of patent families: more than 50 IP5 patent families per three-year period and more than 70% of patents with all inventors matched to gender. The OECD average of the share of inventors does not include Chile, Colombia, Costa Rica, Estonia, Greece, Iceland, Korea, Latvia, Lithuania, Luxembourg, the Slovak Republic and Slovenia. The OECD average of the share of patents does not include Chile, Colombia, Costa Rica, Estonia, Iceland, Korea, Latvia, Lithuania, Luxembourg, the Slovak Republic and Slovenia. For the share of patent families, data for Mexico, New Zealand and Portugal are for 2017-20. Data for Türkiye are for 2015-18. Data for Luxembourg are for 2014-17.
9. The OECD average does not include Chile, Colombia, Costa Rica, Estonia, Greece, Iceland, Korea, Latvia, Lithuania, Luxembourg, the Slovak Republic and Slovenia. For Mexico, data are from 2014 and 2020. For Portugal, data are for 2010 and 2021. For Türkiye, data are for 2011 and 2020.

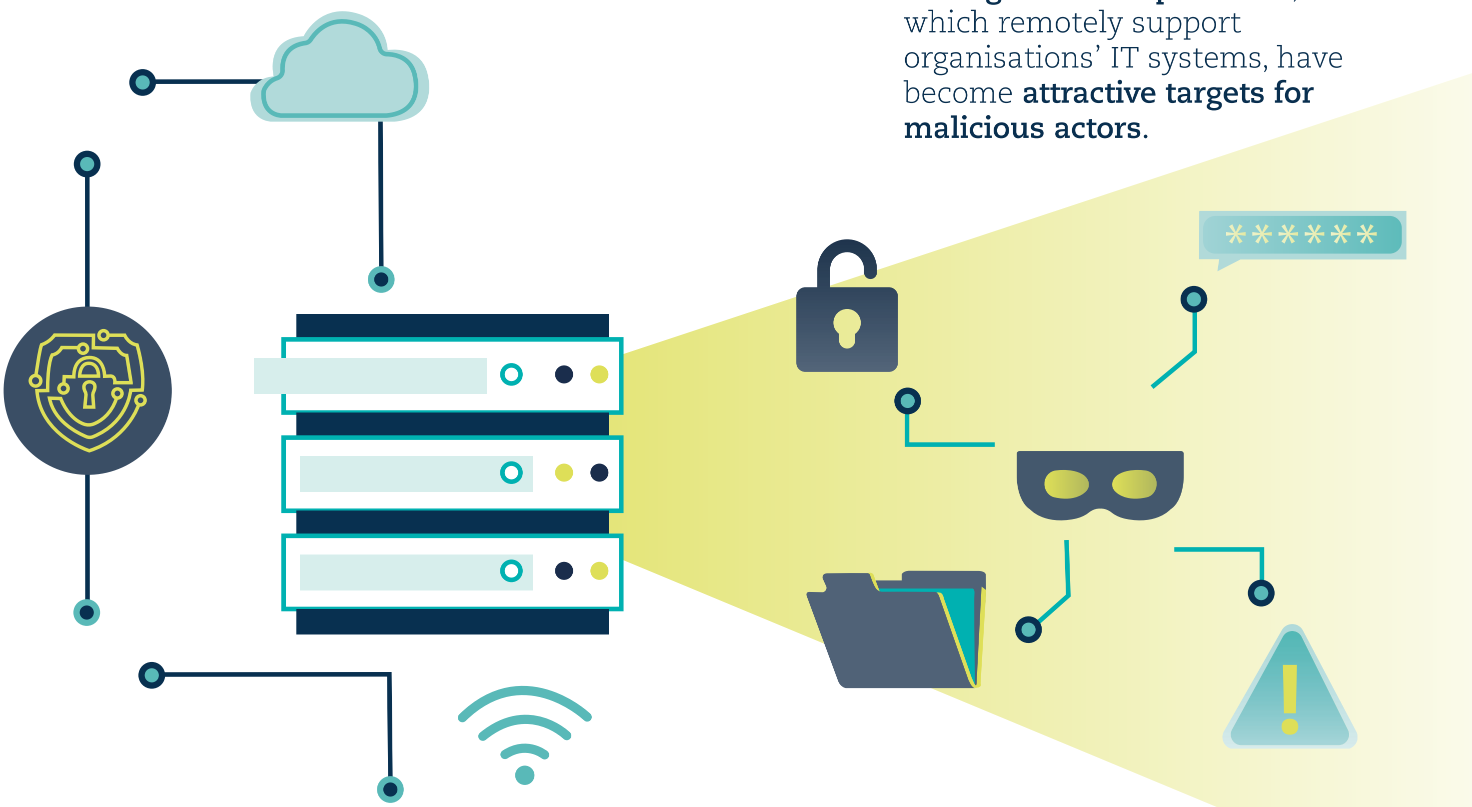


Chapter 4

Key trends in digital security

Digital security is a critical enabler of digital transformation and the global economy, which increasingly depends on digital products and services. Despite advancements in digital security policies, many challenges to reducing digital security risk remain. This chapter outlines one of the policy responses to those challenges – the growing use of security labelling and certification programmes for products and services. It also explains why managed service providers have become one of the main security targets in the supply chain. Finally, it unpacks the digital security implications of evolutions in cryptography and quantum computing.

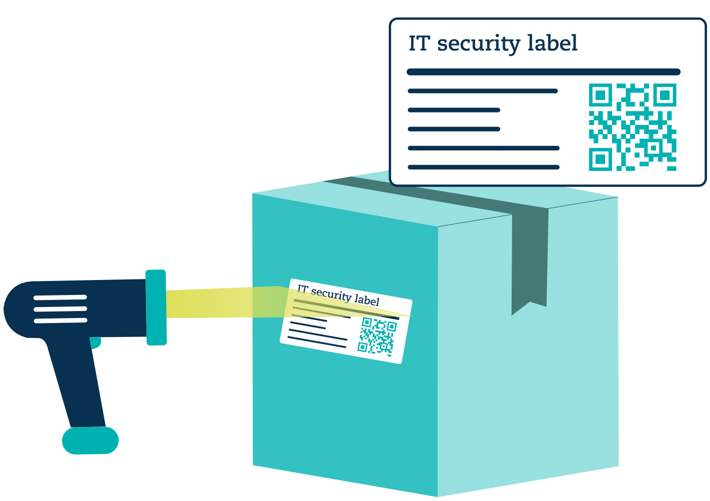
Governments are adapting digital security measures to tackle emerging risks



Managed service providers, which remotely support organisations' IT systems, have become **attractive targets for malicious actors**.

Certifications and labels can boost the **digital security** of **products and services**, helping consumers choose **safer options**.

Quantum technologies may offer **powerful new encryption methods** but may also **threaten existing cryptography**. Recent algorithms can help resist quantum computer attacks.



Key findings

Labels and certifications are complementary tools to improve market transparency and trust

- Certification can provide a basis for increasing trust but on its own is unlikely to influence purchasing decisions.
- Combining certification with easily identifiable labels could help better inform users' purchasing decisions. However, fragmented and divergent approaches to labelling and certification may create confusion and thus reduce their potential utility.

Managed service providers (MSPs) represent a global systemic risk in the supply chain

- MSPs deliver, operate or manage information and communication technology services and functions for their customers, and are a critical part of the supply chain. However, because they have access to their customers' infrastructures and networks, MSPs are attractive targets for malicious actors.
- MSPs can become the weakest point in the chain of security, leading to massive downstream incidents.

Homomorphic encryption and quantum technologies have the potential to disrupt cryptography

- Fully homomorphic encryption (FHE) can improve digital security by allowing software operations to run directly on data that remain encrypted, eliminating the risk of unencrypted data leaking during or after computation. However, computing power, energy and other constraints still limit the development of FHE.
- Quantum information technologies have potential to easily break some widely used encryption methods. Consequently, they are expected to have a disruptive effect on cryptography, and thus on digital security. However, recent progress is boosting development of defences via algorithms that could resist attacks powered by a quantum computer.

As the dependency of economies and societies on digital technologies and data increases, so does digital security risk. In response, governments are stepping up efforts to strengthen cybersecurity. More than two decades ago, governments began encouraging stakeholders such as businesses to adopt better risk management practices. They typically emphasised strategic priorities, such as the establishment of an appropriate institutional framework with clear responsibilities for cybersecurity policy making. They also focused policy efforts on operational support (e.g. through the establishment of a national incident response capacity). Today, most OECD members have an institutional cybersecurity framework.

Government priorities also included measures to enhance the digital security of critical activities such as the delivery of financial, energy, transportation and health services. Such measures stand at the intersection of digital security and critical infrastructure protection policies, generating significant national security implications. As such, they raise complex institutional challenges, which means they can take time to develop and implement.

Governments continue to improve and expand cybersecurity frameworks to further reduce digital security risk in an environment of growing threats and geopolitical tension. This chapter outlines some new digital security areas where governments are placing more policy attention than in the past.

Trends in certification and labelling for digital security

Policy makers are increasingly considering certification and labels to promote the digital security of products and services

Connected products and services have become an integral part of daily life in homes, businesses and infrastructure. They cross all sectors, including the most critical ones such as health, transportation and energy. While connected products and services underpin economic and social activities, they can also bring unexpected and harmful consequences in case of cyberattacks.

Digital products and services should be designed for security throughout their life cycle. While suppliers do not always meet a digital security "duty of care", poor security practices and knowledge on the users' side also heighten risk. Both factors therefore contribute to what could be considered a market failure: market forces alone do not produce adequate security by design or user awareness. Increasing market transparency and reducing information asymmetries is one approach to addressing the market failure (OECD, 2021[1]).

Certifications and labels are widely used in sectors such as food and energy to increase market transparency. Such tools reduce information asymmetries and ensure that products and services meet a certain level of quality or safety. Building on successes in other sectors, governments are increasingly developing and implementing labels and certifications for digital products and services through international and national initiatives.

European Union

The European Union launched a cybersecurity certification framework for information and communication technology (ICT) products, services and processes in 2019. The framework provides a comprehensive set of rules, technical requirements, standards and procedures that defines a mechanism to establish certification programmes throughout the EU membership. Ultimately, it seeks to harmonise both the security requirements for digital products and services, and the methodology for assessing them. Meanwhile, each member carries out its own certification process.

Three certification programmes, called "certification schemes" in the EU, are under development and defined by the European Union Agency for Cybersecurity (ENISA) (ENISA, 2019[2]). The first, known as EUCC, covers ICT security products such as firewalls, encryption devices and electronic signature devices. It also covers ICT products with inbuilt security such as routers, smartphones and bank cards. EUCC is based on an international standard called "Common Criteria" (Common Criteria, 2023[3]). The second programme, called EUCS, covers cloud services. The third one – EU5G – addresses 5G networks.

Each programme will specify the security requirements, the type of evaluation (self-assessment or third party), as well as the intended level of security assurance (basic, substantial and/or high). Implementing regulations are necessary for those programmes to enter into force in the European Union. The first implementing regulation draft for EUCC was released for comments in October 2023 (European Commission, 2023[4]).

EU cybersecurity certificates will be granted to certified ICT products, services and processes. No special EU label is foreseen. Certificates issued under the programme will be valid in all EU members for a limited duration. Extensions will be possible after a security re-assessment.

The EU cybersecurity certification framework is voluntary, but EU legislation linked to digital products and services increasingly makes use of certified products and services mandatory. Under the Network and Information Security (NIS)2 Directive, for instance, essential and important entities may need to use certified digital products, services and processes in accordance with the European certification programme (European Commission, 2022[5]).

Finland

Finland's voluntary Cybersecurity Label, created in 2019, aims to help consumers make more secure choices when purchasing IoT devices or services (Traficom, 2019[7]). The label is mainly intended for smart consumer devices that collect and transmit data such as smart TVs, smart bracelets and home routers.

The label informs end-users that a given product or service meets a defined list of "security by design" requirements. It also guarantees that certain security features are updated for the duration set by the label. In addition, the label supports the competitiveness of companies that invest in their products' security features from the outset and helps them anticipate compliance with future EU requirements on IoT security.

To earn the label, manufacturers must comply with the main security requirements defined by Traficom, the Finnish National Cyber Security Centre. These requirements are based on international IoT cybersecurity standards (ETSI, 2020[8]). A third party must verify products and services. The label, granted for a one-year period, can be renewed.

France

France's "Security Visas" (ANSSI, 2016[6]), developed in 2016, is a voluntary programme for digital security products. It aims for labels to better inform purchasers of cyber security products and services about the level of security provided. The "Security Visa" label, issued by the French national cyber security agency (ANSSI), guarantees that products and services have been thoroughly evaluated.

The programme is mainly intended for critical entities and government authorities that need to use digital security products and services. However, it also enables manufacturers to gain a competitive advantage by displaying the "Security Visa" label on their products and services. Mainstream consumer products, such as Internet of Things (IoT) devices, are outside the scope of the programme.

The French security label encompasses "certification" and "qualification" components. Both include an independent evaluation of the products and services. However, the "qualification" label, though more complete, is also longer and more costly.

The certification process applies only to digital security products such as VPNs, firewalls and chip cards. It only verifies security targets defined by the product manufacturer. A certification can be granted for one to three years.

The qualification process applies to certain digital security products such as encryption or electronic signing devices, and certain security services such as for incident response. It verifies the robustness of all the security features in those products and services. In what amounts to a recommendation from the French government, it demonstrates compliance with certain regulatory, technical and security requirements. Critical infrastructures and French government authorities must use only qualified products and services. Products and services can be qualified for a maximum of three years.

Germany

In 2019, Germany introduced a voluntary IT Security Label to help consumers obtain information on the security functionalities of IT products and services (BSI, 2021[9]). Three categories of products and services can be granted the label: routers, e-mail services, and smart consumer devices connected with other end- consumer devices, such as smart TVs, smart speakers or smart toys. It is envisioned that Germany will make the IT Security Label available for other relevant product groups, such as devices in the smart home sector.

The label is affixed to devices or product packaging and contains a short link, as well as a QR code that links to a government information page. This page displays information about the security features of the device or service and any known security vulnerabilities.

The process for earning the label is based on self-declaration without third-party validation. Manufacturers must apply to the government agency in charge of the label (BSI). They declare their product or service meets certain predefined standards, such as governmental technical guidelines, basic international standards or industry standards. It is up to the manufacturer to ensure compliance with relevant requirements. The BSI, however, can carry out random checks. The label, granted for two years, can be withdrawn at any time for violation of the manufacturer's declaration.

A separate programme in Germany certifies IT products and services used by critical infrastructures and the public sector. Under this certification, an independent evaluation checks the compliance of products and services against security requirements and standards. No specific label or marking is issued to demonstrate that a product or service has been successfully certified.

Japan

In March 2024, the Japanese Ministry of Economy, Trade and Industry (METI) published a draft policy on its IoT Product Security Conformity Assessment Scheme and opened a call for public comments that ran until 15 April 2024 (METI, 2020[10]).

The proposed programme will be voluntary and target a wide range of IoT products, including products indirectly connected to the Internet (excluding PCs, smartphones, etc.). The multi-level programme would establish security requirements to address minimum threats common to all targeted IoT products as a unified baseline (one-star level). It would also provide security requirements to address characteristics of each product category (two, three and four-star levels). METI aims to incorporate the programme into procurement requirements, including those of government agencies, critical infrastructure providers and local governments.

Under the proposal, labels would be granted for one- and two-star levels based on self-declarations of conformity by IoT product vendors. Three-star levels and above, which are intended for procurement use by government agencies, etc., require high reliability. Consequently, for such levels, labels will be granted based on a third-party evaluation by an independent test laboratory.

METI aims to start accepting self-declarations of conformity to the unified baseline criteria for all IoT products (the one-star level) and granting labels by March 2025. Discussions on the higher-level security conformance criteria to be developed per IoT product category (two-star levels and above) began in April 2024. The Information-technology Promotion Agency will operate the proposed programme.

Korea

Korea introduced security certification for IoT in 2017 to prevent security incidents and ensure the safety of various IoT products. As the security of IoT is closely linked to the safety of citizens and business, relevant laws have been updated accordingly to strengthen the security of digital products (Korea Ministry of Government Legislation, 2021[11]).

The Korean Ministry of Science and ICT co-ordinates implementation of IoT certification, and the Internet & Security Agency issues the certificates. The Korea Testing Certificate Institute and the Telecommunications Technology Association assess the technical aspects of IoT devices, including wall pads and medical devices. Once obtained, the certification is valid for three years with the possibility of a two-year extension.

Certification criteria comprise 50 items in seven areas: identification/authentication, data protection, password, software security, update, network security and hardware security (TTA, 2021[12]). They comply with international standards. Certificates come in three types: light (mandatory), basic (general) and standard (comprehensive).

In 2023, the Ministry of Science and ICT introduced the derivative model procedure as part of its certification programme to support its IoT manufacturing industry. This is expected to simplify the certification process for products with design changes that do not affect their security performance (Government of Korea, 2023[13]). In this way, the model encourages firms to release various products that meet market demands.

Türkiye

Türkiye developed a framework for certifying both domestic and foreign services and products. The framework conforms with international standards and considers the technical and functional aspects of the products, as well as secure software development criteria.

Under the Turkish Regulation on Authorisation of Participants in Public IT Service Procurement, certificates have been mandatory in IT service procurement tenders of public administrations since 2023 (Ministry of Industry and Technology, 2023[14]). The Ministry of Industry and Technology can issue three types of authorisation certificates for use in IT service procurement tenders: two for software and one for penetration testing. The certificates are for services, not products. They are granted for a one-year period and can be renewed. Selected companies get a certification document, with a number that can be verified on a government website.

Furthermore, the Cyber Security Products Testing and Certification Project was launched in 2019 to promote widespread use of reliable and mature cyber security products manufactured in Türkiye. The project involves determining criteria, testing and certifying products from various companies. Criteria for 11 product groups, mostly related to the technical functions of the products, were established with input from relevant stakeholders. The product groups comprise Firewall, SIEM, Data Loss Prevention, Vulnerability Management, Cyber Threat Intelligence, Endpoint Security (EPP-EDR), Governance Risk Compliance, Secure Messaging, Identity and Access Management, Video Conferencing and IoT products. Products tested against established criteria that pass the tests are entitled to receive a Product Conformity Certificate. The certificate is issued by a private company that is a subsidiary of several public institutions (TRtest, 2024[15]). As the initiative is not mandatory and the certificate does not have national validity, products that receive a Product Conformity Certificate are encouraged to get involved in public sector projects.

United States

In 2022, the United States launched a national cybersecurity labelling programme, the “US Cyber Trust” for IoT devices (FCC, 2023[16]). The programme, managed by the Federal Communications Commission, aims to raise consumers’ knowledge about their purchased products and incentivise manufacturers to meet higher digital security standards. The programme covers widely used consumer products, including smart refrigerators, smart microwaves, smart televisions and smart fitness trackers. Digital services are out of its scope.

The programme draws on voluntary commitments from manufacturers that have agreed to a certification programme based on cyber security criteria developed by the National Institute of Standards and Technology (NIST). These criteria include unique and strong default passwords, data protection, software updates and incident detection capabilities. Manufacturers that commit to the defined security requirements will be able to mark their products with a distinct shield logo together with a QR code that will link to a national registry of certified smart devices. The programme, which began in 2024, has been developed with the participation of several major IoT retailers.

Singapore

In 2020, as part of efforts to improve IoT security and raise overall cyber hygiene, Singapore launched the Cybersecurity Labelling Scheme for consumer smart devices (CSA, 2020[17]). This voluntary programme is managed by the Cyber Security Agency of Singapore (CSA) – the national cybersecurity agency. It provides different levels of digital security ratings to help users make informed choices about the security features of their smart devices.

The programme was introduced to cover widely used products such as Wi-Fi routers and smart home hubs. However, it has since been extended to include all categories of consumer IoT devices, such as IP cameras, smart door locks, smart lights and smart printers. Services are outside the scope of the programme.

The label on the product package indicates the level of security assurance with one to four stars, the individual ID and the QR code. The QR code directs users to the CSA website for more details, including the validity period of the label. This period, which lasts up to three years, represents how long developers will support devices with security updates.

One or two stars can be obtained through self-declaration of compliance with baseline security requirements and standards. An evaluation by an independent third-party testing laboratory is required to obtain three or four stars.

Singapore has developed international arrangements to foster recognition of certified products. It signed three separate mutual recognition agreements with Finland, Germany and the Connectivity Standards Alliance (CSA, 2022[18]).

Analysis of current labelling and certification programmes

Various countries around the globe have diverse approaches to product certification and labelling. Table 4.1 presents an overview of the labelling and certification programmes described above. Some countries, like Finland, France and Singapore, opt for combined certification and labelling. This entails the issuance of labels after a thorough certification process or some form of evaluation.

However, the scope and focus of these programmes vary significantly among nations. While Finland, Germany, Japan, Singapore and the United States concentrate on mainstream consumer devices, Korea emphasises IoT devices and mobile apps. Conversely, the European Union, France and Türkiye have distinct targets for their labelling and certification initiatives.

These programmes are voluntary. However, some jurisdictions, such as the European Union and Türkiye, are developing legislation that moves them towards potential mandatory compliance.

Interestingly, the development of these programmes predominantly occurs at the national level. Finland, France, Germany, Korea, Singapore, Türkiye and the United States lead the way for national approaches. The European Union stands out with its regional approach to labelling and certification.

The diversity of labels is striking, ranging from simple logos to comprehensive rating systems. Additional information embedded in these labels, such as QR codes linking to websites, product IDs or expiry dates, further enhances consumer transparency and awareness.

Definitions of certifications and labels can vary across sectors and countries (OECD, 2021[1]). However, the summary above demonstrates that both certifications and labels are an attractive tool for policy makers. They help increase transparency and indicate the level of digital security of products and services.

Table 4.1. Overview of current labelling and certification programmes

	Label / certification	Implementation year	Scope	Compulsory / voluntary	Type of programme	Type of label	Label or certif. duration
European Union	Certification	2019	ICT products, services and processes	Voluntary unless required by EU legislation	Regional	None	Not specified
Finland	Labels	2019	Mainstream connected products and services	Voluntary	Governmental	Simple logo	One year
France	Certification	2016	Security products and services	Voluntary	Governmental	Simple logo	From one to three years
Germany	Label	2019	Specific connected products and services	Voluntary	Governmental	Simple logo + QR code	One year
Japan	Label	2024	Mainstream connected products	Voluntary	Governmental	Rating logo + QR code	Two years
Korea	Certification	2018	IoT devices and mobile apps	Voluntary	Governmental	Simple logo	Three years
Türkiye	Certification	2019	Security products	Voluntary	Private	None	One year
	Certification	2023	Public ICT services	Mandatory	Governmental	None	Not specified
United States	Label	2024	Mainstream connected products	Voluntary	Governmental	Simple logo + QR code	Not specified
Singapore	Label following a certification process for certain products	2020	Mainstream connected products	Voluntary	Governmental	Rating logo + ID of the product + QR code	From one to three years

Certifications and labels are two separate but complementary tools to improve market transparency and trust. Both present advantages and disadvantages. Table 4.2 summarises the differences between certifications and labels.

Table 4.2. Simplified view of the differences between certifications and labels

	Certification	Label
Definition	A formal procedure that verifies whether products and services comply with predefined standards, norms or guidance.	A visual indication to signal adherence to specific norms or standards without a formal verification procedure.
Main targets	Industries, governmental administrations.	Consumers.
Pros	**Market differentiation**: competitive advantage for manufacturers and service providers. **B2B trust:** enhanced credibility and trust in B2B contexts. **Enhanced security guarantees:** involves rigorous audits or assessments. **International recognition:** certifications often rely on compliance with international standards, which can enhance international operability.	**Market differentiation**: competitive advantage for manufacturers and service providers. **B2B trust:** enhanced credibility and trust in B2B contexts. **Non-expert friendly tool**: easy for consumers to understand, aiding informed decisions without technical expertise. **Accessibility:** may be more accessible for SMEs in terms of cost and process. **Cost:** not too expensive and time-consuming to obtain and maintain.
Cons	**Limited security assurance:** security threats and vulnerabilities evolve, and certification may become outdated. Furthermore, certifications may not cover all aspects of a product's security. **Confusion**: the technicality and diversity of certifications among countries can create confusion as to their real meaning and value. **Not a non-expert friendly tool**: technical expertise is necessary to understand what certifications are and imply. **Accessibility:** might be complex and cumbersome, especially for SMEs with limited resources. **Cost:** can be expensive and time-consuming to obtain and maintain.	**Limited security assurance**: may not provide thorough assurance of digital security practices due to simplified validation mechanisms. **Confusion**: risks oversimplifying digital levels of security, potentially misguiding consumers. **Limited security guarantees:** only based on self-assessments with fewer security guarantees. **Limited international recognition**: labels do not necessarily rely on compliance with international standards, which can make it more difficult to obtain international recognition.
Pros and cons	**Liability**: might influence liability considerations in case of cybersecurity incidents.	**Liability**: might influence liability considerations in case of cybersecurity incidents.

Note: B2B = Business to business; SMEs = Small and medium-sized enterprises.

Labelling and certification programmes for digital products and services are meant to improve digital security. While each country's approach could be distinct, some baseline approaches could still be considered:

- **User-centric approach**: labels and certifications should be designed with user comprehensibility and accessibility in mind. Feedback mechanisms could gather users' views on the efficiency of certification and labelling to continually refine and enhance the mechanisms and criteria.
- **Consumer education**: awareness campaigns could enlighten consumers on the relevance of certifications and labels and what they mean.
- **Inclusion of SMEs**: more streamlined and accessible certification and labelling processes for SMEs could facilitate their adherence to digital security and could improve their competitiveness.
- **Co-operation of stakeholders**: collaboration between governments, industries, academia and other stakeholders in the digital security ecosystem could be promoted. Collaboration would enable stakeholders to share insights, challenges and solutions pertaining to certification and labelling of digital products and services.
- **Policy frameworks**: policy makers could explore mechanisms that incentivise organisations to adopt and comply with certification and labelling programmes.
- **Mutual recognition and international initiatives**: efforts towards recognition of certification and labelling arrangements or establishment of global harmonised programmes could avoid redundancy and facilitate international trade. Fragmentation increases unnecessary costs, constrains competitiveness, and reduces the reliability of certificates and the security assurances themselves.

Different security options could be considered when defining certification and labelling programmes. These include inclusion of unique and strong default passwords, data protection, software updates, incident detection capabilities, distinct shield logos or QR codes linking to a national registry of certified smart devices.

Technical advancements, such as artificial intelligence, will also surely have an impact on labelling and certification. Artificial intelligence could become part of certification and labelling processes, while automating compliance verifications. It could also provide real-time updates regarding security features, flaws and information on upcoming end-of-support or end-of-life.

One potential challenge with labelling and certification is the level of adoption as most programmes are voluntary.

While certification and labelling programmes are promising, policy makers may also decide not to use them to enhance the digital security of products and services. Instead, they may resort to a law. In 2019, the UK government considered a voluntary label for IoT security. However, a public consultation highlighted important gaps that voluntary labels may not address. Consequently, it opted for a regulatory approach through legislation passed in 2022. The law requires manufacturers of smart products, as well as businesses involved in related supply chains, to meet certain security requirements. The law, which was to come into effect in April 2024, empowers the UK government to take enforcement measures in the event of non-compliance.

Over the years, certification and labelling programmes have been developed to enhance the digital security of products and services, as well as transparency, to enable informed decision making. The main challenge now is to cope with the multiplication of programmes that apply to different types of products and services.

Managed service providers are a major target for threat actors in the supply chain

Managed service providers (MSPs) – which deliver, operate or manage ICT services and functions for customers through contracts – are critical actors in the ICT supply chain (CISA et al., 2022[19]). MSPs manage and oversee certain aspects of their clients' computer systems. The scope of their contracted services can be large, ranging from instance network management, software updates and data backup to recovery and support. MSPs can be found throughout the supply chain of many organisations of varying sizes and across sectors. They enable customers to focus on their core operations, while benefiting from enhanced IT performance and expertise. The global managed services market, valued at nearly USD 279 billion in 2022, is expected to exceed USD 400 billion in 2026 (Statista, 2023[20]). MSPs are increasingly vital to the continuity of critical infrastructure and business operations all over the world.

MSPs enjoy privileged access to their customers' infrastructures and networks. To perform their activities and meet clients' needs, MSPs rely on "remote monitoring and management" tools to monitor customers' IT systems and networks. Generally, MSPs install a software "agent" with a small footprint in their customers' information system to deploy remote monitoring management services. This agent then feeds information about the IT environment and reports back to the MSP. Such tools allow MSPs to gain insight into their client's networks in order to maintain their systems by deploying patches and updates, and to intervene without visiting their physical locations.

Because they have a direct, trusted and privileged access to their customers' networks, MSPs are attractive targets for malicious actors. With a single successful attack on a single MSP, an attacker can leverage such privileged access to breach all or many of the MSPs' customers, including those operating in critical activities and government agencies. When successful, this one-to-many attack can be remarkably effective. It can allow attackers to expand their strategy to micro, small and medium organisations that would otherwise not be worth attacking. As MSPs are pervasive across all sectors' supply chains globally, they represent a global systemic risk.

In hindsight, the so-called SolarWinds attack in 2020 was a wake-up call for the vulnerability of MSPs. While the US-based SolarWinds provided a routine update to customers' systems, attackers embedded stealthy malware in the code applied to their systems. This "supply chain attack" compromised FireEye, one of the most well-known cyber security MSPs, which was also using SolarWinds' software. It took months before these organisations realised they had been victims of one of the most important and sophisticated cyberattacks ever. Confirmed victims included the US National Institute of Health, the Cybersecurity and Infrastructure Security Agency, the Federal Aviation Administration and the Department of Justice, as well as companies such as Equifax, Cisco Systems, Microsoft, Nvidia and Palo Alto Networks. This single attack allowed malicious actors to steal vast amounts of data, ranging from military secrets to corporate intellectual property (Zetter, 2023[21]).

Supply chain attacks represent one of the most important cyber threats. According to the 2022 ENISA Threat Landscape, malicious actors have an increased interest in, and exhibit increasing capabilities for, supply chain attacks (Svetozarov Naydenov et al., 2022[22]). In 2021, ENISA identified supply chain compromises as the second most prevalent initial infection vector. In addition, supply chain attacks accounted for 17% of intrusions in 2021 compared to less than 1% in 2020 (Mandiant, 2022[23]).

In most countries, unregulated customers of MSPs reside outside critical sectors. They are primarily small or medium enterprises that lack the resources, skills and scale to carry out the service and manage the related risk themselves. Instead, they outsource the service to the MSP, without necessarily understanding the risk.

Furthermore, these customers often believe, based on the legal or contractual obligations, that when they outsource the service, they also relieve themselves of managing the associated risk. The MSP does not typically share this assumption. On the supply side, this may result in insufficient incentives for MSPs to invest in security and use security as a market differentiator (OECD, 2023[24]).

MSPs can become the weakest point in the chain of security. While most MSPs do pay attention to digital security, a misalignment of incentives can contribute to limited investments. However, when they serve large customers or customers in critical sectors, MSPs are more likely to embed better security in their service and sell products at a higher cost.

Furthermore, board members who are personally liable for security can also hold the leadership team accountable for implementing robust security that they can validate independently. These firms often have a Chief Information Security Officer and buying power, thereby strengthening MSPs' incentives to invest in digital security. Larger firms may also be better placed to shift towards a "zero trust" security model, thereby incentivising their MSPs to follow this trend as well (Box 4.1).

More specifically, managed security service providers (MSSPs) generally have a higher level of digital security due to the nature of their business. MSSPs specialise in security solutions such as intrusion detection and prevention, or firewall management. This makes them difficult but even more interesting targets for attackers, as demonstrated in the SolarWinds case that compromised FireEye.

Until the 2010s, there seemed to be a clear distinction between the MSPs focusing on providing various IT solutions, such as network management, software updates, or data backup and recovery, and the MSSPs. However, these distinctions have begun to blur in recent years. Clients are more willing to address all their IT needs with a single service provider, although MSPs may differ regarding security considerations and maturity.

Box 4.1. "Zero trust" approach: The future need-to-be security model?

Security perimeters are no longer relevant

The widespread adoption of the IoT, artificial intelligence, cloud technologies and teleworking have created a broader attack surface. This has redefined the traditional notion of security that places threats "inside" or "outside" a perimeter. Consequently, security models have increasingly shifted towards a "zero trust" approach, which would simplify security by levelling up the types of controls that organisations have to implement.

Zero trust operates under the principle of "never trust, always verify", thus assuming all connections to be potential threats

Instead of defining a perimeter and trusting anything inside while racing to block threats from the outside, "zero trust" systematically verifies permissions and trusts nothing by default. Furthermore, a "tipping and cueing" system can also help detect and address malicious actors in a system. A first layer of controls may provide low-resolution evidence about an anomaly within an infrastructure. This allows a second layer of controls to zoom-in at a higher resolution, investigate the intruder proactively and prevent it from breaching assets.

The adoption of such a "zero trust" approach and "tipping and cueing" system will take time and significant investment. However, the combination of a digitally dependent global economy, ever more sophisticated threats and geopolitical tensions calls for considering new security models.

Source: OECD (2023[24]).

MSPs are just one major actor among many in an increasingly complex and opaque supply chain. Organisations rely on a complex ecosystem of suppliers that increasingly include MSPs. In addition to offering their own services, MSPs work with other providers such as cloud services or critical software vendors. This creates a network that can be complex and opaque to enterprise customers and end-users.

Those two kinds of providers may operate for the MSPs, but they may also have a direct relationship with end-users. Cloud service providers handle the ICT needs of their customers via cloud services, thereby creating a direct and privilege access to customers' data and infrastructures. Similarly, critical software vendors are of paramount importance in the supply chain of public and private organisations.

Critical software is defined as software essential for the functioning of an organisation. Critical software can control access to data, have privileged access to the infrastructures, and perform critical functions such as network control and protection, and endpoint security (NIST, 2021[25]). In the case of SolarWinds, Orion's IT performance management and monitoring system had privileged access to customers' systems to produce and distribute updates. Eventually, MSPs themselves can even be software providers and cloud providers, which increases the complexity of their attack surface.

As the risks targeting MSPs and the supply chain in general are global, the solution needs to be collective. Because the supply chain will keep increasing in complexity (N-able, 2022[26]), its dependencies could be clarified for a comprehensive view of all the entities in the supply chain. This could be a first step to better risk management of the supply chain through security measures.

The rise of attacks on MSPs demonstrates that malicious actors understand the potential for their exploitation, but government authorities are responding to the threat. Incidents such as the Cloud Hopper (CISA, 2019[27]) and Kaseya (CISA, 2021[28]) may indicate that MSPs will remain an attractive target for malicious actors. In response, jurisdictions are addressing MSPs as a new threat vector. For example, the NIS2 Directive in the European Commission requires essential and important entities to incorporate cybersecurity risk management when dealing with such providers (European Commission, 2022[5]).

In addition, the European Union is considering adoption of the European cyber security certification programmes for "managed security services" under the Cyber Security Act (European Commission, 2023[29]). In May 2022, cyber security authorities of Canada, New Zealand, the United Kingdom and the United States released a joint advisory on how to protect against cyber threats to MSPs and their customers (CISA et al., 2022[19]). This advisory lists recommendations for

MSPs and their customers to reduce their risk of falling victim to malicious actors. Such initiatives, which complement individual governmental approaches, are necessary to tackle a borderless and increasing risk (CISA et al., 2022[19]). As such, understanding the security practices of, and market dynamics around MSPs, can help in developing approaches to enhance MSPs' security.

Emerging technologies: Evolutions in cryptography technologies

Throughout history, cryptographers have continuously researched new methods and techniques to improve on the cryptographic status quo of their time and respond to new threats. The last disruptive cryptographic innovation was probably the discovery of asymmetric cryptography in the 1970s, widely adopted 25 years later with the advent of the Internet. Two current areas of research could disrupt today's cryptography status quo, with tremendous potential economic and social consequences: homomorphic encryption and quantum information technologies.

Is homomorphic encryption the "Holy Grail" of cryptography?

Homomorphic encryption (HE) is a cryptographic method allowing certain computations to be performed on encrypted data without the need for decryption or access to the secret key. Such computations remain encrypted and can later be revealed by the owner of the secret key (Homomorphic Encryption Standardization, 2024[30]).

Fully homomorphic encryption (FHE) has been described as the "Holy Grail of cryptography" (Tourky, ElKawkagy and Keshk, 2016[31]) and "a technology that will change the world" (Paillier, 2020[32]). FHE allows arbitrary operations on encrypted data in unconstrained combinations. With FHE, programmes can run directly on encrypted data, eliminating the risk of data leakage during or after computation. Other forms of HE, such as partially and somewhat homomorphic encryption are more limited in the number or types of operations they allow over encrypted data.

In principle, FHE has a wide variety of potential applications. For example, sensitive data could be computed in an untrusted cloud environment. Consequently, malicious actors attacking the cloud provider's system would be as blind as the provider itself with respect to the homomorphically encrypted data and processing outputs. This would significantly reduce the risk of data breach.

Moreover, with FHE the cloud platform's location would no longer be a relevant criterion for choosing a cloud provider.

- In certain cases, FHE would eliminate the risk of governments leveraging cloud providers and data transfers under their jurisdiction for monitoring (Paillier, 2020[32]). This could occur as long as no additional obligations, such as the custody of FHE keys, are imposed on cloud providers.
- Third parties could perform analytics without threatening the confidentiality of sensitive data in key areas. These areas include health care (e.g. applying machine learning to genome data for medical research), finance (e.g. analysing transaction records) and law enforcement (e.g. detecting tax evasion, preventing crime, carrying out investigations) (Koerner, 2021[33]). Third parties could also query if specific data exist in a data store without revealing the contents of the query or information about the data store (Creeger, 2022[34]).
- FHE could enable data sharing for machine learning in areas once considered impossible or highly undesirable due to lack of trust, including finance (Masters and Hunt, 2019[35]).
- Stakeholders could use FHE to analyse confidential data from multiple organisations without these organisations having to share the data and results from the computations among themselves or with others. This has been implemented on the SCRAM platform developed at the Massachusetts Institute of Technology.

FHE can also be viewed as a powerful privacy-enhancing technology (OECD, 2023[36]). As such, it could bring a considerable amount of privacy protection to everyday applications. With FHE, for example, no personal data would have to be shared with GPS navigation providers, biometric identification, voice assistant or other services to benefit from their services (Zama, 2024[37]).

HE enthusiasts even envision a next generation FHE-enabled HTTP, the protocol of the web. In this scenario, everything, including data processing, is encrypted by default (Zama, 2024[37]). FHE allows for computation even if the environment is known to be compromised by an attacker (Jordan, 2021[38]). Consequently, it could also be viewed as a building block for a "zero trust" environment.

For now, however, the "Holy Grail" remains more of a dream than a reality due to several important limitations of HE and FHE. While HE has progressed considerably over the last 40 years, it is still evolving. FHE, too, is not yet fully mature. Since the concept was proposed in 1978, four generations of improved FHE have been developed. Each has pros and cons in terms of efficiency and security (van den Nieuwenhoff, 27 May 2021[39]). Today, there are significant limitations to FHE:

- FHE is computationally intensive, slower, less efficient and more energy-consuming compared with processing the same data unencrypted. A computation that would take a millisecond to complete on a standard laptop would take weeks to compute on a conventional server running FHE (DARPA, 2021[40]). Current FHE processing can be from 1 000 to 1 million times slower than the equivalent plaintext processing (Mattsson, 2021[41]), at least until FHE-designed acceleration chips are available (DARPA, 2021[40]; Intel, 2021[42]).
- FHE is also limited in multi-user environments such as outsourced processing. Multi-user HE has been developed but uses several keys, increasing the size of the encrypted data according to the number of users. This, in turn, increases both computation and communication cost proportional to the number of users (Park, 2021[43]). This limitation reduces the potential for some scenarios such as government analysis of financial data for detecting tax evasion.
- It can raise correctness challenges because it generates noise that can accumulate over time and distort the results (Yang et al., 2023[44]). Implementing FHE or other HE computations in a cloud environment does not guarantee accuracy (Fernàndez-València, 2022[45]).
- It is potentially vulnerable to many types of attacks (Yang et al., 2023[44]).
- It is still neither beginner-friendly nor user-friendly and is difficult to understand for programmers who are not also cryptographers (van den Nieuwenhoff, 2021[39]). Some stakeholders, such as Intel, are working to improve HE usability to accelerate HE adoption (Intel, 2024[46]).
- HE standardisation is still at an early stage. In 2019, the International Organization for Standardization and the International Electrotechnical Commission (ISO/IEC) published a standard addressing some mechanisms for homomorphic encryption. It included a "general model" for HE. The US National Institute of Standards and Technology (NIST), the ITU-T Study Group 17 on security, as well as an open consortium of industry, government and academia called HomomorphicEncryption.org, are working on HE standardisation (Albrecht et al., 2018[47]; ISO/IEC, 2019[48]; ITU, 2023[49]; ITU, 2022[50]; NIST, 2023[51]).

Overall, HE and FHE hold promise for significant change in the security landscape with important economic repercussions across all sectors. However, while some HE applications are already in place, FHE does not seem to be ready for everyone to use. According to a well-known cryptographer, "fully homomorphic encryption is today where deep learning was 10 years ago" (Paillier, 2020[32]). It is not clear how much time FHE will need to reach the inflection point after which wide and rapid adoption will follow.

Quantum information technologies: Between cryptographic disruption and innovation

Once mature, quantum information technologies are expected to have a disruptive potential in many areas, including cryptography (Barker, Polk and Souppaya, 2021[52]). For example, a mature quantum computer could in theory easily break some widely used encryption methods. On the more positive side, recent progress in quantum computing is boosting cryptographic innovation. In particular, algorithms are being developed to resist attacks powered by a quantum computer. Furthermore, research on quantum technologies creates opportunities for new cryptographic approaches. These approaches, known as "quantum cryptography" and "quantum key distribution", are based on the laws of quantum physics rather than mathematics.

Quantum computing is a new computing paradigm expected to allow complex computations on a massive scale. It aims to leverage the properties of nature at atomic scales to accomplish tasks not achievable with existing technologies. Initially proposed in 1982, quantum computing has become an established interdisciplinary research area between physics, computer science and engineering involving universities, research centres and companies worldwide (BSI, 2021[53]).

In quantum computers, information is encoded in qubits instead of bits. In traditional computers, an intangible binary digit (bit) reflects the state of a tangible (i.e. physical) transistor similar to a tiny on-off switch, reflecting binary information, i.e. either a 0 or a 1 for each transistor. In contrast, a qubit represents a property called "spin". This is the intrinsic angular momentum of an electron, akin to a tiny compass needle that points either up or down.

Quantum computers manipulate that needle to encode information into the electrons. In so doing, they leverage the possibility of quantum systems to exist in two or more states simultaneously (superposition) to encode the information as 0, 1 or a combination of 0 and 1 at the same time (Nellis, 2022[54]). They also leverage the possibility to intrinsically link qubits (entanglement). In this way, when one qubit is acted upon, such as through measurement, it can reveal information about the other linked qubits regardless of distance. This allows quantum computers to perform parallel computations on entangled qubits (GAO, 2021[55]).

The exponential potential of quantum computers

Quantum computers are expected to demonstrate a gigantic extension of both processing power and speed. The number of possible states in a traditional computer doubles with each additional bit and therefore scales linearly with the number of bits. However, the number of possible states in a quantum computer increases exponentially with the addition of each qubit (Congressional Research Service, 2022[56]).

In theory, quantum computers could outperform the power of classical computers by several orders of magnitude. This would make it possible to solve certain problems much faster. Quantum computers could even solve problems that classical computers cannot solve within a reasonable timeframe, known as "quantum supremacy" or "quantum advantage" (Preskill, 2012[57]). For example, it would take about 18 quadrillion bits (i.e. 2^{54} bits) of classical memory to model a quantum computer with just 54 quadrillion bits. As of 2019, only one classical supercomputer – the IBM Summit – had such capacity. Modelling a 72-qubit quantum computer would require 2^{72} bits, which would require stacking 262 000 Summit-type supercomputers. Modelling a 100-qubit quantum computer would require more bits than there are atoms on the planet. Moreover, a 280-qubit computer would require more bits than there are atoms in the known universe (Sedik, Malaika and Gorban, 2021[58]).

In addition, quantum algorithms leveraging quantum properties differ from algorithms designed to run on classical computers, and can considerably reduce the time needed to perform specific tasks. For example, the best-known quantum algorithms (Grover and Shor) yield a polynomial speedup and an exponential speedup. In a polynomial speedup, a quantum computer solves a problem in time T (say, 1 000 steps) while a classical computer needs time T^2 (i.e. 1 million steps) to solve the same problem. In an exponential speedup, a quantum computer takes time T (say, 100), while a classical computer takes time 2^T (i.e. 2^{100}), which is a 31 digit number (Sedik, Malaika and Gorban, 2021[58]).

However, such figures are purely theoretical because building a quantum computer with sufficient computing qubits to perform useful tasks is extremely complex. Despite enthusiastic announcements and optimistic forecasts by some stakeholders, few independent experts predict a timeframe for the maturity of quantum computing. This is in part because of the significant design and engineering challenges. For example, researchers and engineers must isolate a quantum computer completely from the world around it to protect the fragile state of the qubits. At the same time, it must allow interactions with the qubits to control them (IQC Canada, 2024[59]; BSI, 2021[53]).

The loss of information due to environmental noise, called quantum decoherence, increases with the number of qubits. This requires maintaining current quantum computers at temperatures close to absolute zero (–273,15 °C, –459,67 °F). Quantum error correction techniques can address decoherence, but they require additional qubits.

Error correction in quantum computers is a challenge that may never be overcome

Public announcements of major progress in quantum computing engineering reported only through an out-of-context number of qubits must be taken with caution. While it is an active area of research, no one is willing to predict how long it will take researchers to master error correction (Cho, 2020[60]). Furthermore, quantum algorithms are much more difficult to design than classical ones. According to some experts, only a few dozen quantum algorithms had been developed as of 2019 (Vardi, 2019[61]).

According to a 2019 consensus report of the US National Academies of Sciences, Engineering and Medicine, "it is impossible to project the timeframe for developing a large, operational, error-corrected quantum computer, and while significant progress continues, there is no guarantee that all these challenges will be overcome". In this report, experts note that "the process of bridging this gap might expose unanticipated challenges, require techniques that are not yet invented, or shift owing to new results of foundational scientific research that change our understanding of the quantum world" (Grumbling and Horowitz, 2019[62]). In fact, some researchers have even expressed scepticism over the feasibility of ever building a mature quantum computer that can achieve useful tasks (Kalai, 2011[63]; Dyakonov, 2018[64]).

According to the German Federal Office for Information Security (BSI), the point where quantum computers can no longer be simulated by current supercomputers was reached in 2019. Design limitations prevented impacts on the robustness of current cryptography. However, quantum processors are still several orders of magnitude away from cryptography attacks. An enormous effort would be needed to scale up quantum computing technologies to a cryptographically relevant level (BSI, 2021[53]).

Like quantum computing, quantum communication also makes use of the laws of quantum physics to transmit information via quantum particles such as single photons of light through optical fibre or free space (Kristjánsson, Gardner and Chiri, 2021[65]). Superposition can be exploited to allow quantum particles to travel along multiple lines of communication simultaneously, making the information less susceptible to errors during transmission. Entanglement allows the transfer of quantum information across large distances, whereby the sender holds half of the entangled photons and the receiver holds the other half. Quantum information is transferred via a combination of entanglement and classical communication. Information is encoded in controllable parameters of the photons such as their polarisation. To control the property of individual photons and address noise challenges, the sender and receiver use specialised generation and detection devices. These require conditions such as complete isolation and cryogenic temperatures (below -153°C, -243°F). Importantly, quantum computing is necessary, albeit on a simple level, for quantum communication (Ofcom, 2021[66]).

The quantum computing race has begun, inspired by the considerable potential benefits. Quantum information technologies could support advances in areas such as materials science, pharmaceuticals, energy and finance (The White House, 2022[67]). They are thus attracting the attention and investments of public and private stakeholders. In 2022, private investors poured USD 2.35 billion into quantum technology start-ups (Bogobowicz et al., 2023[68]). Furthermore, many OECD countries are adopting national quantum strategies and allocating significant research budgets, as illustrated in Table 4.3.

Table 4.3. Public sector research investments in quantum technologies in select countries

Country / region	Strategy, policy instrument	Budget	Timeframe
Canada	National Quantum Strategy (2023)	USD 760 million (CAD 1 billion)	2012-23
		USD 272 million (CAD 360 million)	2023
European Union	Quantum Technologies Flagship (2017)	EUR 1 billion	2018-27
France	Stratégie Nationale Quantique (2021)	EUR 1 billion	2021-25
Germany	Research funding	EUR 650 million	2018-22
	Quantum Technologies Action Concept (2023)	EUR 2.18 billon	2023-26
India	National Quantum Mission (2023)	USD 732.8 million (INR 60 billion)	2023-31
Japan	Quantum technology strategy review	USD 170 million (JPY 23.7 billion)	2021
	Quantum technology strategy review	USD 570 million (JPY 80 billion)	2022
Korea	National Quantum Technologies Development Roadmap (2023)	USD 2.6 billion	2023-35
Netherlands	Quantum Delta Netherlands (2021)	EUR 615 million	
United Kingdom	National Quantum Strategy (2023)	GBP 2.5 billion	2023-33
United States	National Quantum Initiative (2018)	USD 449 million	2019
		USD 672 million	2020
		USD 855 million	2021
		USD 918 million	2022
		USD 844 million	2023

Note: These amounts cover funding allocated to research in quantum technologies, not necessarily limited to quantum computing and communications. The People's Republic of China is widely reported as being among the global leaders in terms of quantum research funding, but there is no reliable information on the amount of investment.

Sources: EU (Quantum Flagship, 2024[69]), Canada (Government of Canada, 2023[70]), France (Government of France, 2023[71]), Germany (Clasen, 2023[72]), Korea (Kim, 2023[73]), India (Government of India, 2023[74]), Netherlands (Government of The Netherlands, 2021[75]), United Kingdom (DSIT, 2023[76]), United States (National Science and Technology Council, 2023[77]).

The future disruptive potential of quantum computing to break cryptography is a major challenge for today

Symmetric cryptographic methods such as the Advanced Encryption Standard are not significantly affected by quantum computing if used with suitable key sizes. However, this is not the case with public-key cryptography algorithms (ETSI, 2015[78]; NCSC, 2020[79]; BSI, 2021[80]; BSI, 2021[53]; ANSSI, 2022[81]; D'anvers et al., 2022[82]; NCSC, 2023[83]). Quantum computing directly threatens the continued robustness of public-key cryptography, which is widely used for digital signature and for key agreement between parties. For example, remote parties use it to determine the symmetric keys they intend to use in a communication (NCSC, 2020[79]; GAO, 2021[55]; ANSSI, 2022[81]).

The consequences are immense. The vulnerability of these cryptosystems to a quantum attack implies the vulnerability of all security protocols that derive security from their public-key ciphers, and of any product or security system deriving security from these protocols (ETSI, 2015[78]). While current quantum computers are not a threat to public-key cryptography, a future large general-purpose quantum computer could easily solve the mathematical problems at the core of public-key cryptography (NCSC, 2020[79]). Its availability would break the security of nearly all modern public-key cryptographic systems. Consequently, this could expose all secret symmetric keys and private asymmetric keys that are now protected using current public-key algorithms, as well as the information protected under those keys. Any information still considered to be private or otherwise sensitive would be vulnerable to exposure and undetected modification (Barker, Polk and Souppaya, 2021[52]).

It is impossible to predict when, if ever, modern public-key cryptographic systems would be broken. If it happens sooner rather than later, stakeholders will face a rapid collapse of their cryptographic architecture and have little time to react. Furthermore, some threat actors could carry out a “retroactive attack”. In other words, they could collect today both high-value encrypted data and the data used for key agreement in view of decrypting it later with a quantum computer. There is evidence that some countries have taken such an “intercept and store now, decrypt later” approach (D’anvers et al., 2022[82]).

In addition, a threat actor could use a quantum computer in the future to forge digital signatures and impersonate the legitimate private key owner, or tamper with information whose authenticity is protected by a digital signature. This threat needs to considered today for high-value, root-level public keys intended for long operational lifetimes (NCSC, 2020[79]; ANSSI, 2022[81]; BSI, 2021[80]). Furthermore, a national security agency may operate the first fully functional large quantum computer long before any public announcement about it to gain a significant intelligence advantage over competing nation states (D’anvers et al., 2022[82]).

The US National Security Agency issued an urgent warning in 2015 about the imminent threat to current public-key cryptography posed by the development of quantum computers (BSI, 2021[53]; ANSSI, 2022[81]). Several cybersecurity agencies recommended addressing today the anticipated collapse of the current cryptographic infrastructure resulting from tomorrow’s expected advent of quantum computing. They warned of the need to transition to quantum-resistant cryptography sooner rather than later (Chen et al., 2016[84]; NCSC, 2020[79]; BSI, 2021[80]; ANSSI, 2022[81]).

Post-quantum cryptography can help reduce future disruptions

The solution to the challenge of quantum computers breaking current cryptography is to develop a family of cryptographic algorithms that are immune to attacks by leveraging both classical and quantum computers. This new family of algorithms, called “quantum-resistant cryptography” (QRC), includes key establishment and digital signatures, and can be executed on classical computers with classical communication channels (ANSSI, 2022[81]). Once developed, the algorithms could be deployed in anticipation of a mature quantum computer to address the “intercept and store now, decrypt later” challenge. QRC is also called interchangeably post-quantum, quantum-safe or quantum-secure cryptography.

Since 2006, a large international community of researchers has started to work on QRC, including through publicly funded research projects in the European Union and Japan (Chen et al., 2016[84]). In 2016, NIST initiated a QRC standardisation effort. After a thorough evaluation process in 2022, NIST selected four quantum-resistant algorithms out of 82 proposals from international teams of researchers. At the time of writing, it continues to evaluate four additional candidates for possible future inclusion in the standard (Alagic et al., 2022[85]; NIST, 2022[86]). Many cyber security agencies welcomed the NIST process (NCSC, 2020[79]; BSI, 2021[80]; ANSSI, 2022[81]). This acted as a catalyst for strong involvement of the international cryptography research community, stimulating initiatives to co-ordinate domestic cryptography players such as the French “Risq” project (ANSSI, 2022[81]).

During NIST’s standardisation process, cybersecurity agencies in several countries have issued recommendations encouraging organisations to consider QRC. Agencies in Australia, Canada, France, Germany, the United Kingdom and the United States are all encouraging large organisations to anticipate quantum-related disruptions. They recommend starting the transition to QRC in a hybrid mode, i.e. where both pre- and post-quantum cryptography coexist (NCSC, 2020[79]; BSI, 2021[80]; Cyber Centre, 2021[87]; DHS, 2022[88]; DHS, 2021[89]; ANSSI, 2022[81]; DHS, 2022[88]; ACSC, 2023[90]).

Quantum cryptography and quantum key distribution

Quantum cryptography is often described as a major paradigm shift in cryptography. Instead of relying on mathematical complexity like most current cryptographic algorithms, quantum cryptography takes advantage of the laws of physics. In theory, it can remain secure regardless of the amount of processing power and mathematical innovation an adversary could use.

It is easy to mistake quantum cryptography with QRC. Like QRC, quantum cryptography is robust against future algorithmic and computational advances, including the emergence of quantum computers. However, quantum cryptography is fundamentally different from QRC as it requires special equipment to leverage quantum physics. Therefore, it cannot simply run on classical computers. Quantum cryptography can be viewed as a subset of quantum communication because it leverages the same quantum principles and uses the same modes of operation.

Despite sometimes being presented as synonymous with quantum cryptography, quantum key distribution (QKD) is instead a specific application of quantum cryptography. QKD enables two remote parties to build a secret key through a dialogue on public channels. It ensures that any observation of the secret in transit will be detected, a feature that classical (i.e. non-quantum) cryptographic methods do not provide (ANSSI, 2020[91]; NCSC, 2020[92]; BSI, 2021[53]; NSA, 2020[93]).

In practice, encrypted data are sent as classical bits over the network. Meanwhile, the secret key is transmitted (but not measured and retained) as quantum states of light (Ofcom, 2021[66]). This occurs with special equipment (e.g. single photon detectors) via a fibre or atmospheric (i.e. satellite) link. Because information is encoded in quantum states, an eavesdropper would be unable to observe the data stream without changing the value of some of the qubits and introducing errors. This would make the observation detectable by both sender and recipient (ETSI, 2015[78]). Therefore, QKD provides confidentiality and integrity but not availability (ANSSI, 2020[91]).

Furthermore, the eavesdropper would not be able to copy the qubits transmitted in an unknown state, a consequence of the quantum physics "no-cloning" principle (ETSI, 2015[78]; BSI, 2021[53]). There is no way to save the information for later decryption by more powerful technologies. This means that any attempt to exploit a flaw in an implementation of transmitters or receivers would have to be carried out in real time (ETSI, 2015[78]).

Unlike quantum computing, QKD is feasible with technology available today (BSI, 2021[53]). Several QKD networks based on fibre and free space have been deployed or are under construction worldwide. A review of recent and ongoing large-scale deployment of QKD networks identified projects in Canada, the People's Republic of China, Europe, India, Italy, Japan, Korea, Spain, the Russian Federation, the United Kingdom and the United States. It also identified standardisation efforts by CEN-CENELEC, ETSI, IEEE, ITU-T, ISO/IEC JCT-1, the China Communications Standards Association and the UK British Standards Institute (BSI). Together, these organisations had published 22 standards as of 2022 and were developing 20 more (Stanley et al., 2022[94]).

Nevertheless, several cybersecurity agencies have expressed strong reservations regarding the potential of QKD and quantum computing to match security expectations and compete with QRC algorithms. In theory, the security of QKD is based on laws of physics. In practice, it is based on the degree of technical perfection with which it is implemented. In other words, it is based on the degree to which potential adversaries can exploit possible deviations of real-life quantum cryptography systems from the theoretical requirements, such as in the transmitters or receivers (Lucamarini, Shields and All, 2018[95]). Cybersecurity agencies point out that achieving such a degree of perfection is far from easy and cheap, considerably reducing the number of potential use cases. This main element, as well as additional issues such as security weaknesses and the need for specific hardware, have led these agencies to reject the use of QKD for sensitive government or military applications. They call instead for the promotion of cheaper and more easily implementable QRC algorithms (ANSSI, 2020[91]; NCSC, 2020[92]; BSI, 2021[53]; Cyber Centre, 2021[87]; ACSC, 2023[90]; NSA, 2020[93]).

References

ACSC (2023), "Planning for Post-Quantum Cryptography", webpage, *https://www.cyber.gov.au/resources-business-and-government/governance-and-user-education/governance/planning-post-quantum-cryptography* (accessed on 10 July 2023). [90]

Alagic, G. et al. (2022), "Status report on the third round of the NIST post-quantum cryptography standardization process", *Interagency or Internal Report*, National Institute of Standards and Technology, Gaithersburg, MD, *https://doi.org/10.6028/nist.ir.8413-upd1*. [85]

Albrecht, M. et al. (2018), *Homomorphic Encryption Standard*, 21 November, Homomorphic Encryption Standardization, *https://homomorphicencryption.org/standard*. [47]

ANSSI (2022), "ANSSI views on the post-quantum cryptography transition", *Position Paper*, 4 January, Agence nationale de la sécurité des systèmes d'information, Paris, *https://cyber.gouv.fr/en/publications/anssi-views-post-quantum-cryptography-transition*. [81]

ANSSI (2020), "Should quantum key distribution be used for secure communications?", *Technical Position Paper*, 26 May, Agence nationale de la sécurité des systèmes d'information, Paris, *https://www.ssi.gouv.fr/uploads/2020/05/anssi-technical_position_papers-qkd.pdf*. [91]

ANSSI (2016), *The ANSSI security Visa by the French National Cybersecurity Agency*, Agence nationale de la sécurité des systèmes d'information, Paris, *https://cyber.gouv.fr/publications/anssi-security-visa-french-national-cybersecurity-agency*. [6]

Barker, W., W. Polk and M. Souppaya (2021), "Getting ready for post-quantum cryptography: Exploring challenges associated with adopting and using post-quantum cryptographic algorithms", *Cybersecurity White Paper*, No. 04282021, 28 April, National Institute of Standards and Technology, Gaithersburg, MD, *https://doi.org/10.6028/nist.cswp.04282021*. [52]

Bogobowicz, M. et al. (2023), "Quantum technology sees record investments, progress on talent gap", 24 April, McKinsey Digital, New York, *https://www.mckinsey.com/capabilities/mckinsey-digital/our-insights/quantum-technology-sees-record-investments-progress-on-talent-gap*. [68]

BSI (2021), "Migration to post quantum cryptography: Recommendation for action", Federal Office for Information Security, Bonn, *https://www.bsi.bund.de/SharedDocs/Downloads/EN/BSI/Crypto/Migration_to_Post_Quantum_Cryptography.pdf?__blob=publicationFile&v=2*. [80]

BSI (2021), "Quantum safe cryptography – fundamentals, current developments, and recommendations", (brochure), Federal Office for Information Security, Bonn, *https://www.bsi.bund.de/SharedDocs/Downloads/EN/BSI/Publications/Brochure/quantum-safe-cryptography.pdf*. [53]

BSI (2021), *Transparency through the IT Security Label*, webpage, *https://www.bsi.bund.de/EN/Themen/Unternehmen-und-Organisationen/IT-Sicherheitskennzeichen/it-sicherheitskennzeichen_node.html* (accessed on 10 July 2024). [9]

Chen, L. et al. (2016), "Report on post-quantum cryptography", *Internal Report*, No. 8105, National Institute of Standards and Technology, Gaithersburg, MD, *https://doi.org/10.6028/nist.ir.8105*. [84]

Cho, A. (2020), "No room for error", 8 July, Science, *https://www.science.org/content/article/biggest-flipping-challenge-quantum-computing*. [60]

CISA (2021), *CISA-FBI Guidance for MSPs and their Customers Affected by the Kaseya VSA Supply-Chain Ransomware Attack*, *https://www.cisa.gov/news-events/alerts/2021/07/04/cisa-fbi-guidance-msps-and-their-customers-affected-kaseya-vsa-supply* (accessed on 15 July 2024). [28]

CISA (2019), "Chinese cyber activity targeting managed service providers", *Awareness Briefing*, Cybersecurity and Infrastructure Security Agency, United States, Washington, D.C., *https://www.cisa.gov/sites/default/files/c3vp/Chinese-Cyber-Activity-Targeting-Managed-Service-Providers.pdf*. [27]

CISA et al. (2022), "Protecting Against Cyber Threats to Managed Service Providers and their Customers", 11 May, Cybersecurity and Infrastructure Security Agency, United States, *https://www.cisa.gov/news-events/cybersecurity-advisories/aa22-131a* (accessed on 26 June 2023). [19]

Clasen, A. (2023), "Germany strives to catch up with US, China in quantum tech race", 16 May, Euractiv, *https://www.euractiv.com/section/digital/news/germany-strives-catch-up-with-us-china-in-quantum-tech-race*. [72]

Common Criteria (2023), *The Common Criteria*, website, *https://www.commoncriteriaportal.org* (accessed on 26 June 2024). [3]

Congressional Research Service (2022), "Defense primer: Quantum technology", *CRS Report*, 25 October, Congressional Research Service, United States, Washington, D.C., *https://crsreports.congress.gov/product/pdf/IF/IF11836*. [56]

Creeger, M. (2022), "The rise of fully homomorphic encryption", *Queue*, Vol. 20/4, pp. 39-60, *https://doi.org/10.1145/3561800*. [34]

CSA (2022), "Mutual recognition arrangement on cybersecurity labels between the Cyber Security Agency of Singapore and the Connectivity Standards Alliance", 19 March, News Release, Cyber Security Agency of Singapore, Singapore, *https://www.csa.gov.sg/News-Events/News-Articles/2024/mutual-recognition-arrangement-on-cybersecurity-labels-between-csa-and-the-connectivity-standards-alliance*. [18]

CSA (2020), "Singapore Cybersecurity Labelling Scheme", webpage, *https://www.csa.gov.sg/our-programmes/certification-and-labelling-schemes/cybersecurity-labelling-scheme* (accessed on 26 June 2024). [17]

Cyber Centre (2021), "Preparing your organization for the quantum threat to cryptography – ITSAP.00.017", February, Canadian Centre for Cyber Security, Vanier, Canada, *https://www.cyber.gc.ca/en/guidance/preparing-your-organization-quantum-threat-cryptography-itsap00017* (accessed on 10 July 2023). [87]

D'anvers, J. et al. (2022), *Post-Quantum Cryptography: Current State and Quantum Mitigation*, European Union Agency for Cybersecurity, Athens, *https://www.enisa.europa.eu/publications/post-quantum-cryptography-current-state-and-quantum-mitigation*. [82]

DARPA (2021), "DARPA selects researchers to accelerate use of fully homomorphic encryption", 8 March, Press Release, Defense Advanced Research Projects Agency, United States, Arlington, VA, *https://www.darpa.mil/news-events/2021-03-08*. [40]

DHS (2022), "Post-Quantum Cryptography", webpage, *https://www.dhs.gov/quantum* (accessed on 10 July 2023). [88]

DHS (2021), "Preparing for post-quantum cryptography", Infographic, Department of Homeland Security, United States, Washington, D.C., *https://www.dhs.gov/publication/preparing-post-quantum-cryptography-infographic* (accessed on 10 July 2023). [89]

DSIT (2023), "National quantum strategy", *Policy Paper*, 15 March, Department for Science, Innovation and Technology, United Kingdom, London, *https://www.gov.uk/government/publications/national-quantum-strategy*. [76]

Dyakonov, M. (2018), "The case against quantum computing", 15 November, IEEE Spectrum, *https://spectrum.ieee.org/the-case-against-quantum-computing*. [64]

ENISA (2019), "EU Certification Framework", webpage, *https://digital-strategy.ec.europa.eu/en/policies/cybersecurity-certification-framework* (accessed on 26 June 2024). [2]

ETSI (2020), "EN 303 645 - V2.1.1 - CYBER; Cyber Security for Consumer Internet of Things: Baseline Requirements", webpage, *https://www.etsi.org/deliver/etsi_en/303600_303699/303645/02.01.01_60/en_303645v020101p.pdf* (accessed on 26 June 2024). [8]

ETSI (2015), "Quantum safe cryptography. An introduction, benefits, enablers and challenges", *White Paper*, No. 8, June, European Telecommunications Standards Institute, Sophia Antipolis, France, *https://www.etsi.org/images/files/ETSIWhitePapers/QuantumSafeWhitepaper.pdf*. [78]

European Commission (2023), "Commission implementing regulation as regards the adoption of the European Common Criteria-based cybersecurity certification scheme (EUCC)", 31 January, European Commission, Brussels, *https://digital-strategy.ec.europa.eu/en/library/implementing-regulation-adoption-european-common-criteria-based-cybersecurity-certification-scheme*. [4]

European Commission (2023), "Proposed regulation on managed security services amendment", 17 April, European Commission, Brussels, *https://digital-strategy.ec.europa.eu/en/library/proposed-regulation-managed-security-services-amendment*. [29]

European Commission (2022), "NIS 2 Directive", webpage, *https://digital-strategy.ec.europa.eu/en/policies/nis2-directive* (accessed on 26 June 2024). [5]

FCC (2023), *US Cybersecurity Labeling Program*, webpage, *https://www.fcc.gov/document/fcc-proposes-cybersecurity-labeling-program-smart-device* (accessed on 26 June 2024). [16]

Fernàndez-València, R. (2022), "Verifiable homomorphic encryption: The multi-group setting – one scheme to rule them all", 22 March, Medium, *https://medium.com/iovlabs-innovation-stories/verifiable-homomorphic-encryption-7de41e39c20*. [45]

GAO (2021), "Quantum computing and communications: Status and prospects", *Technology Assessment*, US Government Accountability Office, Washington, D.C., *https://www.gao.gov/assets/gao-22-104422.pdf*. [55]

Government of Canada (2023), "Government of Canada launches National Quantum Strategy to create jobs and advance quantum technologies", 13 January, News Release, Government of Canada, Waterloo, *https://www.canada.ca/en/innovation-science-economic-development/news/2023/01/government-of-canada-launches-national-quantum-strategy-to-create-jobs-and-advance-quantum-technologies.html*. [70]

Government of France (2023), "France 2030: des résultats concrets pour les 2 ans de la stratégie quantique", 3 April, Government of France, Paris, *https://www.gouvernement.fr/sites/default/files/contenu/piece-jointe/2023/03/20230330_france2030_dp_deux_ans_de_la_strategie_nationale_quantique_vdef2_clean.pdf*. [71]

Government of India (2023), "Cabinet approves national quantum mission to scale-up scientific & industrial R&D for quantum technologies", 19 April, Press Release, Government of India, *https://pib.gov.in/PressReleaseIframePage.aspx?PRID=1917888*. [74]

Government of Korea (2023), "Internet of Things (IoT) security certification reduces the burden on businesses and increases consumer convenience! (사물인터넷(IoT) 보안인증, 기업 부담은 줄이고, 소비자 편의성은 높인다!)", 4 July, Ministry of Science and IT, Korea, Sejong, *https://www.korea.kr/briefing/pressReleaseView.do?newsId=156578757#pressRelease*. [13]

Government of The Netherlands (2021), "Innovative projects given additional €1.35 billion boost due to funding from National Growth Fund", 9 April, News Item, Government of The Netherlands, *https://www.government.nl/latest/news/2021/04/21/innovative-projects-given-additional-%E2%82%AC1.35-billion-boost-due-to-funding-from-national-growth-fund*. [75]

Grumbling, E. and M. Horowitz (eds.) (2019), *Quantum Computing*, National Academies Press, United States, Washington, D.C., *https://doi.org/10.17226/25196*. [62]

Homomorphic Encryption Standardization (2024), "Introduction", webpage, *https://homomorphicencryption.org/introduction* (accessed on 26 June 2024). [30]

Intel (2024), "Intel Homomorphic Encryption Toolkit", webpage, *https://www.intel.com/content/www/us/en/developer/tools/homomorphic-encryption/overview.html* (accessed on 26 June 2024). [46]

Intel (2021), "Intel to collaborate with Microsoft on DARPA program", 8 March, News Release, Intel, Santa Clara, CA, *https://www.intel.com/content/www/us/en/newsroom/news/intel-collaborate-microsoft-darpa-program.html#gs.yo43kd*. [42]

IQC Canada (2024), "Quantum Computing", webpage, *https://uwaterloo.ca/institute-for-quantum-computing/quantum-101/quantum-information-science-and-technology/quantum-computing* (accessed on 26 June 2024). [59]

ISO/IEC (2019), "ISO/IEC 18033-6:2019 - IT Security techniques — Encryption algorithms — Part 6: Homomorphic encryption", webpage, *https://www.iso.org/standard/67740.html* (accessed on 26 June 2024). [48]

ITU (2023), "Technical Report: FHE-based Data Collaboration in Machine Learning", webpage, *https://www.itu.int/ITU-T/workprog/wp_item.aspx?isn=17999* (accessed on 26 June 2024). [49]

ITU (2022), "The case for standardizing homomorphic encryption", 7 December, ITU News, *https://www.itu.int/hub/2022/12/the-case-for-standardizing-homomorphic-encryption*. [50]

Jordan, M. (2021), "The next step in homomorphic encryption for Linux on IBM Z and LinuxONE", IBM blog, *https://www.ibm.com/blog/the-next-step-in-homomorphic-encryption-for-linux-on-ibm-z*. [38]

Kalai, G. (2011), "How quantum computers fail: Quantum codes, correlations in physical systems, and noise accumulation", arXiv, 1106.0485, *https://arxiv.org/abs/1106.0485*. [63]

Kim, J. (2023), "S. Korea to invest $2.6 bn in quantum technology by 2035", 11 May, The Korea Economic Daily, *https://www.kedglobal.com/tech,-media-telecom/newsView/ked202305110016*. [73]

Koerner, K. (2021), "Introduction to homomorphic encryption", 20 July, Medium, *https://medium.com/golden-data/introduction-to-homomorphic-encryption-d903d02d4ce0*. [33]

Korea Ministry of Government Legislation (2021), 정보통신망연결기기등 정보보호인증에 관한 고시 *[Notice on information protection certification for information and communication network connected devices, etc.]*, webpage, *https://www.law.go.kr/LSW/admRulLsInfoP.do?admRulSeq=2100000204704* (accessed on 26 June 2024). [11]

Kristjánsson, H., R. Gardner and G. Chiri (2021), "Quantum communications: New potential for the future of communications", 28 July, Ofcom, United Kingdom, London, *https://www.ofcom.org.uk/research-and-data/technology/general/quantum-communications*. [65]

Lucamarini, M., A. Shields and R. All (2018), "Implementation security of quantum cryptography: Introduction, challenges, solutions", *ETSI White Paper*, No. 27, European Telecommunications Standards Institute, Sopha Antiopolis, France. [95]

Mandiant (2022), *M-Trends 2022 Report*, Mandiant, Reston, VA, *https://www.mandiant.com/m-trends*. [23]

Masters, O. and H. Hunt (2019), *Towards a Homomorphic Machine Learning Big Data Pipeline for the Financial Services Sector*, Cryptology ePrint Archive, *https://eprint.iacr.org/2019/1113*. [35]

Mattsson, U. (2021), "Security and performance of homomorphic encryption", June, Global Security Mag, *https://www.globalsecuritymag.com/Security-and-Performance-of,20210601,112333.html*. [41]

METI (2020), *IOT Security and Safety Framework*, Ministry of Economy, Trade and Industry, Tokyo, *https://www.dataguidance.com/news/japan-meti-releases-iot-security-and-safety-framework*. [10]

Ministry of Industry and Technology (2023), *Kamu Bilişim Hizmet Alimi Kapsaminda Katilimcilarin Yetkilendirilmesi Hakkinda Yönetmelik [Regulation on the Authorization of Participants within the Scope of Public Information Technology Service Procurement]*, *https://www.mevzuat.gov.tr/File/GeneratePdf?mevzuatNo=39610&mevzuatTur=KurumVeKurulusYonetmeligi&mevzuatTertip=5* (accessed on 10 July 2024). [14]

N-able (2022), "State of the market: The new threat landscape", *White Paper*, N-able, Burlington, MA. [26]

National Science and Technology Council (2023), “National Quantum Initiative Supplement to the President’s FY 2023 budget”, Committee on Science of the National Science & Technological Council, United States, Washington, D.C., *https://www.quantum.gov/wp-content/uploads/2023/01/NQI-Annual-Report-FY2023.pdf*. [77]

NCSC (2023), “Next steps in preparing for post-quantum cryptography”, *White Paper*, 3 November, National Cyber Security Centre, United Kingdom, London, *https://www.ncsc.gov.uk/whitepaper/next-steps-preparing-for-post-quantum-cryptography* (accessed on 4 January 2024). [83]

NCSC (2020), “Preparing for quantum-safe cryptography”, *White Paper*, National Cyber Security Centre, United Kingdom, London, *https://www.ncsc.gov.uk/whitepaper/preparing-for-quantum-safe-cryptography*. [79]

NCSC (2020), “Quantum security technologies. V1.0”, *White Paper*, National Cyber Security Centre, United Kingdom, London, *https://www.ncsc.gov.uk/whitepaper/quantum-security-technologies*. [92]

Nellis, A. (2022), “The Quantum Internet, Explained”, webpage, *https://news.uchicago.edu/explainer/quantum-internet-explained* (accessed on 26 June 2024). [54]

NIST (2023), *Privacy-Enhancing Cryptography*, webpage, *https://csrc.nist.gov/Projects/pec* (accessed on 26 June 2024). [51]

NIST (2022), “NIST announces first four quantum-resistant cryptographic algorithms”, 5 July, Press Release, National Institute of Standards and Technology, United States, Washington, D.C., *https://www.nist.gov/news-events/news/2022/07/nist-announces-first-four-quantum-resistant-cryptographic-algorithms*. [86]

NIST (2021), “Definition of critical software under executive order (EO) 14028”, 13 October, National Institute of Standards and Technology, Washington, D.C., *https://www.nist.gov/system/files/documents/2021/10/13/EO%20Critical%20FINAL.pdf*. [25]

NSA (2020), “Quantum Key Distribution (QKD) and Quantum Cryptography (QC)”, webpage, *https://www.nsa.gov/Cybersecurity/Quantum-Key-Distribution-QKD-and-Quantum-Cryptography-QC* (accessed on 20 June 2023). [93]

OECD (2023), “Building cyber resilience in a post COVID-19 world: Local challenges, global solutions”, Summary, OECD Global Forum on Digital Security for Prosperity, hosted virtually by Israel, 7-9 June 2021. [24]

OECD (2023), “Emerging privacy-enhancing technologies: Current regulatory and policy approaches”, *OECD Digital Economy Papers*, No. 351, OECD Publishing, Paris, *https://doi.org/10.1787/bf121be4-en*. [36]

OECD (2021), “Enhancing the digital security of products: A policy discussion”, *OECD Digital Economy Papers*, No. 306, OECD Publishing, Paris, *https://doi.org/10.1787/cd9f9ebc-en*. [1]

Ofcom (2021), “Quantum Communications: New potential – Executive summary”, 28 July, Ofcom, London, *https://www.ofcom.org.uk/__data/assets/pdf_file/0013/222601/Executive-Summary.pdf*. [66]

Paillier, P. (2020), “Introduction to FHE”, webpage, *https://fhe.org/meetups/001-introduction-to-fhe* (accessed on 26 June 2024). [32]

Park, J. (2021), “Homomorphic encryption for multiple users with less communications”, *Paper*, No. 2021/1085, *https://eprint.iacr.org/2021/1085*. [43]

Preskill, J. (2012), “Quantum computing and the entanglement frontier”, arXiv 1203.5813, *https://arxiv.org/abs/1203.5813*. [57]

Quantum Flagship (2024), “Introduction”, webpage, *https://qt.eu/about-quantum-flagship* (accessed on 26 June 2024). [69]

Sedik, T., M. Malaika and M. Gorban (2021), “Quantum computing’s possibilities and perils”, September, International Monetary Fund, Washington, D.C., *https://www.imf.org/en/Publications/fandd/issues/2021/09/quantum-computings-possibilitiesand-perils-deodoro*. [58]

Stanley, M. et al. (2022), “Recent progress in quantum key distribution network deployments and standards”, *Journal of Physics: Conference Series*, Vol. 2416/1, p. 012001, *https://doi.org/10.1088/1742-6596/2416/1/012001*. [94]

Statista (2023), “Size of the managed service market worldwide in 2023 with forecast to 2032”, *Statisa* (database), *https://www.statista.com/statistics/590884/worldwide-managed-services-market-size* (accessed on 26 June 2024). [20]

Svetozarov Naydenov, R. et al. (2022), *ENISA Threat Landscape 2022*, European Union Agency for Cybersecurity, Athens, *https://doi.org/10.2824/764318*. [22]

The White House (2022), “National security memorandum on promoting United States leadership in quantum computing while mitigating risks to vulnerable cryptographic systems”, 4 May, The White House, United States, Washington, D.C., *https://www.whitehouse.gov/briefing-room/statements-releases/2022/05/04/national-security-memorandum-on-promoting-united-states-leadership-in-quantum-computing-while-mitigating-risks-to-vulnerable-cryptographic-systems*. [67]

Tourky, D., M. ElKawkagy and A. Keshk (2016), *Homomorphic encryption the “Holy Grail” of cryptography*, 2nd IEEE International Conference on Computer and Communications (ICCC), IEEE, 14-17 October, Chengdu, China, *https://doi.org/10.1109/compcomm.2016.7924692*. [31]

Traficom (2019), “The Finnish cybersecurity label”, (brochure), Finnish Transport and Communications Agency, Helsinki, *https://tietoturvamerkki.fi/sites/default/files/media/file/cybersecurity_label_presentation-280920.pdf*. [7]

TRtest (2024), “Certificates and Documents”, webpage, *https://tr-test.com.tr/trtest/views/portal?lang=en* (accessed on 26 June 2024). [15]

TTA (2021), "TTA designated as an information protection certification testing agency", 14 January, Press Release, Telecommunication Technology Association of Korea, Seongnam, Kyonggi-do, *https://www.tta.or.kr/tta/selectBbsNttView.do;jsessionid=_LxCSNRwGFnOaCHxj8bFDVXO6_PkIQJoUbtrI1meA0CNKO_Atts4!-1151557185?key=76&bbsNo=107&nttNo=12016&searchCtgry=&searchCnd=all&searchKrwd=&integrDeptCode=&pageIndex=10*. [12]

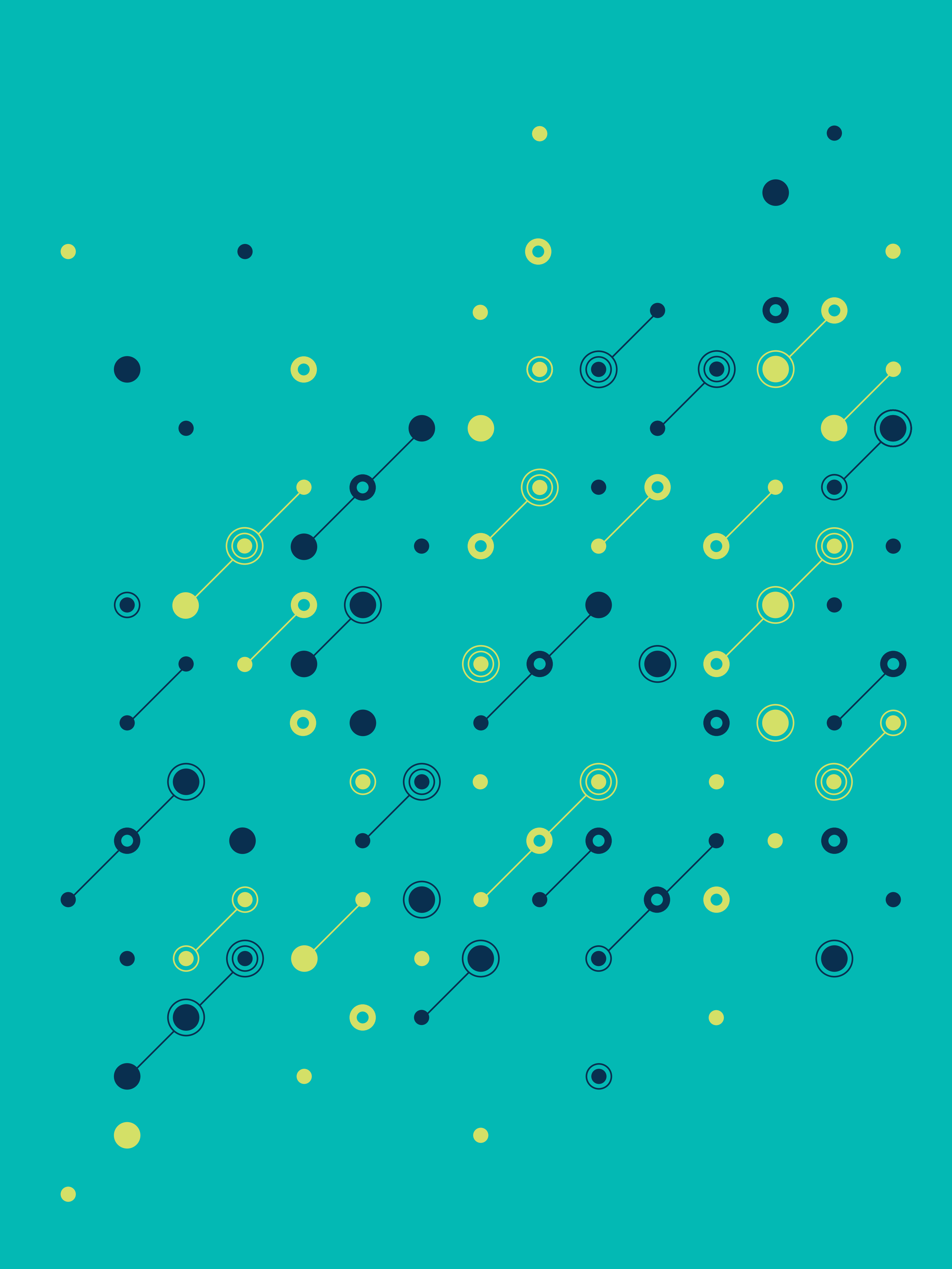
van den Nieuwenhoff, T. (27 May 2021), "Fully homomorphic encryption: The history", Tvdm blog, *https://tvdn.me/fhe/2021-05-27-homomorphic-encryption-history*. [39]

Vardi, M. (2019), "Quantum hype and quantum skepticism", *Communications of the ACM*, Vol. 62/5, p. 7, *https://doi.org/10.1145/3322092*. [61]

Yang, W. et al. (2023), "A review of homomorphic encryption for privacy-preserving biometrics", *Sensors*, Vol. 23/7, p. 3566, *https://doi.org/10.3390/s23073566*. [44]

Zama (2024), "A 6 Minute Introduction to Homomorphic Encryption", webpage, *https://6min.zama.ai* (accessed on 26 June 2024). [37]

Zetter, K. (2023), "The untold story of the boldest supply-chain hack ever", 2 May, Wired, *https://www.wired.com/story/the-untold-story-of-solarwinds-the-boldest-supply-chain-hack-ever*. [21]



Spotlight

Media consumption and privacy

Lies, conspiracy theories, propaganda and other false and misleading content are not new. However, the rise of the Internet and online platforms have changed the scale and speed by which such content can be spread, creating risks to the safety and well-being of people and society. This Spotlight first sheds light on media consumption and trust in media sources. It then presents cross-country data on privacy concerns and individuals' perceived control over their personal data on websites, applications and social media. Insights into how exposure to additional context influences the ability of individuals to identify the veracity of information on line follow. The Spotlight concludes with perspectives on how media literacy initiatives may need to evolve in response.

Trust in the information ecosystem requires rethinking media literacy and addressing privacy concerns

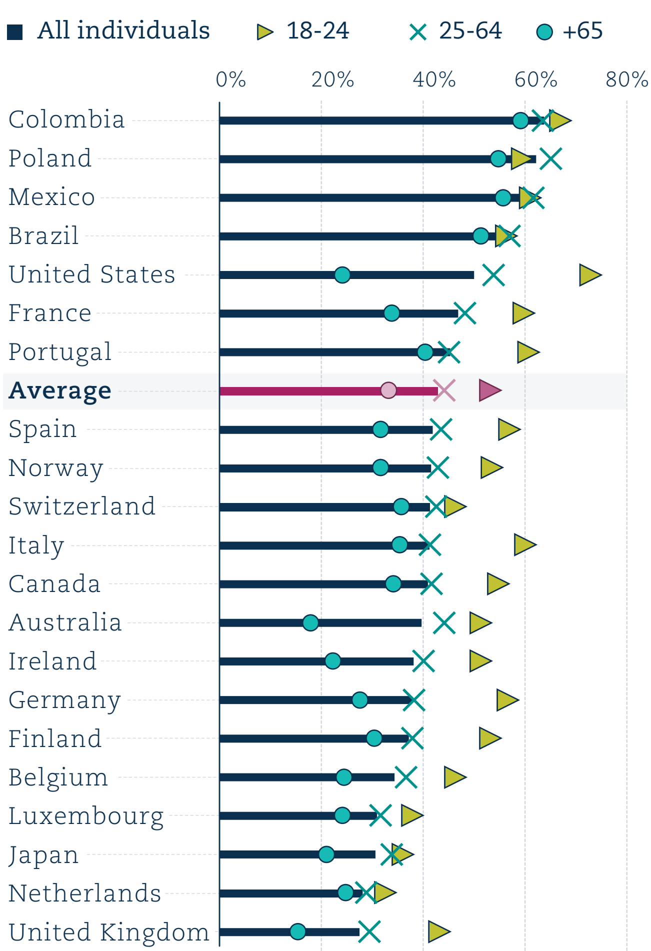
Most people are concerned about privacy on line.

+50% of individuals avoid using certain websites, applications or social media due to privacy concerns.

1/3 of individuals feel they do not have control over their personal data.

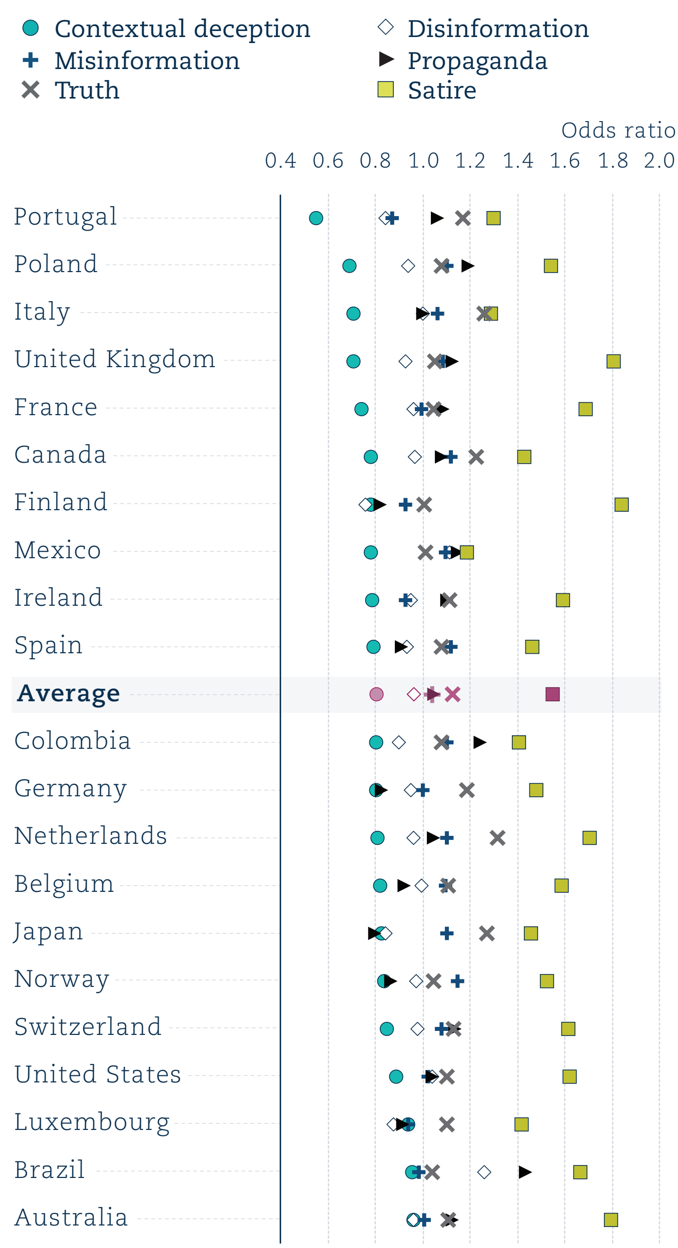
Young people are more likely to source and trust information on social media than older people.

Trust in information on social media, by age, 2024



Reading more does not always help people identify what is true and false.

Odds ratio of correctly identifying the veracity of content on line, by type, 2024



Source: OECD Truth Quest Survey, covering individuals aged 18+ in 21 countries in 2024. The average represents a simple average of the countries covered.

Lies, conspiracy theories, propaganda and other false and misleading content are not new, but the Internet has changed the scale and speed by which such content is developed and spread. False and misleading content is not necessarily illegal, but its rapid and global spread is harmful for society and democracy. In today's information society, information plays a significant role economically, socially and culturally, and information and communication technologies are widespread and intensively used. As people increasingly source information from websites and social media, false and misleading content on line raises risks for the well-being of people and society.

To address the pernicious effects of false and misleading content on line, it is important to understand how people consume information and what influences media consumption. By examining individuals' reported trust in various media sources, it is possible to gain a deeper understanding of the broader information ecosystem in which people are exposed to both factual, and false and misleading content on line. This can in turn support the design of more effective public policies.[1]

Concerns about privacy on line and feeling not in control over personal data reduce trust in the information ecosystem. Understanding the extent to which privacy concerns and feelings of control over personal data vary across countries and demographic groups can shed light on which factors influence trust in digital environments. This, in turn, provides insights into how to build a more trusted information ecosystem.

Moreover, knowing how to help people become better at identifying false and misleading content on line is likewise an important step in mitigating its harmful effects. While technology is certainly one part of the solution, people also play an important role. In particular, equipping people with the skills to detect false and misleading content through media literacy[2] is often advocated. However, more evidence is needed to understand how to best design these initiatives and which demographic groups are most at risk.

This Spotlight presents new evidence from the OECD Truth Quest Survey (Box 3.S.1) on media consumption and privacy. It sheds light on where people source information and how trustworthy they perceive various media sources. It then examines attitudes towards privacy and control over personal data. The Spotlight further analyses the behaviour of people as they interact with true and false and misleading content. It concludes with perspectives on strengthening the information ecosystem by rethinking the design of media literacy initiatives.

Box 3.S.1. The OECD Truth Quest Survey

The OECD Truth Quest Survey measures the ability of people to identify false and misleading content on line in a real life setting across 21 countries (OECD, 2024[1]). The survey provides cross-country comparable evidence on media literacy skills by theme, type and origin (i.e. whether information is generated by humans or artificial intelligence [AI]). It assesses the effect of AI labels on people's performance and offers insights into where people obtain information, as well as their perceptions about their media literacy skills, among other issues. In this way, the survey contributes to the statistical literature on measuring false and misleading content.

In the survey, participants interact with both true and false content on an interface that resembles a "real life" social media site. Design features such as avatars and scores aim to encourage engagement. The survey was designed by the OECD and administered by an external polling company to ensure a representative sample in each country. It was translated and localised into the primary languages of each country covered, and it was administered in January and February 2024.

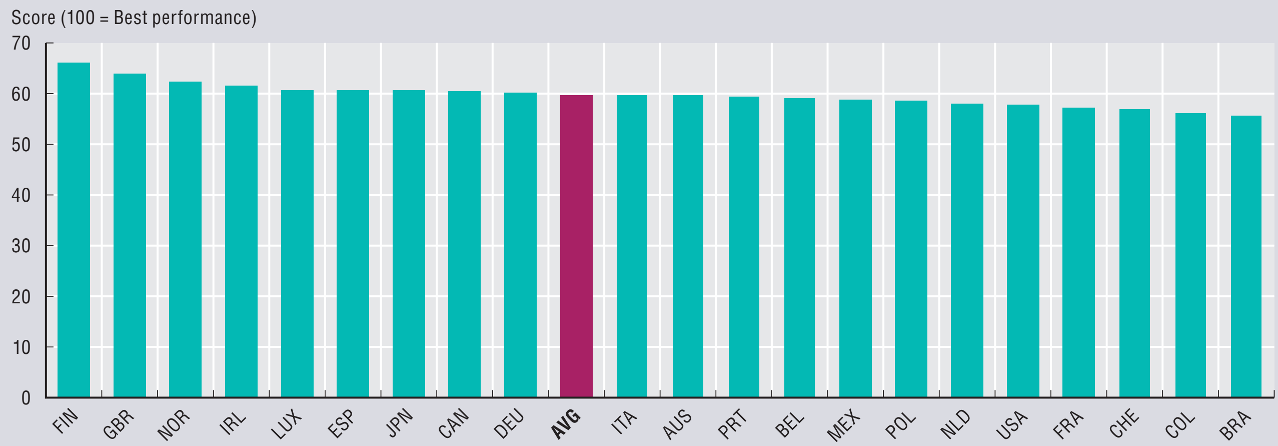
The OECD Truth Quest survey was administered to approximately 2 000 people in each of the 21 countries covered by the survey. The respondents are representative of the population of each country based on demographic variables including age, gender, sub-national region, educational attainment, and income level using country-specific quotas. Quotas were calculated based on data from national statistical offices and related institutes. Post-stratification weights were calculated to ensure nationally representative samples. In total, 40 765 people completed the survey across five continents. More detail about the OECD Truth Quest Survey methodology can be found in OECD (2024[1]).

The overall Truth Quest score measures people's ability to correctly identify false and misleading content on line (Figure 3.S.1)*. Key data from the OECD Truth Quest Survey can be found on the OECD Going Digital Toolkit (OECD, 2024[2]).

Box 3.S.1. The OECD Truth Quest Survey *(cont.)*

Figure 3.S.1. Ability to identify the veracity of information on line varies across countries

Overall OECD Truth Quest score, 2024



Note: AVG = Average. * To calculate the overall Truth Quest score, the total number of correct responses is divided by the total number of claims seen. A country score is thus an average of all respondents' results. The average is calculated as a simple average of the 21 country scores from the OECD Truth Quest Survey: Australia, Belgium, Brazil, Canada, Colombia, Finland, France, Germany, Ireland, Italy, Japan, Luxembourg, Mexico, Netherlands, Norway, Poland, Portugal, Spain, Switzerland, United Kingdom and United States.

Source: OECD (2024[3]), "Ability of adults to identify the veracity of content on line", *OECD Going Digital Toolkit*, based on the OECD Truth Quest Survey, *https://goingdigital.oecd.org/indicator/80*.

StatLink *https://stat.link/zfq312*

Age influences media consumption and trust in media

As digital technologies have increasingly become part of daily life, the channels by which people consume information have multiplied. Smartphones and applications (apps) now play an important role in how people consume information. In response, news outlets have shifted to offering information through a wider variety of channels (Barthel et al., 2020[4]; Al-Zoubi, 2024[5]). Understanding where people source information and how much they trust it plays an important role in improving the integrity of the information ecosystem (OECD, 2024[6]).

Recent data show that some demographic factors influence media consumption. Information from websites or apps is the most common source, on average, across age groups. However, age is nonetheless one of the most important factors that influence the consumption of other media sources (Figure 3.S.2). The largest difference exists for social media[3], where people aged 18-24 are 25 percentage points (pp) more likely to source information from social media than those aged 65 and older. Those aged 65 and older more frequently consume information from all of the other media sources surveyed than people aged 18-24: public TV (20 pp), print publications (19 pp), public radio (16 pp), private TV (11 pp), private radio (4 pp) and news websites or apps (1 pp).

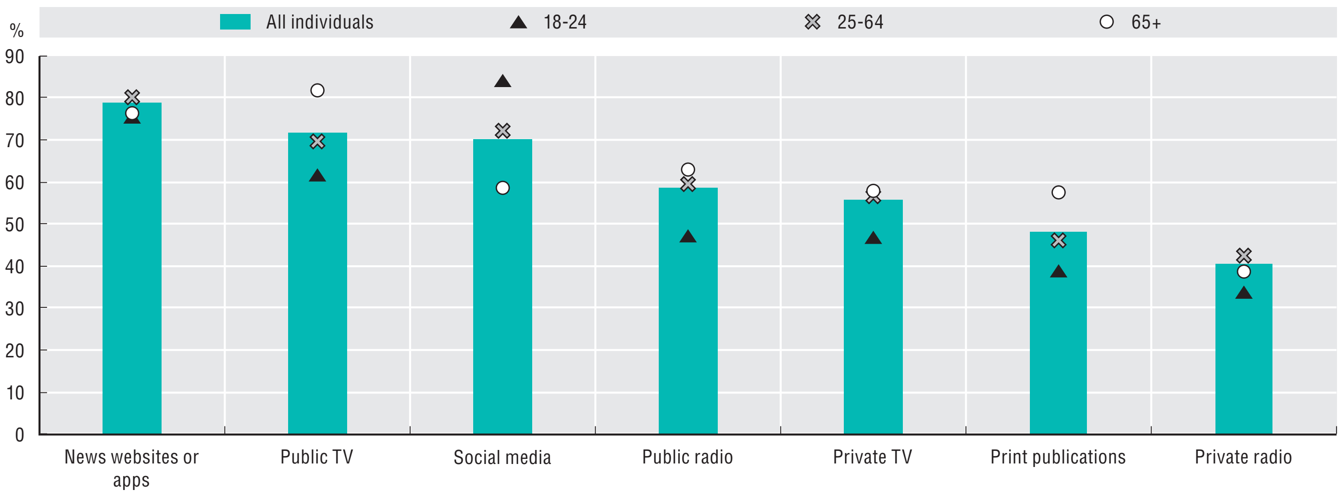
Income and education also play a role in influencing media consumption. Individuals living in high-income households (top 20%) are more likely than those in low-income households (bottom 20%) to get information from any source except for social media (3 pp). Similarly, those with tertiary education are more likely than those with low education to obtain information from any source except for social media (2 pp). The largest gaps between high-income and high-educated people and low-income and low-educated people are related to news websites and apps (11-12 pp), as well as public radio (12 pp). In the United States, the gap for print publications between those with highest and lowest levels of education reaches 30 pp and it is likewise large for news websites and apps (24 pp). In the United States, those with tertiary education are also more likely to get information from social media (10 pp), while the opposite is true for people in Finland (10 pp), Norway (11 pp) and Switzerland (13 pp).

Gender differences in media consumption are less striking. Men tend to obtain information from all sources more frequently except for social media, the source where women are 8 pp on average more likely to get information. Some interesting country-specific results emerge for social media, which is more frequently a source of information for women in all countries except for the United States, where the gap is below 1 pp. In Finland and Norway, women are

16 pp more likely to source information from social media. For other media sources, the largest gap is in Spain where men are 21 pp more likely to get news from private radio. Conversely, women in Spain are 21 pp more likely to get news from private TV.

Figure 3.S.2. Age influences media consumption

Media source by frequency and age, 2024



Notes: Respondents were asked to indicate whether they "often", "sometimes", "rarely" or "never" get news from public television, private television, public radio, private radio, print publications, news websites or apps, and social media sites or apps (e.g. Facebook, Twitter/X, Instagram, WhatsApp, Telegram). Social media sites and apps are surveyed as an aggregate.[3] This figure shows the share of individuals who "often" and "sometimes" get information from the various media sources. All individuals are defined as people aged 18 and older.

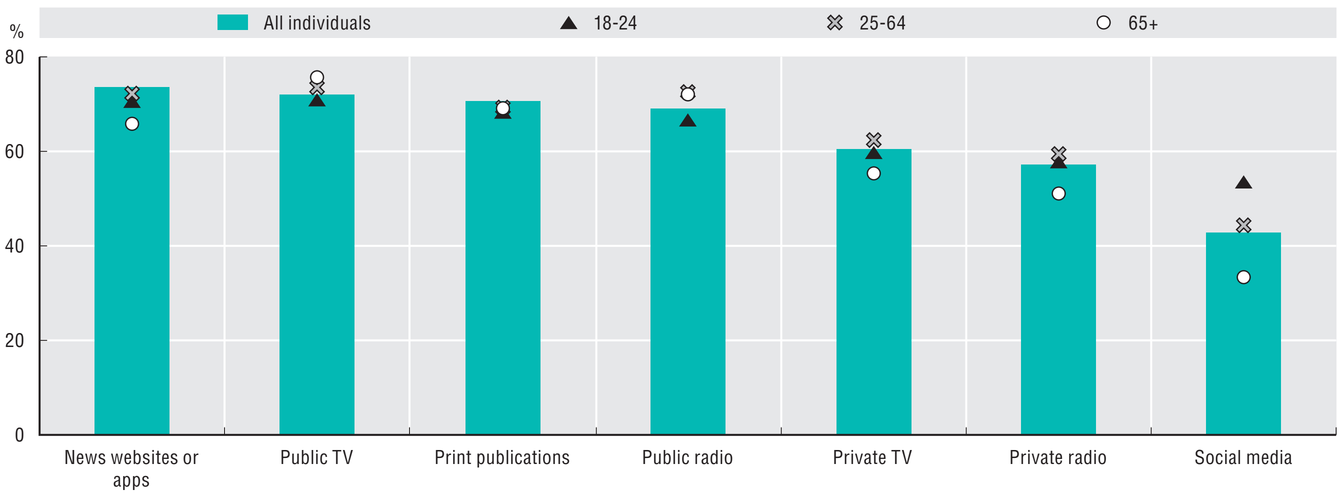
Source: Authors' calculations based on the OECD Truth Quest Survey (OECD, 2024[1]).

StatLink https://stat.link/79vj8k

Age differences are also evident in people's trust in media sources. Young people aged 18-24 generally trust all media sources more than people aged 65 and older. The one exception is public sources (TV and radio), where there is a trust gap of 5 pp with the older cohort trusting information more (Figure 3.S.3). The largest trust gap exists for social media, where people aged 18-24 are 20 pp more likely than those aged 65 and older to trust information they obtain on social media. Social media is also the least trusted source of information overall.

Figure 3.S.3. Social media is the least trusted media source

Trust level, by age, 2024



Notes: Respondents were asked to indicate how much, if at all, they trust the information from public television, private television, public radio, private radio, print publications, news websites or apps, and social media sites or apps (e.g. Facebook, Twitter/X, Instagram, WhatsApp, Telegram). Possible responses include "a lot", "some", "not too much" and "never". Social media sites and apps are surveyed as an aggregate.[3] This figure shows the share of individuals who trust information "a lot" and "some" from the various media sources. All individuals are defined as people aged 18 and older.

Source: Authors' calculations based on the OECD Truth Quest Survey (OECD, 2024[1]).

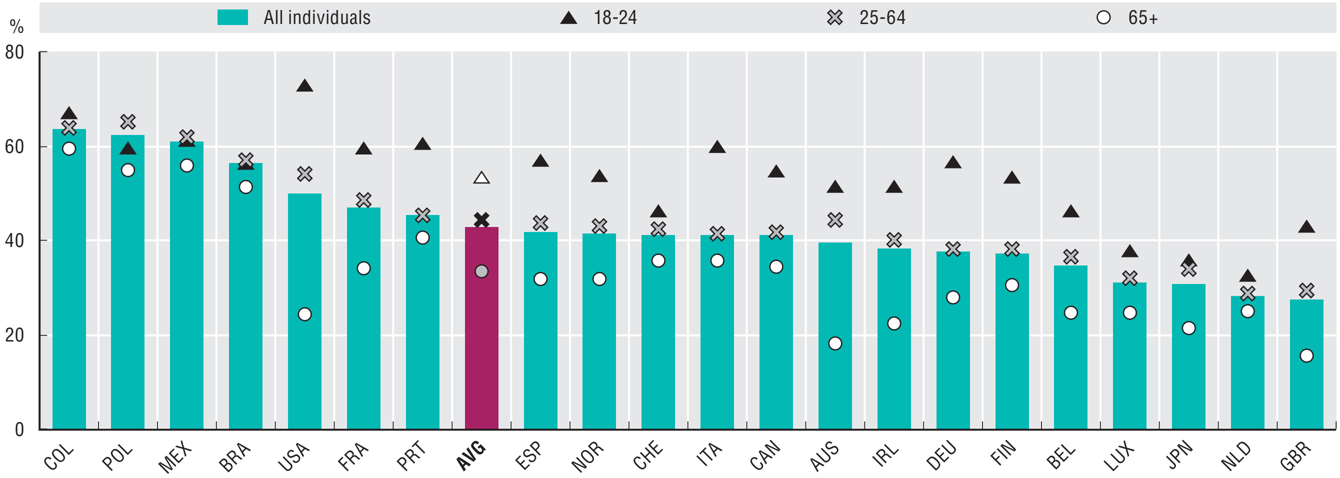
StatLink https://stat.link/1x4om3

Differences in people's trust in various media sources in relation to education and income reflect the same patterns as media consumption. People with tertiary education and those living in high-income households (top 20%) place higher trust in all media sources except for social media. In terms of gender, there are few differences between men and women, although there is some cross-country variation. For example, women in Spain trust all types of media sources more than men in Spain do: print publications (11 pp), public TV (10 pp), public radio (8 pp), social media (8 pp), news websites or apps (7 pp), private TV (6 pp) and private radio (1 pp).

While social media is the least trusted media source overall (43%), there are notable differences across countries (Figure 3.S.4).[4] Individuals in the Latin American countries surveyed tend to trust social media more than people do in other regions.[5] In contrast, individuals from the United Kingdom have the lowest trust in information from social media, with about a quarter of people trusting information on social media some or a lot. Across all countries covered, young people aged 18-24 trust information more than people aged 65 and older (Figure 3.S.4). The most noteworthy trust gap between young and older generations is in the United States, where 49 pp separate the two age groups.

Figure 3.S.4. Young people trust information from social media the most

Trust in information on social media, by age, 2024



Notes: Respondents were asked to indicate how much, if at all, they trust the information from public television, private television, public radio, private radio, print publications, news websites or apps, and social media sites or apps (e.g. Facebook, Twitter/X, Instagram, WhatsApp, Telegram). Possible responses include "a lot", "some", "not too much" and "never". This figure shows the share of individuals who trust information on social media "a lot" and "some". Social media sites and apps are surveyed as an aggregate.[3] All individuals are defined as people aged 18 and older.

Source: OECD (2024[20]), "Share of adults who trust information from social media sites or apps", *OECD Going Digital Toolkit*, based on the OECD Truth Quest Survey, *https://goingdigital.oecd.org/indicator/83*.

StatLink *https://stat.link/6xf0ms*

Other demographic differences are also noteworthy. People living in high-income households and those with tertiary education trust information from social media less than those living in low-income households and those with low or no education. This is true for all countries with relatively few exceptions. The largest gaps between people with tertiary education and those with low education are observed in Finland (17 pp), Japan (17 pp), the Netherlands (16 pp), Norway (19 pp) and Switzerland (22 pp). In terms of income, the largest gaps exist in Italy (16 pp) and the Netherlands (16 pp). While on average the differences between men and women are small (3 pp), women are more likely to trust information from social media at least to some extent in Norway (17 pp) and in Finland (10 pp). Conversely, men trust information from social media more in the United States (7 pp).

Importantly, people who trust information from social media have a lower ability to detect its veracity (OECD, 2024[1]). On average across countries, those who trust information on social media a lot demonstrated lower ability to identify its veracity (54%) compared to those who trust information on social media somewhat (59%) and not much or not at all (62%).[6] When looking at more nuanced levels of trust, the gap between those who trust social media a lot and those who do not trust at all reaches 8 pp. In the United Kingdom, the difference between those who trust information on social media a lot and not at all is 14 pp. However, in countries where trust in information on social media is high, such as Brazil or Colombia, the difference is relatively small (3 pp).

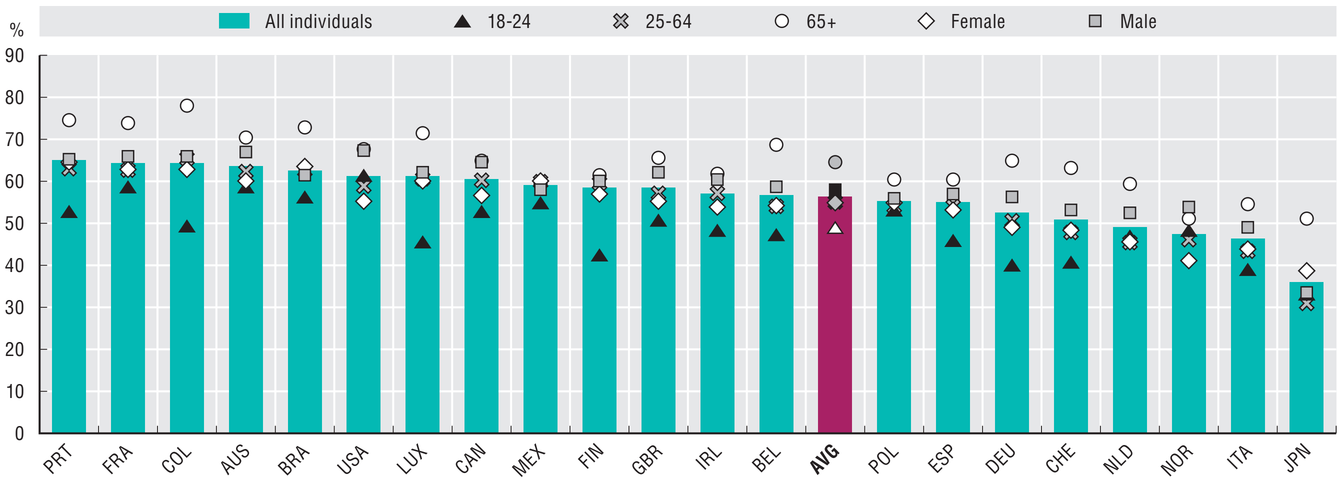
Privacy on line is a concern for most individuals

Protecting individual privacy promotes safety, dignity, and freedom of thought and expression. Concerns about privacy, and control over and the protection of personal data, reduce trust in the information ecosystem. Social media platforms, for example, offer zero price services in exchange for personal data, which are then used as part of the platform's business model (e.g. for targeted advertising). The extensive amount of personal data gathered, processed and exchanged over online platforms generates risks to individuals' privacy, especially as personal data are sometimes used in ways unanticipated at the time of collection. Technological advances have also made it easier to re-identify people via personal data that were intended to be anonymous.

How much does privacy matter to people in digital environments? Data show that privacy on websites, apps or social media is a concern for most people (Figure 3.S.5).[7] On average, over half of people (56%) avoid using certain websites, apps or social media due to privacy concerns. The share of people that avoid certain online spaces because of privacy concerns ranges from 65% in Portugal to 36% in Japan. Only 14% of people on average are not concerned about privacy when using websites, apps or social media.

Figure 3.S.5. Privacy on line is a concern for most people

Share of adults who avoid certain websites, apps or social media due to privacy concerns, by age and gender, 2024



Notes: Respondents were asked to indicate whether they agreed with the following statement: "I avoid using certain websites, apps or social media due to privacy concerns". Possible responses include "strongly agree", "agree", "neither agree nor disagree", "disagree" and "strongly disagree". Social media sites and apps are surveyed as an aggregate.[3] All individuals are defined as people aged 18 and older.

Source: OECD (2024[7]), "Share of adults who avoid using certain websites, apps or social media due to privacy concerns", *OECD Going Digital Toolkit*, based on the OECD Truth Quest Survey, *https://goingdigital.oecd.org/indicator/84*.

StatLink *https://stat.link/qcue5s*

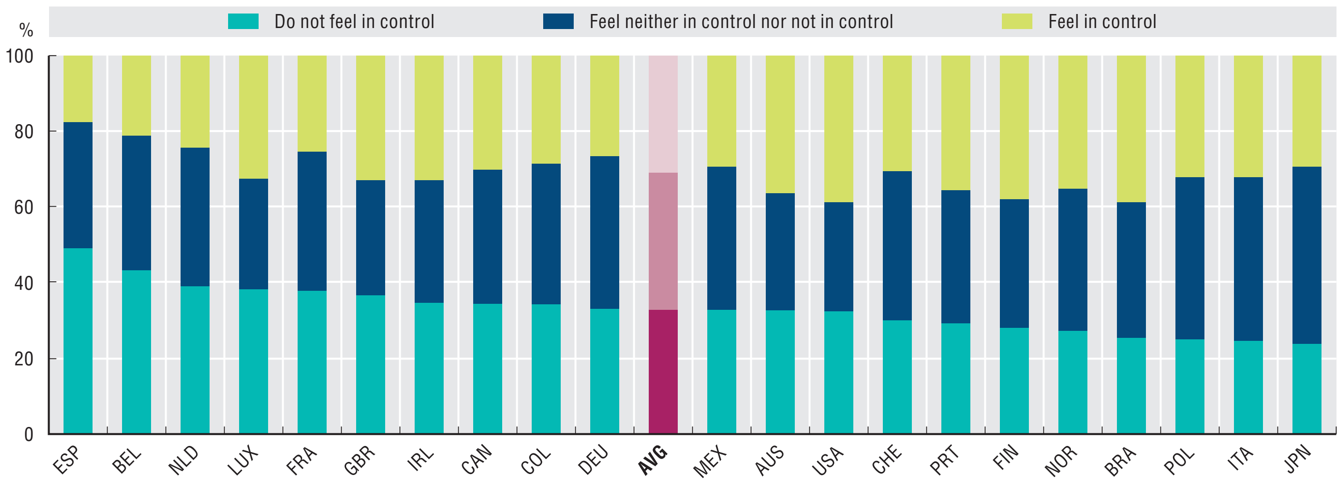
The percentage of people avoiding using certain websites, apps or social media due to privacy concerns increases with age, income and education level. The largest gap exists between the youngest and the oldest generations (16 pp). On average, 65% of people aged 65 and older indicate that they avoid some online spaces due to privacy concerns compared to only 49% of those aged 18-24. In Colombia, the age gap reaches 28 pp, while in Norway the difference between the youngest and the oldest groups is only 3 pp.

People with the highest level of income and education more frequently (5 pp) avoid using certain websites, apps or social media due to privacy concerns than those with the lowest level of education and income. In Finland, people with tertiary education and those living in high-income households (top 20%) are 19 pp more likely to avoid certain websites and apps than Finnish people with the lowest levels of income and education. Conversely, people with tertiary education in Luxembourg (4 pp) and Spain (5 pp) are less likely to avoid online spaces because of privacy concerns. With a few exceptions, such as Japan (5 pp), men are also more likely (4 pp) to avoid using certain websites, apps or social media due to privacy concerns. This trend can be pronounced (i.e. Norwegian men are 13 pp more likely than women to avoid certain online spaces).

Control of personal data is another important aspect of trust. About one-third of people feel they do not have control over their personal information on line and one-third do (Figure 3.S.6).[8] The remaining third neither feel in control nor not in control of their personal information. Cross-country variations emerge, with nearly half of Spaniards (49%) not feeling in control over their personal information compared to nearly one in four Japanese (24%).

Figure 3.S.6. About one-third of people do not feel in control of their personal information on line

Perception of control over personal information on line, 2024



Notes: Respondents were asked to indicate whether they agreed with the following statement: "I feel I have control over my personal information when using websites, apps or social media". Possible responses include "strongly agree", "agree", "neither agree nor disagree", "disagree" and "strongly disagree". Social media sites and apps are surveyed as an aggregate.[3] Respondents include all individuals aged 18 and older.

Source: Authors' calculations based on the OECD Truth Quest Survey (OECD, 2024[1]).

StatLink https://stat.link/j38rvi

On average, 31% of men and 35% of women do not feel in control of their personal information on line. In most of the countries, women are more likely than men not to feel they have control over their personal information when using websites, apps or social media. Only in Germany (0.5 pp) and the United States (2 pp) are men more likely than women to not feel in control of their personal information on line.

The share of individuals who feel they have control over their personal information when using websites, apps or social media tends to decrease with age. On average, 35% of those aged 18-24 feel they are in control over their personal information on line compared to 29% of those aged 65 and older. The largest gap between these two age groups is in the United States (32 pp), while the smallest gap is Italy, Norway and Switzerland (0 pp).

Media sources can increase trust by providing a high level of data protection and giving users control over their data. Further research into developments in the advertising and data protection landscape could be informative in this respect. For example, questions about the interplay between privacy concerns and practices that require consumers to accept the collection of data to purchase online subscription services by different demographic groups could be useful to explore, including in the context of data-driven advertising.

Exposure to additional context does not always help people identify the veracity of information on line

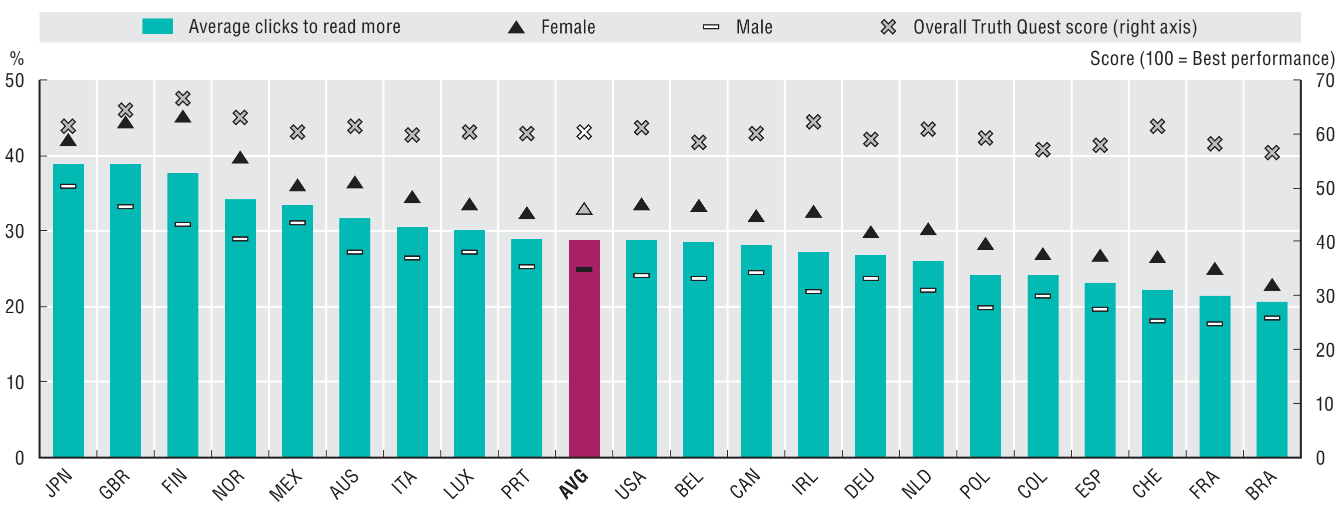
As concerns about the negative effects of false and misleading content intensify, policy makers increasingly focus on media literacy (Canadian Heritage, 2021[8]; US Department of State, 2022[9]). A range of entities engage in media literacy activities, including governments, schools, universities, online platforms and non-profit organisations. These aim to help individuals better assess and verify the accuracy of information on line. Media literacy initiatives tend to focus on developing cognitive, critical and technical skills that help discern fact from fiction, and enable meaningful participation in public interactions, discussions and debates.

As two of their core elements, media literacy initiatives advocate that individuals check facts and critically appraise the information they consume. *A priori*, one would expect that people who search for more information about a headline would be better able to identify its veracity. However, how often do people actually read more context about a headline, and does it influence their ability to identify true, and false and misleading content?

In the OECD Truth Quest Survey, respondents saw a news claim "headline" with the option to "read more" context about the claim.[9] Overall, people clicked to read more context 29% of the time. People in France and Brazil clicked to read more context the least on average (21%), while people in Japan and the United Kingdom did so the most (39%) (Figure 3.S.7).[10] Moreover, in Japan the share of people clicking to read more context in 20 or more claims reached 31%, while in Brazil it was only 8%.

Figure 3.S.7. Almost one-third of the time people read more context about information on line

Average percentage of times an individual clicked to read more context (left-hand scale) and overall Truth Quest score (right-hand scale), by gender, 2024



Notes: The percentages are calculated as the number of times a respondent clicked to read more context divided by the total number of claims seen (left-hand scale). The score is calculated as the total number of correct responses divided by the total number of claims seen (right-hand scale). A country score is thus an average of all respondents' results and expressed as a percentage.

Source: Authors' calculations based on the OECD Truth Quest Survey (OECD, 2024[1]).

StatLink https://stat.link/kcuosj

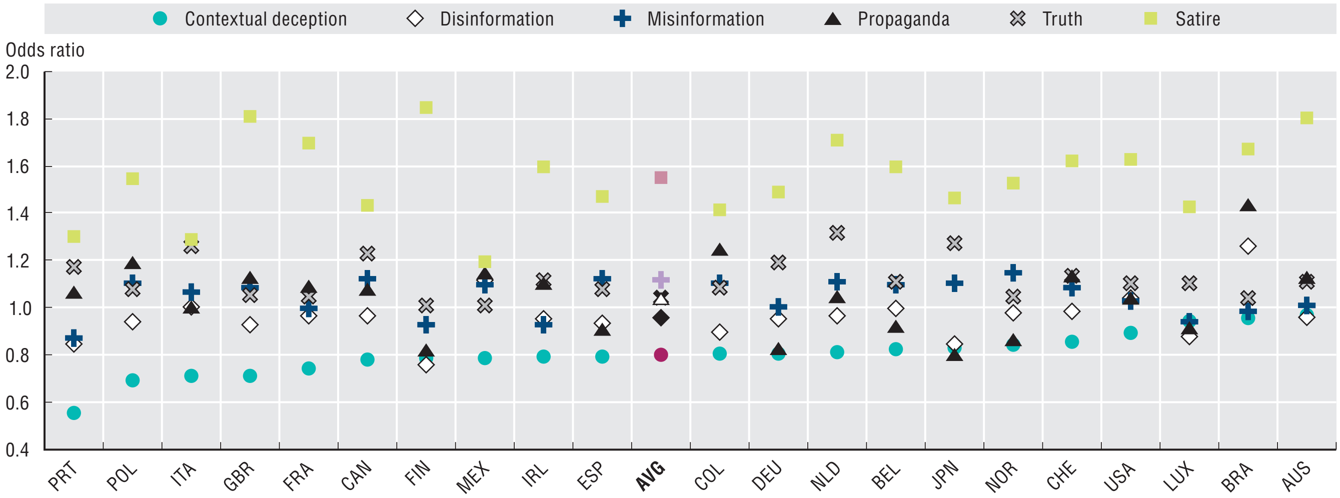
On average, people with low education clicked to read more context 22% of the time, compared to those with secondary (28%) and tertiary education (33%). In all countries, women clicked to read more context (33%) more often than men (25%) on average. The share of people clicking on more context increases with the level of education in all countries except for Japan.

At the same time, exposure to more context increases the odds of correctly identifying the veracity of information on line in ten countries. Counterintuitively, it decreases the odds of correctly identifying the veracity of information on line in two countries (Finland and Portugal). The effect of exposure to additional context varies among content types (Figure 3.S.8).[11] For satire, reading more context increases the odds of a correct answer by as much as 54%. Exposure to more context also increases the odds of correctly identifying true content (+12%). Conversely, exposure to more context for information classified as contextual deception leads to a lower accuracy rate (-20%).

Other studies have also found that not all aspects of traditional media literacy interventions always help people learn how to detect the veracity of information on line (Jones-Jang, Mortensen and Liu, 2021[10]; McGrew, 2024[11]). However, "lateral reading" has been identified as an important aspect of media literacy in the context of false and misleading content on line, although more research is needed in this area. Lateral reading is defined as the "strategy of leaving an unfamiliar website to search for information about a source's credibility via additional sources" (McGrew, 2024[11]).

Figure 3.S.8. Exposure to additional context does not always help identify the veracity of information, especially for some types of content

Odds ratio of correctly identifying the veracity of content, by type, 2024



Note: How to read the figure: A result of 1.54 means that the odds of a correct answer are 54% more likely after clicking to read more context.

Source: Authors' calculations based on the OECD Truth Quest Survey (OECD, 2024[1]).

StatLink https://stat.link/n150z6

Media literacy initiatives need rethinking to strengthen the information ecosystem

To foster a stronger information ecosystem, it is crucial to understand how people consume information and whether they trust it. This Spotlight shows that media consumption and trust levels in media sources vary considerably across demographic groups within and across countries. For example, while social media is an important source of information for many people – particularly young adults – it is also the least trusted source. Thus, social media companies and policy makers could consider developing mechanisms to make social media more trustworthy.

More trustworthy social media is important from a societal perspective because those who trust information from social media tend to have a lower ability to detect the veracity of information on line. On average across countries, those who trust social media a lot had a relatively lower overall Truth Quest score. As a result, governments and other actors may wish to design media literacy initiatives with this in mind, focusing on information on social media and how to better detect true and false content. Again, an understanding of demographic and country-specific differences can help target those most at risk.

As people increasingly consume information on line, either through news websites or social media platforms, media literacy can help people become more critical consumers of information.[12] For example, data from this Spotlight show that on average, about one-third of the time people read more context about a headline in the accompanying text. Understanding people's behaviour in this respect – i.e. people on average are not active searchers for more information – provides insights into the challenges faced by media literacy initiatives to help people become more critical consumers of information.

At the same time, analysis in this Spotlight suggests that reading more context about a headline does not always increase the odds of correctly identifying its veracity. This may indicate that media literacy initiatives should focus on encouraging people to seek additional information on third-party websites through lateral reading. It may also suggest that people simply do not want to expend additional time to verify their understanding, which poses other challenges for media literacy. More research into people's online behaviour as well as more monitoring of the effectiveness of media literacy initiatives (OECD, 2024[12]) is needed to improve the information ecosystem.

References

Al-Zoubi, A. (2024), "The impact of digital technology on media consumption: A case study of smartphone and app usage", in *Technology: Toward Business Sustainability. ICBT 2023. Lecture Notes in Networks and Systems*, Vol. 925, Springer, Cham, *http://dx.doi.org/10.1007/978-3-031-54019-6_39*. [5]

Barthel, M. et al. (2020), "Measuring news consumption in a digital era", 8 December, Pew Research Center, Washington, D.C., *https://www.journalism.org/wp-content/uploads/sites/8/2020/12/PJ_2020.12.08_News-Consumption_FINAL.pdf* (accessed on 8 July 2024). [4]

Basol, M. et al. (2021), "Towards psychological herd immunity: Cross-cultural evidence for two prebunking interventions against COVID-19 misinformation", *Big Data & Society*, Vol. 8/1, *https://doi.org/10.1177/20539517211013868*. [19]

Canadian Heritage (2021), "Ongoing support for research and media literacy projects as Canada continues to fight online disinformation", News Release, 9 February, Canadian Heritage, Gatineau, Quebec, *https://www.canada.ca/en/canadian-heritage/news/2021/02/ongoing-support-for-research-and-media-literacy-projects-as-canada-continues-to-fight-online-disinformation.html* (accessed on 1 August 2024). [8]

Jones-Jang, S., T. Mortensen and J. Liu (2021), "Does media literacy help identification of fake news? Information literacy helps, but other literacies don't", *American Behavioral Scientist*, Vol. 65/1, pp. 271-388, *https://doi.org/10.1177/0002764219869406*. [10]

Lesher, M., H. Pawelec and A. Desai (2022), "Disentangling untruths online: Creators, spreaders and how to stop them", *OECD Going Digital Toolkit Notes*, No. 23, OECD Publishing, Paris, *https://doi.org/10.1787/84b62df1-en*. [13]

McGrew, S. (2024), "Teaching lateral reading: Interventions to help people read like fact checkers", *Current Opinion in Psychology*, Vol. 55/101737, *https://doi.org/10.1016/j.copsyc.2023.101737*. [11]

OECD (2024), "Ability of adults to identify the veracity of content online", *OECD Going Digital Toolkit*, *https://goingdigital.oecd.org/indicator/80* (accessed on 28 June 2024). [3]

OECD (2024), *Facts not Fakes: Tackling Disinformation, Strengthening Information Integrity*, OECD Publishing, Paris, *https://doi.org/10.1787/d909ff7a-en*. [12]

OECD (2024), "OECD Information Integrity Hub", webpage, *https://www.oecd.org/en/blogs/2023/03/oecd-hub-on-information-integrity-joining-forces-to-fight-dis--and-misinformation.html*. [17]

OECD (2024), *OECD Survey on Drivers of Trust in Public Institutions – 2024 Results: Building Trust in a Complex Policy Environment*, OECD Publishing, Paris, *https://doi.org/10.1787/9a20554b-en*. [6]

OECD (2024), "Online safety", *OECD Going Digital Toolkit*, *https://goingdigital.oecd.org/theme/10* (accessed on 28 June 2024). [2]

OECD (2024), "Share of adults who avoid using certain websites, apps, or social media due to privacy concerns", *OECD Going Digital Toolkit*, *https://goingdigital.oecd.org/indicator/84* (accessed on 18 November 2024). [7]

OECD (2024), "Share of adults who trust information from social media sites or apps", *OECD Going Digital Toolkit*, *https://goingdigital.oecd.org/indicator/83* (accessed on 18 November 2024). [20]

OECD (2024), "The OECD Truth Quest Survey: Methodology and findings", *OECD Digital Economy Papers*, No. 369, OECD Publishing, Paris, *https://doi.org/10.1787/92a94c0f-en*. [1]

OECD (2022), "Misinformation and disinformation: An international effort using behavioural science to tackle the spread of misinformation", OECD Public Governance Policy Papers, No. 21, OECD Publishing, Paris, *https://doi.org/10.1787/b7709d4f-en*. [18]

Polizzi, G. (2020), "Information literacy in the digital age: Why critical digital literacy", in *Informed Societies: Why Information Literacy Matters for Citizenship, Participation and Democracy*, Facet Publishing, London, *http://eprints.lse.ac.uk/102993/*. [15]

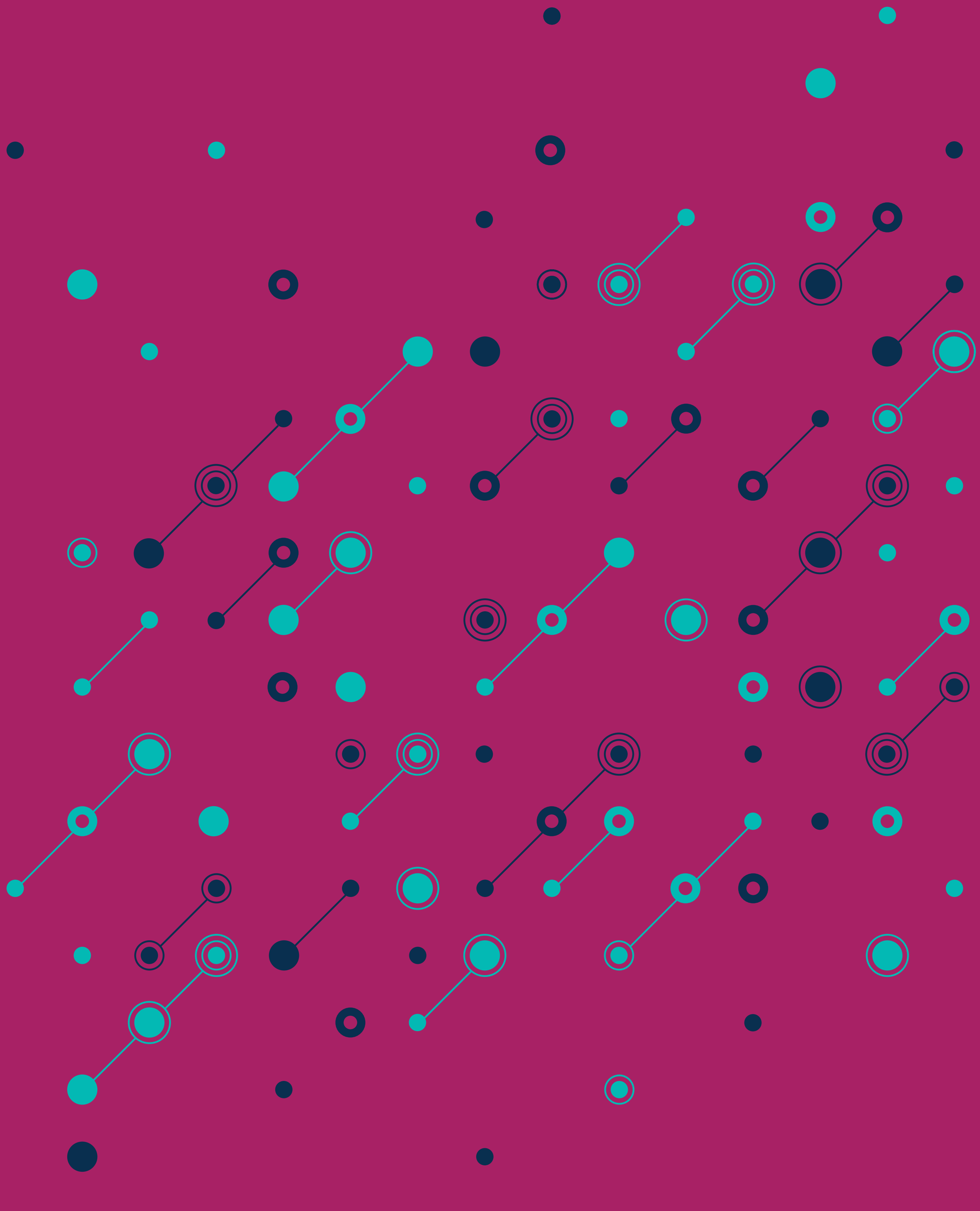
UNESCO (2024), "Digital literacy", webpage, *https://uis.unesco.org/en/glossary-term/digital-literacy* (accessed on 10 July 2024). [14]

UNESCO (2023), "Information Literacy", webpage, *https://www.unesco.org/en/ifap/information-literacy* (accessed on 10 July 2024). [16]

US Department of State (2022), *Media Literacy Design Manual*, US Department of State, Washington, D.C., *https://www.state.gov/wp-content/uploads/2022/08/Media-Literacy-Design-Manual-FINAL.pdf*. [9]

Notes

1. See, for example, Lesher, Pawelec and Desai (2022[13]); OECD (2024[12]) and OECD (2024[17]).
2. There are many types of literacy relevant to false and misleading content on line. Information literacy is an umbrella concept that applies to both analogue and digital media. It is defined as the ability "to seek, evaluate, use and create information effectively to achieve their personal, social, occupational and educational goal" (UNESCO, 2023[16]). The concept of digital literacy, which refers to the skills needed to use digital technologies effectively, as well as awareness of privacy, cybersecurity and critical thinking skills, is closely related. As a result, the term "media literacy" is often used to comprise the range of literacies needed to thrive in the digital age (Polizzi, 2020[15]).
3. Social media platforms are diverse and include a range of activities, including social networking, microblogging, messaging, and video-sharing, and content moderation policies vary across platforms. Perceptions of trustworthiness may be influenced by both the activities offered on a particular platform and the platform's content moderation policies.
4. The figure reflects a simple average of the 21 country scores from the OECD Truth Quest Survey: Australia, Belgium, Brazil, Canada, Colombia, Finland, France, Germany, Ireland, Italy, Japan, Luxembourg, Mexico, Netherlands, Norway, Poland, Portugal, Spain, Switzerland, United Kingdom and United States.
5. The top four countries that trust information on social media some or a lot are: Colombia (64%), Poland (62%), Mexico (61%) and Brazil (57%).
6. The Truth Quest score is a measure of people's ability (or skill) to detect the veracity of content on line. It is calculated as the total number of correct responses divided by the total number of news claims seen. A country score is an average of all respondents' results. On average, respondents correctly identified the veracity of content 60% of the time. More information about the survey methodology can be found in OECD (2024[1]).
7. The figure reflects a simple average of the 21 country scores from the OECD Truth Quest Survey: Australia, Belgium, Brazil, Canada, Colombia, Finland, France, Germany, Ireland, Italy, Japan, Luxembourg, Mexico, Netherlands, Norway, Poland, Portugal, Spain, Switzerland, United Kingdom and United States.
8. The figure reflects a simple average of the 21 country scores from the OECD Truth Quest Survey: Australia, Belgium, Brazil, Canada, Colombia, Finland, France, Germany, Ireland, Italy, Japan, Luxembourg, Mexico, Netherlands, Norway, Poland, Portugal, Spain, Switzerland, United Kingdom and United States.
9. All headlines and additional context were derived from real-life news that was professionally fact-checked (except for the AI-generated claims, which were generated by GPT-4). More information can be found in OECD (2024[1]).
10. The average score is calculated as a simple unweighted average of the 21 country scores from the OECD Truth Quest Survey: Australia, Belgium, Brazil, Canada, Colombia, Finland, France, Germany, Ireland, Italy, Japan, Luxembourg, Mexico, Netherlands, Norway, Poland, Portugal, Spain, Switzerland, United Kingdom and United States.
11. The odds ratios are calculated by dividing the odds of a correct answer after clicking to read more context by the odds of a correct answer without reading the extra context. An odds ratio above 1 indicates that the chance of correctly identifying the veracity of information is increasing after clicking to read more context, and when it is below 1 it is decreasing. All types of content in the OECD taxonomy of false and misleading content were included (Lesher, Pawelec and Desai, 2022[13]). This figure shows the average, which is calculated as a simple unweighted average across the 21 country scores covered by the OECD Truth Quest Survey.
12. Media literacy can take many forms, including games (Basol et al., 2021[19]) and other mechanisms for providing media literacy tips (OECD, 2022[18]).



Statistical Annex

ICT access and usage indicators

The indicators shown in this section are based on the *OECD Access and Usage Database* (*https://oe.cd/dx/ict-access-usage*) which provide a selection of indicators on diffusion and use of information and communication technologies (ICTs). The database comprises 106 indicators related to individuals and households. These include computer and Internet access and usage, activities, e-commerce, e-government, ICT skills, and security and privacy. The data are presented by demographic groups. The database also comprises 59 indicators related to businesses covering connectivity, uptake of ICT tools, e-commerce, digital government, ICT skills, and security and privacy. Data are organised by size and industry.

The indicators originate from two sources:

i) An OECD data collection on the following OECD countries, accession countries, and key partners: Australia, Brazil, Canada, Chile, Colombia, Costa Rica, Israel, Japan, Korea, Mexico, New Zealand, Switzerland and the United States. The data collection methodology followed by these countries is available in each respective country metadata file available in the database.

ii) Eurostat statistics on households and individuals and on businesses for the OECD countries and accession countries or key partners that are part of the European statistical system (26 OECD countries, Bulgaria, Croatia and Romania). For those countries, indicators refer to the indicators as published by EUROSTAT in the respective comprehensive databases (EUROSTAT, 2023[1]).

The Statistical Annex of the *DEO 2024* presents indicators drawn from the *OECD ICT Access and Usage Database* that complete the analysis undertaken in different chapters of the publication and provide more insights on technology uptake and diffusion.

Table 1. Internet users by reference period, most recent year

As a share of the individuals aged 16-74

Country	Year	In the last 3 months	In the last 12 months
Austria	2023	95.3	95.7
Belgium	2023	94.6	95.3
Brazil	2023	86.1	88.1
Bulgaria	2023	80.4	84.0
Canada	2022	96.9	97.9
Chile	2017	83.5	84.6
Colombia	2022	..	76.5
Costa Rica	2023	91.9	..
Croatia	2023	83.4	84.4
Czech Republic	2023	92.0	92.8
Denmark	2023	98.8	99.0
Estonia	2023	93.2	93.7
Finland	2023	97.7	97.8
France	2023	92.8	93.8
Germany	2023	92.5	93.4
Greece	2023	85.0	86.2
Hungary	2023	91.5	91.8
Iceland	2021	99.4	99.5
Ireland	2023	93.3	93.5
Israel	2021	92.5	..
Italy	2023	86.9	87.7
Japan	2022	..	93.0
Korea	2023	97.4	97.6
Latvia	2023	92.3	92.8
Lithuania	2023	88.5	89.0
Luxembourg	2023	99.3	99.4
Mexico	2020	81.2	..
Netherlands	2023	99.2	99.3
Norway	2023	99.7	99.8
Poland	2023	86.4	88.1
Portugal	2023	85.8	86.4
Romania	2023	89.2	91.6
Slovak Republic	2023	87.2	89.1
Slovenia	2023	90.4	90.8
Spain	2023	95.4	96.0
Sweden	2023	97.6	98.1
Switzerland	2023	99.3	99.3
Türkiye	2023	86.0	86.5
United Kingdom	2020	97.3	97.8
United States	2021	83.86	..

Notes: For Costa Rica, data relate to individuals aged 18 to 74; for Israel, to individuals aged 20 and over; for Japan, to individuals aged 15 to 74. For the United States, the reference period is six months.

Source: OECD (2024), ICT Access and Usage Database, *https://oe.cd/dx/ict-access-usage* (accessed on 28 February 2024).

StatLink *https://stat.link/w2bdmn*

Table 2. Internet users by gender, most recent year

As a percentage of the population in each group

Country	Year	Women	Men	All
Austria	2023	94.2	96.5	95.3
Belgium	2023	94.7	94.6	94.6
Brazil	2023	87.4	84.7	86.1
Bulgaria	2023	79.8	81.0	80.4
Canada	2022	97.2	96.6	96.9
Chile	2017	82.5	84.6	83.5
Colombia	2022	77.7	75.3	76.5
Costa Rica	2023	92.7	91.0	91.9
Croatia	2023	80.0	86.9	83.4
Czech Republic	2023	91.8	92.4	92.0
Denmark	2023	98.7	98.9	98.8
Estonia	2023	94.4	91.9	93.2
Finland	2023	97.7	97.7	97.7
France	2023	93.5	92.1	92.8
Germany	2023	91.5	93.5	92.5
Greece	2023	84.8	85.2	85.0
Hungary	2023	91.8	91.1	91.5
Iceland	2021	99.4	99.5	99.4
Ireland	2023	89.4	97.4	93.3
Israel	2021	92.5	92.5	92.5
Italy	2023	86.0	87.9	86.9
Japan	2022	92.5	93.6	93.0
Korea	2023	96.7	98.1	97.4
Latvia	2023	92.5	92.2	92.3
Lithuania	2023	90.7	86.1	88.5
Luxembourg	2023	99.3	99.4	99.3
Mexico	2022	80.8	81.6	81.2
Netherlands	2023	99.1	99.2	99.2
Norway	2023	99.7	99.7	99.7
Poland	2023	86.7	86.1	86.4
Portugal	2023	85.0	86.6	85.8
Romania	2023	88.5	90.0	89.2
Slovak Republic	2023	87.1	87.4	87.2
Slovenia	2023	89.8	90.9	90.4
Spain	2023	95.6	95.3	95.4
Sweden	2023	97.6	97.6	97.6
Switzerland	2023	99.0	99.5	99.3
Türkiye	2023	82.1	89.8	86.0
United Kingdom	2020	97.5	97.1	97.3
United States	2021	84.2	83.5	83.9

Notes: The reference period is 3 months, except for Colombia and Japan (12 months) and the United States (6 months). For Costa Rica, data relate to individuals aged 18 to 74; for Israel, to individuals aged 20 and over; and for Japan, to individuals aged 15 to 74.

Source: OECD (2024), ICT Access and Usage Database, *https://oe.cd/dx/ict-access-usage* (accessed on 28 February 2024).

StatLink *https://stat.link/w2bdmn*

Table 3. Internet users by age, most recent year

As a percentage of the population in each age group

Country	Year	16-24	25-54	55-74	All
Austria	2023	99.9	99.2	87.3	95.3
Belgium	2023	98.1	97.5	88.5	94.6
Brazil	2023	95.1	91.1	66.4	86.1
Bulgaria	2023	93.6	91.7	60.4	80.4
Canada	2022	99.1	98.9	92.7	96.9
Chile	2017	98.6	92.5	52.1	83.5
Colombia	2022	88.3	81.5	53.2	76.5
Costa Rica	2023	95.9	95.0	83.6	91.9
Croatia	2023	99.8	96.4	59.5	83.4
Czech Republic	2023	99.8	98.7	77.7	92.0
Denmark	2023	99.6	99.4	97.5	98.8
Estonia	2023	99.8	98.2	82.0	93.2
Finland	2023	100.0	99.8	93.6	97.7
France	2023	97.9	97.0	84.1	92.8
Germany	2023	96.8	96.0	86.0	92.5
Greece	2023	98.4	94.3	65.7	85.0
Hungary	2023	99.5	97.5	77.8	91.5
Iceland	2021	100.0	99.9	98.2	99.4
Ireland	2023	99.7	99.8	77.6	93.3
Israel	2021	95.3	94.7	86.1	92.5
Italy	2023	98.1	93.0	74.7	86.9
Japan	2022	98.6	..	..	93.0
Korea	2023	99.9	99.7	93.1	97.4
Latvia	2023	100.0	98.1	81.0	92.3
Lithuania	2023	99.6	95.9	73.3	88.5
Luxembourg	2023	100.0	99.9	97.9	99.3
Mexico	2022	95.2	86.2	53.9	81.2
Netherlands	2023	100.0	99.7	98.0	99.2
Norway	2023	100.0	99.9	99.1	99.7
Poland	2023	98.9	96.5	66.1	86.4
Portugal	2023	100.0	95.7	65.6	85.8
Romania	2023	97.8	95.3	75.5	89.2
Slovak Republic	2023	98.4	95.6	68.0	87.2
Slovenia	2023	100.0	98.0	75.6	90.4
Spain	2023	99.8	98.6	88.3	95.4
Sweden	2023	99.1	98.0	96.2	97.6
Switzerland	2023	100.0	99.9	97.9	99.3
Türkiye	2023	96.6	93.9	57.4	86.0
United Kingdom	2020	100.0	99.5	92.3	97.3
United States	2021	85.7	85.4	80.4	83.9

Notes: The reference period is 3 months, except for Colombia and Japan (12 months) and the United States (6 months). For Costa Rica, data relate to individuals aged 18 to 74; for Israel, to individuals aged 20 and over; and for Japan, to individuals aged 15 to 74. For Ireland, data for individuals aged 16 to 24 refer to 2019 instead of 2023.

Source: OECD (2024), ICT Access and Usage Database, *https://oe.cd/dx/ict-access-usage* (accessed on 28 February 2024).

StatLink *https://stat.link/w2bdmn*

Table 4. Internet use in the last three months, by income quintile (Panel A) and quartile (Panel B), most recent year

As a percentage of the population in each group

Country	A. By quintile						
	Year	1st Q	2nd Q	3rd Q	4th Q	5th Q	All
Austria	2023	93.7	93.7	94.3	96.9	98.5	95.3
Belgium	2023	88.0	92.0	94.7	96.8	98.7	94.6
Brazil	2023	73.8	86.1	94.1	95.8	97.4	86.1
Bulgaria	2023	55.5	73.3	83.9	91.0	96.2	80.4
Canada	2022	91.4	96.4	97.9	98.7	99.1	96.9
Costa Rica	2023	81.9	89.5	92.6	96.4	98.7	91.9
Croatia	2023	56.8	72.9	94.8	97.7	98.2	83.4
Czech Republic	2023	82.0	86.3	90.7	97.4	98.9	92.0
Denmark	2023	95.5	98.0	99.0	99.2	99.8	98.8
Estonia	2023	80.5	90.5	96.5	97.7	98.5	93.2
Finland	2023	95.5	96.1	98.7	97.8	99.7	97.7
France	2023	88.8	89.6	93.0	95.5	97.9	92.8
Germany	2023	84.1	89.4	92.9	95.6	97.8	92.5
Greece	2023	76.1	81.7	84.2	92.4	96.4	85.0
Hungary	2023	80.5	89.7	92.8	96.5	98.9	91.5
Iceland	2017	96.6	98.3	98.6	98.6	99.4	99.4
Ireland	2023	100.0	100.0	75.7	99.6	99.5	93.3
Israel	2019	70.8	82.7	91.1	97.3	98.8	92.5
Italy	2023	80.1	84.7	88.8	91.7	91.5	86.9
Korea	2023	84.8	95.9	98.0	98.5	98.6	97.4
Latvia	2023	74.3	88.0	95.9	98.0	99.4	92.3
Lithuania	2023	85.6	72.9	92.3	94.5	98.3	88.5
Luxembourg	2023	100.0	97.2	99.1	99.4	99.5	99.3
Netherlands	2023	97.8	98.5	99.3	99.4	99.9	99.2
Norway	2023	99.6	99.3	99.6	99.8	100.0	99.7
Poland	2023	77.9	82.6	88.0	89.8	93.6	86.4
Portugal	2023	67.8	81.0	88.6	93.8	97.0	85.8
Romania	2023	79.8	85.1	85.7	92.0	97.6	89.2
Slovak Republic	2023	83.4	74.4	88.4	91.7	97.2	87.2
Slovenia	2023	85.3	81.2	92.0	95.5	99.0	90.4
Spain	2023	88.3	93.9	97.4	98.5	99.4	95.4
Sweden	2023	93.4	96.5	97.2	99.3	99.5	97.6
Türkiye	2023	67.3	85.3	86.9	90.2	94.7	86.0
United States	2021	74.0	81.2	85.0	87.6	89.0	83.9

Table 4. Internet use in the last three months, by income quintile (Panel A) and quartile (Panel B), most recent year *(cont.)*

Country	B. By quartile					
	Year	1st Q	2nd Q	3rd Q	4th Q	All
Austria	2020	81.9	83.6	87.5	94.4	95.3
Belgium	2020	82.5	81.4	91.4	97.8	94.6
Brazil	2019	59.8	75.4	84.0	95.2	86.1
Bulgaria	2020	30.2	63.2	77.6	87.3	80.4
Canada	2020	89.4	95.0	96.9	98.3	96.9
Chile	2017	76.6	78.3	83.2	92.2	83.5
Colombia	2022	55.0	70.4	81.2	91.2	76.5
Costa Rica	2020	75.8	82.7	87.8	95.0	91.9
Croatia	2020	65.3	88.6	94.4	97.4	83.4
Czech Republic	2020	62.1	80.7	93.7	96.1	92.0
Denmark	2020	94.7	97.7	99.9	99.9	98.8
Estonia	2020	66.5	87.5	95.2	98.1	93.2
Finland	2020	95.4	97.1	99.1	100.0	97.7
France	2019	78.8	86.8	91.6	96.3	92.8
Germany	2020	85.3	91.5	96.5	98.8	92.5
Greece	2020	57.3	69.9	83.0	94.2	85.0
Hungary	2020	60.6	76.7	89.4	95.2	91.5
Iceland	2017	96.6	98.2	99.1	99.3	99.4
Ireland	2020	95.5	94.5	99.2	100.0	96.2
Israel	2019	72.6	87.2	96.6	98.4	92.5
Korea	2020	78.8	95.8	98.5	98.7	97.2
Latvia	2020	73.8	86.7	91.2	97.1	92.3
Lithuania	2020	59.3	82.7	93.7	98.2	88.5
Luxembourg	2020	97.5	99.4	99.8	99.2	99.3
Netherlands	2020	86.4	93.2	97.5	97.7	99.2
Norway	2020	94.4	97.1	99.0	99.7	99.7
Poland	2020	70.5	82.3	86.9	87.8	86.4
Portugal	2020	52.0	66.8	85.7	95.5	85.8
Romania	2020	57.3	70.0	83.0	89.6	89.2
Slovak Republic	2020	84.8	82.5	96.0	97.5	87.2
Slovenia	2020	72.4	80.1	94.4	97.0	90.4
Spain	2020	84.6	91.6	96.5	99.0	95.4
Sweden	2020	89.8	98.6	99.4	99.7	97.6
United States	2019	70.5	81.9	86.6	89.3	83.9

Notes: Income levels increase as the number of quintiles and quartiles increase, 1st Q being the lowest. The reference period is of 3 months, except for Colombia (12 months) and the United States (6 months). For Costa Rica, data relate to individuals aged 18 to 74 and for Israel, to individuals aged 20 and over. For the United States, income quintiles or quartiles are approximate because family income is a categorical variable.

Source: OECD (2024), ICT Access and Usage Database, *https://oe.cd/dx/ict-access-usage* (accessed on 28 February 2024).

StatLink *https://stat.link/w2bdmn*

Table 5. Diffusion of selected online activities among Internet users, most recent year

As a percentage of Internet users performing each activity

Country	Year	Internet banking	Year	Telephoning/ video calling	Year	Interacting with public authorities' websites
Austria	2023	80.9	2023	73.6	2023	66.9
Belgium	2023	84.1	2023	76.9	2023	73.0
Brazil	2023	61.5	2023	85.6	2023	53.7
Bulgaria	2023	29.1	2023	85.9	2023	27.5
Canada	2022	84.6	2022	70.6	2022	83.5
Chile	2017	28.5	2017	39.0	2017	34.5
Colombia	2022	23.1	..	..	2022	12.0
Costa Rica	2018	25.4	2018	71.3	2018	38.4
Croatia	2023	74.2	2023	68.8	2023	55.3
Czech Republic	2023	86.7	2023	70.9	2023	66.2
Denmark	2023	97.4	2023	79.9	2023	92.7
Estonia	2023	91.1	2023	70.6	2023	89.2
Finland	2023	96.7	2023	75.7	2023	94.7
France	2023	78.0	2023	72.6	2023	73.7
Germany	2023	61.9	2023	69.0	2023	43.4
Greece	2023	61.2	2023	84.1	2023	71.2
Hungary	2023	71.6	2023	87.4	2023	80.0
Iceland	2021	95.4	2021	76.1	2021	94.7
Ireland	2023	89.8	2023	82.6	2023	80.5
Israel	2021	75.1	2021	65.7	2020	59.9
Italy	2023	59.3	2023	78.6	2023	47.5
Japan	2022	28.4	2019	60.3	..	..
Korea	2023	84.8	2023	69.7	..	..
Latvia	2023	90.7	2023	80.9	2023	68.6
Lithuania	2023	85.6	2023	84.7	2023	74.7
Luxembourg	2023	71.6	2023	73.1	2023	77.4
Mexico	2022	18.8	2022	87.3	2022	45.4
Netherlands	2023	95.9	2023	85.4	2023	84.7
Norway	2023	97.2	2023	79.4	2023	92.0
Poland	2023	68.4	2023	64.9	2023	50.1
Portugal	2023	68.6	2023	82.4	2023	69.8
Romania	2023	24.5	2023	78.9	2023	15.7
Slovak Republic	2023	66.2	2023	70.5	2023	67.9
Slovenia	2023	67.2	2023	63.4	2023	67.1
Spain	2023	74.9	2023	79.7	2023	63.7
Sweden	2023	86.6	2023	77.4	2023	84.2
Switzerland	2023	84.4	2023	75.3	2023	75.9
Türkiye	2023	67.1	2023	92.5	2023	82.7
United Kingdom	2020	82.6	2020	53.5	2020	58.9
United States	2021	76.5	2021	67.3	2021	39.4

Notes: The reference period is of 3 months, except for Colombia and Japan (12 months) and the United States (6 months). For Brazil, "Interacting with public authorities' websites" relates to "Looking for information provided on government sites" and "Carrying out some type of public service, such as issuing documents, filling and sending forms, or paying taxes and fees on line". For Costa Rica, data relate to individuals aged 18 to 74. For Israel, data relate to individuals aged 20 and over instead of 16 to 74. Interacting with public authorities' websites relates to a question asked without time limit: "Do you use the sites of government bodies, ministries, the National Insurance Institute, etc.?". For Japan, data relate to individuals aged 15 to 74. For Mexico, "Telephoning/Video calling" relates to "Internet telephone conversations (VoIP)". For the United States, "Internet banking" also includes investing, paying bills on line and other financial services.

Source: OECD (2024), ICT Access and Usage Database, *https://oe.cd/dx/ict-access-usage* (accessed on 28 February 2024).

StatLink *https://stat.link/w2bdmn*

Table 6. Technology adoption, by size, most recent year

As a percentage of enterprises in each group, Cloud computing (Panel A), Internet of Things (Panel B), Big data analysis (Panel C) and Artificial intelligence (Panel D)

Country	A. Cloud computing					B. Internet of Things (IoT)				
	Year	Small	Medium	Large	All (10+)	Year	Small	Medium	Large	All (10+)
Australia	2022	70.4	82.7	83.2	72.4	2022	12.2	13.9	25.9	12.8
Austria	2023	42.5	62.6	84.9	46.5	2021	48.0	63.2	73.9	50.8
Belgium	2023	47.1	67.7	88.2	51.7	2021	25.5	38.6	51.2	28.2
Brazil	2023	66.1	86.0	87.5	68.7	2023	12.1	28.7	36.0	14.3
Bulgaria	2023	14.7	27.1	52.1	17.5	2021	13.8	19.8	26.3	15.0
Canada	2021	46.0	69.0	81.0	49.0	2021	22.8	36.1	48.1	24.7
Colombia	2020	57.5	77.1	86.5	65.1	2020	6.0	11.7	21.3	8.8
Croatia	2023	42.0	57.0	78.2	45.1	2021	20.9	32.6	42.5	23.2
Czech Republic	2023	42.9	60.0	78.9	47.2	2021	28.2	40.8	55.0	31.4
Denmark	2023	66.6	79.2	93.7	69.5	2021	16.8	31.0	49.1	20.0
Estonia	2023	54.7	74.0	91.5	58.6	2021	16.2	21.1	36.3	17.4
Finland	2023	75.0	91.5	99.1	78.3	2021	39.2	42.3	63.1	40.5
France	2023	23.2	41.2	67.2	26.8	2021	20.1	31.6	42.1	22.0
Germany	2023	43.3	59.4	77.6	47.0	2021	33.7	42.7	48.7	35.6
Greece	2023	21.2	35.3	55.7	23.6	2021	21.6	32.3	35.3	22.8
Hungary	2023	41.2	61.3	85.8	44.9	2021	20.3	31.5	41.3	22.3
Ireland	2023	59.4	79.1	86.1	63.1	2021	30.9	46.5	56.1	34.0
Israel	2020	46.6	67.7	78.8	50.9	2020	4.7	11.9	17.8	6.2
Italy	2023	59.3	74.4	85.7	61.4	2021	30.5	42.3	59.0	32.3
Japan	2021	20.6	34.0	56.6	24.1	2021	15.3	22.3	37.3	17.2
Korea	2022	69.6	68.0	72.9	69.5	2022	52.1	59.1	65.5	53.2
Latvia	2023	32.0	51.7	79.7	35.8	2021	25.0	41.0	67.8	28.4
Lithuania	2023	32.7	57.4	78.9	38.4	2021	24.4	41.1	61.0	28.4
Luxembourg	2023	33.2	49.8	68.0	37.0	2021	19.6	29.6	47.1	22.2
Netherlands	2023	57.9	72.1	84.5	61.2	2021	18.4	27.5	40.6	20.7
New Zealand	2022	54.9	62.5	74.8	56.3	2022	36.4	47.5	56.7	38.3
Norway	2023	68.7	84.8	90.7	71.3	2021	22.0	30.1	49.9	23.6
Poland	2023	51.0	73.2	88.4	55.7	2021	14.9	31.8	51.2	18.6
Portugal	2023	33.7	48.9	78.9	37.5	2021	19.9	35.0	46.1	23.1
Romania	2023	16.3	24.2	43.0	18.4	2021	9.4	13.5	23.6	10.5
Slovak Republic	2023	30.0	46.9	67.5	34.4	2021	23.8	39.4	47.0	27.4
Slovenia	2023	35.0	59.0	85.5	40.2	2021	46.4	60.8	77.9	49.5
Spain	2023	25.5	48.2	72.9	30.0	2021	25.7	35.9	43.7	27.5
Sweden	2023	68.3	85.5	91.2	71.6	2021	38.1	49.9	60.9	40.3
Switzerland	2019	42.0	48.6	67.9	43.4	..	..	..	..	..
Türkiye	2023	13.7	26.6	48.2	16.4	2021	19.6	27.2	35.9	21.1
United Kingdom	2021	59.8	57.7	..	59.4	..	..	..	..	..
United States	2018	42.7	56.8	68.1	44.3	..	..	..	..	..

Table 6. Technology adoption, by size, most recent year *(cont.)*

Country	C. Big data analytics					D. Artificial intelligence				
	Year	Small	Medium	Large	All (10+)	Year	Small	Medium	Large	All (10+)
Australia	2022	7.6	15.5	39.5	9.5	2022	3.1	3.7	11.0	3.4
Austria	2023	20.8	36.6	55.8	23.9	2023	8.9	16.9	35.2	10.8
Brazil	2023	5.4	13.7	24.0	6.7	2023	10.9	23.6	40.8	12.9
Bulgaria	2023	18.8	33.3	53.0	21.9	2023	3.0	5.5	13.8	3.6
Belgium	2023	38.9	65.7	82.7	44.5	2023	10.6	23.0	47.9	13.8
Canada	2021	1.6	7.3	24.1	2.6	2021	3.5	11.4	26.5	4.7
Colombia	2020	2.9	11.9	26.8	7.3	2020	4.3	9.9	21.0	7.2
Croatia	2023	47.7	69.8	83.9	51.7	2023	7.0	11.2	19.3	7.9
Czech Republic	2023	15.3	32.3	51.5	19.5	2023	4.0	9.8	28.3	5.9
Denmark	2023	44.1	69.3	88.3	49.5	2023	12.4	22.6	51.4	15.2
Estonia	2023	21.4	40.8	69.7	25.6	2023	4.1	8.1	23.0	5.2
Finland	2023	35.2	60.0	85.5	40.6	2023	11.5	26.4	53.3	15.1
France	2023	29.8	51.9	72.0	33.9	2023	4.7	10.2	20.9	5.9
Germany	2023	31.7	57.0	74.6	37.1	2023	9.7	16.2	35.4	11.6
Greece	2023	22.8	35.7	54.9	25.0	2023	3.5	5.7	14.0	4.0
Hungary	2023	51.1	62.6	75.9	53.2	2023	3.0	5.5	17.4	3.7
Ireland	2023	32.0	57.4	77.4	37.1	2023	5.3	17.8	36.3	8.0
Israel	2020	4.1	7.7	17.9	5.1	2020	3.2	5.1	10.9	3.7
Italy	2023	22.9	48.8	74.1	26.6	2023	4.4	7.3	24.1	5.0
Japan	2021	3.9	6.2	19.3	4.8	2021	2.2	5.9	21.7	3.5
Korea	2022	39.2	41.0	51.2	39.7	2022	28.8	21.2	36.4	28.0
Latvia	2023	32.8	54.9	77.8	36.9	2023	3.5	8.3	21.3	4.5
Lithuania	2023	34.7	60.1	81.6	40.5	2023	3.4	8.8	21.3	4.9
Luxembourg	2023	28.4	45.6	64.3	32.4	2023	12.3	19.7	41.8	14.4
Netherlands	2023	42.8	68.9	84.8	48.6	2023	11.0	19.1	39.9	13.4
New Zealand	..	..	..	..	..	2022	7.7	14.7	28.0	9.0
Norway	2023	16.4	29.6	51.4	19.0	2023	7.1	17.9	34.4	9.2
Poland	2023	14.4	35.2	65.7	19.3	2023	2.2	6.5	24.4	3.7
Portugal	2023	34.6	15.5	71.7	38.6	2023	5.8	16.4	35.4	7.9
Romania	2023	19.1	31.0	48.4	21.9	2023	1.1	2.4	8.1	1.5
Slovak Republic	2023	25.2	44.3	68.7	30.2	2023	6.0	8.6	21.9	7.0
Slovenia	2023	14.1	34.8	72.8	19.1	2023	8.9	16.8	53.2	11.4
Spain	2023	33.7	56.1	76.2	38.0	2023	6.4	19.6	39.7	9.2
Sweden	2023	30.0	53.0	78.8	35.0	2023	8.7	13.5	37.8	10.4
Switzerland	2020	20.9	33.7	48.6	22.8	2021	8.9	11.8	29.0	9.6
Türkiye	2023	12.3	22.5	41.2	14.5	2023	4.9	6.5	18.5	5.5
United Kingdom	2019	25.1	32.4	49.9	26.9	2020	3.7	4.9	11.5	4.1
United States	..	..	..	..	..	2021	5.0	7.5	16.1	5.7

Notes: For countries in the European Statistical System, 2023 data for "Big data analytics" relate to "Data analytics". For Canada, "Artificial intelligence" refers to enterprises using software and hardware using artificial intelligence. For Japan, data originate from the Japan National Innovation Survey 2022 and refer to the three-year period 2019-21. For Switzerland, data refer to businesses with five or more employees (instead of ten or more) and for "Cloud computing", to proportion of total businesses using (rather than buying) cloud computing services. For the United Kingdom, Cloud computing data for large firms relate to the year 2020 instead of 2021. For the United States, "Cloud computing" refers to proportion of total businesses using cloud computing services in 2018, asked in the context of use in production processes or methods (i.e. with regards to cloud "use" and not to cloud "purchase") over the three-year period 2016-18.

Source: OECD (2024), ICT Access and Usage Database, *https://oe.cd/dx/ict-access-usage* (accessed on 28 February 2024).

StatLink *https://stat.link/w2bdmn*

Table 7. Technology adoption, by industry, most recent year

As a percentage of enterprises in each group, Cloud computing (Panel A), Internet of Things (Panel B), Big data analysis (Panel C) and Artificial intelligence (Panel D)

Country	A. Cloud computing						
	Year	Manufacturing (ISIC C)	Construction (ISIC F)	Wholesale trade, except of motor vehicles and motorcycles (ISIC G: Division 46)	Retail trade, except of motor vehicles and motorcycles (ISIC G. Division 47)	Transportation and storage (ISIC H)	Accommodation and food service activities (ISIC I)
Australia	2022	67.8	73.9	73.4	78.2	71.7	53.8
Austria	2023	45.7	39.7	54.5	34.5	35.3	40.8
Belgium	2023	51.8	47.7	62.6	39.0	30.2	21.6
Brazil	2023	66.6	70.4	67.7	..	67.4	54.2
Bulgaria	2023	13.2	10.8	19.5	14.5	16.5	12.5
Canada	2021	58.0	57.0	59.0	39.0	53.0	25.0
Colombia	2020	62.4	..	65.8	52.0	81.0	70.4
Croatia	2023	41.2	36.9	58.5	36.5	40.8	33.5
Czech Republic	2023	45.7	43.0	58.0	41.3	34.8	37.4
Denmark	2023	69.7	61.4	79.4	60.0	61.2	51.7
Estonia	2023	56.2	52.7	66.9	55.0	56.9	43.5
Finland	2023	86.9	78.1	..	40.8	63.5	59.3
France	2023	24.0	20.0	34.7	16.0	18.8	16.3
Germany	2023	42.7	35.1	53.7	42.7	36.4	41.6
Greece	2023	28.5	33.6	38.8	17.2	26.5	9.3
Hungary	2023	46.1	34.0	57.8	36.0	41.7	28.8
Ireland	2023	70.5	64.8	67.4	46.4	66.2	44.6
Israel	2020	49.6	40.7	60.7	40.7	31.4	31.5
Italy	2023	61.2	61.7	..	58.4	57.9	47.2
Japan	2021	23.2	20.4	32.4	18.9	14.4	13.7
Korea	2022	76.3	57.0	77.0	..	39.3	55.5
Latvia	2023	32.9	27.2	46.9	24.9	28.7	20.6
Lithuania	2023	40.3	34.5	45.5	37.1	29.4	28.0
Luxembourg	2023	28.5	27.7	..	30.1	34.3	12.4
Netherlands	2023	59.1	53.4	65.4	58.4	54.7	42.6
New Zealand	2022	59.8	58.2	54.7	47.2	64.8	39.5
Norway	2023	74.7	74.9	82.7	54.3	56.4	50.3
Poland	2023	58.2	44.6	65.1	44.5	43.5	51.9
Portugal	2023	33.8	27.5	37.2	24.3	23.5	29.0
Romania	2023	16.1	13.2	23.8	13.8	16.0	10.6
Slovak Republic	2023	34.3	28.6	31.6	33.4	28.9	18.0
Slovenia	2023	39.6	19.6	54.7	55.5	41.7	24.0
Spain	2023	27.3	21.5	32.2	25.5	25.4	18.6
Sweden	2023	70.6	78.7	77.8	53.6	61.7	51.7
Switzerland	2019	40.4	36.0	43.5	28.5	53.9	33.0
Türkiye	2023	15.8	10.3	24.1	16.1	10.4	11.0
United Kingdom	2021	56.4	55.7	58.0	53.2	54.4	56.9
United States	2018	30.6	24.0	32.4	25.4	25.7	22.7

Table 7. Technology adoption, by industry, most recent year *(cont.)*

Country	A. Cloud computing						
	Year	Information and communication (ISIC J)	Financial and insurance activities (ISIC K)	Real estate activities (ISIC L)	Professional, scientific and technical activities (ISIC M)	Administrative and support service activities (ISIC N)	All
Australia	2022	86.4	88.7	87.9	90.7	74.1	72.4
Austria	2023	82.1	..	..	65.9	41.3	46.5
Belgium	2023	85.1	..	..	71.4	45.1	51.7
Brazil	2023	86.1	..	80.5	67.4	..	68.7
Bulgaria	2023	59.0	..	6.5	35.9	14.1	17.5
Canada	2021	76.0	75.0	54.0	75.0	43.0	49.0
Colombia	2020	85.0	..	68.0	82.6	73.3	65.1
Croatia	2023	79.4	..	60.8	59.3	29.7	45.1
Czech Republic	2023	79.1	..	53.7	62.4	35.1	47.2
Denmark	2023	93.0	..	73.0	80.4	67.0	69.5
Estonia	2023	83.7	..	55.8	82.9	44.0	58.6
Finland	2023	98.2	..	91.3	91.2	85.1	78.3
France	2023	68.3	..	45.3	45.2	26.9	26.8
Germany	2023	82.9	..	58.8	64.7	46.5	47.0
Greece	2023	58.9	..	25.0	50.0	30.2	23.6
Hungary	2023	81.7	..	37.4	61.3	44.3	44.9
Ireland	2023	87.1	..	80.1	82.2	65.4	63.1
Israel	2020	85.3	..	72.9	70.6	53.5	50.9
Italy	2023	83.7	..	68.9	80.6	62.7	61.4
Japan	2021	63.6	..	32.3	40.5	25.6	24.1
Korea	2022	93.7	92.3	94.2	75.8	79.6	69.5
Latvia	2023	70.5	..	34.7	62.6	38.3	35.8
Lithuania	2023	79.9	..	33.2	42.5	37.3	38.4
Luxembourg	2023	69.6	..	..	57.4	32.6	37.0
Netherlands	2023	82.6	..	77.6	77.7	55.7	61.2
New Zealand	2022	77.4	73.9	71.0	79.4	56.8	56.3
Norway	2023	93.6	..	75.7	89.5	76.8	71.3
Poland	2023	80.8	..	67.4	70.6	52.4	55.7
Portugal	2023	77.5	..	38.9	40.0	51.2	37.5
Romania	2023	56.3	..	16.6	34.5	15.0	18.4
Slovak Republic	2023	59.3	..	38.9	41.0	43.7	34.4
Slovenia	2023	69.9	..	56.0	63.8	40.5	40.2
Spain	2023	74.1	..	50.2	44.0	28.6	30.0
Sweden	2023	92.4	..	89.8	90.3	61.5	71.6
Switzerland	2019	75.8	34.2	62.2	52.0	34.4	43.4
Türkiye	2023	49.6	..	21.9	23.7	12.0	16.4
United Kingdom	2021	71.6	..		76.0	65.0	59.4
United States	2018	61.6	52.1	40.3	55.0	31.6	44.3

Table 7. Technology adoption, by industry, most recent year *(cont.)*

Country	B. Internet of Things						
	Year	Manufacturing (ISIC C)	Construction (ISIC F)	Wholesale trade, except of motor vehicles and motorcycles (ISIC G: Division 46)	Retail trade, except of motor vehicles and motorcycles (ISIC G. Division 47)	Transportation and storage (ISIC H)	Accommodation and food service activities (ISIC I)
Australia	2022	14.1	16.9	19.1	8.9	11.6	8.1
Austria	2021	53.4	45.5	49.3	54.9	58.9	52.7
Belgium	2021	34.4	36.9	25.8	27.9	30.3	..
Brazil	2023	14.4	9.5	13.3	..	15.8	10.0
Bulgaria	2021	15.1	9.6	15.8	17.3	18.1	10.5
Canada	2021	27.4	17.5	27.2	25.8	36.1	23.1
Colombia	2020	8.3	..	7.8	6.5	14.2	7.6
Croatia	2021	21.7	6.5	25.3	25.9	20.2	27.9
Czech Republic	2021	36.9	30.0	34.1	21.6	36.5	25.2
Denmark	2021	20.6	17.6	17.8	21.3	26.9	17.5
Estonia	2021	20.5	13.6	14.0	10.5	32.8	17.3
Finland	2021	45.8	39.5	..	47.3	41.2	37.5
France	2021	21.1	19.2	21.8	29.8	25.8	23.9
Germany	2021	35.7	31.3	38.3	38.4	35.2	40.6
Greece	2021	23.4	16.9	31.6	15.2	25.1	21.0
Hungary	2021	22.1	19.1	31.2	18.4	27.9	15.4
Ireland	2021	37.1	27.6	33.0	34.0	34.9	33.5
Israel	2020	11.3	3.9	7.9	3.5	6.1	5.3
Italy	2021	36.5	36.0	..	26.4	38.1	22.0
Japan	2021	20.0	14.1	17.2	16.1	17.9	14.3
Korea	2022	51.8	24.6	67.4	..	53.5	73.5
Latvia	2021	30.4	22.4	35.7	26.2	30.0	18.4
Lithuania	2021	29.1	17.4	32.5	36.1	35.9	24.5
Luxembourg	2021	26.5	16.3	..	26.8	27.0	18.0
Netherlands	2021	21.5	24.0	22.6	22.7	21.9	16.8
New Zealand	2022	38.2	35.8	41.5	50.6	41.4	38.1
Norway	2021	24.1	20.5	28.3	29.4	18.3	23.4
Poland	2021	16.3	16.5	21.8	11.3	35.7	7.8
Portugal	2021	22.8	10.6	27.8	..	18.3	28.3
Romania	2021	9.4	8.0	13.0	13.4	10.4	7.1
Slovak Republic	2021	30.7	22.1	30.0	24.1	32.5	28.0
Slovenia	2021	52.6	38.2	50.3	60.9	61.8	52.5
Spain	2021	27.9	22.5	28.9	26.6	30.2	27.3
Sweden	2021	44.1	37.6	38.0	48.1	43.0	37.3
Türkiye	2021	21.9	13.4	24.4	26.7	23.8	21.8

Table 7. Technology adoption, by industry, most recent year *(cont.)*

Country	B. Internet of Things						
	Year	Information and communication (ISIC J)	Financial and insurance activities (ISIC K)	Real estate activities (ISIC L)	Professional, scientific and technical activities (ISIC M)	Administrative and support service activities (ISIC N)	All
Australia	2022	31.3	10.1	6.7	10.1	15.7	12.8
Austria	2021	..	..	..	42.6	46.1	50.8
Belgium	2021	23.5	..	..	20.5	20.5	28.2
Brazil	2023	37.3	..	17.0	14.3	..	14.3
Bulgaria	2021	23.6	..	..	19.4	11.3	15.0
Canada	2021	31.0	36.8	19.2	32.0	16.5	24.7
Colombia	2020	18.0	..	10.2	14.8	10.1	8.8
Croatia	2021	32.4	..	25.5	23.6	19.3	23.2
Czech Republic	2021	30.6	..	27.2	24.4	19.2	31.4
Denmark	2021	29.6	..	19.5	17.4	15.6	20.0
Estonia	2021	17.5	..	9.4	13.8	9.4	17.4
Finland	2021	33.2	..	33.5	33.7	31.4	40.5
France	2021	22.9	..	15.3	18.9	17.4	22.0
Germany	2021	44.3	..	34.8	29.0	31.2	35.6
Greece	2021	21.5	..	34.1	25.6	27.7	22.8
Hungary	2021	27.7	..	26.1	21.3	17.8	22.3
Ireland	2021	48.6	..	31.0	36.3	28.4	34.0
Israel	2020	8.9	..	0.0	4.3	2.7	6.2
Italy	2021	31.0	..	23.5	27.1	22.3	32.3
Japan	2021	27.1	..	20.0	18.4	15.7	17.2
Korea	2022	72.1	82.3	78.5	52.0	23.0	53.2
Latvia	2021	35.8	..	31.3	23.2	32.8	28.4
Lithuania	2021	29.1	..	27.8	25.1	19.0	28.4
Luxembourg	2021	20.9	..		20.3	22.0	22.2
Netherlands	2021	25.6	..	22.9	18.1	14.2	20.7
New Zealand	2022	51.8	40.1	45.0	39.8	31.1	38.3
Norway	2021	30.3	..	15.1	20.5	14.4	23.6
Poland	2021	21.8	..	13.9	11.2	14.8	18.6
Portugal	2021	23.5	..	15.5	17.1	23.1	23.1
Romania	2021	24.7	..	7.1	9.5	7.3	10.5
Slovak Republic	2021	28.5	..	31.0	19.8	17.3	27.4
Slovenia	2021	54.7	..	17.6	36.1	36.1	49.5
Spain	2021	38.5	..	21.6	28.6	21.4	27.5
Sweden	2021	38.5	..	57.9	35.6	30.0	40.3
Türkiye	2021	23.5	..	23.6	15.9	11.9	21.1

Table 7. Technology adoption, by industry, most recent year *(cont.)*

Country	C. Big data analysis						
	Year	Manufacturing (ISIC C)	Construction (ISIC F)	Wholesale trade, except of motor vehicles and motorcycles (ISIC G: Division 46)	Retail trade, except of motor vehicles and motorcycles (ISIC G. Division 47)	Transportation and storage (ISIC H)	Accommodation and food service activities (ISIC I)
Australia	2022	12.7	2.9	14.5	8.1	10.2	4.8
Austria	2023	22.6	11.2	35.4	29.2	12.0	24.1
Belgium	2023	52.2	24.9	61.0	41.4	37.5	24.7
Brazil	2023	6.5	6.5	6.2	..	4.6	3.1
Bulgaria	2023	19.0	12.2	27.4	25.3	21.7	17.5
Canada	2021	2.8	0.2	2.8	1.3	1.7	0.3
Colombia	2020	5.7	..	6.0	3.3	13.6	8.3
Croatia	2023	50.4	40.2	67.3	60.7	59.2	34.4
Czech Republic	2023	20.3	8.0	32.4	22.3	14.6	13.4
Denmark	2023	49.3	22.0	65.0	55.1	43.8	34.9
Estonia	2023	20.4	20.9	28.8	36.1	16.1	14.0
Finland	2023	36.1	26.1	..	45.4	25.1	37.9
France	2023	35.7	20.1	50.6	42.1	26.6	27.7
Germany	2023	40.1	16.4	56.3	47.5	32.1	28.7
Greece	2023	28.9	20.5	43.1	28.7	23.5	14.5
Hungary	2023	56.0	47.6	64.0	50.1	52.1	48.3
Ireland	2023	35.7	13.6	54.1	41.5	27.6	29.7
Israel	2020	3.5	2.0	0.9	1.1	4.7	3.2
Italy	2023	29.3	15.3	..	29.7	23.2	14.3
Japan	2021	4.3	2.1	4.2	9.6	1.8	3.2
Korea	2022	45.6	14.3	47.5	..	27.5	37.8
Latvia	2023	38.4	20.9	53.8	35.4	36.8	24.8
Lithuania	2023	41.4	31.0	59.9	44.3	33.3	24.1
Luxembourg	2023	32.8	19.8	..	43.8	36.4	25.2
Netherlands	2023	48.4	31.9	62.3	57.5	42.9	28.8
Norway	2023	15.8	10.5	25.6	31.3	17.9	11.4
Poland	2023	17.0	7.1	32.4	18.1	15.9	16.0
Portugal	2023	39.3	27.0	11.5	13.9	12.0	31.2
Romania	2023	21.6	11.2	32.5	18.8	26.4	17.7
Slovak Republic	2023	27.3	18.4	43.7	31.1	25.2	16.2
Slovenia	2023	18.2	5.5	29.9	35.6	14.6	10.2
Spain	2023	38.8	24.9	52.0	41.9	31.9	32.5
Sweden	2023	35.1	14.9	56.9	46.8	23.7	24.5
Switzerland	2020	18.4	19.3	22.9	15.4	27.5	24.4
Türkiye	2023	15.4	8.7	17.7	13.3	12.5	13.0
United Kingdom	2019	19.1	20.2	25.2	..	26.7	..

Table 7. Technology adoption, by industry, most recent year *(cont.)*

Country	C. Big data analysis						
	Year	Information and communication (ISIC J)	Financial and insurance activities (ISIC K)	Real estate activities (ISIC L)	Professional, scientific and technical activities (ISIC M)	Administrative and support service activities (ISIC N)	All
Australia	2022	29.2	14.7	17.4	7.9	12.0	9.5
Austria	2023	50.3	..	17.6	25.2	22.1	23.9
Belgium	2023	..	..	8.0	55.4	41.0	44.5
Brazil	2023	23.4	..	8.6	5.7	..	6.7
Bulgaria	2023	39.2	..		30.8	16.6	21.9
Canada	2021	11.2	16.0	1.8	8.2	0.6	2.6
Colombia	2020	24.0	..	10.7	16.7	10.0	7.3
Croatia	2023	82.8	..	51.3	45.7	39.0	51.7
Czech Republic	2023	41.3	..	13.1	20.2	11.1	19.5
Denmark	2023	75.6	..	63.3	59.1	44.2	49.5
Estonia	2023	52.7	..	34.7	31.9	29.8	25.6
Finland	2023	68.9	..	41.6	50.7	36.9	40.6
France	2023	54.4	..	38.8	35.9	30.5	33.9
Germany	2023	56.3	..	37.3	37.1	28.9	37.1
Greece	2023	46.8	..	39.8	32.6	26.8	25.0
Hungary	2023	57.8	..	52.3	51.7	49.7	53.2
Ireland	2023	69.2	..	34.9	42.8	28.6	37.1
Israel	2020	33.6	..	0.0	6.5	2.1	5.1
Italy	2023	39.1	..	24.5	33.8	22.7	26.6
Japan	2021	17.1	..	5.8	5.9	2.7	4.8
Korea	2022	68.0	78.3	75.9	51.7	50.7	39.7
Latvia	2023	55.7	..	33.3	48.1	36.8	36.9
Lithuania	2023	65.0	..	34.5	50.5	42.1	40.5
Luxembourg	2023	42.4	..		32.7	40.5	32.4
Netherlands	2023	67.0	..	53.1	54.2	40.5	48.6
Norway	2023	28.2	..	15.7	22.8	15.8	19.0
Poland	2023	41.5	..	18.6	29.6	18.9	19.3
Portugal	2023	53.2	..	14.0	7.5	38.2	38.6
Romania	2023	38.8	..	27.0	31.5	17.7	21.9
Slovak Republic	2023	47.3	..	29.8	38.5	30.3	30.2
Slovenia	2023	45.8	..	19.1	28.9	12.8	19.1
Spain	2023	60.0	..	56.9	41.1	26.5	38.0
Sweden	2023	63.5	..	47.2	43.8	23.0	35.0
Switzerland	2020	44.6	15.3	24.4	27.3	30.9	22.8
Türkiye	2023	41.2	..	18.8	12.5	11.5	14.5
United Kingdom	2019	45.1	..	..	23.6	29.9	26.9

Table 7. Technology adoption, by industry, most recent year *(cont.)*

Country	D. Artificial intelligence						
	Year	Manufacturing (ISIC C)	Construction (ISIC F)	Wholesale trade, except of motor vehicles and motorcycles (ISIC G: Division 46)	Retail trade, except of motor vehicles and motorcycles (ISIC G. Division 47)	Transportation and storage (ISIC H)	Accommodation and food service activities (ISIC I)
Australia	2022	5.1	0.1	2.7	6.8	0.6	1.0
Austria	2023	12.3	4.3	12.7	5.1	8.3	3.6
Belgium	2023	15.3	5.2	14.0	7.7	14.9	8.0
Brazil	2023	11.3	9.6	11.9	..	14.2	6.0
Bulgaria	2023	2.5	1.5	2.3	2.4	1.9	0.8
Canada	2021	5.3	0.7	4.1	3.5	3.1	1.8
Colombia	2020	5.8	..	5.8	3.9	16.0	6.9
Croatia	2023	6.7	3.1	5.8	3.9	7.6	5.8
Czech Republic	2023	6.0	1.3	5.1	6.1	4.4	2.6
Denmark	2023	14.8	3.2	17.0	12.5	15.2	6.6
Estonia	2023	3.1	3.6	3.3	3.4	5.6	1.6
Finland	2023	13.0	5.2	..	7.5	8.4	2.5
France	2023	4.9	2.1	4.8	2.9	2.4	2.5
Germany	2023	9.3	4.5	13.0	9.2	7.0	5.4
Greece	2023	5.2	3.4	4.7	3.7	5.9	1.3
Hungary	2023	4.2	1.8	3.5	3.0	2.2	2.5
Ireland	2023	7.2	5.9	5.1	5.5	6.1	2.7
Israel	2020	3.3	1.1	0.9	0.6	1.3	1.5
Italy	2023	4.9	2.6	..	3.6	3.5	4.0
Japan	2021	3.7	0.8	2.4	4.1	2.0	4.3
Korea	2022	31.6	21.6	28.3		11.6	22.9
Latvia	2023	4.1	1.5	3.8	0.8	4.1	1.0
Lithuania	2023	4.8	2.4	5.0	4.0	5.0	0.6
Luxembourg	2023	16.2	10.0	..	12.9	10.0	4.9
Netherlands	2023	11.5	4.7	11.5	15.9	8.3	5.9
New Zealand	2022	7.8	4.6	9.5	7.8	9.5	5.7
Norway	2023	8.4	3.6	12.5	3.5	5.4	5.1
Poland	2023	2.9	1.2	4.5	3.7	1.8	1.6
Portugal	2023	8.7	2.9	10.0	4.9	8.3	5.3
Romania	2023	1.3	0.1	1.6	1.2	0.4	0.1
Slovak Republic	2023	6.1	4.1	8.0	5.4	3.3	2.3
Slovenia	2023	12.3	3.5	17.1	16.6	7.5	6.5
Spain	2023	8.7	4.6	7.4	5.1	7.0	6.4
Sweden	2023	7.5	2.8	11.6	9.7	4.7	3.2
Switzerland	2021	7.7	4.5	12.7	4.4	9.3	11.3
Türkiye	2023	6.0	4.9	4.7	4.4	3.5	3.2
United Kingdom	2020	3.1	0.2	3.4	1.9	2.7	0.9
United States	2021	4.6	..	..	..	..	..

Table 7. Technology adoption, by industry, most recent year *(cont.)*

Country	D. Artificial intelligence						
	Year	Information and communication (ISIC J)	Financial and insurance activities (ISIC K)	Real estate activities (ISIC L)	Professional, scientific and technical activities (ISIC M)	Administrative and support service activities (ISIC N)	All
Australia	2022	19.2	2.0	10.8	1.3	2.0	3.4
Austria	2023	37.1	..	10.0	25.8	7.8	10.8
Belgium	2023	34.8	..	4.5	28.3	11.0	13.8
Brazil	2023	40.0	..	18.3	13.3	..	12.9
Bulgaria	2023	21.4	..	0.0	9.6	6.2	3.6
Canada	2021	15.5	17.7	6.6	11.1	7.7	4.7
Colombia	2020	19.4	..	9.8	14.1	11.5	7.2
Croatia	2023	40.0	..	6.9	12.9	6.8	7.9
Czech Republic	2023	24.8	..	4.9	9.4	5.4	5.9
Denmark	2023	44.3	..	13.8	23.6	9.3	15.2
Estonia	2023	20.5	..	1.7	10.7	7.1	5.2
Finland	2023	48.2	..	18.8	31.5	14.8	15.1
France	2023	29.6	..	7.0	13.7	5.6	5.9
Germany	2023	33.1	..	11.4	26.3	11.0	11.6
Greece	2023	17.5	..	8.1	8.7	4.7	4.0
Hungary	2023	14.5	..	3.4	5.2	2.9	3.7
Ireland	2023	28.5	..	16.7	15.8	6.6	8.0
Israel	2020	33.3	..	0.0	1.7	0.3	3.7
Italy	2023	21.0	..	2.7	9.2	6.7	5.0
Japan	2021	19.9	..	3.2	7.9	1.0	3.5
Korea	2022	51.7	39.3	66.6	36.6	11.6	28.0
Latvia	2023	20.9	..	5.8	11.4	6.6	4.5
Lithuania	2023	26.7	..	2.7	4.1	5.5	4.9
Luxembourg	2023	31.7	..		22.0	13.4	14.4
Netherlands	2023	34.2	..	21.0	22.6	11.7	13.4
New Zealand	2022	20.3	18.7	16.2	19.2	9.4	9.0
Norway	2023	31.5	..	6.1	19.3	8.9	9.2
Poland	2023	17.6	..	2.4	9.1	4.8	3.7
Portugal	2023	29.8	..	7.5	10.7	10.3	7.9
Romania	2023	8.1	..	0.0	7.2	1.6	1.5
Slovak Republic	2023	21.6	..	6.5	12.2	10.2	7.0
Slovenia	2023	32.5	..	10.4	22.2	3.2	11.4
Spain	2023	32.4	..	9.4	16.1	9.0	9.2
Sweden	2023	36.8	..	17.8	20.7	8.3	10.4
Switzerland	2021	36.4	13.3	2.7	8.3	14.7	9.6
Türkiye	2023	28.1	..	8.2	6.6	5.2	5.5
United Kingdom	2020	7.6	..	..	6.5	8.3	4.1
United States	2021	..	..	..	..	..	5.7

Table 7. Technology adoption, by industry, most recent year *(cont.)*

Notes: Unless otherwise stated, data relate to firms with ten or more employees.

For countries in the European Statistical System, 2023 data for "Big data analytics" relate to "Data analytics".

For Belgium, "Cloud computing" data for Transport and for Accommodation and food services activities relate respectively to 2017 and 2018 instead of 2023.

For Belgium and Portugal, data for "Big Data Analysis" for Real Estate relate to 2019 instead of 2023.

For Bulgaria, "Cloud computing" data for Real Estate relate to 2017 instead of 2023.

For Canada, Wholesale trade includes all of NAICS 41 (inclusive of motor vehicles) and Retail trade includes all NAICS 44 and 45 (inclusive of motor vehicles). "Artificial Intelligence" refers to "enterprises using software and hardware using Artificial Intelligence".

For Croatia, "Cloud computing" data for Real Estate and for Administrative and support service relate respectively to 2017 and 2021 instead of 2023. "IoT" data for Transport, Information and communication and Real Estate relate to 2020 instead of 2021.

For Greece and the Slovak Republic, "Cloud computing" data for Real Estate relate to 2021 instead of 2023.

For Italy, Norway and Portugal, "IoT" data for Real Estate relate to 2020 instead of 2021.

For Japan, data originate from the Japan National Innovation Survey 2022 and refer to the three-year period 2019-21 instead of 2021.

For Korea, Wholesale trade, except of motor vehicles and motorcycles (ISIC G: Division 46) includes Retail, except of motor vehicles and motorcycles (ISIC G: Division 47).

For Latvia, data for Professional, scientific and technical activities and Administrative and support service for "IoT" relate to 2020 instead of 2021.

For Portugal, "Cloud computing" data for Retail Trade relate to 2018 instead of 2023, and data for Transportation, Real Estate and Professional, scientific and technical activities relate to 2017 instead of 2023. "IoT" data for Real Estate relate to 2020 instead of 2021. Data for "Big Data Analysis" for Wholesale, Retail, Transport, and for Professional, scientific and technical activities relate to 2019 instead of 2023.

For Romania, "Cloud computing" data for Retail trade relate to 2021 instead of 2023.

For Switzerland, data refer to businesses with five or more employees instead of ten or more. For "Cloud computing", data refer to the share of total businesses using (rather than buying) cloud computing services.

For the United Kingdom, "Cloud computing" data for Wholesale Trade, Professional, scientific and technical activities and Administrative and support service relate to 2020 instead of 2021.

For the United States, "Cloud computing" data refer to proportion of total businesses using cloud computing services in 2018, asked in the context of use in production processes or methods (i.e. with regards to cloud "use" and not to cloud "purchase") over the three-year period 2016-18.

For international comparison purpose, All (Total businesses) relate to results including only firms with ten and more employees. However, data provided by industry are not limited to firms with ten or more employees and relate to results including all employment firms, regardless of the size.

Source: OECD (2024), ICT Access and Usage Database, *https://oe.cd/dx/ict-access-usage* (accessed on 28 February 2024).

StatLink *https://stat.link/w2bdmn*

Communication markets indicators: Communication price baskets and telecommunication annual investment and revenues

The OECD has been collecting prices of communication services for 30 years. In that time, it has developed a unique set of basket methodologies comparing communications services in OECD countries. Internationally comparable measures on prices of communication services allows for the evaluation of the affordability services and is an important factor in understanding competition in communication markets. The basket methodologies have been revised and updated over the years to keep pace with service offerings and technological developments. The latest revised version of the methodology for price baskets for mobile broadband services (called "mobile voice and data") and fixed broadband services were adopted in 2017 (OECD, 2017[2]). In 2020, OECD delegates approved and adopted a new price basket methodology, the "OECD bundled communication price baskets" (OECD, 2020[3]). The baskets for bundled communication services range from dual play (fixed broadband and fixed voice) to quadruple play baskets (fixed broadband, fixed voice, television and mobile broadband). These include different combinations of fixed broadband, fixed voice, mobile voice and data (i.e. mobile broadband) and pay-TV services. With increased convergence and the prevalence of communication bundles in most OECD countries, this methodology sets a clear reference for discussions on price baskets for bundled communication services in international fora.

The Statistical Annex presents tables from the three different basket methodologies (i.e. mobile voice and data, fixed broadband services, and bundles of communication services). The features of different offers of communication services are evaluated and compared, including the number of calls, download speed, data allowance, number of TV channels and premium channels (in the case of bundles). The basket methodology consists of selecting, for every OECD country, the cheapest offers in the market meeting all criteria for a given user profile (i.e. Low, Medium, High usage profiles).

For more details on OECD's measurement methodologies of communication services prices, please refer to: OECD (2020[3]) and OECD (2017[2]).

The Statistical Annex also contains data on annual investment and revenues in the telecommunication sector. These tables are also part of the database *OECD Telecommunications and Internet Statistics* (*https://doi.org/10.1787/tel_int-data-en*).

Table 8. Mobile voice and data (MVD), low usage, August 2023

100 calls + 500 MB, USD/PPP, including VAT per month

Country	Provider	Package, option	Fixed	Add-on	Voice	Message	Data	Grand Total	Pre-paid?
Australia	Optus	Optus Flex Annual 60 GB, MyData 5120 MB, 12 months	9.3	0.0	0.0	0.0	0.0	9.3	Pre-paid
Austria	Magenta	Mobile KLAX S, Data 33280 MB	13.2	0.0	0.0	0.0	0.0	13.2	Pre-paid
Belgium	Proximus	Mobilus Easy 5G, Data 10240 MB, 1 month	23.3	0.0	0.0	0.0	0.0	23.3	
Canada	Fido (Rogers)	6 Month Prepaid - Talk & Text & Data 150, Data 1024 MB, 6 months	22.4	0.0	0.0	0.0	0.0	22.4	Pre-paid
Chile	Entel Movil	Bolsa Datos + Minutos, $5000 Top up - 30 days, Mobile Internet 10240 MB, 1 month	9.7	0.0	0.0	3.9	0.0	13.5	Pre-paid
Colombia	Movistar	Combo Mes TODO EN UNO ULTRA $16000 (6 GB) promo 4x1, Datos Full 24576 MB, 1 month	10.0	0.0	0.0	0.0	0.0	10.0	Pre-paid
Costa Rica	Liberty	Plan libre Prepago, Data 4096 MB, SIM only	15.8	0.0	1.6	0.0	0.0	17.4	Pre-paid
Czech Republic	T-Mobile	POŘÁD ONLINE 4 GB Plus, Data 4096 MB, SIM only, 1 month	35.4	0.0	0.0	0.0	0.0	35.4	
Denmark	Telenor	Mobil 20 GB 5G, frisurf 20480 MB, SIM only, 1 month	19.9	0.0	0.0	0.0	0.0	19.9	
Estonia	Telia	Super Calling Card, Call 200, EMT Internet on the Phone 1024 MB, Voicemail option	0.0	6.3	0.6	0.0	0.0	6.9	Pre-paid
Finland	Telia	Prepaid, Paketit S, Internet access 1024 MB	10.8	0.0	7.7	0.0	0.0	18.6	Pre-paid
France	SFR Red (SFR)	Illimite 5 GB, Internet 5120 MB, SIM only	6.6	0.0	0.0	0.0	0.0	6.6	
Germany	O2	My Prepaid Jahrestarife, Data 1024 MB, 12 months	7.6	0.0	0.0	0.0	0.0	7.6	Pre-paid
Greece	What's Up (Cosmote)	PAYG, Calls to all, Mobile Internet Package 512 MB	17.2	0.0	0.0	0.0	0.0	17.2	Pre-paid
Hungary	T-Mobile	Domino Fix, Domino Most Opcion, Domino Renewwable + Maraton 1024 MB	1.0	6.0	14.9	2.6	0.0	24.5	Pre-paid
Iceland	Nova	Nova 2 GB, Data 2048 MB	11.7	0.0	0.0	0.0	0.0	11.7	
Ireland	Three	3 Prepay Hero 5G, Unlimited data, SIM only	15.2	0.0	0.0	0.0	0.0	15.2	Pre-paid
Israel	Partner	Classic 300 GB 5G, Mobile surfing 307200 MB, SIM only, 24 months	9.9	0.0	0.0	0.0	0.0	9.9	
Italy	Kena (TIM)	4.99 1 GB, Internet 1024 MB, SIM only, 1 month	6.8	0.0	0.0	0.0	0.0	6.8	Pre-paid
Japan	NTT DoCoMo	irumo 0.5 GB, 5 minute free call option, Data Plus 512 MB, 1 month, Voicemail option	6.1	11.2	1.0	1.2	0.0	19.5	
Korea	SK 7 (SK Telecom)	LTE uSIM 1GB/200Min, DATA 1843.2 MB, SIM only	7.3	0.0	0.0	0.0	0.0	7.3	
Latvia	LMT	Sarunas, Internets Telefona 1300 MB, SIM only, 1 month	19.9	0.0	0.0	0.0	0.0	19.9	Pre-paid
Lithuania	Tele2	PILDYK Sets - 199 min + 5 GB, Data 5120 MB	9.8	0.0	0.0	0.0	0.0	9.8	Pre-paid
Luxembourg	Tango	Smart LU SIM Only 5G, Data 5120 MB, SIM only, 12 months	10.2	0.0	0.0	0.0	0.0	10.2	
Mexico	MoviStar	Paquete Prepago Rollover $150, Internet por Tiempo 2224.76190476191 MB, 1 month	13.9	0.0	0.2	0.0	0.0	14.1	Pre-paid
Netherlands	Vodafone	PAYG, Bel 200, Internet 500 MB	0.2	12.8	0.0	6.8	0.0	19.7	Pre-paid
New Zealand	One New Zealand	MyFlex Prepay 200 mins (Data to 5 GB), Data 1112.38095238095 MB	9.7	0.7	0.3	0.0	0.0	10.7	Pre-paid
Norway	Telia	Smart Kontant 14 Days, Data 543.154761904762 MB	21.0	0.0	0.0	0.0	0.0	21.0	Pre-paid
Poland	Orange	Orange Free - 200 mins + 200 SMS, Internet on the phone 1024 MB	6.4	2.3	0.0	4.5	0.0	13.2	Pre-paid
Portugal	UZO (MEO)	fácil - 1 GB + 2000 mins/SMS, Mobile Internet 1024 MB, 24 months	12.8	0.0	0.0	0.0	0.0	12.8	
Slovak Republic	Slovak Telekom	Connection - 5G, Mobile Internet 3072 MB, SIM only, 24 months	22.3	0.0	0.0	0.0	0.0	22.3	
Slovenia	A1	A1 miniSIMPL, Mobile Internet 1032.48898678414 MB, SIM only	7.6	0.0	0.0	0.0	0.0	7.6	Pre-paid
Spain	O2 (MoviStar)	20 GB llamadas ilimitadas, Data 20480 MB, SIM only	14.1	0.0	0.0	0.0	0.0	14.1	
Sweden	Comviq (Tele 2)	Fastpris mini, Mobilsurf 3072 MB	9.7	0.0	0.0	0.0	0.0	9.7	Pre-paid
Switzerland	M-Budget (Swisscom)	Mini, Data traffic 2048 MB, SIM only, 12 months	11.5	0.0	0.0	0.0	0.0	11.5	
Türkiye	Turkcell	Mutlu Mega - Happy 70 GB - 12M, Mobile Internet Packs 5973.3 MB, 12 months	11.5	0.0	0.0	0.0	0.0	11.5	Pre-paid
United Kingdom	O2	Pay & Go Big Bundle 4G 7 GB, Data 7168 MB, 1 month	12.8	0.0	0.0	0.0	0.0	12.8	Pre-paid
United States	TracFone (Verizon)	$15 500 MB, Data 500 MB, 1 month	17.5	0.0	0.0	0.0	0.0	17.5	Pre-paid
OECD average			**12.4**	**1.0**	**0.7**	**0.5**	**0.0**	**14.6**	

Source: Teligen/TechInsights (2023), "Teligen tariff & benchmarking market data using the OECD methodology", *www.techinsights.com*.

StatLink https://stat.link/lsxa5v

Table 9. Mobile voice and data (MVD), medium usage, August 2023

300 calls + 1 GB, USD/PPP, including VAT per month

Country	Provider	Package, option	Fixed	Add-on	Voice	Message	Data	Grand Total	Pre-paid?
Australia	Optus	Optus Flex Annual 60 GB, MyData 5120 MB, 12 months	9.3	0	0	0	0	9.31	Pre-paid
Austria	Magenta	Mobile KLAX S, Data 33280 MB	13.2	0	0	0	0	13.17	Pre-paid
Belgium	Proximus	Mobilus Easy 5G, Data 10240 MB, 1 month	23.3	0	0	0	0	23.33	
Canada	Fido (Rogers)	6 Month Prepaid - Talk & Text & Data 150, Data 1024 MB, 6 months	22.4	0	0	0	0	22.43	Pre-paid
Chile	Entel Movil	Recarga Facil $8000, 4 GB + 150 mins, Mobile Internet 40 960 MB	15.5	0	0	0	0	15.48	Pre-paid
Colombia	Movistar	Combo Mes TODO EN UNO ULTRA $16000 (6 GB) promo 4x1, Datos Full 24576 MB, 1 month	10.0	0	0	0	0	9.96	Pre-paid
Costa Rica	Liberty	Plan @1, Extra minutos 120, Data 10240 MB, SIM only, 1 month	29.1	8.0	0	0.3	0	37.41	
Czech Republic	T-Mobile	POŘÁD ONLINE 4 GB Plus, Data 4096 MB, SIM only, 1 month	35.4	0	0	0	0	35.45	
Denmark	Telenor	Mobil 20 GB 5G, frisurf 20480 MB, SIM only, 1 month	19.9	0	0	0	0	19.92	
Estonia	Elisa	Elisa Standard, Internet mobilis 1024 MB	8.2	0	0.6	0	0	8.78	Pre-paid
Finland	Telia	Telia Dot - 4G Unlimited 100 Mbit/s, Unlimited data	24.5	0	0	0	0	24.51	
France	SFR Red (SFR)	Illimite 5 GB, Internet 5120 MB, SIM only	6.6	0	0	0	0	6.59	
Germany	O2	My Prepaid Jahrestarife, Data 1024 MB, 12 months	7.6	0	0	0	0	7.56	Pre-paid
Greece	CU (Vodafone)	PAYG, CU MeApOla 7.2, Surf & email 2336 MB	17.4	0	0.0	0	0	17.45	Pre-paid
Hungary	T-Mobile	Mobil L + 4 GB, NetPlusz 4096 MB, SIM only, 12 months	43.7	0	0	0	0	43.73	
Iceland	Nova	Nova 2 GB, Data 2048 MB	11.7	0	0	0	0	11.69	
Ireland	Three	3 Prepay Hero 5G, Unlimited data, SIM only	15.2	0	0	0	0	15.21	Pre-paid
Israel	Partner	Classic 300 GB 5G, Mobile surfing 307200 MB, SIM only, 24 months	9.9	0	0	0	0	9.90	
Italy	Kena (TIM)	4.99 1 GB, Internet 1024 MB, SIM only, 1 month	6.8	0	0	0	0	6.79	Pre-paid
Japan	NTT DoCoMo	irumo 0.5 GB, 5 minute free call option, Data Plus 512 MB, 1 month, Voicemail option	6.1	11.2	3.0	2.4	10.2	32.97	
Korea	SK 7 (SK Telecom)	LTE uSIM 2GB/2000Min, DATA 1843.2 MB, SIM only	7.60	0	0	0	0	7.60	
Latvia	LMT	Sarunas, Internets Telefona 1300 MB, SIM only, 1 month	19.9	0	0	0	0	19.89	Pre-paid
Lithuania	Tele2	PILDYK Sets - Unltd Min + 5 GB, Data 5120 MB	13.2	0	0	0	0	13.17	Pre-paid
Luxembourg	Tango	Smart LU SIM Only 5G, Data 5120 MB, SIM only, 12 months	10.2	0	0	0	0	10.20	
Mexico	MoviStar	Paquete Prepago Rollover $150, Internet por Tiempo 2224.76190476191 MB, 1 month	13.9	0	0.6	0	0	14.51	Pre-paid
Netherlands	Vodafone	Start M + 5G, Onbeperkt Bellen Blox, Internet 2560 MB, 24 months	17.6	3.5	0	0	0	21.06	
New Zealand	One New Zealand	MyFlex Prepay Unltd Mins (Data to 5 GB), Data 1112.38095238095 MB	17.4	0.7	0.77	0	0	18.82	Pre-paid
Norway	Telia	Smart 3 GB - 5G, Data 3072 MB, 12 months	25.1	0	0	0	0	25.13	
Poland	Play	Play na Kartę odNOWA - S, Data 30720 MB, SIM only	13.7	0	0	0	0	13.69	Pre-paid
Portugal	UZO (MEO)	fácil - 1 GB + 2000 mins/SMS, Mobile Internet 1024 MB, 24 months	12.8	0	0	0	0	12.82	
Slovak Republic	Slovak Telekom	Relax - 5G, Mobile Internet 8192 MB, SIM only, 24 months	33.5	0	0	0	0	33.46	
Slovenia	A1	A1 maxiSIMPL, Mobile Internet 7612.25096639905 MB, SIM only	10.5	0	0	0	0	10.53	Pre-paid
Spain	O2 (MoviStar)	20 GB llamadas ilimitadas, Data 20480 MB, SIM only	14.1	0	0	0	0	14.12	
Sweden	Comviq (Tele 2)	Fastpris 5 GB, Mobilsurf 5120 MB	14.8	0	0	0	0	14.82	
Switzerland	M-Budget (Swisscom)	Mini, Data traffic 2048 MB, SIM only, 12 months	11.5	0	0	0	0	11.51	
Türkiye	Turkcell	Mutlu Mega - Happy 70 GB - 12M, Mobile Internet Packs 5973.3 MB, 12 months	11.5	0	0	0	0	11.47	Pre-paid
United Kingdom	O2	Pay & Go Big Bundle 4G 7 GB, Data 7168 MB, 1 month	12.8	0	0	0	0	12.85	Pre-paid
United States	TracFone (Verizon)	$199 365 Days 24 GB, Data 2048 MB, 1 month	18.6	0	0	0	0	18.63	Pre-paid
OECD average			**16.2**	**0.6**	**0.1**	**0.1**	**0.3**	**17.30**	

Source: Teligen/TechInsights (2023), "Teligen tariff & benchmarking market data using the OECD methodology", *www.techinsights.com*.

StatLink https://stat.link/lsxa5v

Table 10. Mobile voice and data (MVD), high usage, August 2023

900 calls + 2 GB, USD/PPP, including VAT per month

Country	Provider	Package, option	Fixed	Add-on	Voice	Message	Data	Grand Total	Pre-paid?
Australia	Optus	Optus Flex Annual 60 GB, MyData 5120 MB, 12 months	9.3	0	0	0	0	9.3	Pre-paid
Austria	Hi! (Magenta)	Einfach, Data 15360 MB, SIM only, 1 month	14.7	0	0	0	0	14.7	
Belgium	Proximus	Mobilus Easy 5G, Data 10240 MB, 1 month	23.3	0	0	0	0	23.3	
Canada	Fido (Rogers)	6 Month Prepaid - Talk & Text & Data 200, Data 3072 MB, 6 months	29.9	0	0	0	0	29.9	Pre-paid
Chile	Movistar	Plan 5G Libre Full, Bolsa de Internet 204800 MB, SIM only, 18 months	26.4	0	0	0	0	26.4	
Colombia	Movistar	Combo Mes TODO EN UNO ULTRA $16000 (6 GB) promo 4x1, Datos Full 24576 MB, 1 month	10.0	0	0	0	0	10.0	Pre-paid
Costa Rica	Kölbo	Ultra K3, Extra minutos 100, Data 20480 MB, SIM only, 1 month	54.3	6.2	13.2	0	0	73.7	
Czech Republic	T-Mobile	POŘÁD ONLINE 4 GB Plus, Data 4096 MB, SIM only, 1 month	35.4	0	0	0	0	35.4	
Denmark	Telenor	Mobil 20 GB 5G, frisurf 20480 MB, SIM only, 1 month	19.9	0	0	0	0	19.9	
Estonia	Elisa	Elisa Soodsad Konepaketid, Interniti Lisamaht 2048 MB, SIM only	9.0	0	0	0	0	9.0	
Finland	Telia	Telia Dot - 4G Unlimited 100 Mbit/s, Unlimited data	24.5	0	0	0	0	24.5	
France	SFR Red (SFR)	Illimite 5 GB, Internet 5120 MB, SIM only	6.6	0	0	0	0	6.6	
Germany	T-Mobile	MagentaMobil Prepaid Jahrestaif 5G, Data start 3072 MB, 12 months	10.5	0	0	0	0	10.5	Pre-paid
Greece	What's Up (Cosmote)	PAYG, Unlimited Calls, Mobile Internet Package 2560 MB	21.2	0	14.2	0	0	35.4	Pre-paid
Hungary	T-Mobile	Mobil L + 4 GB, NetPlusz 4096 MB, SIM only, 12 months	43.7	0	0	0	0	43.7	
Iceland	Nova	Nova 2 GB, Data 2048 MB	11.7	0	0	0	0	11.7	
Ireland	Three	3 Prepay Hero 5G, Unlimited data, SIM only	15.2	0	0	0	0	15.2	Pre-paid
Israel	Partner	Classic 300 GB 5G, Mobile surfing 307200 MB, SIM only, 24 months	9.9	0	0	0	0	9.9	
Italy	Kena (TIM)	6.99 130 GB, Internet 133120 MB, SIM only, 1 month	9.2	0	0	0	0	9.2	Pre-paid
Japan	NTT DoCoMo	ahamo Basic, 5 minute free call option, Data Plus 20480 MB, 1 month, Voicemail option	27.5	3.1	9.8	4.9	0.0	45.3	
Korea	SK 7 (SK Telecom)	LTE uSIM 2GB/2000Min, DATA 1843.2 MB, SIM only	7.6	0	0	0	0	7.6	
Latvia	Tele2	Tarifu plāns 3 GB, Data 3072 MB, 1 month	22.2	0	0	0	0	22.2	
Lithuania	Tele2	PILDYK Sets - Unltd Min + 5 GB, Data 5120 MB	13.2	0	0	0	0	13.2	Pre-paid
Luxembourg	Tango	Smart LU SIM Only 5G, Data 5120 MB, SIM only, 12 months	10.2	0	0	0	0	10.2	
Mexico	MoviStar	Paquete Prepago® Rollover $150, Internet por Tiempo 2224.7 MB, 1 month	13.9	0	1.8	0	0	15.7	Pre-paid
Netherlands	Vodafone	Start M + 5G, Onbeperkt Bellen Blox, Internet 2560 MB, 24 months	17.6	3.5	0	0	0	21.1	
New Zealand	One New Zealand	MyFlex Prepay Unltd Mins (Data to 5 GB), 5000 SMS, Data 2224.7 MB	17.4	6.9	2.3	0	0	26.6	Pre-paid
Norway	Telia	Smart 3 GB - 5G, Data 3072 MB, 12 months	25.1	0	0	0	0	25.1	
Poland	Play	Play na Kartę odNOWA - S, Data 30720 MB, SIM only	13.7	0	0	0	0	13.7	Pre-paid
Portugal	UZO (MEO)	fácil - 3 GB + 2000 mins/SMS, Mobile Internet 3072 MB, 24 months	16.6	0	0	0	0	16.6	
Slovak Republic	Slovak Telekom	Relax - 5G, Mobile Internet 8192 MB, SIM only, 24 months	33.5	0	0	0	0	33.5	
Slovenia	A1	A1 maxiSIMPL, Mobile Internet 6958.17619678592 MB, SIM only	10.5	0	0	0	0	10.5	Pre-paid
Spain	O2 (MoviStar)	20 GB llamadas ilimitadas, Data 20480 MB, SIM only	14.1	0	0	0	0	14.1	
Sweden	Comviq (Tele 2)	Fastpris 5 GB, Mobilsurf 5120 MB	14.8	0	0	0	0	14.8	
Switzerland	M-Budget (Swisscom)	Mini, Data traffic 2048 MB, SIM only, 12 months	11.5	0	0	0	0	11.5	
Türkiye	Turkcell	Mutlu Mega - Happy 70 GB - 12M, Mobile Internet Packs 5973.3 MB, 12 months	11.5	0	0	0	0	11.5	Pre-paid
United Kingdom	O2	Pay & Go Big Bundle 4G 7 GB, Data 7168 MB, 1 month	12.8	0	0	0	0	12.8	Pre-paid
United States	TracFone (Verizon)	$199 365 Days 24 GB, Data 2048 MB, 1 month	18.6	0	0	0	0	18.6	Pre-paid
OECD average			**18.3**	**0.5**	**1.1**	**0.1**	**0.0**	**20.1**	

Source: Teligen/TechInsights (2023), "Teligen tariff & benchmarking market data using the OECD methodology", *www.techinsights.com*.

StatLink https://stat.link/lsxa5v

Table 11. Mobile voice and data (MVD), very high usage, August 2023

900 calls + 10 GB, USD/PPP including VAT per month

Country	Provider	Package, option	Fixed	Add-on	Voice	Message	Data	Grand Total	Pre-paid?
Australia	Boost (Telstra)	Pre-paid - Anytime Plus $230 (12 Months), MyData 13653 MB, 12 months	12.6	0	0	0	0	12.6	Pre-paid
Austria	Hi! (Magenta)	Einfach, Data 15360 MB, SIM only, 1 month	14.7	0	0	0	0	14.7	
Belgium	Proximus	Mobilus Easy 5G, Data 10240 MB, 1 month	23.3	0	0	0	0	23.3	
Canada	Virgin (Bell Mobility)	BYOP Data, Talk & Text 10 GB, Data 10240 MB, SIM only, 12 month	36.5	0.0	0	0	0	36.5	
Chile	Movistar	Plan 5G Libre Full, Bolsa de Internet 204800 MB, SIM only, 18 months	26.4	0	0	0	0	26.4	
Colombia	Movistar	Combo Mes TODO EN UNO ULTRA $16000 (6 GB) promo 4x1, Datos Full 24576 MB, 1 month	10.0	0	0	0	0	10.0	Pre-paid
Costa Rica	Kölbo	Ultra K3, Extra minutos 100, Data 20480 MB, SIM only, 1 month	54.3	6.2	13.2	0	0	73.7	
Czech Republic	T-Mobile	POŘÁD ONLINE 10 GB Plus, Data 10240 MB, SIM only, 1 month	43.6	0	0	0	0	43.6	
Denmark	Telenor	Mobil 20 GB 5G, frisurf 20480 MB, SIM only, 1 month	19.9	0	0	0	0	19.9	
Estonia	Elisa	11 GB Pilsavalt Ulmet, Interniti Lisamaht 11264 MB	16.4	0	0	0	0	16.4	
Finland	Telia	Telia Dot - 4G Unlimited 100 Mbit/s, Unlimited data	24.5	0	0	0	0	24.5	
France	SFR Red (SFR)	Illimite 20 GB, Internet 20480 MB, SIM only	12.9	0	0	0	0	12.9	
Germany	O2	Prepaid M 5G, Data 13312 MB, 1 month	24.5	0	0	0	0	24.5	Pre-paid
Greece	CU (Vodafone)	PAYG, CU MeApOla 11.5, Surf & email 11776 MB	18.3	17.2	19.8	0	0	55.3	Pre-paid
Hungary	T-Mobile	Mobil L + 10 GB, NetPlusz 10240 MB, SIM only, 12 months	53.4	0	0	0	0	53.4	
Iceland	Nova	Frelsi 20 GB, Data 20480 MB	15.7	0	0	0	0	15.7	Pre-paid
Ireland	Three	3 Prepay Hero 5G, Unlimited data, SIM only	15.2	0	0	0	0	15.2	Pre-paid
Israel	Partner	Classic 300 GB 5G, Mobile surfing 307200 MB, SIM only, 24 months	9.9	0	0	0	0	9.9	
Italy	Kena (TIM)	6.99 130 GB, Internet 133120 MB, SIM only, 1 month	9.2	0	0	0	0	9.2	Pre-paid
Japan	NTT DoCoMo	ahamo Basic, 5 minute free call option, Data Plus 20480 MB, 1 month, Voicemail option	27.5	3.1	9.8	2.4	0	42.9	
Korea	SK 7 (SK Telecom)	LTE uSIM 10GB/2000Min, DATA 1843.2 MB, SIM only	14.9	0	0	0	0	14.9	
Latvia	Tele2	Tarifu plāns 10 GB, Data 10240 MB, 1 month	29.8	0	0	0	0	29.8	
Lithuania	Tele2	PILDYK Sets - Unltd Min + 10 GB, Data 10240 MB	18.3	0	0	0	0	18.3	Pre-paid
Luxembourg	Tango	Smart LU SIM Only 5G, Data 10240 MB, SIM only, 12 months	10.2	5.1	0	0	0	15.3	
Mexico	MoviStar	Giga Move 10 GB 5G, Data 10240 MB, SIM only, 1 month	21.9	0.0	1.8	0	0	23.7	
Netherlands	KPN	SIM Only KPN Unlimited Calls/SMS 12 GB + 5G, Data 12288 MB, SIM only, 24 months	25.3	0	0	0	0	25.3	
New Zealand	Skinny (Spark)	$50 Endless Data 5G, Data 16640 MB	34.6	0	0	0	0	34.6	Pre-paid
Norway	Telenor	Forskudd 10 GB, Ekstrasurf 10240 MB	38.5	0	0	0	0	38.5	Pre-paid
Poland	Play	Play na Kartę odNOWA - S, Data 30720 MB, SIM only	13.7	0	0	0	0	13.7	Pre-paid
Portugal	UZO (MEO)	fácil - 15 GB + 2000 mins/SMS, Mobile Internet 15360 MB, 24 months	24.1	0	0	0.0	0	24.1	
Slovak Republic	Orange	Flat Medium - 5G, Mobile Internet 10240 MB, SIM only, 12 months	33.9	0	0	0	0	33.9	
Slovenia	A1	A1 miniMIO, Mobile Internet Plus 20480 MB, 24 months	21.3	0	0	0	0	21.3	
Spain	O2 (MoviStar)	20 GB llamadas ilimitadas, Data 20480 MB, SIM only	14.1	0	0	0	0	14.1	
Sweden	Comviq (Tele 2)	Fastpris 10 GB - 5G, Mobilsurf 10240 MB	19.9	0	0	0	0	19.9	
Switzerland	Yallo (Sunrise)	Regular Plus, Mobiles Internet 20480 MB	16.0	0	0	0	0	16.0	
Türkiye	Vodafone	6 Aylık Kolay Paket 60, Mobile Internet Packs 10240 MB	13.6	0	11.4	0	0	25.0	Pre-paid
United Kingdom	O2	Pay & Go Rolling Plan 4G 10 GB, Data 10240 MB, 1 month	12.8	0	0	0	0	12.8	Pre-paid
United States	AT&T	ATT Prepaid - 16 GB 12M, Data 16384 MB, 12 months	31.7	0	0	0	0	31.7	Pre-paid
OECD average			**22.7**	**0.8**	**1.5**	**0.1**	**0.0**	**25.1**	

Source: Teligen/TechInsights (2023), "Teligen tariff & benchmarking market data using the OECD methodology", *www.techinsights.com*.

StatLink https://stat.link/lsxa5v

Table 12. Fixed broadband (FBB), low usage, September 2023

20 GB per month, 25 Mbps and above, USD/PPP, including VAT per month

Country	Provider	Package, option	Speed	Connection	Rental	Usage	Total
Australia	Optus	Everyday Basic 4G	25 600 / 5 120	0.0	37.2	0	37.2
Austria	Drei	DataNet 50	51 200 / 10 240	0.7	26.2	0	26.9
Belgium	Proximus	Scarlet - Internet Poco	30 720 / 2 048	1.0	28.1	0	29.1
Canada	Rogers	Ignite 50U	51 200 / 10 240	0.0	62.8	0	62.8
Chile	Telmex - Claro Chile	1 Play 200 Mbps	2 04 800 / 10 240	0.0	32.5	0	32.5
Colombia	Movistar	Fibra Optica Paga 200 y recibe 300 Megas	3 07 200 / 3 07 200	0.0	35.2	0	35.2
Costa Rica	Liberty	Mega 30	30 720 /	0.0	56.6	0	56.6
Czech Republic	Starnet	Internet Optical 100	1 02 400 / 1 02 400	10.8	15.5	0	26.2
Denmark	YouSee/TDC Erhverv	YouSee Cable 200/20	2 04 800 / 20 480	1.1	33.3	0	34.4
Estonia	STV	Docsis 3 PAKETID 20/2 Mbit/s	25 600 / 2 048	0.0	27.5	0	27.5
Finland	DNA Welho	DNA Net 5G 600M	6 14 400 / 10 240	0.1	32.6	0	32.8
France	Free	Freebox Mini 4K	10 48 576 / 6 14 400	1.7	36.2	0	38.0
Germany	Vodafone	GigaZuhause 50 Kabel + Phone	51 200 / 25 600	-1.8	39.4	0	37.7
Greece	Nova	Internet 50	51 200 / 5 120	0.9	47.3	0	48.2
Hungary	Vodafone	Just M	2 56 000 / 20 480	0.0	21.8	0	21.8
Iceland	Nova	Fiber 1000 500 GB	10 24 000 /	0.0	62.9	0	62.9
Ireland	Vodafone	500 Mbps	5 12 000 / 92 160	0.0	37.8	0	37.8
Israel	018	Simple net 100 MB / Bezeq line	1 02 400 / 10 240	0.0	25.6	0	25.6
Italy	Telecom Italia - TIM.it	Wifi Power FWA	1 02 400 / 51 200	0.0	33.9	0	33.9
Japan	Yahoo! BB/NTT-East	SoftBank Hikari Yahoo! BB (optical line) - Apartment plan	10 48 576 / 10 48 576	0.8	38.7	0	39.5
Korea	SK Broadband	Cable fibre optic 100M	1 02 400 /	1.1	20.1	0	21.1
Latvia	Baltcom	300 Mbit	2 56 000 / 51 200	0.3	15.9	0	16.2
Lithuania	Cgates	Internet 250	2 56 000 /	0.5	19.9	0	20.4
Luxembourg	Luxembourg Online	LOL 4G	1 02 400 / 15 360	0.0	43.0	0	43.0
Mexico	Telmex	Infinitum 60	61 440 / 6 144	0.0	30.0	0	30.0
Netherlands	Ziggo	Internet Lite	1 02 400 / 25 600	0.0	29.0	0	29.0
New Zealand	Spark	Basic Wireless	33 792 / 16 384	2.6	25.9	0	28.4
Norway	NextGen Tel	Fiber 30	30 000 / 30 000	0.0	49.2	0	49.2
Poland	Play	Play internet 150 GB	50 995.2 / 28 672	2.6	21.1	0	23.7
Portugal	Vodafone	Fibra 2 Plus	30 720 / 3 072	0.0	38.7	0	38.7
Slovak Republic	Orange Slovensko	Fiber Basic	51 200 / 20 480	0.4	16.5	0	16.9
Slovenia	T-2	Fiber T3 100/20	1 02 400 / 20 480	0.0	40.3	0	40.3
Spain	Orange Jazztel	Jazztel - Fibra 300 Mb + Phone	3 07 200 / 3 07 200	0.0	35.7	0	35.7
Sweden	Telenor	Bredband 100	1 02 400 / 1 02 400	0.0	35.2	0	35.2
Switzerland	Quickline	Cable S	1 02 400 / 10 240	5.3	36.7	0	42.0
Türkiye	Superonline	Fiber 25 Mbps (20 GB)	25 600 / 5 120	1.9	8.3	0	10.3
United Kingdom	BT	Fibre Essential	35 840 / 9 216	0.4	36.2	0	36.7
United States	Spectrum	Internet 300	3 07 200 / 10 240	-0.5	51.3	0	50.9
OECD average				**0.8**	**33.8**	**0.0**	**34.6**

Source: Teligen/TechInsights (2023), "Teligen tariff & benchmarking market data using the OECD methodology", *www.techinsights.com*.

StatLink https://stat.link/lsxa5v

Table 13. Fixed broadband (FBB), medium usage, September 2023

120 GB per month, 100 Mbps and above, USD/PPP, including VAT per month

Country	Provider	Package, option	Speed	Connection	Rental	Usage	Total
Australia	TPG	5G Home 100 Mbps	1 02 400 / 20 480	0.0	40.9	0	40.9
Austria	Drei	DataNet 100	1 02 400 / 15 360	0.7	31.4	0	32.0
Belgium	Telenet	Easy Internet	1 02 400 / 10 240	1.7	40.7	0	42.4
Canada	Shaw	Fibre 250	2 56 000 / 25 600	-1.2	79.7	0	78.5
Chile	Telmex - Claro Chile	1 Play 200 Mbps	2 04 800 / 10 240	0.0	32.5	0	32.5
Colombia	Movistar	Fibra Optica Paga 200 y recibe 300 Megas	3 07 200 / 3 07 200	0.0	35.2	0	35.2
Costa Rica	Liberty	Mega 100	1 02 400 /	0.0	62.9	0	62.9
Czech Republic	Starnet	Internet Optical 100	1 02 400 / 1 02 400	10.8	15.5	0	26.2
Denmark	YouSee/TDC Erhverv	YouSee Cable 200/20	2 04 800 / 20 480	1.1	33.3	0	34.4
Estonia	STV	Docsis 3 PAKETID 100/10 Mbit/s	1 02 400 / 10 240	0.0	38.5	0	38.5
Finland	DNA Welho	DNA Net 5G 600M	6 14 400 / 10 240	0.1	32.6	0	32.8
France	Free	Freebox Mini 4K	10 48 576 / 6 14 400	1.7	36.2	0	38.0
Germany	Vodafone	GigaZuhause 100 Kabel + Phone	1 02 400 / 51 200	-3.6	46.9	0	43.3
Greece	Vodafone	Vodafone Home double play Fiber 100 Pro (price list)	1 02 400 / 10 240	2.1	51.9	0	54.0
Hungary	Vodafone	Just M	2 56 000 / 20 480	0.0	21.8	0	21.8
Iceland	Vodafone	Ljósnet - 500 GB	1 02 400 / 25 600	0.0	70.2	0	70.2
Ireland	Vodafone	500 Mbps	5 12 000 / 92 160	0.0	37.8	0	37.8
Israel	018	Simple net 100 MB / Bezeq line	1 02 400 / 10 240	0.0	25.6	0	25.6
Italy	Telecom Italia - TIM.it	Wifi Power FWA	1 02 400 / 51 200	0.0	33.9	0	33.9
Japan	Yahoo! BB/NTT-East	SoftBank Hikari Yahoo! BB (optical line) - Apartment plan	10 48 576 / 10 48 576	0.8	38.7	0	39.5
Korea	SK Broadband	Cable fibre optic 100M	1 02 400 /	1.1	20.1	0	21.1
Latvia	Baltcom	300 Mbit	2 56 000 / 51 200	0.3	15.9	0	16.2
Lithuania	Cgates	Internet 250	2 56 000 /	0.5	19.9	0	20.4
Luxembourg	Luxembourg Online	LOL 4G	1 02 400 / 15 360	0.0	43.0	0	43.0
Mexico	Telmex	Infinitum 100	1 02 400 / 10 240	0.0	38.6	0	38.6
Netherlands	Ziggo	Internet Lite	1 02 400 / 25 600	0.0	29.0	0	29.0
New Zealand	One NZ	HFC	9 34 912 / 1 05 472	0.0	44.7	0	44.7
Norway	Telia	Wireless Boradband 100	1 02 400 /	0.0	65.6	0	65.6
Poland	Plus	Fiber 300 Mbps	3 07 200 / 51 200	0.0	24.5	0	24.5
Portugal	Vodafone	Fibra 2 Gold 100	1 02 400 / 1 02 400	0.0	45.8	0	45.8
Slovak Republic	UPC	Internet 100 + TV	1 02 400 / 6 144	0.0	18.2	0	18.2
Slovenia	T-2	Fiber T3 100/20	1 02 400 / 20 480	0.0	40.3	0	40.3
Spain	Orange Jazztel	Jazztel - Fibra 300 Mb + Phone	3 07 200 / 3 07 200	0.0	35.7	0	35.7
Sweden	Telenor	Bredband 100	1 02 400 / 1 02 400	0.0	35.2	0	35.2
Switzerland	Quickline	Cable S	1 02 400 / 10 240	5.3	36.7	0	42.0
Türkiye	Superonline	VDSL Speed Festival Kampanyası 100 Mbps (Promotion)	1 02 400 / 2 048	0.1	33.5	0	33.6
United Kingdom	Sky	Superfast 100	1 48 480 / 27 648	0.0	46.0	0	46.0
United States	Spectrum	Internet 300	3 07 200 / 10 240	-0.5	51.3	0	50.9
OECD average				**0.6**	**38.2**	**0.0**	**38.7**

Source: Teligen/TechInsights (2023), "Teligen tariff & benchmarking market data using the OECD methodology", *www.techinsights.com*.

StatLink https://stat.link/lsxa5v

Table 14. Fixed broadband (FBB), high usage, September 2023

900 GB per month, 1000 Mbps and above, USD/PPP, including VAT per month

Country	Provider	Package, option	Speed	Connection	Rental	Usage	Total
Austria	Magenta	Gigakraft 1000	10 24 000 / 51 200	2.7	77.0	0	79.7
Belgium	VOO	Giga Giga (Net + TV)	10 24 000 / 51 200	0.0	80.9	0	80.9
Canada	Shaw	Fibre 1Gig	10 24 000 / 1 02 400	-1.2	97.2	0	96.0
Chile	Movistar	Plan Internet Hogar Fibra 2000 Megas	20 48 000 / 20 48 000	0.0	86.4	0	86.4
Colombia	Claro	1000 Megas	10 24 000 /	0.0	215.4	0	215.4
Costa Rica	Telecable	Fiber Optic 1000 Mb	10 24 000 / 10 24 000	0.0	212.5	0	212.5
Czech Republic	T-Mobile	Fibre Optic Internet L	10 24 000 / 5 12 000	0.0	34.0	0	34.0
Denmark	YouSee/TDC Erhverv	YouSee Cable 1000/100	10 24 000 / 1 02 400	1.1	40.0	0	41.1
Estonia	Telia	Symmetric 1 Gbp/s	10 24 000 / 10 24 000	0.0	104.6	0	104.6
Finland	Elisa - Saunalahti	5G XXL	10 24 000 /	0.5	51.9	0	52.5
France	Free	Freebox Mini 4K	10 48 576 / 6 14 400	1.7	36.2	0	38.0
Germany	Vodafone	GigaZuhause 1000 Kabel + Phone	10 24 000 / 51 200	-6.2	64.0	0	57.7
Greece	Nova	Fiber Ultra 1 Gbps	10 24 000 / 1 02 400	0.0	89.8	0	89.8
Hungary	DIGI	Diginet 1000 (FTTH area)	10 24 000 / 3 07 200	0.1	31.5	0	31.5
Iceland	Nova	Fiber 1000	10 24 000 /	0.0	74.5	0	74.5
Ireland	Vodafone	1000 Mbps	10 24 000 / 92 160	0.0	47.3	0	47.3
Israel	012 Smile	1000 Mb Fiber	10 24 000 / 1 02 400	0.0	34.3	0	34.3
Italy	Fastweb	Fastweb Home Light FWA	10 24 000 / 2 04 800	0.0	33.9	0	33.9
Japan	Yahoo! BB/NTT-East	SoftBank Hikari Yahoo! BB (optical line) - Apartment plan	10 48 576 / 10 48 576	0.8	38.7	0	39.5
Korea	SK Broadband	Cable Giga 1G	10 24 000 /	1.1	35.5	0	36.6
Latvia	Baltcom	1000 Mbit	10 24 000 / 2 56 000	0.3	19.5	0	19.9
Lithuania	Init	Internet Super Maksi	10 24 000 / 1 02 400	0.3	28.8	0	29.0
Luxembourg	Luxembourg Online	LOL Fiber L	10 24 000 / 2 56 000	0.0	55.3	0	55.3
Mexico	Megacable	Double Pack - Internet 1000 Mbps + Illimitado Plus	10 24 000 / 25 600	0.0	93.6	0	93.6
Netherlands	Odido	Glasvezel 1000	10 24 000 / 10 24 000	1.0	50.2	0	51.2
Norway	NextGen Tel	Fiber 1000	10 24 000 / 6 00 000	0.0	112.9	0	112.9
Poland	Plus	Fiber 1 Gbps	10 48 576 / 1 02 400	0.0	33.8	0	33.8
Portugal	MEO	M1 - 1000/400	10 24 000 / 4 09 600	0.0	60.4	0	60.4
Slovak Republic	Antik Telecom	1 Gbit/s + Phone	10 24 000 / 10 24 000	1.5	25.3	0	26.8
Slovenia	Telemach	EON Fiber Light (price list)	20 52 096 / 2 04 800	0.0	66.3	0	66.3
Spain	Orange Jazztel	Jazztel - Fibra 1 Gb + Phone	10 48 576 / 10 48 576	0.0	44.3	0	44.3
Sweden	Telenor	Bredband 1000	10 24 000 / 10 24 000	0.0	51.3	0	51.3
Switzerland	Sunrise	Up Internet L + Phone	10 24 000 / 10 24 000	2.3	55.5	0	57.8
Türkiye	Vodafone	Fiber at home 1000	10 24 000 / 5 120	0.0	78.5	0	78.5
United Kingdom	Virgin Media	Gig1 Fibre	11 57 120 / 1 06 496	0.0	71.5	0	71.5
United States	AT&T	1000 Mbps	10 24 000 / 10 24 000	-4.6	88.0	0	83.4
OECD average				**0.0**	**67.2**	**0.0**	**67.3**

Source: Teligen/TechInsights (2023), “Teligen tariff & benchmarking market data using the OECD methodology”, *www.techinsights.com*.

StatLink https://stat.link/lsxa5v

Table 15. Two play: Fixed broadband (FBB) + Television (TV), low usage, January 2023

25 Mbps, TV: 20 channels, USD/PPP including VAT per month

Country	Provider	Package, option	Speed	Channels (SD/HD)	Mobile data (GB)	Connection	Rental	Fixed voice	Mobile voice and data	Pay-TV	Total
Australia	BigPond/Telstra	Internet + TV plans	25 Mbps	25 / 7		1.1	58.9	0	0	0	60.0
Austria	A1 Telekom Austria	TV Kombi	30 Mbps	66 / 25		0.0	39.9	0	0	0	39.9
Belgium	Scarlet	Trio	50 Mbps	41 / 9		0.0	51.1	0	0	0	51.1
Canada	Telus	Pick TV + Internet bundle	75 Mbps	33 / 5		-1.2	90.9	0	0	0	89.7
Chile	Claro Chile	2 Play - Internet Cable + TV HD	200 Mbps	37 / 26		0.0	57.8	0	0	0	57.8
Colombia	Claro Colombia	Arma tu Play - internet + TV Digital Plus	200 Mbps	159 / 62		0.9	64.2	0	0	0	65.1
Costa Rica	Telecable	Internet + TV Digital Plus	30 Mbps	133 / 58		0.0	78.3	0	0	0	78.3
Czech Republic	Starnet	Internet + TV	50 Mbps	69 / 24		6.2	15.5	0	0	0	21.7
Denmark	YouSee	Broadband	200 Mbps	26 / 0		1.5	75.6	0	0	0	77.1
Estonia	STV	valmisolev lahendus 50/50 Mbps + 100 Kanali	50 Mbps	97 / 31		3.0	39.0	0	0	0	42.0
Finland	Telia Finland	Connection to Home + Telia TV	50 Mbps	18 / 21		0.9	51.2	0	0	0	52.1
France	Free	Freebox Mini 4K	1024 Mbps	20 / 100		1.8	37.4	0	0	0	39.2
Germany	Vodafone Deutschland	Internet & Phone Cable	50 Mbps	147 / 89		3.3	56.5	0	0	0	59.8
Greece	Wind Greece	Wind Fiber +EON Plus	100 Mbps	26 / 61		0.0	65.4	0	0	0	65.4
Hungary	Vodafone Hungary	Vodafone Home TV HD Basic	250 Mbps	34 / 38		0.0	31.9	0	0	0	31.9
Iceland	Siminn	Heimilispakkinn	100 Mbps	22 / 1		0.0	124.4	0	0	0	124.4
Ireland	eir	Complete Broadband and Phone	100 Mbps	56 / 4		-2.7	71.0	0	0	0	68.3
Italy	Vodafone Italy	Internet Unlimited Fiber (Online Offer) with TV	100 Mbps	71 / 0		5.0	55.4	0	0	0	60.3
Japan	NTT East -BB Excite	Flet Hikari	100 Mbps	0 / 36		5.5	53.7	0	0	0	59.2
Korea	LG U+	Internet + IPTV	100 Mbps	4 / 211		1.2	16.2	0	0	0	17.4
Latvia	BALTICOM	Interaktīvā Televīzija 31Ch + Internets	100 Mbps	12 / 19		0.7	23.5	0	0	0	24.2
Lithuania	Cgates	TV-Internetas	200 Mbps	14 / 12		0.2	23.9	0	0	0	24.1
Luxembourg	Tango	Tango Duo M	300 Mbps	80 / 0		5.3	63.0	0	0	0	68.3
Mexico	IZZI (cablemas)	Internet + Telefonia + TV 100ch	500 Mbps	67 / 42		1.1	30.9	0	0	0	32.0
Netherlands	T-Mobile NL	Build Your Own Bundle	100 Mbps	5 / 59		0.0	54.8	0	0	0	54.8
Norway	Telia Norway	Bredband	100 Mbps	56 / 0		0.0	57.8	0	0	0	57.8
Poland	Play	internet-swiatlowodowy	300 Mbps	48 / 0		0.0	22.1	0	0	0	22.1
Portugal	NOS	NOS 3 - Fibra 30 Mbps - 120 Canais	30 Mbps	96 / 24		0.0	51.1	0	0	0	51.1
Slovak Republic	UPC Slovakia	Internet + Internet Smart TV	100 Mbps	16 / 52		0.0	28.9	0	0	0	28.9
Slovenia	Telemach	EON Light	200 Mbps	62 / 90		0.0	56.3	0	0	0	56.3
Spain	Orange - Jazztel	Fibra + Llamadas + TV	300 Mbps	60 / 0		0.0	49.7	0	0	0	49.7
Sweden	Telenor Bredbands-bolaget	Kombo	100 Mbps	21 / 11		0.0	57.5	0	0	0	57.5
Switzerland	Sunrise	Essential Internet + TV	1024 Mbps	320 / 0		-2.3	52.8	0	0	0	50.4
Türkiye	Superonline	Her Ev İçin TV+ Ve Yüksek Hız Kampanyası	50 Mbps	119 / 37		0.1	41.0	0	0	0	41.1
United Kingdom	Virgin Media UK	Big Bundle	54 Mbps	97 / 12		0.0	58.5	0	0	0	58.5
United States	Verizon	Fios - Create your own Bundle	300 Mbps	77 / 26		0.0	55.0	0	0	0	55.0
OECD average						**0.9**	**51.7**	**0.0**	**0.0**	**0.0**	**52.6**

Source: Teligen/TechInsights (2023), “Teligen tariff & benchmarking market data using the OECD methodology”, *www.techinsights.com*.

StatLink *https://stat.link/lsxa5v*

Table 16. Two play: Fixed broadband (FBB) + Television (TV), high usage, January 2023

600 Mbps, TV: 80 channels with Premium Movies and Sports and DVR, USD/PPP, including VAT per month

Country	Provider	Package, option	Speed	Channels (SD/HD)	Mobile data (GB)	Connection	Rental	Fixed voice	Mobile voice and data	Pay-TV	Total
Austria	Magenta Austria	Internet + TV	1000 Mbps	74 / 92		0.7	114.6	0.0	0	42.8	158.1
Belgium	Voo	Net + TV Max	1000 Mbps	96 / 27		0.0	88.1	0.0	0	36.5	124.6
Canada	Telus	Internet + Optik TV	940 Mbps	102 / 52		-2.4	125.0	0.0	0	25.1	147.7
Chile	Movistar Chile	Pack Duo Internet + TV HD	800 Mbps	43 / 98		0.0	92.8	0.0	0	34.3	127.0
Colombia	Movistar Colombia	Trio Fibra	650 Mbps	89 / 56		5.1	139.8	0.0	0	30.3	175.2
Czech Republic	O2 Czech	Internet	1000 Mbps	34 / 46		0.2	74.0	0.0	0	32.6	106.8
Estonia	Telia Estonia	Telia 1	1024 Mbps	165 / 0		13.7	163.4	0.0	0	0.0	177.1
Finland	DNA	DNA Netti + TV Hubi	600 Mbps	64 / 19		0.4	63.0	0.0	0	43.3	106.7
France	SFR France	Fibre Power de SFR	2048 Mbps	202 / 0		4.0	47.0	0.0	0	34.3	85.3
Germany	Vodafone Deutschland	Internet & Phone Cable	1000 Mbps	147 / 106		-1.3	85.9	0.0	0	54.1	138.7
Hungary	Vodafone Hungary	Vodafone Home TV HD Extra HBO Pak	1000 Mbps	58 / 62		0.0	62.7	0.0	0	0.0	62.7
Ireland	Vodafone Ireland	Broadband and TV	1000 Mbps	72 / 25		0.0	86.7	0.0	0	44.1	130.8
Japan	NTT East -BB Excite	Flet Hikari	1024 Mbps	0 / 93		5.5	79.3	0.0	0	24.7	109.6
Lithuania	Cgates	TV-Internetas	1024 Mbps	45 / 41		0.2	62.9	0.0	0	13.4	76.6
Luxembourg	Post Luxembourg	TV + Landline + Internet XL	1000 Mbps	72 / 74		1.8	94.5	1.0	0	0.0	97.3
Mexico	Megacable	TV Conecta + Ilimitado Plus + Internet Ilimitado	1000 Mbps	40 / 58		0.6	86.8	0.0	0	24.1	111.5
Netherlands	KPN	Internet and TV	1000 Mbps	48 / 54		0.8	86.5	0.0	0	27.6	115.0
Norway	Telenor Norway	Fiber Bredband	600 Mbps	90 / 0		5.7	158.3	0.0	0	0.0	164.0
Poland	Play	internet z telewizja	600 Mbps	61 / 146		0.0	39.1	0.0	0	0.0	39.1
Portugal	MEO	M3 Fibra - Pack Standar+Extra TV	1000 Mbps	216 / 110		0.0	119.6	0.0	0	0.0	119.6
Slovak Republic	UPC Slovakia	Internet + Digital Komfort TV	600 Mbps	43 / 86		0.0	47.3	0.0	0	10.4	57.6
Slovenia	Telemach	EON Premium	1024 Mbps	102 / 135		0.0	82.9	0.0	0	0.0	82.9
Spain	Vodafone España	Vodafone Hogar Ilimitable	1024 Mbps	113 / 0	Unlimited	0.0	142.5	0.0	0	16.1	158.6
Sweden	Tele2 Sweden	Premium 600	600 Mbps	45 / 37		1.6	102.5	0.0	0	0.0	104.0
Switzerland	Sunrise	Essential Internet + TV	1024 Mbps	320 / 17		-2.3	52.8	0.0	0	33.5	84.0
Türkiye	TTNet	Tivibu'lu İnternet Kampanyasi - Ev Süper	1000 Mbps	131 / 20		0.0	103.5	0.0	0	0.0	103.5
United Kingdom	BT	Broadband & Phone + TV	900 Mbps	103 / 16		1.5	79.7	6.6	0	0.0	87.7
United States	Comcast	SuperFast	800 Mbps	65 / 74		1.2	187.6	0.0	0	9.9	198.7
OECD average						1.3	95.3	**0.3**	**0**	**19.2**	**116.1**

Source: Teligen/TechInsights (2023), "Teligen tariff & benchmarking market data using the OECD methodology", *www.techinsights.com*.

StatLink https://stat.link/lsxa5v

Table 17. Two play: Fixed broadband (FBB) + Fixed voice (FV), low usage, January 2023

25 Mbps, 20 calls, USD/PPP, including VAT per month

Country	Provider	Package, option	Speed	Channels (SD/HD)	Mobile data (GB)	Connection	Rental	Fixed voice	Mobile voice and data	Pay-TV	Total
Australia	TPG	FTTB Superfast	90 Mbps			0.2	46.3	0.0	0	0	46.5
Austria	Magenta Austria	Internet + Fixed Voice	50 Mbps			0.7	35.2	6.8	0	0	42.8
Belgium	Scarlet	Trio	50 Mbps	41 / 9		0.0	51.1	5.7	0	0	56.7
Canada	Shaw	Internet + Fixed Voice	75 Mbps			-1.2	73.0	18.2	0	0	90.0
Chile	VTR	VTR WIFI + Fono ilimitados 600 Movil	500 Mbps			0.0	48.4	0.0	0	0	48.4
Colombia	Movistar Colombia	Duo Fibra Internet + Telefonia	300 Mbps			6.0	45.2	0.0	0	0	51.2
Costa Rica	Kolbi	Fibra Optica + Telefonia Fija	30 Mbps			0.0	68.6	2.0	0	0	70.5
Czech Republic	O2 Czech	Internet	250 Mbps			0.9	29.8	23.2	0	0	53.9
Denmark	YouSee	Broadband	200 Mbps			1.5	35.8	13.2	0	0	50.5
Estonia	STV	Koosta endale sobiv pakett	50 Mbps			1.4	31.8	3.0	0	0	36.2
France	Free	Freebox Mini 4K	1024 Mbps	20 / 100		1.8	37.4	2.0	0	0	41.1
Germany	Vodafone Deutschland	Internet & Phone Cable	50 Mbps			1.4	40.2	2.1	0	0	43.7
Greece	Wind Greece	Wind Double Play	50 Mbps			0.0	49.0	0.0	0	0	49.0
Hungary	Digi Hungary	Digi Full Pack DIGINet (FTTB)	100 Mbps	67 / 41		0.1	38.7	1.5	0	0	40.4
Iceland	Vodafone Iceland	Build Your Own	1000 Mbps			0.0	64.9	15.0	0	0	79.9
Ireland	Vodafone Ireland	Broadband and Talk	100 Mbps			0.0	47.4	1.7	0	0	49.1
Italy	Wind Italy	Super Fibra	100 Mbps			3.8	34.3	0.0	0	0	38.1
Japan	J Com	NET + PHONE	320 Mbps			1.8	53.3	4.7	0	0	59.8
Korea	LG U+	Internet + IPTV + Internet Phone	100 Mbps	4 / 211		1.2	16.2	3.1	0	0	20.4
Latvia	BALTICOM	Digitālā Televīzija 18 Ch + Internets + Home Phone	100 Mbps	8 / 10		0.7	20.4	7.7	0	0	28.7
Lithuania	Init	Internetas + Skaitmenine Televizija	100 Mbps			2.5	17.4	0.0	0	0	19.8
Luxembourg	Post Luxembourg	Bamboo Internet + landline M	100 Mbps			1.8	55.2	2.7	0	0	59.6
Mexico	IZZI (cablemas)	Internet + Telefonia + TV 100ch	500 Mbps	67 / 42		1.1	30.9	0.0	0	0	32.0
Netherlands	KPN	Internet	100 Mbps			0.8	49.6	14.4	0	0	64.8
New Zealand	Spark	Broadband and Landline	30 Mbps			4.9	35.6	11.0	0	0	51.5
Norway	Telenor Norway	Fiber Bredband	100 Mbps			5.7	76.0	23.1	0	0	104.8
Poland	Orange Polska	Orange Światłowód + TV	300 Mbps	39 / 96		0.8	46.7	0.0	0	0	47.5
Portugal	Vodafone Portugal	Net + Voz	30 Mbps			0.0	43.3	7.4	0	0	50.7
Slovak Republic	T-Com Slovakia	Chytrý balík - KlasikNET & Pevná linka (FBB + FV)	30 Mbps			0.0	21.5	16.0	0	0	37.4
Slovenia	Telemach	EON Light	200 Mbps	62 / 90		0.0	56.3	3.6	0	0	59.9
Spain	Orange España	Home Fibra 500 Mb + Fijo	500 Mbps			0.0	45.4	1.5	0	0	46.8
Sweden	Tele2 Sweden	Bredband + Fast telefoni + TV	150 Mbps			1.6	40.8	15.3	0	0	57.7
Switzerland	Sunrise	Internet + Phone	200 Mbps			0.0	44.4	11.6	0	0	56.0
Türkiye	Superonline	VDSL Hiz Festivali Kampanyasi	35 Mbps			0.1	31.5	1.3	0	0	32.9
United Kingdom	Virgin Media UK	Broadband and Phone	54 Mbps			0.0	48.0	3.9	0	0	51.9
United States	Comcast	Connect	75 Mbps			1.2	43.6	33.0	0	0	77.9
OECD average						**1.1**	**43.1**	**7.1**	**0.0**	**0.0**	**51.3**

Source: Teligen/TechInsights (2023), "Teligen tariff & benchmarking market data using the OECD methodology", *www.techinsights.com*.

StatLink https://stat.link/lsxa5v

Table 18. Two play: Fixed broadband (FBB) + Fixed voice (FV), high usage, January 2023

600 Mbps, 140 calls, USD/PPP, including VAT per month

Country	Provider	Package, option	Speed	Channels (SD/HD)	Mobile data (GB)	Connection	Rental	Fixed voice	Mobile voice and data	Pay-TV	Total
Austria	Magenta Austria	Internet + Fixed Voice	1000 Mbps			0.7	98.2	31.5	0	0	130.4
Belgium	Voo	Trio Net + TV + Tel Max	1000 Mbps	96 / 21		2.0	103.3	6.1	0	0	111.4
Canada	Shaw	Internet Fibre Gig + Fixed Voice	1024 Mbps			-1.2	96.1	24.3	0	0	119.2
Chile	Movistar Chile	Duo Telefonia Fibra Simetrica	800 Mbps			-0.6	62.9	0.0	0	0	62.3
Colombia	Movistar Colombia	Duo Fibra Internet + Telefonia	650 Mbps			5.1	95.9	0.0	0	0	101.0
Czech Republic	O2 Czech	Internet	1000 Mbps			0.9	46.4	23.2	0	0	70.5
Denmark	YouSee	Broadband	1000 Mbps			0.0	38.7	13.2	0	0	51.9
Estonia	Telia Estonia	Telia 1	1024 Mbps			13.7	104.1	28.0	0	0	145.8
France	Free	Freebox Mini 4K	1024 Mbps	20 / 100		1.8	37.4	3.9	0	0	43.1
Germany	Vodafone Deutschland	Internet & Phone Cable	1000 Mbps			-3.1	69.6	13.0	0	0	79.5
Hungary	Digi Hungary	Digi Full Pack DIGINet 1000 (FTTH)	1000 Mbps	67 / 41		0.1	41.4	12.5	0	0	54.0
Iceland	Vodafone Iceland	Build Your Own	1000 Mbps			0.0	64.9	15.0	0	0	79.9
Ireland	Vodafone Ireland	Broadband and Talk	1000 Mbps			0.0	63.8	19.7	0	0	83.5
Italy	Wind Italy	Super Fibra	2 500 Mbps			0.8	37.0	0.0	0	0	37.8
Japan	NTT East -BB Excite	Flet Hikari	1024 Mbps			6.8	47.9	41.1	0	0	95.8
Korea	SK Telecom	Fixed Internet and fixed voice	1024 Mbps			0.9	28.2	17.9	0	0	46.9
Latvia	BALTICOM	Interaktīvā Televīzija 31Ch + Internets + Home Phone	600 Mbps	12 / 19		0.7	29.8	14.9	0	0	45.4
Lithuania	Init	Internetas + Skaitmenine Televizija	1000 Mbps			2.5	28.4	0.0	0	0	30.9
Luxembourg	Visual Online	Fiber XL sur le réseau dégroupé	600 Mbps			6.8	52.9	9.7	0	0	69.5
Mexico	Megacable	ilimitado Plus + Internet Ilimitado	1000 Mbps			0.6	78.5	0.0	0	0	79.1
Netherlands	KPN	Internet	1000 Mbps			0.8	59.6	14.4	0	0	74.9
New Zealand	Vodafone NZ	Unlimited Broadband	813 Mbps			0.3	53.8	30.5	0	0	84.6
Norway	Telenor Norway	Fiber Bredband	600 Mbps			5.7	114.6	23.1	0	0	143.4
Poland	Orange Polska	Orange Światłowód + TV	600 Mbps	39 / 96		0.8	51.2	0.0	0	0	51.9
Portugal	MEO	M2 Fibra + Chamadas Nacionais	1000 Mbps			0.0	66.1	57.8	0	0	123.9
Slovak Republic	UPC Slovakia	Internet + Digital Klassik TV	600 Mbps	14 / 46		0.0	39.8	127.1	0	0	166.9
Slovenia	Telekom Slovenije	NEO A	1024 Mbps	96 / 6		2.0	83.3	13.3	0	0	98.6
Spain	Vodafone España	Fibra + Llamadas	600 Mbps			0.0	47.5	0.0	0	0	47.5
Sweden	Tele2 Sweden	Bredband + Fast telefoni + TV	600 Mbps			1.6	54.8	15.3	0	0	71.8
Switzerland	Sunrise	Internet + Phone	1024 Mbps			0.0	50.0	12.6	0	0	62.5
Türkiye	Superonline	Superonline Fiberli Olma Zamanı	1000 Mbps			0.1	67.4	5.6	0	0	73.1
United Kingdom	BT	Broadband & Phone	900 Mbps			0.4	56.1	10.5	0	0	66.9
United States	Comcast	SuperFast	800 Mbps			1.2	75.9	33.0	0	0	110.1
OECD average						**1.6**	**62.0**	**18.7**	**0.0**	**0.0**	**82.2**

Source: Teligen/TechInsights (2023), "Teligen tariff & benchmarking market data using the OECD methodology", *www.techinsights.com*.

StatLink https://stat.link/lsxa5v

Table 19. Three play: Fixed broadband (FBB) + Fixed voice (FV) + Television (TV), low usage, January 2023

25 Mbps, 20 calls (OECD 2017), 20 channels, USD/PPP, including VAT per month

Country	Provider	Package, option	Speed	Channels (SD/HD)	Mobile data (GB)	Connection	Rental	Fixed voice	Mobile voice and data	Pay-TV	Total
Australia	BigPond/Telstra	Internet + TV plans	25 Mbps	25 / 7		1.1	58.9	0	0	0	60.0
Austria	A1 Telekom Austria	TV Kombi	30 Mbps	66 / 25		0.0	39.9	8.0	0	0	47.9
Belgium	Scarlet	Trio	50 Mbps	41 / 9		0.0	51.1	5.7	0	0	56.7
Canada	Rogers	Ignite Starter 150 MB	150 Mbps	29 / 30		0.0	96.7	12.2	0	0	108.9
Chile	Claro Chile	3 Play - Internet Cable + TV HD	200 Mbps	37 / 26		0.0	67.2	0.0	0	0	67.2
Colombia	Movistar Colombia	Trio Fibra	350 Mbps	89 / 51		5.1	63.2	0.0	0	0	68.3
Costa Rica	Liberty	Tripleplay	30 Mbps	242 / 67		0.0	83.0	1.4	0	0	84.4
Czech Republic	Vodafone Czech	Spojte-Sluzby	250 Mbps	22 / 40	Unlimited	0.2	24.5	4.6	35.8	0	65.1
Denmark	YouSee	Broadband	200 Mbps	26 / 0		1.5	75.6	13.2	0	0	90.3
Estonia	STV	valmisolev lahendus 50/50 Mbps + 100 Kanali	50 Mbps	97 / 31		3.0	39.0	3.5	0	0	45.6
France	Free	Freebox Mini 4K	1024 Mbps	20 / 100		1.8	37.4	2.0	0	0	41.1
Germany	Vodafone Deutschland	Internet & Phone Cable	50 Mbps	147 / 89		3.3	56.5	2.1	0	0	61.9
Greece	Wind Greece	Wind Fiber +EON Plus	100 Mbps	26 / 61		0.0	65.4	0.0	0	0	65.4
Hungary	Digi Hungary	Digi Full Pack DIGINet (FTTB)	100 Mbps	67 / 41		0.1	38.7	1.5	0	0	40.4
Iceland	Siminn	Heimilispakkinn	100 Mbps	22 / 1		0.0	124.4	0.0	0	0	124.4
Ireland	Vodafone Ireland	Broadband & Talk and TV	100 Mbps	72 / 25		0.0	73.6	1.7	0	0	75.3
Italy	Vodafone Italy	Internet Unlimited Fiber (Online Offer) with TV	100 Mbps	71 / 0		5.0	55.4	0.0	0	0	60.3
Japan	NTT East -BB Excite	Flet Hikari	100 Mbps	0 / 36		6.8	53.7	10.1	0	0	70.6
Korea	LG U+	Internet + IPTV + Internet Phone	100 Mbps	4 / 211		1.2	16.2	3.1	0	0	20.4
Latvia	BALTICOM	Interaktīvā Televīzija 31Ch + Internets + Home Phone	100 Mbps	12 / 19		0.7	23.5	7.7	0	0	31.8
Lithuania	Init	Internetas + Skaitmenine Televizija	100 Mbps	10 / 13		2.5	23.4	0.0	0	0	25.9
Luxembourg	Tango	Tango Duo M	300 Mbps	80 / 0		5.3	63.0	2.1	0	0	70.4
Mexico	IZZI (cablemas)	Internet + Telefonia + TV 100ch	500 Mbps	67 / 42		1.1	30.9	0.0	0	0	32.0
Netherlands	T-Mobile NL	Build Your Own Bundle	100 Mbps	5 / 59		0.0	54.8	13.6	0	0	68.3
Norway	Telenor Norway	Fiber Bredband	100 Mbps	90 / 0		5.7	132.1	23.1	0	0	160.9
Poland	Orange Polska	Orange Światłowód + TV	300 Mbps	39 / 96		0.8	46.7	0.0	0	0	47.5
Portugal	NOS	NOS 3 - Fibra 30 Mbps - 120 Canais	30 Mbps	96 / 24		0.0	51.1	5.4	0	0	56.5
Slovak Republic	UPC Slovakia	Internet + Internet Smart TV	100 Mbps	16 / 52		0.0	28.9	15.4	0	0	44.4
Slovenia	Telemach	EON Light	200 Mbps	62 / 90		0.0	56.3	3.6	0	0	59.9
Spain	Orange - Jazztel	Fibra + Llamadas + TV	300 Mbps	60 / 0		0.0	49.7	4.4	0	0	54.1
Sweden	Tele2 Sweden	Standard 300	300 Mbps	12 / 18		1.6	63.1	15.3	0	0	80.0
Switzerland	Sunrise	Essential Internet + TV	1024 Mbps	320 / 0		-2.3	52.8	11.6	0	0	62.0
Türkiye	Superonline	Her Ev İçin TV+ Ve Yüksek Hız Kampanyası	50 Mbps	119 / 37		0.1	41.0	1.3	0	0	42.4
United Kingdom	Virgin Media UK	Big Bundle	54 Mbps	97 / 12		0.0	58.5	3.9	0	0	62.4
United States	Verizon	Fios - Create your own Bundle	300 Mbps	77 / 26		0	55.0	27.5	0	0	82.5
OECD average						**1.3**	**55.7**	**5.8**	**1.0**	**0.0**	**63.9**

Source: Teligen/TechInsights (2023), “Teligen tariff & benchmarking market data using the OECD methodology”, *www.techinsights.com*.

StatLink https://stat.link/lsxa5v

Table 20. Three play: Fixed broadband (FBB) + Fixed voice (FV) + Television (TV), medium-high usage, January 2023

250 Mbps, 60 calls (OECD 2017), 40 channels including Premium Movies, USD/PPP including VAT per month

Country	Provider	Package, option	Speed	Channels (SD/HD)	Mobile data (GB)	Connection	Rental	Fixed voice	Mobile voice and data	Pay-TV	Total
Australia	BigPond/Telstra	Internet + TV plans	250 Mbps	50 / 20		0.2	130.8	0.0	0.0	0.0	131.0
Austria	A1 Telekom Austria	TV Kombi	300 Mbps	66 / 25		-3.5	65.1	23.5	0.0	35.2	120.4
Belgium	Voo	Trio Net + TV + Tel Max	1000 Mbps	96 / 27		2.0	103.3	6.1	0.0	29.5	140.9
Canada	Rogers	Ignite Flex 5 500 MB	500 Mbps	29 / 37		0.0	98.1	18.2	0.0	25.1	141.4
Chile	VTR	VTR Plus 3	500 Mbps	92 / 86		0.0	84.0	0.0	0.0	0.0	84.0
Colombia	Movistar Colombia	Trio Fibra	350 Mbps	89 / 56		5.1	63.2	0.0	0.0	12.7	81.0
Costa Rica	Liberty	Tripleplay	325 Mbps	242 / 75		0.0	162.0	3.9	0.0	0.0	165.9
Czech Republic	Vodafone Czech	Spojte-Sluzby	250 Mbps	22 / 43	Unlimited	0.2	24.5	13.2	35.8	13.2	86.8
Denmark	YouSee	Broadband	1000 Mbps	46 / 0		0.0	105.2	13.2	0.0	0.0	118.4
Estonia	STV	Koosta endale sobiv pakett	250 Mbps	54 / 18		1.4	53.5	9.2	0.0	10.1	74.3
France	SFR France	Fibre Power de SFR	2048 Mbps	202 / 0		4.0	47.0	0.0	0.0	34.3	85.3
Germany	Vodafone Deutschland	Internet & Phone Cable	250 Mbps	147 / 93		1.4	69.6	9.7	0.0	35.9	116.6
Hungary	Digi Hungary	Digi Full Pack DIGINet (FTTB)	500 Mbps	67 / 41		0.1	39.8	4.7	0.0	15.7	60.2
Iceland	Vodafone Iceland	Build Your Own	1000 Mbps	54 / 0		0.0	200.4	15.0	0.0	0.0	215.4
Ireland	Vodafone Ireland	Broadband & Talk and TV	500 Mbps	72 / 25		0.0	80.2	8.0	0.0	21.6	109.7
Israel	Vodafone Italy	Internet Unlimited Fiber (Online Offer) with TV	2500 Mbps	71 / 0		5.0	55.4	0.0	0.0	19.2	79.5
Japan	NTT East -BB Excite	Flet Hikari	1024 Mbps	0 / 89		6.8	79.3	20.2	0.0	24.7	131.1
Korea	LG U+	Internet + IPTV + Internet Phone	500 Mbps	4 / 211		1.2	26.0	7.4	0.0	9.5	44.1
Latvia	Baltcom	komplekti - Internets + Digitālā Televīzija	300 Mbps	84 / 23		1.8	33.7	9.4	0.0	8.7	53.6
Lithuania	Init	Internetas + Skaitmenine Televizija	400 Mbps	29 / 23		2.5	33.4	0.0	0.0	8.3	44.2
Luxembourg	Post Luxembourg	TV + Landline + Internet XL	1000 Mbps	72 / 68		1.8	94.5	1.0	0.0	13.4	110.6
Mexico	IZZI (cablemas)	Internet + Telefonia + TV 100ch	500 Mbps	67 / 42		1.1	30.9	0.0	0.0	12.3	44.3
Netherlands	T-Mobile NL	Build Your Own Bundle	400 Mbps	5 / 63		0.0	59.4	18.0	0.0	17.8	95.2
Norway	Telenor Norway	Fiber Bredband	350 Mbps	90 / 0		5.7	144.9	23.1	0.0	0.0	173.7
Poland	Orange Polska	Orange Światłowód + TV	300 Mbps	39 / 104		0.8	46.7	0.0	0.0	21.7	69.2
Portugal	MEO	M3 Fibra - Pack Standar TV	500 Mbps	181 / 78		0.0	67.6	23.3	0.0	15.7	106.7
Slovak Republic	UPC Slovakia	Internet + Digital Klassik TV	400 Mbps	14 / 49		0.0	32.4	49.9	0.0	10.4	92.7
Slovenia	Telemach	EON Full	500 Mbps	82 / 103		0.0	66.9	13.0	0.0	10.4	90.3
Spain	Movistar España	Movistar Max	300 Mbps	41 / 9	30	0.0	84.9	0.0	0.0	14.7	99.5
Sweden	Telia Sweden	Bredband via Fiber 250 with TV and Telephony	250 Mbps	35 / 19		1.1	61.6	18.4	0.0	19.9	101.1
Switzerland	Sunrise	Essential Internet + TV	1024 Mbps	320 / 0		-2.3	52.8	12.6	0.0	12.6	75.6
Türkiye	Superonline	Her Ev İçin TV+ Ve Yüksek Hız Kampanyası	500 Mbps	119 / 48		0.1	57.9	2.3	0.0	0.0	60.3
United Kingdom	Virgin Media UK	Bigger Bundle	264 Mbps	120 / 69		0.0	81.8	6.6	0.0	0.0	88.4
United States	Verizon	Fios - Create your own Bundle	300 Mbps	77 / 37		0.0	55.0	27.5	0.0	16.5	99.0
OECD average						**1.1**	**73.3**	**10.5**	**1.1**	**13.8**	**99.7**

Source: Teligen/TechInsights (2023), “Teligen tariff & benchmarking market data using the OECD methodology”, *www.techinsights.com*.

StatLink https://stat.link/lsxa5v

Table 21. Three play: Fixed broadband (FBB) + Fixed voice (FV) + Television (TV), high usage, January 2023

600 Mbps, 140 calls (OECD 2017), 80 channels including Premium Movies and Sports and DVR, USD/PPP, including VAT per month

Country	Provider	Package, option	Speed	Channels (SD/HD)	Mobile data (GB)	Connection	Rental	Fixed voice	Mobile voice and data	Pay-TV	Total
Austria	Magenta Austria	Internet + Fixed Voice + TV	1000 Mbps	74 / 92		0.7	114.6	31.5	0.0	42.8	189.6
Belgium	Voo	Trio Net + TV + Tel Max	1000 Mbps	96 / 27		2.0	103.3	6.1	0.0	36.5	147.8
Canada	Telus	Internet + Fixed Voice + Optik TV	940 Mbps	102 / 52		-2.4	127.9	29.9	0.0	25.1	180.4
Chile	Movistar Chile	Pack Trío Internet + TV + Telefonia	800 Mbps	43 / 98		-0.6	107.9	0.0	0.0	34.3	141.6
Colombia	Movistar Colombia	Trio Fibra	650 Mbps	89 / 56		5.1	139.8	0.0	0.0	30.3	175.2
Czech Republic	O2 Czech	Internet	1000 Mbps	34 / 46		0.2	74.0	23.2	0.0	32.6	130.0
Estonia	Telia Estonia	Telia 1	1024 Mbps	165 / 0		13.7	163.4	28.0	0.0	0.0	205.0
France	SFR France	Fibre Power de SFR	2048 Mbps	202 / 0		4.0	47.0	0.0	0.0	34.3	85.3
Germany	Vodafone Deutschland	Internet & Phone Cable	1000 Mbps	147 / 106		-1.3	85.9	13.0	0.0	54.1	151.8
Hungary	Vodafone Hungary	Vodafone Home TV HD Family	1000 Mbps	58 / 62		0.0	49.7	30.3	0.0	13.0	93.0
Ireland	Vodafone Ireland	Broadband & Talk and TV	1000 Mbps	72 / 25		0.0	90.0	19.7	0.0	44.1	153.8
Japan	NTT East -BB Excite	Flet Hikari	1024 Mbps	0 / 93		6.8	79.3	41.1	0.0	24.7	152.0
Lithuania	Cgates	TV-Internetas	1024 Mbps	45 / 41		0.2	62.9	10.5	0.0	13.4	87.1
Luxembourg	Post Luxembourg	TV + Landline + Internet XL	1000 Mbps	72 / 74		1.8	94.5	1.0	0.0	0.0	97.3
Mexico	Megacable	TV Conecta + Ilimitado Plus + Internet Ilimitado	1000 Mbps	40 / 58		0.6	86.8	0.0	0.0	24.1	111.5
Netherlands	KPN	Internet and TV	1000 Mbps	48 / 54		0.8	86.5	14.4	0.0	27.6	129.4
Norway	Telenor Norway	Fiber Bredband	600 Mbps	90 / 0		5.7	158.3	23.1	0.0	0.0	187.1
Poland	Orange Polska	Orange Światłowód + TV	600 Mbps	39 / 110		0.8	51.2	0.0	0.0	21.7	73.7
Portugal	MEO	M3 Fibra - Pack Standar+Extra TV	1000 Mbps	216 / 110		0.0	119.6	57.8	0.0	0.0	177.4
Slovak Republic	UPC Slovakia	Internet + Digital Komfort TV	600 Mbps	43 / 86		0.0	47.3	127.1	0.0	10.4	184.7
Slovenia	Telekom Slovenije	NEO A	1024 Mbps	96 / 9		2.0	83.3	13.3	0.0	10.9	109.4
Spain	Vodafone España	Vodafone Hogar Ilimitable	1024 Mbps	113 / 0	Unlimited	0.0	142.5	0.0	0.0	16.1	158.6
Sweden	Tele2 Sweden	Premium 600	600 Mbps	45 / 37		1.6	102.5	15.3	0.0	0.0	119.4
Switzerland	Sunrise	Essential Internet + TV	1024 Mbps	320 / 17		-2.3	52.8	12.6	0.0	33.5	96.5
Türkiye	TTNet	Tivibu'lu İnternet Kampanyasi - Ev Süper	1000 Mbps	131 / 20		0.0	103.5	3.9	0.0	0.0	107.3
United Kingdom	BT	Broadband & Phone + TV	900 Mbps	103 / 16		1.5	79.7	10.5	0.0	0.0	91.7
United States	Comcast	SuperFast	800 Mbps	65 / 74		0.0	165.6	33.0	0.0	9.9	208.4
OECD average						**1.5**	**97.0**	**20.2**	**0.0**	**20.0**	**138.7**

Source: Teligen/TechInsights (2023), "Teligen tariff & benchmarking market data using the OECD methodology", *www.techinsights.com*.

StatLink *https://stat.link/lsxa5v*

Table 22. Three play: Fixed broadband + Fixed voice (FV) + Mobile voice and data (MVD), low usage, January 2023

25 Mbps, FV: 20 calls (OECD 2017), MVD: 30 calls, 1 GB, USD/PPP including VAT per month

Country	Provider	Package, option	Speed	Channels (SD/HD)	Mobile data (GB)	Connection	Rental	Fixed voice	Mobile voice and data	Pay-TV	Total
Austria	Magenta Austria	Internet + Fixed Voice	50 Mbps		16	0.7	35.2	6.8	15.7	0	58.5
Belgium	Telenet	One	150 Mbps		40	0.0	84.0	1.5	0.0	0	85.5
Canada	Shaw	Internet + Fixed Voice + Shaw Mobile	75 Mbps		10	-1.2	73.0	18.2	18.4	0	108.4
Colombia	Movistar Colombia	Movistar Total Duo - Internet 350 Megas + Movil 60 Gigas	350 Mbps		60	5.1	68.2	0.0	0.0	0	73.2
Czech Republic	Vodafone Czech	Spojte-Sluzby	250 Mbps	22 / 40	Unlimited	0.2	24.5	4.6	35.8	0	65.1
France	Orange France	Pack Open ADSL Forfait 2h Internet 100 MB	50 Mbps	120 / 40	2.1	1.4	48.7	2.4	6.5	0	59.0
Germany	United Internet (1und1)	1 & 1 DSL	50 Mbps		1	2.9	45.6	2.1	12.8	0	63.4
Greece	Vodafone Greece	RED + Home 93 Mbps	93 Mbps		16	0.0	82.0	0.0	0.5	0	82.4
Hungary	Digi Hungary	Digi Full Pack DIGINet 1000 (FTTH)	1000 Mbps	67 / 41	15	0.1	41.4	1.5	6.8	0	49.8
Iceland	Vodafone Iceland	Build Your Own	1000 Mbps		10	0.0	64.9	15.0	13.8	0	93.7
Ireland	eir	Complete Broadband and Phone	100 Mbps		120	-2.7	54.6	9.8	16.3	0	78.1
Italy	Wind Italy	Fisso e Mobile	100 Mbps		Unlimited	0.0	32.9	0.0	13.7	0	46.6
Korea	LG U+	Internet + IPTV + Internet Phone + Mobile	100 Mbps	4 / 211	1.5	1.2	24.8	3.1	27.5	0	56.5
Luxembourg	Tango	Tango Duo M	300 Mbps	80 / 0	4	5.3	63.0	2.1	5.2	0	75.6
Netherlands	T-Mobile NL	T-Mobile Home + Mobile	100 Mbps	5 / 59	3	0.0	48.8	13.6	13.2	0	75.5
New Zealand	Slingshot	Broadband Plan	31.9 Mbps		1.5	0.3	48.6	11.7	13.0	0	73.5
Norway	Telenor Norway	Fiber Bredband	100 Mbps		3	5.7	76.0	23.1	25.9	0	130.7
Poland	Orange Polska	Love Standard	300 Mbps	32 / 103	50	0.8	59.2	0.0	0.0	0	60.0
Portugal	NOS	NOS 4 - Fibra 100 Mbps - 150 Canais + Cartão 2 GB (inclui 3 meses Sport TV)	100 Mbps	121 / 33	2	0.0	81.8	5.4	0.0	0	87.2
Slovenia	T-2	T4	500 Mbps	49 / 0	5	4.7	58.5	3.7	0.0	0	66.9
Spain	Orange - Jazztel	Fibra + Movil	300 Mbps		40	0.0	64.4	0.0	0.0	0	64.4
Sweden	Tele2 Sweden	Bredband + Fast telefoni + TV	150 Mbps		10	1.6	40.8	15.3	25.6	0	83.3
Switzerland	Quickline	Quickline Start	100 Mbps	206 / 125	5	6.3	45.3	12.6	14.0	0	78.1
United Kingdom	Virgin Media UK	Volt Fibre Broadband and Phone	108 Mbps		10	0.0	48.0	3.9	15.8	0	67.7
United States	Comcast	Connect	75 Mbps		1	1.2	32.6	33.0	16.5	0	83.4
OECD average						**1.3**	**53.9**	**7.6**	**11.9**	**0.0**	**74.7**

Source: Teligen/TechInsights (2023), "Teligen tariff & benchmarking market data using the OECD methodology", *www.techinsights.com*.

StatLink *https://stat.link/lsxa5v*

Table 23. Three play: Fixed broadband + Fixed voice (FV) + Mobile voice and data (MVD), medium-high usage, January 2023

250 Mbps, FV: 60 calls (OECD 2017), MVD: 100 calls, 10 GB, USD/PPP, including VAT per month

Country	Provider	Package, option	Speed	Channels (SD/HD)	Mobile data (GB)	Connection	Rental	Fixed voice	Mobile voice and data	Pay-TV	Total
Austria	Magenta Austria	Internet + Fixed Voice	250 Mbps		16	0.7	53.1	14.9	15.7	0.0	84.4
Belgium	Telenet	One	1024 Mbps		40	0.0	109.4	7.3	0.0	0.0	116.7
Canada	Shaw	Internet + Fixed Voice + Shaw Mobile	250 Mbps		10	-1.2	78.8	20.0	18.4	0.0	115.9
Colombia	Movistar Colombia	Movistar Total Duo - Internet 350 Megas + Movil 60 Gigas	350 Mbps		60	5.1	68.2	0.0	0.0	0.0	73.2
Czech Republic	Vodafone Czech	Spojte-Sluzby	250 Mbps	22 / 40	Unlimited	0.2	24.5	13.2	35.8	0.0	73.6
France	Free	Freebox Pop	10245 Mbps	80 / 100	Unlimited	1.8	47.8	0.0	13.0	0.0	62.6
Germany	Vodafone Deutschland	Internet & Phone Cable & Giga Kombi	250 Mbps		21	-0.4	53.3	0.0	39.1	0.0	92.0
Hungary	Digi Hungary	Digi Full Pack DIGINet 1000 (FTTH)	1000 Mbps	67 / 41	15	0.1	41.4	4.7	6.8	0.0	52.9
Iceland	Vodafone Iceland	Build Your Own	1000 Mbps		10	0.0	64.9	15.0	13.8	0.0	93.7
Ireland	eir	Complete Broadband and Phone	500 Mbps		120	-2.7	76.5	9.8	16.3	0.0	100.0
Italy	Wind Italy	Fisso e Mobile	1000 Mbps		Unlimited	0.0	32.9	0.0	13.7	0.0	46.6
Korea	KT	Fixed and mobile connections	500 Mbps		10	0.8	30.6	9.2	41.2	0.0	81.8
Luxembourg	Tango	Tango Duo M	300 Mbps	80 / 0	15	5.3	63.0	4.9	21.2	0.0	94.4
Netherlands	T-Mobile NL	T-Mobile Home + Mobile	400 Mbps	5 / 59	12	0.0	53.4	18.0	21.0	0.0	92.5
New Zealand	Vodafone NZ	Unlimited Broadband	813 Mbps		12	0.3	47.3	16.5	38.9	0.0	102.9
Norway	Telenor Norway	Fiber Bredband	350 Mbps		11	5.7	91.4	23.1	41.4	0.0	161.6
Poland	Orange Polska	Love Standard	300 Mbps	32 / 103	50	0.8	59.2	0.0	0.0	0.0	60.0
Portugal	NOS	NOS 4 - Fibra 500 Mbpps - 180 Canais + Cartão (inclui 6 meses Sport TV)	500 Mbps	136 / 48	10	0.0	96.0	25.2	0.0	0.0	121.2
Slovenia	T-2	T4	500 Mbps	49 / 0	5	4.7	58.5	13.5	4.8	0.0	81.5
Spain	Orange - Jazztel	Fibra + Movil	300 Mbps		40	0.0	64.4	0.0	0.0	0.0	64.4
Sweden	Tele2 Sweden	Bredband + Fast telefoni + TV	300 Mbps		10	1.6	45.2	15.3	25.6	0.0	87.8
Switzerland	Quickline	Quickline Start	500 Mbps	206 / 125	Unlimited	6.3	56.4	12.6	22.4	0.0	97.6
United Kingdom	Virgin Media UK	Volt Fibre Broadband and Phone	264 Mbps		10	0.0	55.8	6.6	15.8	0.0	78.2
United States	Spectrum	Fixed broadband + Fixed Voice	300 Mbps		20	0.6	69.6	22.0	33.3	0.0	125.5
OECD average						**1.2**	**60.1**	**10.5**	**18.3**	**0.0**	**90.0**

Source: Teligen/TechInsights (2023), “Teligen tariff & benchmarking market data using the OECD methodology”, *www.techinsights.com*.

StatLink *https://stat.link/lsxa5v*

Table 24. Three play: Fixed broadband + Fixed voice (FV) + Mobile voice and data (MVD), high usage, January 2023

600 Mbps, FV: 140 calls (OECD 2017), MVD: 300 calls, 20 GB, USD/PPP, including VAT per month

Country	Provider	Package, option	Speed	Channels (SD/HD)	Mobile data (GB)	Connection	Rental	Fixed voice	Mobile voice and data	Pay-TV	Total
Austria	Austria	Internet + Fixed Voice	1000 Mbps		32	0.7	98.2	31.5	22.0	0.0	152.5
Belgium	Belgium	One	1024 Mbps		40	0.0	109.4	18.1	0.0	0.0	127.5
Canada	Canada	Internet Fibre Gig + Fixed Voice + Shaw Mobile	1024 Mbps		10	-1.2	96.1	24.3	18.4	0.0	137.6
Czech Republic	Czechia	Spojte-Sluzby	1000 Mbps	22 / 40	Unlimited	0.2	39.7	13.2	35.8	0.0	88.8
France	France	Freebox Pop	10245 Mbps	80 / 100	Unlimited	1.8	47.8	0.0	13.0	0.0	62.6
Germany	Germany	Internet & Phone Cable & Giga Kombi	1000 Mbps		21	-3.1	69.6	0.0	39.1	0.0	105.6
Hungary	Hungary	Digi Full Pack DIGINet 1000 (FTTH)	1000 Mbps	67 / 41	30	0.1	41.4	12.5	21.8	0.0	75.8
Iceland	Iceland	Build Your Own	1000 Mbps		30	0.0	64.9	15.0	19.8	0.0	99.7
Ireland	Ireland	Complete Broadband and Phone	1000 Mbps		120	-2.7	86.4	9.8	16.3	0.0	109.8
Italy	Italy	Fisso e Mobile	1000 Mbps		Unlimited	0.0	32.9	0.0	13.7	0.0	46.6
Korea	Korea	Fixed and mobile connections	1024 Mbps		30	0.8	36.7	9.2	49.0	0.0	95.7
Luxembourg	Luxembourg	Tango Duo L	1000 Mbps	130 / 0	25	5.3	76.6	4.9	31.8	0.0	118.6
Netherlands	Netherlands	Internet with Mobile	1000 Mbps		20	0.8	59.6	14.4	27.0	0.0	101.9
New Zealand	New Zealand	Unlimited Broadband	813 Mbps		Unlimited	0.3	47.3	30.5	51.8	0.0	129.9
Norway	Norway	Fiber Bredband	600 Mbps		Unlimited	5.7	114.6	23.1	52.9	0.0	196.3
Poland	Poland	Love Standard	600 Mbps	32 / 103	50	0.8	63.2	0.0	0.0	0.0	63.9
Portugal	Portugal	M4 Fibra - Pack Standar + Extra TV	1000 Mbps	216 / 92	20	0.0	107.0	57.8	6.3	0.0	171.1
Slovenia	Slovenia	NEO C	1024 Mbps	200 / 14	20	2.0	76.6	13.3	18.2	0.0	110.1
Spain	Spain	Vodafone One Illimitada Básica	600 Mbps		Unlimited	0.0	73.1	0.0	0.0	0.0	73.1
Sweden	Sweden	Bredband + Fast telefoni + TV	600 Mbps		30	1.6	54.8	15.3	30.8	0.0	102.6
Switzerland	Switzerland	Quickline Start	10240 Mbps	206 / 125	Unlimited	6.3	62.0	12.6	22.4	0.0	103.2
United Kingdom	United Kingdom	Volt Fibre Broadband and Phone	1130 Mbps		30	0.0	76.2	19.7	19.7	0.0	115.6
United States	United States	SuperFast	800 Mbps		20	1.2	42.9	33.0	49.5	0.0	126.6
OECD average						**0.9**	**68.6**	**15.6**	**24.3**	**0.0**	**109.4**

Source: Teligen/TechInsights (2023), "Teligen tariff & benchmarking market data using the OECD methodology", *www.techinsights.com*.

StatLink https://stat.link/lsxa5v

Table 25. Four play: Fixed broadband + Fixed voice + Mobile voice and data (MVD)+ TV, low usage, January 2023

25 Mbps, FV: 20 calls (OECD 2017), MVD: 30 calls, 1 GB, 20 channels, USD/PPP, including VAT per month

Country	Provider	Package, option	Speed	Channels (SD/HD)	Mobile data (GB)	Connection	Rental	Fixed voice	Mobile voice and data	Pay-TV	Total
Austria	Magenta Austria	Internet + Fixed Voice + MagentaEINS Mobile + TV	50 Mbps	35 / 30	16	0.7	44.0	6.8	15.7	0.0	67.3
Belgium	Voo	Quattro Relax	200 Mbps	96 / 21	5	0.0	98.0	1.5	0.0	0.0	99.5
Canada	Shaw	Internet + TV Total + Fixed Voice + Shaw Mobile	250 Mbps	17 / 103	10	-4.8	129.3	18.2	18.4	0.0	161.1
Colombia	Movistar Colombia	Movistar Total Trio - Internet 350 Megas + Movil 60 Gigas	350 Mbps	89 / 51	60	5.1	91.0	0.0	0.0	0.0	96.1
Czech Republic	Vodafone Czech	Spojte-Sluzby	250 Mbps	22 / 40	Unlimited	0.2	24.5	4.6	35.8	0.0	65.1
France	Orange France	Pack Open ADSL Forfait 2h Internet 100 MB	50 Mbps	120 / 40	2.1	1.4	48.7	2.4	6.5	0.0	59.0
Germany	United Internet (1und1)	1 & 1 DSL	50 Mbps	50 / 37	1	2.9	58.7	2.1	12.8	0.0	76.5
Greece	Vodafone Greece	RED + Home 50 Mbps +TV Entertainment	50 Mbps	28 / 1	16	0.0	86.3	0.0	0.5	0.0	86.8
Hungary	Digi Hungary	Digi Full Pack DIGINet 1000 (FTTH)	1000 Mbps	67 / 41	15	0.1	41.4	1.5	6.8	0.0	49.8
Iceland	Vodafone Iceland	Build Your Own	1000 Mbps	23 / 0	10	0.0	128.0	15.0	13.8	0.0	156.8
Ireland	eir	Complete Broadband and Phone	100 Mbps	56 / 4	120	-2.7	71.0	9.8	16.3	0.0	94.4
Korea	LG U+	Internet + IPTV + Internet Phone + Mobile	100 Mbps	4 / 211	1.5	1.2	24.8	3.1	27.5	0.0	56.5
Luxembourg	Tango	Tango Duo M	300 Mbps	80 / 0	4	5.3	63.0	2.1	5.2	0.0	75.6
Netherlands	T-Mobile NL	T-Mobile Home + Mobile	100 Mbps	5 / 59	3	0.0	48.8	13.6	13.2	0.0	75.5
Norway	Telenor Norway	Fiber Bredband	100 Mbps	90 / 0	3	5.7	132.1	23.1	25.9	0.0	186.8
Poland	Orange Polska	Love Standard	300 Mbps	32 / 103	50	0.8	59.2	0.0	0.0	0.0	60.0
Portugal	NOS	NOS 4 - Fibra 100 Mbps - 150 Canais + Cartão 2 GB (inclui 3 meses Sport TV)	100 Mbps	121 / 33	2	0.0	81.8	5.4	0.0	0.0	87.2
Slovenia	T-2	T4	500 Mbps	49 / 0	5	4.7	58.5	3.7	0.0	0.0	66.9
Spain	Orange - Jazztel	Fibra + Movil + TV	300 Mbps	60 / 0	40	0.0	71.7	0.0	0.0	0.0	71.7
Sweden	Telia Sweden	Bredband via Fiber 250 with TV and Telephony	250 Mbps	35 / 19	3	2.0	61.6	18.4	21.6	0.0	103.7
Switzerland	Quickline	Quickline Start	100 Mbps	206 / 125	5	6.3	45.3	12.6	14.0	0.0	78.1
United Kingdom	Virgin Media UK	Big Volt Bundle	108 Mbps	97 / 12	10	0.0	56.5	3.9	15.8	0.0	76.2
United States	Comcast	Connect	75 Mbps	65 / 60	1	0.0	122.3	33.0	16.5	0.0	171.8
OECD average					**17.4**	**1.3**	**71.6**	**7.9**	**11.6**	**0.0**	**92.3**

Source: Teligen/TechInsights (2023), "Teligen tariff & benchmarking market data using the OECD methodology", *www.techinsights.com*.

StatLink https://stat.link/lsxa5v

Table 26. Four play: Fixed broadband + Fixed voice + Mobile voice and data (MVD)+ TV, medium-high usage, January 2023

250 Mbps, FV: 60 calls (OECD 2017), MVD: 100 calls, 10 GB, 40 channels including Premium Movies, USD/PPP including VAT per month

Country	Provider	Package, option	Speed	Channels (SD/HD)	Mobile data (GB)	Connection	Rental	Fixed voice	Mobile voice and data	Pay-TV	Total
Austria	Magenta Austria	Internet + Fixed Voice + MagentaEINS Mobile + TV	250 Mbps	74 / 90	16	0.7	69.4	14.9	15.7	35.7	136.4
Belgium	Voo	Quattro Max	1000 Mbps	96 / 27	15	0.0	112.6	6.1	6.1	29.5	154.3
Canada	Shaw	Internet + TV Total + Fixed Voice + Shaw Mobile	250 Mbps	17 / 113	10	-4.8	129.3	20.0	18.4	17.3	180.2
Colombia	Movistar Colombia	Movistar Total Trio - Internet 350 Megas + Movil 60 Gigas	350 Mbps	89 / 56	60	5.1	91.0	0.0	0.0	12.7	108.8
Czech Republic	Vodafone Czech	Spojte-Sluzby	250 Mbps	22 / 43	Unlimited	0.2	24.5	13.2	35.8	13.2	86.8
France	Free	Freebox Pop	10245 Mbps	80 / 101	Unlimited	1.8	47.8	0.0	13.0	45.2	107.9
Germany	Vodafone Deutschland	Internet & Phone Cable & Giga Kombi	250 Mbps	147 / 93	21	1.4	69.6	0.0	39.1	35.9	146.0
Hungary	Digi Hungary	Digi Full Pack DIGINet 1000 (FTTH)	1000 Mbps	67 / 41	15	0.1	41.4	4.7	6.8	15.7	68.6
Iceland	Vodafone Iceland	Build Your Own	1000 Mbps	54 / 0	10	0.0	200.4	15.0	13.8	0.0	229.2
Ireland	Virgin Media Ireland	500 Mb Broadband + TV	500 Mbps	68 / 22	Unlimited	1.4	84.1	14.7	14.7	18.0	132.9
Korea	LG U+	Internet + IPTV + Internet Phone + Mobile	500 Mbps	4 / 211	12	1.2	29.7	7.4	45.9	9.5	93.7
Luxembourg	Post Luxembourg	Pack Advantage Internet XL	1000 Mbps	72 / 68	Unlimited	1.8	94.5	1.0	63.6	13.4	174.3
Netherlands	T-Mobile NL	T-Mobile Home + Mobile	400 Mbps	5 / 63	12	0	53.4	18.0	21.0	17.8	110.3
Norway	Telenor Norway	Fiber Bredband	350 Mbps	90 / 0	11	5.7	144.9	23.1	41.4	0.0	215.1
Poland	Orange Polska	Love Standard	300 Mbps	32 / 111	50	0.8	59.2	0	0.0	21.7	81.7
Portugal	NOS	NOS 4 - Fibra 500 Mbpps - 180 Canais + Cartão (inclui 6 meses Sport TV)	500 Mbps	136 / 51	10	0	96.0	25.2	0.0	15.7	136.9
Slovenia	T-2	T4	500 Mbps	49 / 0	5	4.7	58.5	13.5	4.8	16.0	97.5
Spain	Movistar España	Movistar Max	300 Mbps	41 / 9	30	0	84.9	0.0	0.0	14.7	99.5
Sweden	Telia Sweden	Bredband via Fiber 250 with TV and Telephony	250 Mbps	35 / 19	15	2.0	61.6	18.4	36.7	19.9	138.7
Switzerland	Quickline	Quickline Start	500 Mbps	206 / 148	Unlimited	6.3	56.4	12.6	22.4	18.4	116.1
United Kingdom	Virgin Media UK	Bigger Volt Bundle	362 Mbps	120 / 69	10	0.0	81.8	6.6	15.8	0.0	104.1
United States	Comcast	SuperFast	800 Mbps	65 / 64	20	0.0	132.6	33.0	49.5	9.5	224.5
OECD average					**18.9**	**1.3**	**82.9**	**11.2**	**21.1**	**17.3**	**133.8**

Source: Teligen/TechInsights (2023), "Teligen tariff & benchmarking market data using the OECD methodology", *www.techinsights.com*.

StatLink https://stat.link/lsxa5v

Table 27. Four play: Fixed broadband + Fixed voice + Mobile voice and data (MVD)+ TV, high usage, January 2023

600 Mbps, FV: 140 calls (OECD 2017), MVD: 300 calls, 20 GB, 80 channels with Premium Movies and Sports and DVR, USD/PPP, including VAT per month

Country	Provider	Package, option	Speed	Channels (SD/HD)	Mobile data (GB)	Connection	Rental	Fixed voice	Mobile voice and data	Pay-TV	Total
Austria	Magenta Austria	Internet + Fixed Voice + MagentaEINS Mobile + TV	1000 Mbps	74 / 92	32	0.7	114.6	31.5	22.0	42.8	211.6
Belgium	Voo	Quattro Max	1000 Mbps	96 / 27	30	0.0	112.6	6.1	18.2	36.5	173.3
Canada	Shaw	Internet Fibre Gig + TV Total + Fixed Voice + Shaw Mobile	1024 Mbps	17 / 116	10	-4.8	146.6	24.3	18.4	17.3	201.8
Czech Republic	O2 Czech	Spolu	1000 Mbps	34 / 46	20	0.2	100.3	23.2	23.1	32.6	179.5
France	SFR France	Fibre Power de SFR	2048 Mbps	202 / 0	80	4.0	47.0	0.0	33.9	34.3	119.1
Germany	Vodafone Deutschland	Internet & Phone Cable & Giga Kombi	1000 Mbps	147 / 106	21	-1.3	85.9	0.0	39.1	54.1	177.9
Hungary	Telekom Hungary	Magenta 1	1000 Mbps	121 / 65	50	0.0	63.4	19.3	58.5	13.0	154.2
Ireland	Virgin Media Ireland	1 Gb Broadband + Bigger TV	1000 Mbps	118 / 32	Unlimited	1.4	98.8	30.4	19.6	44.0	194.2
Luxembourg	Post Luxembourg	Pack Advantage Internet XL	1000 Mbps	72 / 74	Unlimited	1.8	94.5	1.0	63.6	0.0	160.9
Netherlands	KPN	Internet and TV with Mobile	1000 Mbps	48 / 54	20	0.8	78.1	14.4	27.0	27.6	148.0
Norway	Telenor Norway	Fiber Bredband	600 Mbps	90 / 0	Unlimited	5.7	158.3	23.1	52.9	0.0	240.0
Poland	Orange Polska	Love Standard	600 Mbps	32 / 117	50	0.8	63.2	0.0	0.0	21.7	85.7
Portugal	MEO	M4 Fibra 1000 Mbps - Pack Standar+Extra TV - GB ilimitados	1000 Mbps	216 / 110	Unlimited	0.0	158.9	57.8	0.0	0.0	216.7
Slovenia	Telekom Slovenije	NEO C	1024 Mbps	200 / 17	20	2.0	76.6	13.3	18.2	10.9	121.0
Spain	Vodafone España	Vodafone Hogar Ilimitable	1024 Mbps	113 / 0	Unlimited	0.0	142.5	0.0	0.0	16.1	158.6
Sweden	Tele2 Sweden	Premium 600	600 Mbps	45 / 37	30	1.6	102.5	15.3	30.8	0.0	150.2
Switzerland	Sunrise	Comfort Home - Internet + Phone + TV + Mobile	10240 Mbps	315 / 182	Unlimited	1.3	107.8	12.6	0.0	21.0	142.6
United Kingdom	Virgin Media UK	Bigger Volt Bundle	1000 Mbps	120 / 74	30	0	97.6	19.7	19.7	0.0	137.0
United States	Comcast	SuperFast	800 Mbps	65 / 74	20	0	132.6	33.0	49.5	9.9	224.9
OECD average						**0.7**	**104.3**	**17.1**	**26.0**	**20.1**	**168.3**

Source: Teligen/TechInsights (2023), "Teligen tariff & benchmarking market data using the OECD methodology", *www.techinsights.com*.

StatLink *https://stat.link/lsxa5v*

Table 28. Revenue from all telecommunication services, USD PPP, 2010-23

Country	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Australia	27 039	27 949	27 267	28 537	28 342	28 517	29 860	30 101	31 614	31 686	31 381	30 813	32 215	..
Austria	5 657	5 453	5 496	5 200	4 920	4 921	5 269	5 335	5 275	5 737	5 876	6 202	6 168	6 717
Belgium	9 412	9 329	9 267	8 863	8 799	8 976	9 288	9 259	9 429	9 839	10 003	10 155	10 441	10 522
Canada	34 143	34 446	35 437	36 739	37 346	38 241	40 279	41 588	43 885	44 438	44 524	46 828	49 270	50 769
Colombia	..	..	13 287	13 255	14 017	13 968	13 983	14 192	14 756	16 465	17 572	18 086	7 161	7 197
Costa Rica	..	..	..	..	..	2 010	2 123	2 187	2 255	2 361	2 223	2 215	2 212	2 267
Czech Republic	9 312	8 914	8 749	8 293	8 191	8 817	9 104	9 433	9 461	10 003	10 024	10 413	6 664	6 806
Denmark	5 349	5 283	5 273	5 079	5 465	5 377	5 417	5 516	5 653	6 685	6 832	7 069	7 387	..
Estonia	1 366	1 451	1 405	1 245	1 132	1 141	1 106	1 131	1 153	1 174	1 281	1 313	1 265	1 423
Finland	4 300	4 206	4 011	3 841	3 780	3 725	3 955	4 045	4 092	4 035	4 121	4 259	4 452	..
France	47 667	47 372	45 000	43 426	41 770	40 685	41 912	40 911	40 729	43 447	44 964	45 798	47 905	49 040
Germany	73 086	73 165	73 418	74 026	73 766	73 590	75 867	76 622	77 027	79 861	60 775	63 029	64 580	65 571
Greece	9 854	9 325	9 063	8 663	7 965	7 196	7 466	7 471	7 604	8 096	7 926	8 317	8 594	..
Hungary	7 033	7 155	7 091	6 638	6 803	6 836	7 016	6 910	6 998	0	6 223	6 196	6 464	6 758
Iceland	189	193	195	202	209	208	202	198	187	193	187	187	203	209
Ireland	4 549	4 607	3 949	3 895	3 687	3 757	3 892	3 995	4 447	4 433	4 460	4 557	4 783	4 895
Israel	6 866	7 408	6 641	6 091	5 664	5 457	5 360	5 121	4 880	4 600	4 396	4 603	5 028	..
Italy	54 747	53 409	51 488	46 884	43 789	42 982	45 596	46 698	45 900	46 265	45 476	44 917	44 902	45 241
Japan	1 19 669	1 23 511	1 24 246	1 34 634	1 32 852	1 35 635	1 34 441	1 33 433	1 33 479	1 44 072	1 51 285	1 49 211	1 56 204	..
Korea	62 247	57 140	57 904	58 664	60 163	62 559	64 860	65 678	67 806	69 690	73 884	77 043	80 925	85 544
Latvia	..	..	..	..	1 058	1 076	1 106	1 133	1 084	1 085	1 106	1 113	1 128	1 178
Lithuania	5 719	5 322	5 050	4 875	4 761	1 257	1 345	1 394	1 395	1 660	1 702	1 772	1 711	1 764
Luxembourg	534	562	616	633	608	611	646	662	677	683	677	703	722	721
Mexico	..	..	..	49 649	53 118	52 811	54 007	52 291	53 177	54 247	53 110	54 147	58 303	62 284
Netherlands	16 482	16 531	14 880	16 442	14 940	14 433	13 527	13 555	12 634	14 227	15 027	15 731	14 156	13 019
New Zealand	3 307	3 376	3 500	3 593	3 590	3 453	3 667	3 755	3 686	3 691	3 706	3 624	3 645	3 797
Norway	3 720	3 678	3 676	3 721	3 636	3 409	3 409	3 537	3 551	3 639	3 654	4 054	4 448	4 385
Poland	23 873	24 005	24 073	22 876	22 417	22 403	22 937	22 683	22 382	23 349	23 996	23 719	22 861	22 950
Portugal	12 258	10 527	10 848	10 813	9 950	9 876	10 265	10 177	10 313	10 955	10 505	11 414	12 931	..
Slovak Republic	3 962	3 822	3 741	3 615	3 447	3 387	3 369	3 201	3 217	3 356	3 490	3 871	3 457	..
Slovenia	1 748	1 965	1 987	1 820	1 810	1 807	1 859	1 984	1 907	2 011	2 017	2 085	2 170	2 237
Spain	54 410	53 349	50 858	48 574	46 371	46 217	51 215	54 123	54 575	57 045	54 141	58 372	59 926	60 756
Sweden	5 721	58 921	5 982	5 997	5 961	5 883	6 050	6 088	5 720	5 878	5 906	5 925	5 949	5 978
Switzerland	11 941	12 382	13 077	13 581	14 460	14 912	15 288	15 212	15 674	15 549	15 484	14 810	15 955	16 119
Türkiye	23 020	27 881	29 513	29 251	30 602	34 121	36 476	37 063	36 215	36 241	36 535	33 837	28 267	32 218
United Kingdom	64 051	60 350	64 896	61 823	59 852	60 596	61 482	61 278	53 914	53 634	54 606	52 104	48 918	..
United States	5 17 507	5 39 611	5 56 587	5 58 935	5 88 172	6 01 970	6 11 166	5 99 077	6 11 867	6 19 826	6 15 635	6 62 843	6 66 715	..
OECD	**12 30 738**	**13 02 600**	**12 78 470**	**13 30 373**	**13 53 413**	**13 72 819**	**14 04 811**	**13 97 038**	**14 08 619**	**14 40 157**	**14 34 710**	**14 91 336**	**14 98 086**	**15 16 269**

Notes: The OECD total for 2022, includes 2021 data as estimates for the missing 2022 data. For Chile, revenue data are not available.

Source: OECD Telecommunications and Internet Statistics (database), *https://doi.org/10.1787/tel_int-data-en* (accessed on 4 March 2024).

StatLink *https://stat.link/lsxa5v*

Table 29. Annual total investment in telecommunication services, USD PPP, 2010-23

Country	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Australia	2 563	2 934	3 408	4 443	4 876	5 472	6 794	7 839	8 913	8 241	7 040	6 092	6 751	..
Austria	830	617	688	643	689	827	770	812	878	1 201	1 213	1 061	1 232	1 112
Belgium	1 334	1 528	1 504	1 777	1 854	1 763	2 033	2 150	2 253	2 075	2 037	2 448	3 346	3 593
Canada	6 885	7 466	7 800	7 296	7 576	8 369	9 554	9 968	10 217	9 710	9 471	11 153	11 897	11 397
Chile	2 723	3 356	3 451	2 945	2 887	2 464	2 433	2 520	2 685	2 638	2 450	3 216	3 272	2 690
Costa Rica	..	..	..	..	..	718	587	879	508	646	247	644	435	419
Czech Republic	1 108	1 096	1 119	1 106	1 703	1 122	1 332	1 221	1 292	1 131	1 481	1 461	1 390	1 548
Denmark	972	894	866	837	854	918	934	1 061	1 037	1 315	1 610	1 728	1 829	..
Estonia	134	170	228	175	167	168	176	152	165	170	221	200	189	..
Finland	..	667	626	621	659	747	670	707	953	735	950	883	777	..
France	7 545	8 684	8 803	8 952	8 694	9 668	11 498	13 042	13 804	17 068	19 435	21 590	21 696	20 577
Germany	7 284	7 975	8 101	8 571	9 870	10 256	11 067	11 486	12 297	13 611	15 211	16 429	19 420	18 929
Greece	1 486	1 327	1 072	1 243	1 511	1 095	1 473	860	955	1 026	849	1 004	1 228	..
Hungary	1 126	1 031	1 192	1 027	1 231	1 393	1 312	1 339	1 176	1 240	1 396	1 535	1 569	..
Iceland	32	29	36	40	34	36	49	53	54	77	56	59	75	88
Ireland	522	538	981	678	690	688	716	834	860	887	828	867	1 288	..
Israel	908	920	784	611	633	716	689	751	779	699	737	909	1 052	..
Italy	7 987	7 907	8 421	8 037	8 293	9 850	10 063	10 411	12 201	12 477	12 066	12 086	11 354	10 743
Japan	13 308	13 357	13 760	15 827	9 853	11 559	11 360	10 413	12 008	11 362	13 402	33 044	29 739	..
Korea	6 767	7 815	9 317	7 806	7 752	6 764	6 694	6 365	6 602	11 323	9 979	9 915	10 089	9 615
Latvia	..	..	157	130	226	196	183	140	159	156	151	165	182	202
Lithuania	713	800	591	680	646	175	222	175	179	172	190	259	248	233
Luxembourg	99	126	146	168	177	149	132	122	95	96	109	133	148	126
Mexico	..	..	..	8 131	6 443	10 356	11 957	9 539	8 750	8 545	8 645	7 703	7 127	5 645
Netherlands	3 450	3 491	3 304	5 284	3 471	2 875	2 963	2 907	2 881	2 909	2 787	3 606	5 178	5 419
New Zealand	1 030	829	847	1 090	1 174	1 196	1 106	1 103	1 127	1 184	1 131	1 111	1 027	1 106
Norway	..	..	862	936	969	1 010	1 124	1 119	1 155	1 408	1 477	1 680	1 915	1 722
Poland	4 124	3 850	3 612	3 862	3 802	3 653	8 992	3 517	4 528	4 381	4 705	5 174	6 277	5 909
Portugal	1 737	1 451	1 268	1 279	1 061	1 082	1 069	1 116	1 062	1 092	1 270	1 584	1 652	1 629
Slovak Republic	718	734	410	458	644	641	706	730	671	760	793	786	774	..
Slovenia	239	202	284	256	307	317	372	433	453	433	536	485	517	572
Spain	6 118	8 319	5 744	5 677	7 667	7 791	7 553	7 413	7 697	9 592	8 212	10 397	9 900	10 446
Sweden	778	1 074	1 112	1 132	1 245	1 411	1 781	1 978	1 746	1 688	1 593	1 808	1 770	1 588
Switzerland	1 467	1 716	2 422	2 220	2 631	2 499	2 675	2 469	2 370	2 474	2 423	2 668	2 862	2 951
Türkiye	4 088	5 774	5 649	5 105	5 155	14 892	5 990	5 909	5 769	6 987	7 907	7 982	6 744	7 519
United Kingdom	7 333	7 230	..	..	..	..	..	..	9 412	9 693	10 863	12 256	12 192	..
United States	70 223	73 531	81 038	87 240	86 631	84 498	87 659	94 472	94 997	90 914	82 425	88 006	1 07 255	..
OECD	**1 65 629**	**1 77 434**	**1 86 833**	**2 03 514**	**1 99 308**	**2 14 564**	**2 21 916**	**2 23 237**	**2 32 689**	**2 40 116**	**2 35 896**	**2 72 127**	**2 94 396**	**2 90 421**

Notes: The OECD total for 2022, includes 2021 data as estimates for the missing 2022 data. For Colombia, investment data are not available.

Source: OECD Telecommunications and Internet Statistics (database), *https://doi.org/10.1787/tel_int-data-en* (accessed on 4 March 2024).

StatLink *https://stat.link/lsxa5v*

References

EUROSTAT (2023), *Statistics on households and individuals and Statistics on enterprises, Comprehensive Database* (database), *https://ec.europa.eu/eurostat/web/digital-economy-and-society/database/comprehensive-database* (accessed on 12 July 2024). [1]

OECD (2017), *Revised Telecommunication Price Baskets*, Working Party on Communication Infrastructures and Services Policy, OECD, Paris, *https://one.oecd.org/document/DSTI/CDEP/CISP(2017)4/FINAL/En/pdf*. [2]

OECD (2020), "OECD bundled communication price baskets", *OECD Digital Economy Papers*, No. 300, OECD Publishing, Paris, *http://dx.doi.org/10.1787/64e4c18a-en*. [3]

List of Figures

List of Tables

List of Boxes

OECD Digital Economy Outlook 2024 (Volume 2)

STRENGTHENING CONNECTIVITY, INNOVATION AND TRUST

Rapid technological changes characterise the most recent phase of digital transformation, bringing opportunities and risks for the economy and society. *Volume 2* of the *OECD Digital Economy Outlook 2024* examines new directions in digital priorities, policies and governance across countries. It further analyses developments in the foundations that support digital transformation, drive digital innovation and foster trust in the digital age. Toward this end, *Volume 2* assesses access and connectivity trends, and the skills needed to thrive in a digital economy and society. It also explores how to push out the digital technology frontier by harnessing the untapped potential of women. Moreover, it considers how technological innovations can help reach net-zero targets and contribute to protecting the planet. Finally, *Volume 2* examines digital security developments and presents new trends in media consumption and trust, attitudes toward privacy and control over personal data, and insights into how exposure to additional context influences the ability of individuals to identify the veracity of information on line. A Statistical Annex completes the volume.

PAPERBACK ISBN 978-92-64-45881-9
PDF ISBN 978-92-64-59635-1

9 789264 458819