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Contents

List of abbreviations

Abbreviation	Meaning
AI	Artificial Intelligence
AGV	Autonomous Driving Vehicles
AM	Algorithmic management
API	Application Programming Interface
AR	Augmented Reality
BEREC	Body of European Regulators for Electronic Communications
BT	British Telecom
CEDEFOP	European Centre for the Development of Vocational Training
CNF	Cloud-based network functions
CRAN	Centralised RAN
CRQCs	Cryptographically Ready Quantum Computers
CRM	Customer Relationship Management
DevSecOps	Development, Security, and Operations
DT	Deutsche Telekom
DUFA	Digital Upskilling For All!
DRAN	Decentralised RAN
EGDC	European Green Digital Coalition
EU	European Union
EU27	The 27 Member States of the EU (excluding the United Kingdom)
ETNO	European Telecommunications Network Operators
ETUC	European Trade Union Confederation
ETUI	European Trade Union Institute
EVA	Energy Visual Analytics
FTTH	Fibre To The Home
FTTP	Fibre To The Premises
GDPR	General Data Protection Regulation
GPON	Gigabit Passive Optical Network
GSMA	Global System for Mobile Communications Association
HFC	Hybrid fibre-coaxial
HR	Human Resources
HVAC	Heating, Ventilation, and Air Conditioning
ICT	Information and Communication Technology
ID	Identity
ILO	International Labour Organisation
IoT	Internet of Things
IT	Information Technology
ITU	International Telecommunication Union
JRC	Joint Research Centre
JSCs	Swedish Job Security Councils
KPN	Koninklijke PTT Nederland (Royal PTT Netherlands)
LTE	Long Term Evolution
MIMO	Multiple-Input Multiple-Output
ML	Machine Learning
MoU	Minutes of Usage

MR	Mixed Reality
NB-IoT	Narrowband-Internet of Things
NeGP	National e-Governance Plan (India)
NPCI	National Payments Corporation of India
OECD	Organization for Economic Cooperation and Development
ORAN	Open RAN
PON	Passive Optical Network
QIVICON	Deutsche Telekom's open Connected Home platform
RAN	Radio Access Network
RE	Radio Exchange
R&D	Research & Development
RPA	Robotic Process Automation
RIC	Ran Intelligent Controller
SA	Stand Alone
SAAS	Software-as-a-Service
Telecoms	Telecommunications
Telcos	Telecommunications or communication service provider
TIM	Telecom Italia Mobile
UV	Ultra-Violet
VDSL	Very-High-Bit-Rate Digital Subscriber Line
VHCN	Very High-Capacity Network
VR	Virtual Reality
vRAN	Virtual RAN
XR	Extended Reality
xRAN	Emerging RAN technologies
3D	Three-dimensional
3GPP	3rd Generation Partnership Project
5G	Fifth-Generation mobile network
6G	Sixth-Generation mobile network

Executive summary

This study supports the project 'Accelerating sustainability in telecoms', led by the social partners in telecoms ETNO and UNI Europa ICTS. The aim of the study is to analyse 11 key emerging technologies which are likely to considerably impact the telecommunication industry, and their impact on social and environmental sustainability. The selected technologies are:

- Artificial intelligence (AI)
- Big data and analytics
- Cloud computing
- Edge computing
- Internet of Things (IoT)
- 5G and 6G
- Optic Fibre and GPON
- Quantum technologies
- Blockchain and technologies for cybersecurity
- Extended reality
- xRAN

The report will also provide a solid foundation for the subsequent project activities, and is based on inputs derived from desk research, interviews with experts from the sector, and inputs from stakeholder engagement collected during the first roundtable of the project. Together with the report, a set of 11 infographics has been developed in order to facilitate the distribution of knowledge about key impactful technologies in the European telecommunication industry. The study does not aim to be comprehensive regarding the technologies chosen for analysis. Rather, it aims to provide a window of knowledge on those technologies that have been identified as potentially impactful by ETNO members. Moreover, given the novelty of the topic examined, the methods employed have been predominantly qualitative, as statistics specific to selected technologies' use in telcos are not yet comprehensive. With these limitations in mind, the analysis constitutes a 'technology handbook', aimed at enhancing the capacity of social partners to facilitate change in telecom companies.

These technologies' **impact on environmental sustainability** has been found to be potentially substantial, and the solutions converge on their possibility to make telcos more energy efficient. While some solutions are aimed at streamlining processes and reallocating energy flows only where they are the most needed (e.g., data analytics and AI), others (such as 5G, optic fibre, and edge computing) represent newer generations of known technologies, which consume inherently less energy than their predecessors. Additionally, as part of a broader trend in the ICT sector, some telcos are exploring new roles as digital service providers, offering to their customers digital and technological solutions to become more energy efficient. This confirms the role of telcos as key enablers of sustainability in the wider society.

Concerning the technologies' impact on **workers and the labour market**, the analysis presented some favourable impacts, and some points for concern. Most prominently, certain AI and IoT applications (e.g. algorithmic management and biometric monitoring) raised concerns around workers' rights, such as the infringement of privacy and potential reductions in individual autonomy. Nevertheless, the same technologies can also be positively harnessed to create better safety conditions for workers, particularly during hazardous and repetitive tasks, creating positive wellbeing outcomes. Other technologies, such as 5G/6G, optic fibre, cloud computing, and edge computing, will be pivotal to the growing prevalence of telework and hybrid work, which are also emerging as key trends in the labour sphere with significance for telcos. In particular, the reorganisation of work tasks and workspaces is expected to have implications for workers' health and safety, tied to the availability of equipment and the 'right to disconnect' (the right of employees to not be continuously available outside of working hours). In parallel, nearly all the technologies examined had an impact on workers' skills, which are constantly evolving and in need to be upgraded.

Due to the impact of technology on workers being potentially both positive and negative, the **involvement of employees and social partners** at an early stage of technology roll-out takes on a particularly important role in the road to the twin transition. This is why the study also analyses the **role of social dialogue** in promoting sustainability and mitigating the negative effects of technology implementation. The study shows that a historically good relationship between telcos and trade unions can be a key element of trust during the negotiation process, as well as willingness from both parties to listen and understand the specific implications of new technologies. Nevertheless, some hurdles still emerge, mainly tied to the fast pace of technological change and innovation, which may weaken each party's negotiating position due to a fundamental lack of knowledge of the solution itself. For this reason, a selection of case studies was included throughout the report to be treated as best practice scenarios of technology implementation and/ or social dialogue involvement throughout the process.

Introduction

Accelerating Sustainability in Telecoms is a project led by the European social partners in telecom, ETNO and UNI Europa ICTS. The project aims to analyse and identify technologies that can enable the twin transition in the telecommunication sector. As part of the broader project, this research report presents desk research activities undertaken by Visionary Analytics.

This report serves as the backbone for all of the other project activities; its results will provide material for three **roundtable discussions,** to inform the telecom social partners regarding the role of innovative technologies in the twin transition of telecommunications. Specifically, Roundtables 1 and 2 will focus on discussing disruptive technological innovations while Roundtable 3 will focus on enhancing understanding of the impact of the twin transition on the labour market and skills relevant to the telecoms sector. The combined findings will set the stage for a stakeholder conference, which will include panel(s) providing company good practice examples on the application of disruptive technologies, and the role of social partners in addressing the implementation of new technologies and in mitigating their impact on the labour market and skills.

The results of both desk research and roundtable discussions will help us develop guidelines to support social partners in the implementation of sustainability initiatives in telcos. Further findings will be documented in two key outputs:

1. A set of 11 **infographics** to help the reader quickly grasp the emerging technology in focus (what it is and why it is important for the telecoms sector), to showcase good practices of how these technologies can be harnessed by the telecoms sector to achieve sustainability and to highlight the impact of these technologies on labour market and skills needs to increase awareness of these implications and readiness to address them.

2. A **policy recommendations and guidelines report,** aimed at enhancing the capacity of social partners to facilitate change in telecom companies through the adoption of disruptive technological innovations and mitigation of their impacts on skills.

The Report focuses on the following **research questions**:

- Research question 1: What are the drivers of change in the ICT sector? This research question is explored in *Chapter 1*, which discusses megatrends in the world of ICT employment, reflecting a shift towards sustainable company values and increased digitalisation of skills.
- Research question 2: What emerging (disruptive) technologies have the potential to enable the twin transition in the telecoms sector? This research question is explored in *Chapter 2*, which analyses each disruptive technology, its potential for increased sustainability, and the possible impact it might create in the work organisation, skills demand, and occupational health and safety of telco workers.
- Research question 3: What are the good practice examples on the potential application of new technologies in the telecoms sector to achieve sustainability? Examples of good practices in technology applications are included in *Chapter 2* and discussed for each technology examined, when available. An overview of the intersection between new technologies and sustainable practices relative to the telecommunication sector can be found in *Chapter 1.1.*
- Research question 4: What is the impact of disruptive technologies on the labour market and skills in the telecoms sector? The impact of the single technologies on the labour market and skills is discussed in *Chapter 2*, separately for each technology, under the 'Projected social impact' sections. An overview of the new trends within the labour market in the ICT sector can be found in *Chapter 3.*
- Research question 5: What is the role of social partners in adapting to the twin transition in the telecoms sector? This research question is explored in *Chapter 3*, detailing the benefits of social dialogue in the context of the twin transition.

The Report concludes by providing **preliminary lessons** learned (*Chapter 4*), including technology-neutral **recommendations** and a **checklist of issues** that social partners need to consider during negotiations.

1. Key drivers of change in the ICT and telecoms sector

Within a world increasingly shaped by technological change and innovation, new challenges and opportunities emerge for industries and companies to examine future scenarios and shape their growth accordingly. Technological developments are often at the core of innovation processes, and the telecommunications sector is today in a unique position to act as a key enabler of new technologies that are going to bring profound change not only in industrial ecosystems but also in the social realm of everyday life. To highlight broad trends of change, the European Commission has identified **'megatrends'** across economic sectors, 'long-term driving forces that are observable now and will most likely have a global impact'[1]. Among them, this report will explore the megatrend of **'Accelerating technological change and hyperconnectivity'**, which is concerned with the increased development and use of technology in human societies and economies, in connection with a greater **need for environmental sustainability**[2].

Within this megatrend, the ICT sector is projected to grow by 11% by 2030 as technological developments demand personnel with adequate skills to manage general-purpose technologies in all sectors[3]. Workers, and the skills required from them, will be subjected to the following drivers of change[4]:

- **A shift towards purpose-driven work** which emphasizes the need to strengthen company values in all sectors and put **sustainability** and **social responsibility** at the heart of companies' missions. Companies successful in working towards a meaningful green transition, while keeping up with technological advancements ('twin transition'), will be able to retain more employees, who increasingly demand jobs with purpose. We will discuss the importance of sustainability for the telecommunication sector in *Chapter 1.1, 'Technology and sustainability in telcos'.*
- **The reorganisation of work in a networked society** looks at the new needs of workers within a changing society, which may translate into new work arrangements, such as hybrid and remote work, changing sectoral competitive landscapes, and restructured roles within companies. This aspect will be unpacked in *Chapter 1.2, 'Reorganisation of work and the new labour market'.*
- **The digital transformation** of skills, machinery, and managerial strategies may result in the loss of jobs due to automation. **New disruptive technologies will emerge**, changing the demands within the job market. These technologies will be examined in detail in *Chapter 2, 'Emerging disruptive technologies'*, which will discuss their area of application in telecommunication companies (telcos), their potential for sustainability, and their projected social impact.
- These drivers of change produce social impacts that have **implications for social partners** and increase the need for **social dialogue**. *Chapter 3, 'Role of social partners in the twin transition',* will explore these implications and the benefits of social dialogue.

As part of each trend considered above, **competitiveness** will remain an important horizontal consideration for the European telecommunications ecosystem. Investment in new digital infrastructure (namely 5G, FTTH, as well as innovations such as edge computing and quantum networks) is deemed as a necessary driver to maintain relevance and competitiveness at a global level, in Europe, but also in many developing economies.

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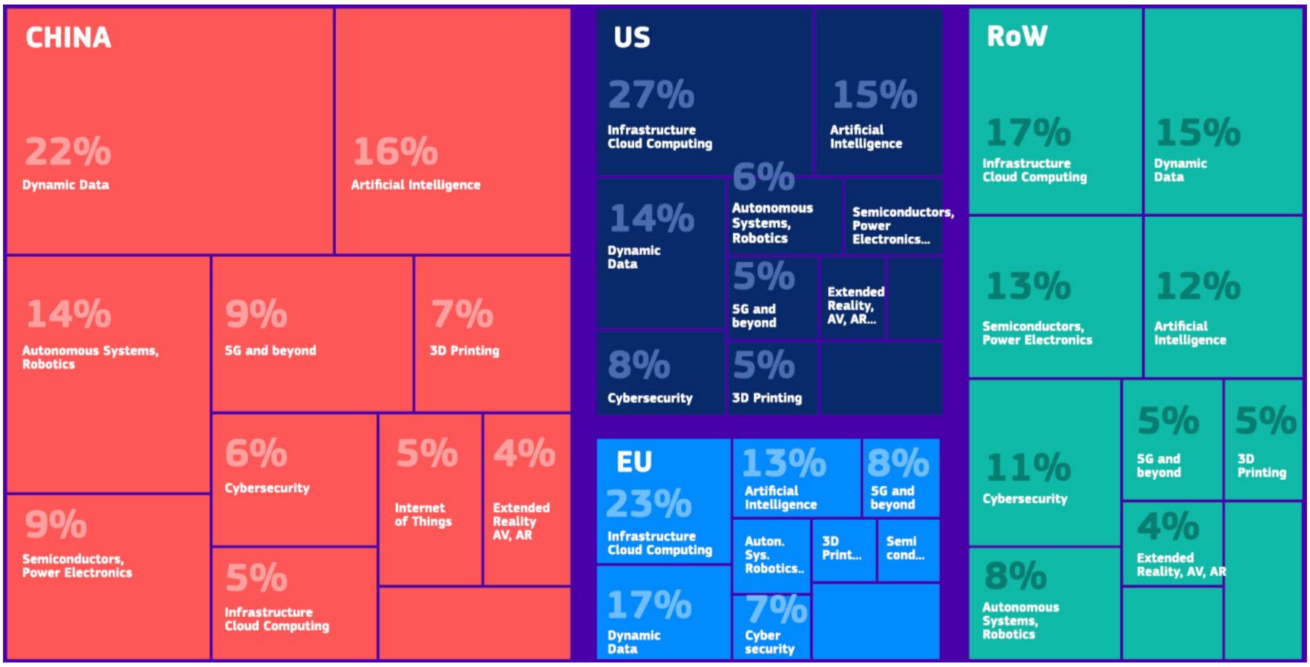
[1] EU Foresight, 'The Megatrends Hub'. Available at: https://knowledge4policy.ec.europa.eu/foresight/tool/megatrends-hub_en
[2] EU Foresight, 'Accelerating technological change and hyperconnectivity'. Available at: https://knowledge4policy.ec.europa.eu/accelerating-technological-change-hyperconnectivity_en
[3] EURES, 'The future of work: ICT professionals'. Available at: https://eures.ec.europa.eu/future-work-ict-professionals-2020-09-25_en#:~:text=Employment%20for%20IT%20professionals%20is,filled%20between%202018%20and%202030
[4] EU Foresight, 'Changing nature of work'. Available at: https://knowledge4policy.ec.europa.eu/foresight/changing-nature-work_en#megatrend

This is because a number of non-EU countries are rising in importance and developing solutions that may (out)compete European industries and capabilities. The ETNO report on '**State of Digital Communications**' (2024)[5] outlines how European telcos are at a crossroads: 5G standalone networks are present in Europe in higher numbers (10) than North America (4), but lower than in Asia (17). Asia and Japan also count a higher number of Open RAN trials and deployments (19) than Europe (11). Lastly, cloud computing commercial offers are also more numerous in Asia (17) and in North America (9) than in Europe (4). More generally, the EU's position in the global digital market is one of reliance on other economies: 80% of digital products consumed in Europe (including services, infrastructures, and intellectual property) are produced in foreign countries, especially in Asia. Moreover, the share of EU revenue in the global digital market has fallen in the last decade, while it has increased in other parts of the world (notably, the US)[6]. *Figure 1* illustrates the EU's share in the global digital ecosystem, by digital product or service.

Figure 1. Composition of activities by digital area in selected geographical areas (2009-2022)



Source: European Commission (2023), '2023 Report on the state of the Digital Decade'. Available at: https://digital-strategy.ec.europa.eu/en/library/2023-report-state-digital-decade

In this context, ensuring European competitiveness goes hand-in-hand with securing employment and growth in the sector, but also with maintaining strategic autonomy and avoiding infrastructural interference from non-European actors[7]. Indeed, securing investment in new technological applications in the telecommunication sector is paramount to the **European Commission's Digital Decade strategy**, which lay out a comprehensive plan for transitioning European industries, government, and citizens towards a sustainable and digital industrial ecosystem across the Union and beyond[8]. Within the ICT sector, the telecommunications (telecoms) sector will be crucial as global scenarios unfold, to ensure a steady provision of connectivity services that will be required by future markets. Nevertheless, operators note that the current

[5] ETNO (2024), *State of Digital Communications 2024*. Available at: https://etno.eu//downloads/reports/etno%20state%20of%20digital%20communications%20-%202024.pdf
[6] European Commission (2023), '2023 Report on the state of the Digital Decade'. Available at: https://digital-strategy.ec.europa.eu/en/library/2023-report-state-digital-decade
[7] European Commission (2023), 'Results of the exploratory consultation on the future of the electronic communications sector and its infrastructure'. Available at: https://digital-strategy.ec.europa.eu/en/library/results-exploratory-consultation-future-electronic-communications-sector-and-its-infrastructure
[8] More information about the Digital Decade targets can be found at: https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/europe-fit-digital-age/europes-digital-decade-digital-targets-2030_en#:~:text=The%20Digital%20Decade%20policy%20programme%202030%20sets%20up%20an%20annual,the%20Commission%20and%20Member%20States.

economic and competitive circumstances they face hamper their ability to meet the aspirations of European policy. As aggravating factors, they cite market fragmentation, low returns on investments, and an overabundance of regulatory obstacles[9]. These factors could leave the ecosystem vulnerable to the above-mentioned foreign threats, with consequences on the European strategic autonomy. Moreover, the repercussions of foreign industry interference (and possible dependence for certain products and services) are likely to be felt by workers, which face a possible reduction in opportunities for talented experts, and the availability of fewer jobs in Europe. In light of these considerations, ETNO members have issued a joint statement, together with European industry members, on 'European business calls for deepening the EU Single Market and renewing the dynamic of European integration'[10]. The statement outlines possible actions to be taken at the EU level to increase the competitivity of the ecosystem.

The below sections will examine the trends described above, which remain crucial in the international stage and will need to be addressed by European telcos. The focus of the report, and of the following chapters, will be on sustainability potential and predicted social impact of disruptive technologies.

1.1. Technology and sustainability in telcos

Together with the digital transformation and a changing demand for skills and jobs, the European Commission identifies a trend towards employees increasingly prioritising work in purpose-driven environments. This translates in more and more companies incorporating visions and missions that align with the values of employees and society as a whole; studies demonstrate that purpose-driven organisations can attract and retain more talent, as well as perform better in the market[11]. A key demand from the new workforce to their employers is values concerning sustainability. In this sense, workers' concerns align with broader European policies: the European Commission has set global climate targets to make Europe the first climate neutral continent by 2050[12]. As part of that strategy, the 2030 Climate and Energy Framework includes plans to reduce emissions of greenhouse gases by at least 55% by 2030, compared to 1990 levels[13]. As set out in the last COP28 (World Climate Action Summit) in Dubai, the two most effective levers to achieve these goals are the use of **renewable energy** and the improvement of global **energy efficiency**[14].

In the telecoms sector, most companies are taking steps to enhance their sustainability as part of the twin transition towards the employment of sustainable solutions that are in line with European values and policies, such as the European Green Deal[15] and the EU Digital Compass[16]. In both digital and green transitions, **technology plays a key role**, and in particular, the technologies related to the ICT sector, which are a key factor in forming virtuous synergies within productive and service-based industries to harness sustainable solutions across sectors[17]. Thanks to new technological developments, European networks are becoming increasingly 'smarter' and more energy efficient: some examples include switching to 5G or optic fibre, implementing smart networks that modulate activity according to user traffic, and creating software upgrades that enhance energy efficiency. In particular, telcos facilitate the twin transition in several different ways:

[9] ETNO (2024), *State of Digital Communications 2024*. Available at: https://etno.eu//downloads/reports/etno%20state%20of%20digital%20communications%20-%202024.pdf

[10] Available at: https://etno.eu//downloads/news/24_02_13%20single%20market%20coalition_joint%20statement_with%20quotes.pdf

[11] EU Foresight, 'Purpose driven work'. Available at: https://knowledge4policy.ec.europa.eu/foresight/purpose-driven-work_en

[12] More information on the 2050 long-term strategy is available at: https://climate.ec.europa.eu/eu-action/climate-strategies-targets/2050-long-term-strategy_en

[13] European Commission, 'Climate targets 2030'. Available at:https://climate.ec.europa.eu/eu-action/climate-strategies-targets/2030-climate-targets_en

[14] European Commission (2023), 'Global targets for renewables and energy efficiency'. Available at: https://energy.ec.europa.eu/topics/international-cooperation/global-targets-renewables-and-energy-efficiency_en

[15] Full text available at EUR-Lex, 'The European Green Deal': https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A52019DC0640

[16] '2030 Digital Compass: the European way for the Digital Decade', full text available at: https://commission.europa.eu/system/files/2023-01/cellar_12e835e2-81af-11eb-9ac9-01aa75ed71a1.0001.02_DOC_1.pdf

[17] ETNO (2021), 'Why ICT is the real (green) deal for Europe'. Available at: https://etno.eu/news/8-news/709-ict-green-deal.html

- Indirectly, by creating networks and infrastructure (such as 5G and optic fibre) that broadly allow the implementation of sustainable technological solutions across society.
- By adopting generalised sustainability solutions that are not specific to telecoms, such as the use of renewable energy to power data centres.
- By directly developing ad-hoc innovative solutions, thanks to advanced technologies, to make telecom operations more efficient and/or sustainable.

Indirect environmental action sees telcos as key enablers of a multitude of green technologies, for the wider benefit of societies[18]. In particular, the **5G technology**, rolled out by telcos, is crucial for the development of IoT, cloud and edge computing, AI applications, big data processors and more emerging technologies and solutions. The role of enablers represents a further opportunity for telcos to offer new products and services, by creating synergies beyond ICT environments and leveraging possibilities for partnerships with industries working on increasing their sustainability and efficiency through technology, for example with the logistics industry[19]. According to GSMA, telecoms today are enabling decarbonisation and sustainable strategies in those industries that generate around 80% of global greenhouse gas emissions (manufacturing, power and energy, transport and buildings)[20]. An example of this action is provided in *Box 1* below.

Box 1. Indirect environmental action: the case of LoRa

One instance of telcos enabling sustainable solutions in other sectors is the **LoRa connectivity network by KPN**, a well-known Dutch telecom operator. The LoRa (Long Range, Low Power) network is based on IoT technology and is available throughout the Netherlands; it enables smart devices and systems to connect efficiently, without using great amounts of energy. Use cases of this network include smart cargo bikes employed by logistics enterprise DHL to deliver and track packages in city centres, or the municipality of Leusden, which has implemented smart waste bins and smart parking thanks to the LoRa network[21].

Source: Visionary Analytics, based on sources indicated in the text

Generalised solutions for sustainability have been implemented by most telcos in Europe and saw the telecoms sector as a leader in European industry regarding the cutting of CO_2 emissions. These actions depend on technologies and solutions that are mostly outside the scope of ICT, such as the use of renewable energies, carbon offsetting strategies, energy sobriety, and circular design of supply chains[22]. The European telecom sector's energy consumption is now made up by at least 80% of energy coming from renewable sources (data relative to ETNO members only)[23], and telcos have been setting ambitious targets to cut their carbon emissions (see *Figure 2* below, detailing European telcos' targets for emissions reduction). Moreover, examples abound of new data centres that are designed to be carbon neutral through integrated solutions, such as in-built dedicated renewable plants[24]. Within the twin transition, there is real potential for these 'external' solutions to be optimised and developed thanks to advanced technologies. Additionally, the nature of the telecoms market today is particularly conducive to the expansion of telecom services towards other sectors to create 'digital ecosystems'[25], and energy-based sustainable solutions are now being explored together with ICT and network-related solutions (see *Box 2* below).

[18] ETNO, 'EU Taxonomy and the European telecommunications sector'. Available at: https://etno.eu/library/482-eu-taxonomy-and-the-european-telecommunications-sector.html
[19] EISMEA, Advanced Technologies.
[20] GSMA, 'Mobile Net Zero'.
[21] KPN (2019), 'Smart Cities in the Netherlands: what are they, benefits and areas for improvement'. Available at: https://www.kpn.com/zakelijk/blog/smart-cities-in-nederland-voorbeelden-voordelen-en-verbeterpunten.htm
[22] ETNO, 'EU Taxonomy'.
[23] ETNO (2024), *State of Digital Communications 2024*. Available at: https://etno.eu//downloads/reports/etno%20state%20of%20digital%20communications%20-%202024.pdf
[24] World Broadband Association (2022), 'The Importance of Environmental Sustainability in Telecom Service Providers' Strategy'. Available at: https://worldbroadbandassociation.com/wp-content/uploads/2022/09/The-Importance-of-Environmental-Sustainability-in-Telecom-Service-Providers-Strategy-World-Broadband-Association-White-Paper.pdf
[25] EISMEA, Technological Trends.

Box 2. Telcos and renewables: the Orange Energy case

The **Orange Energy solution**, now offered to the public as an energy product in 11 African countries, was first deployed by Orange telecom towers and corporate sites in Africa, which often required the use of generators as energy sources in a landscape where access to grid-supplied energy can be unreliable. As a result of these challenges, Orange developed a mini-grid-based solution, powered by solar plants and connected to the Orange Smart Energy digital platform. The platform employs IoT technology by connecting to the customers' smart meters and the entire system. This way, it is easier for Orange to locate the kit, manage customer payments, and carry out repairs remotely where possible.

Source: Visionary Analytics, based on GSMA, 'Mobile Net Zero', and Orange Energy, available at: https://www.orange.com/en/how-orange-energy-makes-clean-and-affordable-electricity-more-accessible-africa

Figure 2. Selected scope 1 and 2 and scope 3 emission reduction targets, ETNO members at the group level

Operator	Target date for net-zero emissions (scope 1 and 2)	Target date for net-zero emissions (scope 3)
BT	2031	2041
Deutsche Telekom	2025	2040
KPN	2030	2040
Orange	2040	2040
TDC	2028	2030
Telefónica	2040	2040
Telenor	2030	2045
Telia Company	2030	2040
TIM Group	2030	2040
United Group	2040	2040

Note: This table refers to net-zero targets as announced by companies and does not take into account if these targets have been validated against the Science Based Targets initiative (SBTi) Net-Zero Standard. To check progress in SBTi, click here https://sciencebasedtargets.org/companies-taking-action
Source: ETNO (2024), *State of Digital Communications 2024*, and input from a United Group representative, 26/04/2024.

As part of the twin transition, the ICT ecosystem is experimenting with an increased drive to design and employ **sustainable solutions based on advanced technologies**. Particularly relevant to discussions surrounding sustainability in ICT is the **European Green Digital Coalition (EGDC)**, an initiative based on a request of the European Council that investigates ways to enhance industry sustainability by harnessing the potential of emerging digital technologies. Companies participating in the initiative sign a declaration, committing to investing in greener technological solutions, to develop methods and tools to monitor their sustainability performance, and to co-create recommendations and guidelines to advance the twin transition across sectors. As part of the initiative, EGDC will aim to study and assess 18 case studies, which will be evaluated according to their net environmental impact. The assessment will represent a rigorous and sustained effort of evaluation of sustainable solutions, which will be beneficial for the purposes of this study, as well as for the ICT ecosystem more broadly. Some of the case studies in object come from telcos and are described in *Box 3* below. A comprehensive list of advanced technologies being employed in telcos, which are showing potential for sustainability, will be explored in detail in *Chapter 2*, and their sustainable application will be highlighted under the 'Potential for Sustainability' sections throughout that chapter.

Box 3. Telcos for sustainable technologies: EGDC case studies

The 'Port of the Future' project at the port of Livorno, Italy, is piloting 5G connectivity throughout the site thanks to a collaboration with Swedish telco Ericsson. Thanks to 5G, the Port benefits from the application of IoT and AI technologies, as well as virtual reality. These technologies are set to reduce the Port's overall greenhouse gas emissions by 8.2%, as a result of the optimisation of cargo handling processes and intra-terminal operations, which include personnel monitoring in potentially dangerous situations, smart ships with augmented navigation, remotely controlled quay cranes, and unmanned aerial vehicles for potential real-time threat detection (including cybersecurity threats)[26].

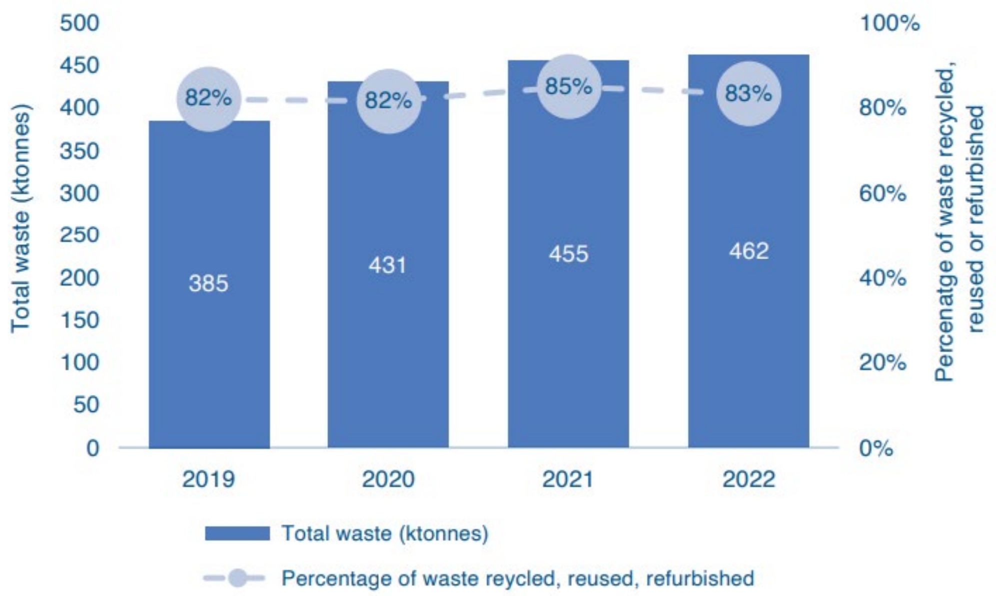
Ekobot is a robot aimed at mechanical weed control in the agricultural sector. Its application in fields allows for more efficient and environmentally conscious farming. The robot features AI technology and advanced camera sensors to identify and remove unwanted weeds, and it is powered by Telia's 5G network. Ekobot is a solution developed in collaboration with Telia, research institute and aggrotech specialists RISE, and network video leaders Axis Communications. The pilot was run at a farm outside the city of Västerås (Sweden)[27].

Source: Visionary Analytics, based on sources indicated in the text, and Green Digital Coalition, available at: https://www.greendigitalcoalition.eu/case-studies/

Lastly, the employment of new technologies for environmental purposes comes with a note of caution. Ironically, despite the potential impact of advanced technologies on reducing energy usage, the manufacturing, deployment, and eventual disposal of the hardware and infrastructure on which technological solutions are operated may contribute to **electronic waste,** posing challenges to environmental conservation efforts. E-waste contains harmful substances such as lead, mercury, and cadmium, posing a risk of soil and water pollution, thereby threatening human health and the environment. For instance, the training of a single AI model can produce about 283,995 kilograms of carbon dioxide. This is equivalent to nearly 300 round-trip flights between New York and San Francisco, or almost five times the lifetime emissions of the average car[28]. Efforts to reduce the problem of e-waste come from the philosophy of circular economy, which is a model of economic activity in which there is no linear movement from raw materials to waste, but instead, the maximum effort is made at every level of the value chain to reuse and recycle, and thereby to reduce the volume of materials and resources required[29]. Even though the problem of e-waste is not new to European telcos, several significant steps have been taken to increase the circularity of supply chains, by recycling, reusing, or refurbishing the waste generated from technology use (*Figure 3* below illustrates this).

[26] Ericsson, Port Network Authority of the North Mediterranean Sea, cnit and FEEM (2020), 'Port of the future Addressing efficiency and sustainability at the Port of Livorno with 5G'. Available at: https://www.ericsson.com/4ac696/assets/local/cases/customer-cases/2020/ericsson_portofthefuture_report.pdf
[27] Telia Company (2021), 'Robots go 5G: Telia and Ekobot in partnership for sustainable farming'. Available at: https://www.teliacompany.com/en/news-articles/robots-go-5g-telia-and-ekobot-in-partnership-for-sustainable-farming
[28] Earth.org (2023), 'The Green Dilemma: Can AI fulfil its potential without harming the environment'. Available at: https://earth.org/the-green-dilemma-can-ai-fulfil-its-potential-without-harming-the-environment/
[29] ETNO (2024), 'State of Digital', p.88.

Figure 3. Total waste generated, and percentage of waste recycled, reused, or refurbished, ETNO members, group level, 2019-2022.



Source: ETNO (2024), *State of Digital Communications*. Based on Analysys Mason, 2023.

1.2. Reorganisation of work and the new labour market

Alongside the emergence of sustainability concerns, the labour market has undergone profound changes, some of which are direct consequences of technological advancements. In terms of **labour trends**, the JRC identifies ICT-based mobile work as the most relevant new form of work across European countries[30]. However, other trends emerge, among which the predicted high rate of **job transformation thanks to technological advancements**, led by the increasing interest across sectors of AI applications[31]. As well as potentially making some jobs obsolete, AI and other technologies shape the labour market by altering the demand for specific skills. In particular, in the telecoms sector[32]:

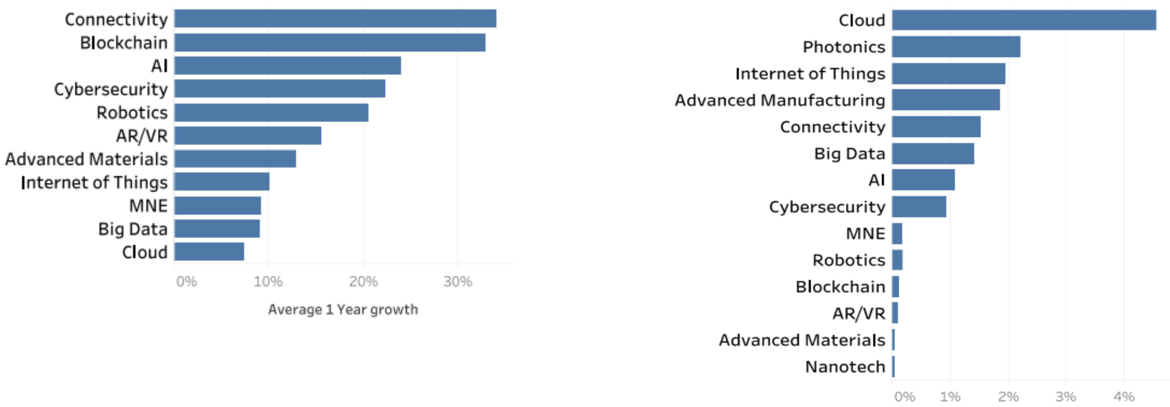
- **Cloud computing** takes up the highest share of professionals with advanced technological skills, followed by **photonics and IoT** (see *Figure 4* below*)*.
- The share of professionals with advanced technological skills concerning the total number of professionals is highest for those possessing knowledge in **AI and big data** (respectively).
- The advanced technologies that were the most demanded by telcos in 2019-2020 were, respectively, **connectivity**[33]**, blockchain and AI** (while others followed) (see *Figure 4* below). Together with **big data**, these technologies are also those that were in the most demand by telcos in the same year.
- Across the sector, a marked shift towards the uptake of **telework and/or hybrid work** is being observed[34].

[30] JRC (2019), *The changing nature of work and skills in the digital age*. Luxembourg: Publication Office of the European Union. Available at: https://publications.jrc.ec.europa.eu/repository/handle/JRC117505
[31] Ibid.
[32] EISMEA, Advanced Technologies.
[33] 'Connectivity' is an umbrella term that refers to 'all those technologies and services that allow end-users to connect to a communication network. It encompasses an increasing volume of data, wireless and wired protocols and standards, and combinations within a single use case or location.' It includes IoT and 5G as well as wired (e.g., LPWAN) and wireless (e.g., Bluetooth) technologies. Source: European Commission, 'Advanced Technologies for Industry: Connectivity'. Available at: https://ati.ec.europa.eu/technologies/connectivity
[34] JRC, The changing nature of work.

In terms of **general skills**, 'using ICT, being autonomous, gathering and evaluating information' are projected to be the key skills for ICT professionals in the future[35]. The projected demand for ICT professionals is also expected to be high, albeit these changes will potentially not be exclusive to the telecoms industry[36]. The future of work in telecoms, and other relevant industries, will be affected by the growth of these demands, along with other trends that are not directly related to technological developments. In particular, changes in **demographics** (an ageing population that remains in the workforce for longer), the emergence of new **atypical employment patterns** (e.g., self-employment, telework and temporary employment), and the rise of the **platform economy** have been identified as drivers of change for the world of work[37].

Regarding the direct impact of new technologies, instead, some professions will be at higher **risk of automation,** particularly as a consequence of the widespread use of AI[38]. CEDEFOP estimates that about 1.4 million jobs will be at stake in the EU27 in all sectors by 2030; however, teleworkable[39] jobs will be less (or not at all) at risk, as well as occupations in highly skilled work groups like ICT professionals and technicians[40]. Other categories of occupation that may be employed in the telecoms sector, such as those related to logistics (e.g., drivers and mobile plant operators) may be replaced by machines in the future[41].

Figure 4. 1-year growth of advanced technological skills in the telecommunication sector (2019 to 2020) (left) and the share of professionals with advanced technological skills in the telecommunication sector, EU27, 2020 (right)



Source: EISMEA, Advanced Technologies, based on Technopolis group.

As the population ages and careers typically last longer, many jobs will likely be outpaced by technological advancements and changing labour market requirements. For this reason, companies across sectors report the need to reskill or upskill workers to fit emerging profiles, and/or to cooperate with educational or training institutions to increase the supply of workers in the sector[42]. In an ideal scenario, to cope with the changes in requirements, ICT companies should develop default **upskilling and reskilling** practices, as part of a new 'corporate skilling responsibility', which would aim at regularly 'topping up' skills of current workers as markets change (upskilling)[43]. Reskilling, in this scenario, would be equally relevant and involve re-training

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[35] CEDEFOP (2019), 'ICT professionals: skills opportunities and challenges (2019 update)'. Available at: https://www.cedefop.europa.eu/en/data-insights/ict-professionals-skills-opportunities-and-challenges-2019-update
[36] Ibid.
[37] European Parliamentary Research Service (EPRS) (2021), 'The future of work: Trends, challenges and potential initiatives'. *EPRS Ideas Paper* (briefing). Available at: https://www.europarl.europa.eu/RegData/etudes/BRIE/2021/679097/EPRS_BRI(2021)679097_EN.pdf
[38] Peruffo, E. (n.d.), 'Artificial intelligence and the world of work'. *Eurofound*, available at: https://www.eurofound.europa.eu/en/artificial-intelligence-and-world-work
[39] A teleworkable job is a job that can be performed remotely in practical terms (for instance, a job only requiring access to a computer is teleworkable, versus a job requiring access to a lab on the employer's premises). Source: European Commission, 'Who can Telework today?' Available at: https://joint-research-centre.ec.europa.eu/system/files/2020-11/policy_brief_-_who_can_telework_today_-_the_teleworkability_of_occupations_in_the_eu_final.pdf
[40] CEDEFOP (2020), 'Coronavirus, automation and the future of work'. Available at: https://www.cedefop.europa.eu/en/news/coronavirus-automation-and-future-work
[41] Ibid.
[42] Eurofound (n.d.), 'What about skills in the digital age?'. Available at: https://www.eurofound.europa.eu/en/what-about-skills-digital-age
[43] EISMEA (2021), Skills for industry – Upskilling and reskilling in the post-covid era – Fostering new services and jobs creation – Three scenarios for 2030 – Final report. Luxembourg: Publications Office of the European Union. Available at: https://data.europa.eu/doi/10.2826/59135

of personnel that became obsolete in other sectors that are more subjected to job automation[44]. Regarding industry cooperation with external entities, possible solutions include the development of joint **standards on ICT certifications**, the joint creation of upskilling and reskilling **courses and platforms**, and the need for an increased personal commitment of workers to **lifelong learning**[45].

Lastly, an important development in the world of work led by the development of new technologies is the **rise of telework** (or remote work)[46]. Telework is defined by the ETUC as "a form of organising and/or performing work, using information technology, in the context of an employment contract/relationship, where work, which could also be performed at the employer's premises, is carried out away from those premises regularly'. This work configuration has exponentially grown in popularity since the COVID-19 pandemic made it an emergency requirement to keep the economy afloat and manage health risks. Today, many companies have kept teleworking arrangements, sparking a '**work from home revolution'** that is forcing enterprises to rethink their organisational strategies. In particular, offices are getting smaller, working hours more flexible, and corporate cultures (including the relationships between employees, and between them and employers) are finding ways to adapt to the new normal while retaining distinctive identities.

At the research level, early studies show that telework may bring risks and benefits for the **health and safety of workers**, with longer hours, the 'right to disconnect' and problems tied to precarious ergonomic equipment being the top concerns[47]. Nevertheless, these risks can be successfully mitigated by sufficiently flexible and tailored company programs and managerial attitudes which must be focused on outcomes and workers' autonomy. Research shows that company-wide efforts to manage the shift to telework (i.e., including all levels of management and employees) can bring considerable benefits, such as increased work-life balance and more productivity[48]. Indeed, the wide implementation of this practice across the sector led to the creation of a formal **joint declaration by ETNO and UNI Europa ICTS**, recommending guidelines to ensure equal treatment and representation of remote and/or hybrid workers[49]. Enabled by technology, these new forms of work have the potential to increase the sustainability of telcos under certain conditions, as employees may generate less carbon emissions by not commuting, as well as giving employers the possibility to reorganise and decrease the surface space of offices[50]. The key principles include voluntary nature (telework should be a choice, not an imposition), equal treatment (remote workers should have the same rights and working conditions as on-site colleagues), data protection and privacy (clear guidelines are needed for data collection and the use of monitoring tools within telework), right to disconnect (measures to prevent working outside of established hours are crucial to maintain work-life balance), support and training (companies should provide adequate equipment and training for successful remote work), and well-being focus (proactive steps are needed to address potential isolation and mental health challenges for teleworkers).

An ETUI Publication - The Future of Remote Work[51] also explores the **evolving landscape of remote work across Europe**, examining the post-pandemic situation and future trends. Key considerations for social partners concern hybrid models (finding the right balance between on-site and remote presence will require negotiation and ongoing adaptation), preventing isolation (ensuring team cohesion and addressing new forms of workplace inequality between remote and on-site workers), surveillance and control (the rise of

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[44] Ibid.
[45] Nikou, S.A. (2023), 'Digital Experts: a deep-dive'. *European Digital Skills & Jobs Platform*, available at: https://digital-skills-jobs.europa.eu/en/latest/briefs/digital-experts-deep-dive-0
[46] Source: Visionary Analytics and Notus (2023), 'Study exploring the social, economic and legal context and trends of telework and the right to disconnect, in the context of digitalisation and the future of work, during and beyond the Covid-19 pandemic'. Report for the European Commission, DG EMPL. Available at: https://ec.europa.eu/social/main.jsp?catId=738&langId=en&pubId=8595&furtherPubs=yes
[47] Ibid.
[48] Ibid.
[49] UNI Europa ICTS and ETNO (2023), 'The EU Telecom Social Partners' Guidelines on Remote Work'. Available at: https://etno.eu//downloads/news/telecom-remote-work-guidelines.pdf
[50] Bisello (2022), 'Is telework really a 'green' choice?', *Eurofound*, available at: https://www.eurofound.europa.eu/en/blog/2022/telework-really-green-choice#:~:text=One%20of%20the%20most%20widely,and%20capitals%20most%20of%20all.
[51] ETUI (2023), 'The future of remote work'. Available at: https://www.etui.org/sites/default/files/2023-05/The%20future%20of%20remote%20work_2023.pdf

digital monitoring tools in remote settings requires clear ethical frameworks and union involvement), sustainable work (rethinking productivity metrics and workload management with remote work in mind). The publication also discusses links with the green transition, in particular, potential reduction in commuting (less commuting lowers emissions, a positive aspect of remote work), shifting energy burden (employers must be held accountable to ensure they're not simply offloading energy costs onto individual workers who work from home), and equity concerns (green tech and connectivity infrastructure need to be accessible to all workers to fully reap remote work benefits).

2. Emerging disruptive technologies

In a context in which revenue has stagnated and competition struggles to provide vastly different services and value propositions, telecommunications service providers (telcos) are leveraging the potential of new digital technologies to enable greater revenues and a more varied offer to their customers[52]. Their application within the industry affects the quality and quantity of telcos employees, and the skills that may be required of them, as well as having implications for the sustainability of operations.

Some new technologies have such a broad impact on the industry that they can be defined as '**disruptive**'. We define disruptive technology, or disruptive innovation, as 'an innovation that helps create a new market and value network, and eventually goes on to disrupt an existing market and value network'[53]. We further understand them as technologies which may not originate from big companies, but that gradually take over the market from the ground up, disrupting conventional tools and practices, and making themselves indispensable in their application areas. Some disruptive technologies discussed in this chapter will have disruptive effects on the broader society as well as on telcos (see sections *2.1* to *2.6*; others will be more focused on the world of telecommunications (see sections *2.7* to *2.11*).

Generally speaking, across technologies and their applications, the telecoms ecosystem is undergoing a process of **virtualisation**, which is understood as a shift towards software-based solutions for networking. This shift has improved hardware standardisation in the last years and helped develop centralised network intelligence and control systems, eliminating the need to work directly on the hardware. One key feature of virtualisation, enabling the shift to software-based solutions (e.g., the development of SAAS services), is the shift to cloud-based network architecture (which will be further explored in Chapter 2.2). Software is also used for network programmability (i.e., to manage and troubleshoot network elements) and to manage automation. The shift towards virtualisation helped to make disruptive technological solutions more easily applicable and to reduce environmental impact that would have been generated by hardware-driven technological updates[54]. In parallel, and thanks to, virtualisation, **emerging technologies** are finding applications in the telecoms sector, representing new opportunities for work organisation, sustainability, and overall efficiency for telcos.

Telcos are taking different approaches to **innovation**. The general trend sees telcos seeking to provide digital services to their customers as part of their operations, increasingly separating the customer-facing and network-facing side of their business[55]. This is mainly due to the competitive environment, which pushes telcos to find new avenues to increase revenue outside of 'traditional' connectivity services provision[56]. To this end, companies are looking to increase in-house competences around new technologies in order to develop and offer innovative services to their customers. The stakeholder engagement conducted for this

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[52] EU Foresight, 'Changing nature of work'. Available at: https://knowledge4policy.ec.europa.eu/foresight/changing-nature-work_en#megatrend
[53] Frishberg, L. and Lambdin, C. (2015), 'Chapter 3 - PrD and an Agile Way of Business'. In Frishberg, L. and Lambdin, C., *Presumptive Design: Design Provocations for Innovation*. Elsevier.
[54] GSMA, 'Mobile Net Zero: State of the Industry on Climate Action 2022'. Available at: https://www.gsma.com/betterfuture/wp-content/uploads/2022/05/Moble-Net-Zero-State-of-the-Industry-on-Climate-Action-2022.pdf
[55] ETNO (2024), 'State of Digital'.
[56] Ibid.

project found three examples of how telcos can identify and implement innovative projects using advanced technologies:

- Through **in-house research departments**, engaged in collaborations with academia and the wider industry, which take the form of small teams specialised in investigating the potential of one or few advanced technologies. One example of this is BT's research departments (see *Box 6* and *Box 14* for some of BT's outputs)[57].
- Through **separate entities** formed within the company group, tasked exclusively with the aim to investigate and develop services based on advanced technologies. It is the case of Altice Labs, a subsidiary company of Altice group in Portugal. Altice Labs conducts research on new technologies, investigating their potential, and conducts pilot projects collaborating with academia, industry partners, and public entities[58]. An example of a project conducted can be found in *Box 4*.
- Through the **direct engagement of employees**. One instance of this practice emerged from A1, which leveraged the enthusiasm and knowledge of its own employees to find the best avenues to implement Artificial Intelligence in its operations and services[59]. In this case, the company organised targeted events with employees in order to collect interest and showcase the possibilities of AI; then, interested and/or knowledgeable employees were encouraged to form dedicated groups and provided with appropriate communication channels to exchange and create ideas of implementation. At the last stage of the process, a number of focus themes were chosen by the management to select the most appropriate, and actionable ideas emerged (see *Box 13* for an example).

The most relevant emergent advanced technologies that are being researched and implemented in the telco ecosystem are outlined in the rest of this chapter and summarised in Table 1. Their relevance for this study has been assessed according to:

- Their fit with the definition of '**disruptive technology**', as outlined above in this chapter.
- Their potential **application in the sector** of telecommunication. Some technologies are specific to telcos (i.e., they have been designed to be used mainly in the telecom sector, even if their impact will be felt in other sectors as well), while other technologies are expected to have a broad impact on society, and their roll-out will occur throughout all economic sectors (see Table 1).
- Their potential to enable **sustainability** for telcos and the broader ecosystem, as discussed in section *1.1*.
- Their potential to alter the **skills** required in the telecom sector, as well as the **organisation of work and OHS**, as discussed in section *1.2.*

Table 1. List of disruptive technologies

Technology	Application areas	Sustainability for telcos	Sustainability for others	Impact on Work Organisation and OHS
Big data and analytics	Broad impact	√√√	√√√	√
Cloud computing	Broad impact	√	√√	√
Edge computing	Broad impact	√√	√√	√
Internet of Things	Broad impact	√√√	√√√	√√

[57] Interview with a BT researcher, 05/04/2024.
[58] Interview with an Altice representative, 04/04/2024.
[59] Interview with an A1 representative, 13/03/2024. First Roundtable on disruptive technologies, 09/04/2024.

Artificial Intelligence	Broad impact	√√√	√√√	√√√
Quantum technology	Broad impact	√	√√	√√
Optic fibre and GPON technologies	Telco-specific	√√√	N/A	√
Blockchain and technologies for cybersecurity	Telco-specific	√√	√√	√
Extended Reality	Broad impact	√√	√√	√√
5G and 6G networks	Telco-specific	√√√	√√√	√√
xRAN	Telco-specific	√√	N/A	√√

Source: Visionary Analytics, own elaboration based on sources consulted during desk research. Note: the ranking takes into account the existing evidence of impact, including the existence of case studies, and does not make judgement on the positivity or negativity of the projected impact. One tick – purely theoretical and/or controversial impact; two ticks - some evidence of impact; three ticks – considerable evidence of positive impact.

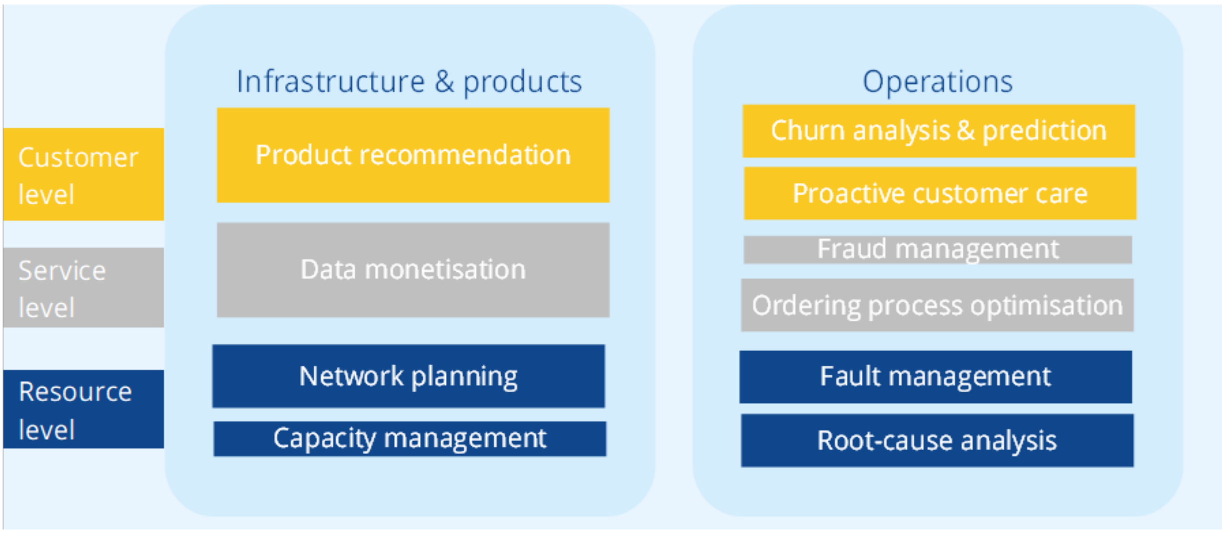
2.1. Big data and analytics

The term 'big data' refers to '**large amounts of data produced very quickly by a high number of diverse sources**'[60]. In practice, recent discussion about this solution refers to the increased application of powerful computers and processors able to analyse and make use of ever greater amounts of data. Increasingly, businesses and organisations of all sizes are looking to gather data from their operations, analyse it (often in real-time, as technology allows) and make data-informed decisions on their products, services, operations and/or policies[61]. In the telecommunications ecosystem, this solution presents huge potential for a wide variety of applications that interest both the operational side of the industry and its infrastructure and product areas (summarized in *Figure 5* below)[62]:

- At the **customer** level, customers' data is used to give personalised product recommendations based on preferences, location, or device usage; while on the side of operations, proactive customer care identifies potential criticalities before they arise, through constant monitoring of quality-of-service parameters. Churn analysis works similarly, predicting customers who might switch providers and providing insights on the reasons why.
- At the **service** level, data usage patterns can be monetised by providing insights from aggregated network data to interested companies or monitored to reduce the presence of fraud. History data on ordering processes can help shorten the time from order to revenue.
- At the **resource** level, networks and user devices can be monitored in real-time to streamline their operation, by planning and managing the network's capacity and optimizing network performance. In case of faults, the data allows for the analysis of root causes and their smooth management.

[60] European Commission (2022), 'Shaping Europe's Digital Future: Big Data'. Available at: https://digital-strategy.ec.europa.eu/en/policies/big-data#:~:text=Big%20data%20refers%20to%20large,%2C%20GPS%20signals%2C%20and%20more. .
[61] https://www.sas.com/en_us/insights/analytics/big-data-analytics.html
[62] Bullet list adapted from Chen, C.M. (2016), 'Use cases and challenges in telecom big data analytics'. *APSIPA Transactions on Signal and Information Processing*, Volume 5, e19. https://doi.org/10.1017/ATSIP.2016.20

Figure 5. Use cases of big data analytics in the telecommunications sector



Source: Chen, C.M. (2016), 'Use cases and challenges in telecom big data analytics'. *APSIPA Transactions on Signal and Information Processing*, Volume 5, e19. https://doi.org/10.1017/ATSIP.2016.20

Importantly, recent implementation of big data in all industries has been enabled by previous technological advancements, some of which were spearheaded by telcos themselves – primarily, the speed and reliability of 4G and 5G[63]. Nevertheless, challenges remain for the implementation of large-scale big data solutions in telcos tied to the quality of data collected and to the management and storage of multiple datasets, and data sources[64]. Technical solutions and linkages with other advanced technologies can represent a potential avenue for improvement of big data analytics in telcos; for instance, Deutsche Telekom proposes a data technology that harnesses edge computing solutions to optimise storage of large influxes of data, increasing the processing speed and capacity of data analysis[65].

Data privacy regulations represent another key issue, particularly for telcos operating in the EU; in fact, big data applications are susceptible to compliance with the General Data Protection Regulation[66], as well as with sector-specific legislation on the processing of traffic and location data. This has long limited the applicability of some big data analytics models to telcos, while comparatively, other sectors (e.g. technology firms) enjoy a less strict regulatory environment, putting the telecommunications industry at a comparative disadvantage[67].

Other challenges and possible developments tied to big data and analytics, and their application in telcos, are strictly connected to environmental sustainability and changes in the social dimensions of the workforce. These two important aspects will be discussed in the two following subsections, and in *Box 4* below.

Box 4. A public data solution: Altice Labs' Live! Urban

One of the solutions offered by Altice Labs in the field of Big Data is the Live! Urban data platform. Live! Urban allows municipalities to collect and visualised anonymised telco data to derive insights on urban mobility, energy consumption and needs, environment-related services, and more. The data aims to help local governments manage their resources more efficiently, understand their citizens' needs better, and provide more tailored public services. The collection and visualisation of data through platforms such as Live! Urban also open doors to 'smart cities' applications, when integrated with other advanced technologies - most commonly, the Internet of Things and Artificial intelligence, which will be analysed separately in the following sections of the report.

[63] Kastouni and Lahcen (2020), 'Big data analytics in telecommunications: Governance, architecture and use cases'. *Journal of King Saud University – Computer and Information Sciences*, 34, pp. 2758–2770. Available at: https://doi.org/10.1016/j.jksuci.2020.11.024 .
[64] Ibid.
[65] See https://www.t-systems.com/de/en/data-intelligence/solutions/big-data-analytics
[66] Available at: https://eur-lex.europa.eu/legal-content/IT/TXT/?uri=celex%3A32016R0679
[67] Written input from Paolo Grassia, Senior Director of Public Policy at ETNO (19/02/2024).

Source: First Roundtable on disruptive technologies, 09/04/2024.

Potential for sustainability

As discussed above, big data analytics is currently being employed to **optimise operations**, with substantial gains in terms of sustainability. Accurate data on company operations is instrumental for telcos to design and implement their sustainability plans, ensuring that solutions are commensurate with the challenges[68]. The availability of information also allows them to track needs and progress on climate and energy efficiency targets[69]. In particular, the objective is largely the optimisation of machine resources in data centres, by making predictions and enabling the ideal sharing of workload between machines according to the most energy-efficient pathways and strategies. These mechanisms have the advantage of not compromising service continuity while providing ad-hoc insights[70].

The same benefits can be reflected in other sectors if telcos can aim to provide more sustainable strategies in their data centres thanks to data-based optimisation of resources. However, some commentators argue that the benefits of big data for sustainability might not be so straightforward. In particular, a growing amount of data stands for a requirement for more data storage capabilities, which in turn implies **larger data centres**, which may consume more energy in the first place, even if optimised[71]. Particularly, the need to reduce data storage space will need to distinguish between useful and superfluous data, which might have repercussions on some of the use cases, such as data monetisation: storing an excessive amount of customer data to monetise it or to derive generalised insights, might not be worth the environmental cost[72]. Furthermore, the construction of new data centres needs to consider the physical footprint of the infrastructure, where new centres might be constructed on arable land, subtracting space from agriculture and/or wildlife habitats.

On these crucial issues, the ecosystem seems to be turning to **other technologies to increase efficiency and sustainability**. Specifically, the intersection with edge computing might eliminate the need to build new extensive data centres, making the elaboration of data possible in the proximity of its source (see the box below)[73]. Another much-discussed technology intersection is that between big data and artificial intelligence; in this case, telcos might rely on AI applications to coordinate other technologies in data centres, such as robotics and digital twins, that can help make data centres more efficient from the standpoint of maintenance, energy consumption, data storage efficiency, and improved cybersecurity[74].

Box 5. Deutsche Telekom's Big Data services

Deutsche Telekom (DT) has provided an end-to-end solution for big data analysis that allows for faster evaluations and more efficient data management. The solution is part of DT's comprehensive **Data Intelligence services**, designed for customer businesses looking for cutting-edge strategies to improve their internal decision-making. Overall, the services provided by DT in this field include:

- **The Data Intelligence Hub**, a data-sharing ecosystem that ensures the security and sovereignty of customer data while providing the possibility to exchange data with experts and gain customer-tailored insights for service development. Importantly, the solution eliminates the need for enterprises to build their data infrastructures.
- **Big data and global edge analytics**, which employs edge computing infrastructure to reduce costs and response times in the analysis and retrieval of data.
- **Data spaces** offer an alternative to standard contract-based data sharing, by making the process of data sharing automated. Suppliers can, through this solution, attach guidelines to data transactions, guaranteeing their sovereignty.

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[68] IBM (2022), 'How telcos can navigate their sustainability paradox'. https://www.ibm.com/downloads/cas/J6ZNBZ1W
[69] IBM 'How telcos can navigate'.
[70] Kastouni and Lahcen, 'Big data analytics'.
[71] Burge, A. (2023), 'Telcos, There's More to Sustainability Than 5G and Data Analytics'. *The Fast Mode*, available at: https://www.thefastmode.com/expert-opinion/32087-telcos-there-s-more-to-sustainability-than-5g-and-data-analytics
[72] Ibid.
[73] Deutsche Telekom, 'Big Data Analytics to Boost your Business in the Digital Age'. Available at: https://b2b-europe.telekom.com/digitalization/big-data-analytics
[74] EY (2022), 'How AI and automation make data centers greener and more sustainable'. https://www.ey.com/en_in/technology/how-ai-and-automation-make-data-centers-greener-and-more-sustainable

- **Motion data** insights are provided by DT to customers needing data relevant to movement, such as traffic in public spaces, visitor flows, customer base analysis and advertising, and are cross analysed with data relevant to demographics to gain valuable insights. The solution also ensures privacy and anonymity.

Source: Deutsche Telekom, 'Big Data Analytics to Boost your Business in the Digital Age'. Available at: https://b2b-europe.telekom.com/digitalization/big-data-analytics

Projected social impact

Regarding the social impact on the workplace, the 'big data' trend should lead to demand for **strong data analytical skills** and skills for scaling and managing data for enterprises. New occupations are expected to emerge as a result, such as data scientists, data managers, and chief data officers[75]. These new specialists are likely to find employment not just in telcos but in a variety of sectors, wherever there is a need for data-based insights.

In terms of working conditions, most of the new data jobs are likely to be **teleworkable**, that is they can be performed remotely from outside the company's premises. This fact alone brings important questions and future challenges for the restructuring of work organisations across sectors. But, regarding changes specific to big data technologies, they can translate into the availability and analysis of data to **improve work organisation and workflow**. While this can be an advantage from an organisational perspective, it can also potentially represent a risk to the privacy and well-being of workers. The plethora of collected data might deepen power **asymmetries** between employers and employees, who might find it difficult to contest management decisions[76]. Finally, there are concerns regarding algorithms' infringement on **privacy and data** protection rights and discrimination[77]; nevertheless, the European legal framework for data protection and privacy law fully apply to the use of algorithms in big data, and it is the position of the Social Partners that the existing framework is adequate to ensure 'trust and acceptance by all' and to avoid the risk of algorithmic discrimination in the workplace[78].

2.2. Cloud computing

According to the European Commission[79], cloud computing is a **technology that allows users to access computing resources such as storage, processing power, and applications over the Internet, without having to own or manage the underlying infrastructure**[80]. Cloud computing is a flexible, scalable, and cost-effective way to access computing resources. It enables businesses and individuals to store and process data, run applications, and perform other computing tasks without having to invest in expensive hardware or software. Cloud computing also offers several other benefits such as increased efficiency, improved collaboration, and enhanced security. By leveraging the cloud, businesses and organisations can reduce their IT costs, improve their productivity, and gain a competitive edge in the market.

Cloud computing has impacted the telecom sector by providing a range of benefits such as cost reduction, flexibility, and scalability. Some applications of cloud computing in the sector are:

[75] EURES (2020), 'The future of work: ICT Professionals'. Available at: https://eures.europa.eu/future-work-ict-professionals-2020-09-25_en#:~:text=Employment%20for%20IT%20professionals%20is,filled%20between%202018%20and%202030
[76] Bednorz, J. And Sadauskaite, A. for EP-EMPL (2022), 'Unionisation and the Twin Transition'. Available at: https://www.europarl.europa.eu/RegData/etudes/STUD/2022/733972/IPOL_STU(2022)733972_EN.pdf
[77] Ibid.
[78] ETNO and UNI Europa (2020), *Joint Declaration on Artificial Intelligence*. Available at: https://etno.eu/downloads/news/ue-etno%20declaration%20ai.pdf
[79] Cloud computing | Shaping Europe's digital future (europa.eu)
[80] It must be noted, however, that the underlying infrastructure is also the enabler and prerequisite for cloud services and edge computing. Telco investments in cloud first require a comprehensive connectivity infrastructure.

- **Cloud-based network functions (CNFs)**: Cloud-based network functions are software implementations of traditional network functions that run inside Linux containers[81], typically orchestrated by Kubernetes[82][83]. They replace specialized hardware and offer several benefits over traditional network functions. For instance, they are reusable, and flexible, and act as common infrastructure that enables the rapid creation and deployment of new apps and services over time[84]. CNFs have been developed using cloud-native principles and technology[85]. CNFs are designed to be highly scalable, flexible, and cost-effective, and can be used to build and operate private clouds for telecommunications companies. CNFs cover all branches of the service provider market, including cable, mobile, video, security, and network infrastructure[86]. They are managed by Kubernetes-style orchestration, support dynamic elasticity and scale, and offer improved feature velocity and resilience.
- **Cloud-based customer relationship management (CRM)**: Cloud-based customer relationship management (CRM) is a software solution that enables telecom companies to manage their customer interactions and data in the cloud[87]. It provides a centralized platform for managing customer information, such as contact details, purchase history, and service requests, and enables telecom companies to deliver personalized customer experiences. Cloud-based CRM offers several benefits over traditional on-premises CRM solutions. For instance, it provides greater scalability, flexibility, and cost-effectiveness, as well as improved performance and reliability[88]. In the telecoms industry, cloud-based CRM can help companies improve their customer service, increase customer satisfaction, and reduce churn rates. It can also help companies identify new revenue opportunities and improve their marketing campaigns by providing valuable insights into customer behaviour and preferences[89].
- **Cloud-based data analytics**: Cloud-based data analytics in telecoms refers to the use of cloud computing technology to analyse and process large amounts of data generated by telecommunications networks[90]. It involves the deployment of data analytics tools and techniques such as machine learning, artificial intelligence, and big data analytics in the cloud to extract insights from the data. Cloud-based data analytics offers several advantages over traditional data analytics solutions[91]. For instance, it provides greater scalability, flexibility, and cost-effectiveness, as well as improved performance and reliability. In the telecoms industry, cloud-based data analytics can help companies improve their operational efficiency, reduce costs, and enhance customer experiences. It can also help companies identify new revenue opportunities and improve their marketing campaigns by providing valuable insights into customer behaviour and preferences.
- **Cloud-based security**: Cloud-based security in telecoms refers to the use of cloud computing technology to provide security services to telecommunications networks. It involves the deployment of security measures such as firewalls, intrusion detection systems, and virtual private networks (VPNs) in the cloud to protect against cyber threats[92]. Cloud-based security offers several advantages over

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[81] Linux containers are a set of processes that are isolated from the system and run from a distinct image that provides all the files necessary to support them. They combine lightweight application isolation with the flexibility of image-based deployment methods. Linux containers are used to package and distribute applications in a way that is portable, scalable, and efficient. They are widely used in cloud computing and are an important part of modern software development. There are several containerization platforms available, including Docker, LXC, and Kubernetes.

[82] Kubernetes, also known as K8s, is an open-source system for automating deployment, scaling, and management of containerized applications. It was developed by Google and is now maintained by the Cloud Native Computing Foundation (CNCF). Kubernetes provides a platform for managing containerized workloads and services, which facilitates both declarative configuration and automation. Kubernetes is cloud-agnostic, meaning it can be used with any cloud provider.

[83] SDx Central Studios (2020), 'What is Cloud Networking or Cloud-Based Networking?'. Available at: https://www.sdxcentral.com/networking/sdn/definitions/enterprise-data-center-networking/all-about-cloud-networking/

[84] RCR Wireless News (2021), 'What is a Cloud native Network Function?'. Available at: https://www.rcrwireless.com/20211025/telco-cloud/what-is-a-cloud-native-network-function

[85] CISCO (2018), 'Cloud-Native Network Functions'. Available at: https://www.cisco.com/c/en/us/solutions/service-provider/industry/cable/cloud-native-network-functions.html

[86] Ibid.

[87] Techjockey (2023), 'Top 10 CRM in Telecom Industry: Its Roles & Benefits'. Available at: https://www.techjockey.com/blog/crm-in-telecom-industry

[88] Ibid.

[89] Ibid.

[90] Kanerika Inc (2023), 'Data Analytics in Telecom Industry: A Comprehensive Guide'. Available at: https://medium.com/@kanerika/data-analytics-in-telecom-industry-a-comprehensive-guide-da9735565ae9

[91] Ibid.

[92] Google Cloud (2023), 'Cloud network security'. Available at: https://cloud.google.com/learn/what-is-cloud-network-security

traditional security solutions. For instance, it provides greater scalability, flexibility, and cost-effectiveness, as well as improved performance and reliability[93]. In addition, cloud-based security can help telecom companies meet regulatory compliance requirements, such as those set by the General Data Protection Regulation (GDPR)[94].

Potential for sustainability

Cloud computing has the potential to significantly increase sustainability in telecoms. Cloud-powered technologies such as AI and machine learning can unlock substantial value and **optimize resource use**[95]. The cloud can also aid companies in achieving their **decarbonization goals** by providing virtually limitless computing, storage, networking capabilities, and advanced software applications. Using cloud-powered technologies can accelerate the implementation of 101—or 47 per cent—of the 217 representative decarbonization initiatives that are required to achieve the global 1.5° pathway by 2050[96]. The cloud's potential contribution through these technologies could be worth hundreds of billions of dollars annually.

A review of cloud computing on sustainable development also highlights the **advantages of cloud computing in sustainable development**, such as easy maintenance, positive economic impact, resource pooling, and large network access[97]. In addition, selecting a carbon-thoughtful provider is the first step towards a sustainable cloud journey as cloud operators set different corporate commitments towards sustainability, which in turn determine how they plan, build, power, operate, and retire their data centres[98].

A study for the European Commission proposes **policy measures that enhance energy efficiency and circular economy practices** in the ICT value chains[99]. It focuses on cloud computing data centres, and electronic communications services and networks. The study proposes the following concrete policy measures:

- Improvements to the Code of Conduct on energy-efficient data centres;
- Strengthen green public procurement criteria for data centres, server rooms and cloud services; and
- Setting up a European Data Centre Registry.

In addition, it offers a definition of what constitutes a data centre and indicators to measure progress towards meeting the 2030 objective. Regarding electronic communications networks and services, the study proposes the introduction of an energy-efficiency–a type of label for telecommunications services to provide greater transparency to businesses and consumers.

While cloud computing has the potential to increase sustainability in telecoms, there are also some **potential downsides** to consider. One of the main concerns is the **energy consumption** of data centres that power cloud computing. Data centres consume a significant amount of energy, and their carbon footprint can be substantial[100]. However, cloud providers are increasingly adopting renewable energy sources to power their data centres, which can help mitigate this issue, and finding innovative solutions to decrease the energy consumption of cloud technologies (see Box 6 below). Another potential downside is the **privacy and security** of data stored in the cloud. Cloud computing involves storing data on remote

[93] Corbo, A. (2023), 'What is Cloud Security?'. Available at: https://builtin.com/cybersecurity/cloud-security
[94] Siddiqui, L. (2023), 'What is Cloud Security? Types, Risks & Benefits Defined'. Available at: https://www.splunk.com/en_us/blog/learn/cloud-security.html
[95] McKinsey Digital (2023), 'Cloud-powered technologies for sustainability'. Available at: https://www.mckinsey.com/capabilities/mckinsey-digital/our-insights/cloud-powered-technologies-for-sustainability
[96] Ibid.
[97] Tim, H.W. and Rana, M.E. (2023), 'A Review off Cloud computing on Sustainable Development'. Available at: https://ieeexplore.ieee.org/document/10041482
[98] Accenture (2020), 'The green behind the cloud'. Available at: https://www.accenture.com/us-en/insights/strategy/green-behind-cloud
[99] European Commission (2022), 'Study on Greening Cloud Computing and Electronic Communications Services and Networks: Towards Climate Neutrality by 2050'. Available at: https://digital-strategy.ec.europa.eu/en/library/study-greening-cloud-computing-and-electronic-communications-services-and-networks-towards-climate
[100] Ahmad, A., Khan, R.A., Khan, S.U. et al. (2023), 'Green cloud computing adoption challenges and practices: a client's perspective-based empirical investigation'. Cogn Tech Work 25, 427–446. Available at: https://doi.org/10.1007/s10111-023-00734-6

servers, which can raise concerns about data privacy and security[101]. However, cloud providers have implemented various security measures to protect data, such as encryption and multi-factor authentication. Finally, there is also the concern of **vendor lock-in**. Once a company has adopted a cloud provider, it can be difficult and costly to switch to another provider[102]. This can limit competition and innovation in the cloud computing market due to a dependency on few, large cloud providers. Vendor lock-in is also an effect of low competition (concentration) in the cloud market and disproportionate bargaining power of 'hyper-scalers' versus their clients.

Box 6. Making Cloud more sustainable: BT's innovative liquid cooling solutions

A big factor in technology sustainability is the number of resources required to cool technical equipment that supports the application of various technologies, including cloud and quantum. BT elaborated a new type of cooling fluid, to be used instead of air-based cooling systems, to keep network equipment running at the required temperature while saving energy and improving efficiency. The liquid is an oil-based, non-toxic fluid that is respectful of the environment and does not harm workers through exposure. The use of this innovative fluid will be trialled on BT's network equipment, following different methods according to the type of equipment in need of cooling, and it will bring an estimated 40 to 50% reduction on the energy required for this task compared to traditional air-cooling systems.

Source: Interview with a BT researcher, 05/04/2024, and BT (2023), 'BT takes the plunge with new liquid cooling trials'. Available at: https://newsroom.bt.com/bt-takes-the-plunge-with-new-liquid-cooling-trials/

Projected social impact

Concerning the impact on job content and skills, the shift towards cloud computing is expected to accelerate for both enterprises and consumers, which could **reduce the demand for technical knowledge** on the part of users, since services are outsourced to cloud providers. This could lead to a **shift in the types of skills that are in demand** in the telecom industry. Enterprises will need skills in service integration, service management, designing and managing clouds, and building and optimizing cloud data centres[103]. These skills will be critical for organizations that want to take advantage of the benefits of cloud computing while also ensuring that their operations are efficient and sustainable.

In addition, cloud computing adoption can also have an impact on the work environment. Cloud-powered technologies such as AI and machine learning can help **automate routine tasks and free up employees to focus on more strategic work**[104]. This can lead to a more dynamic and flexible work environment, which can have a positive impact on employee satisfaction and well-being. Concerning work organisation, shifting company data to the cloud means that business-related information can be accessed by employees from nearly anywhere, facilitating remote work. Cloud computing is a much more agile method than on-premises data storage, in which physical servers in offices hold the information needed. Many applications and software are now cloud-based, which means that they can be accessed from anywhere as well.

2.3. Edge computing

Edge computing is a **distributed computing framework that brings enterprise applications closer to data sources** such as IoT devices or local edge servers[105]. It is an architecture rather than a specific technology, and a topology- and location-sensitive form of distributed computing. According to a report by

[101] Besfamilnyi, K. (2021), 'Overcoming crucial barriers to cloud adoption in the telecommunications sector'. Available at: https://www.rcrwireless.com/20211014/opinion/overcoming-crucial-barriers-to-cloud-adoption-in-the-telecommunications-sector-reader-forum
[102] Khan MJ, Ullah F, Imran M, Khan J, Khan A, AlGhamdi AS, Alshamrani SS. (2022), 'Identifying Challenges for Clients in Adopting Sustainable Public Cloud Computing'. Sustainability: 14(16). Available at: 9809. https://doi.org/10.3390/su14169809
[103] de Paula, A.C.M., de Carneiro, G.d.F. (2016), 'A Systematic Literature Review on Cloud Computing Adoption and Migration'. In: Maciaszek, L., Filipe, J. (eds) Evaluation of Novel Approaches to Software Engineering. ENASE 2016. Communications in Computer and Information Science, vol 703. Springer, Cham. Availabe at: https://doi.org/10.1007/978-3-319-56390-9_11
[104] Nanos, I. (2023), 'Cloud Computing Adoption in Public Sector: A Literature Review about Issues, Models and Influencing Factors'. In: Matsatsinis, N.F., Kitsios, F.C., Madas, M.A., Kamariotou, M.I. (eds) Operational Research in the Era of Digital Transformation and Business Analytics. BALCOR 2020. Springer Proceedings in Business and Economics. Springer, Cham. https://doi.org/10.1007/978-3-031-24294-6_26
[105] IBM (2023), 'What is edge computing?'. Available at: https://www.ibm.com/topics/edge-computing

the European Commission, **edge computing is the logical evolution of the dominant cloud computing model**, avoiding the transfer of mission-critical data to the cloud, supporting resilience, real-time operations, security, privacy and protection while at the same time reducing energy consumption and carbon footprint[106]. Edge computing involves processing data closer to the source of the data, rather than in a centralized data centre. This allows for faster processing times and reduced latency, which can be critical for applications that require real-time data processing.

Edge computing has many applications in the telecoms sector. Many telecommunications service providers are moving workloads and services out of the core network (in data centres) toward the network's edge, to points of presence and central offices[107]. This shift is driven by the need to reduce latency and provide better application response times by processing and storing data closer to users and devices. Some specific applications of edge computing in the telecoms sector include:

- **Virtualizing network functions**: Virtualizing network functions allows telcos to abstract functions away from hardware, allowing standard servers to be used for functions that once required expensive proprietary hardware. This can help telcos modernize their networks and improve flexibility, availability, efficiency, reliance, and scalability[108].
- **Open radio access networks**: Open radio access networks (RANs) are a new approach to building wireless networks that use software to control network functions, rather than proprietary hardware. This can help telcos reduce costs and improve flexibility and innovation[109].
- **Real-time analytics**: Edge computing can enable real-time analytics of network data, which can help telcos optimize network performance and improve customer experience[110].
- **Internet of Things (IoT)**: Edge computing can enable IoT devices to process data locally, reducing the need for data to be sent to the cloud for processing. This can help reduce latency and improve reliability[111].
- **Augmented and virtual reality**: Edge computing can enable augmented and virtual reality applications to run locally on devices, reducing the need for data to be sent to the cloud for processing. This can help reduce latency and improve the user experience[112].

Potential for sustainability

Every piece of the edge tech stack is – typically and ideally – highly optimized for resource efficiency. Any computing done more efficiently helps reduce energy consumption. In some situations, edge is preferable to cloud technology, because the data does not need to travel further than it must to fulfil its purpose, and this **increases energy efficiency** as well as network efficiency. By keeping processing at the edge, the volume of data that are sent to the data centre for processing and storage can be significantly reduced, potentially opening the way for **data centre consolidation**, reducing energy consumption and **accelerating decarbonization**[113]. Also, edge computing enables companies to use existing hardware and infrastructure (retrofitting), taking advantage of the available computing power[114].

While edge computing has the potential to increase sustainability in the telecoms sector, there are also some **potential downsides** to consider. Edge computing can lead to **geographic disparities**, where some regions

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[106] European Commission (2021), 'Next-Generation Internet of Things and Edge Computing'. Available at: https://digital-strategy.ec.europa.eu/en/library/next-generation-internet-things-and-edge-computing
[107] RedHat (2021), 'Understanding edge computing for telecommunications'. Available at: https://www.redhat.com/en/topics/edge-computing/telecommunications
[108] Ibid.
[109] Ibid.
[110] Vella, H. (2024), 'edge computing and the future of telecommunications'. Available at: https://www.verizon.com/business/resources/articles/s/edge-computing-and-the-future-of-telecommunications/
[111] Ibid.
[112] Ibid.
[113] Fleisch, B. (2022), 'Cut your data centre's energy appetite and boost sustainability'. Available at: https://www.globalservices.bt.com/en/insights/blogs/cut-your-data-centres-energy-appetite-and-boost-sustainability
[114] Sustainability Success (2023), 'How can Edge computing Be Used To Improve sustainability?'. Available at: https://sustainability-success.com/how-can-edge-computing-be-used-to-improve-sustainability/

may be at a disadvantage when it comes to edge implementation[115]. In addition, edge computing can require more storage capacity, and the **cost of edge computing can be high**[116]. **Security challenges** in edge computing are also high due to the huge amount of data involved. However, these risks can be mitigated through effective company policies and infrastructure. For example, companies can use energy-efficient hardware to reduce the energy consumption of edge computing infrastructure[117], use renewable energy sources to power their edge computing infrastructure thereby reducing the carbon footprint of edge computing and improving sustainability, implement robust data privacy and security measures to protect data stored and processed at the edge in the process mitigating the risks associated with data privacy and security[118], manage vendors effectively to ensure that they are meeting sustainability standards and reducing their carbon footprint thereby ensuring that the entire supply chain is working towards sustainability, and provide training to employees on how to use edge computing infrastructure safely and effectively, in the process reducing the risks associated with edge computing adoption.

Projected social impact

The large-scale adoption of edge technology will result in a surge of data and computation in mobile networks, and the development of new technologies and solutions. To remain competitive, companies will need to hire skilled IT professionals who can help them develop and implement these solutions. The IT skills that will be in demand following the implementation of edge solutions will be cybersecurity, programming, application development, application architecture, networking and connectivity, infrastructure-related, and platform-related skills[119]. Overall, the adoption of edge technology in the telecoms sector will require companies to hire skilled IT professionals with a diverse range of skills and/or to upskill the existing workforce accordingly to help them develop and implement these solutions. In theory, there should not be significant disruptions to work organisation, working conditions and occupational safety beyond those discussed in the section on cloud computing.

2.4. Internet of Things

The **Internet of Things (IoT)** is a pivotal force in the ongoing digital transformation of the global economy, standing alongside Artificial Intelligence, as highlighted by the European Commission[120]. IoT involves **physical objects embedded with sensors and actuators that communicate through wired or wireless networks**. An example of IoT is Smart Home systems, which connect various appliances and devices, enabling homeowners to conveniently (and automatically) control them via an internet connection.

Given that connectivity stands at the core of IoT, this technology can bring many benefits to the telecoms industry. The global revenue of IoT in Europe is projected to reach 5.1b EUR by 2030, and the number of IoT connections is expected to increase at a compounded average growth rate of 46% by 2031[121]. According to a recent report by the IoT market research firm Berg Insight, the global number of cellular IoT subscribers surged by 22% in 2021, reaching a total of 2.1 billion. Berg Insight anticipates that by 2026, the number of IoT devices connected to cellular networks worldwide will climb to 4.3 billion[122]. Key markets, including China,

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[115] Datamation (2021), 'The Pros and cons of Edge computing'. Available at: https://www.datamation.com/edge-computing/pros-cons-edge-computing/
[116] Geeksforgeeks (2022), 'Advantages and Disadvantages of Edge Compuing'. Available at: https://www.geeksforgeeks.org/advantage-and-disadvantage-of-edge-computing/
[117] Cisco (2024), 'Establishing the Edge'. Available at: https://www.cisco.com/c/en/us/solutions/service-provider/edge-computing/establishing-the-edge.html
[118] IBM (2024), 'What is IT Infrastructure?'. Available at: https://www.ibm.com/topics/infrastructure
[119] Deloitte (2023), '2023 telecommunications industry outlook'. Available at: https://www.deloitte.com/global/en/Industries/tmt/perspectives/telecommunications-industry-outlook.html
[120] European Commission (n.d.), 'Europe's Internet of Things Policy'. Available at: https://digital-strategy.ec.europa.eu/en/policies/internet-things-policy
[121] ETNO (2024), 'State of Digital'.
[122] Berg Insight (2022), 'Berg Insight says global cellular IoT connections grew 22 percent to reach 2.1 billion in 2021'. Available at: https://www.berginsight.com/berg-insight-says-global-cellular-iot-connections-grew-22-percent-to-reach-21-billion-in-2021

Western Europe, and North America, experienced similar growth patterns as the world emerged from the impact of the COVID-19 pandemic; however, IoT revenue growth is now rising more quickly in China, thanks to national plans to implement smart city plans and widespread 5G connectivity[123]. The substantial expansion of IoT in Europe creates a vast market opportunity for telcos, while the rapid expansion in third countries constitutes a meaningful benchmark for European progress.

Since many IoT systems will require fast network connections for their operation as well as expertise in connecting multiple devices, telcos play a crucial role in driving the adoption of IoT[124], e.g., through their 5G deployment (further explored in section 2.10). Also, telcos possess extensive knowledge in the deployment and management of the myriad devices within their networks, which will be necessary for the development of IoT systems[125].

Potential for sustainability

The adoption of the Internet of Things presents strong potential for sustainability within the telecommunications industry. IoT technologies **enhance network management efficiency** by providing real-time data and automation, allowing telecom companies to **optimize resources**. This leads to reduced energy consumption and lower operational costs as they can better monitor and control their infrastructure based on actual usage patterns and demands[126]. To be specific, it has been estimated that the integration of IoT can help telcos reduce operational costs by 1.3 times compared to those not utilizing IoT. Some telcos are already employing this technology to save energy, for example by installing smart meters for energy and water consumption in network and corporate sites, as well as using IoT-based fleet management in their company operations[127].

Beyond the telecommunications sector, IoT holds important potential for promoting sustainability across various industries and stakeholders by **reducing energy consumption**. Telia – a technology and telco company operating in the Nordic and Baltic regions – estimates that in 2021 its IoT solutions contributed to energy reductions of approximately 800 GWh. This reduction is equivalent to the annual electricity consumption of 90,000 households in Sweden[128]. An example is Telia's Narrowband IoT (NB-IoT) technology, introduced in 2017. NB-IoT is a specialized cellular network made for the Internet of Things[129]. It is significant for its long-range and deep underground penetration, which is suitable for devices in hard-to-reach places (e.g., inside buildings and remote areas). Thus, it allows for connecting a large number of devices over long distances. Telia's NB-IoT has been deployed to connect one million homes in Sweden[130].

Other applications of IoT such as smart cities, smart agriculture, and smart offices all have crucial implications for sustainability in the broader society. For example, smart agriculture applies IoT and ICT solutions to grow crops and manage cultivation, and by using IoT sensors to collect environmental and machine metrics, farmers can make informed decisions and improve just about every aspect of their work – from livestock to crop farming, with considerable gains in environmental impact. The box below shows an example of this application from Portugal, which helps farmers save precious resources and increase their sustainability.

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[123] Ibid.
[124] Tryson, M. (n.d), 'How High Speed Connectivity is Enabling IoT'. Available at: https://www.te.com/usa-en/about-te/perspectives-on-technology/high-speed-connectivity-enabling-iot.html
[125] Todosioska, A. (2020), ' The role of telecommunication companies in Internet of Things'. Available at: https://run.unl.pt/handle/10362/94883
[126] Orient (2024), 'When technologies collide: Exploring the powerful impact of IoT in Telecommunications'. Available at: https://www.orientsoftware.com/blog/iot-in-telecommunications/
[127] See for example: Swisscom, 'Responsibility for the Environment', available at: https://www.swisscom.ch/en/about/sustainability/environment.html and Swisscom, 'A pan-European player in the fleet management technology sector is born!' Available at: https://ventures.swisscom.com/a-pan-european-player-in-the-fleet-management-technology-sector-is-born/
[128] Telia Company (2023), 'IoT speeds up effort to reduce energy consumption in challenging times'. Available at: https://www.teliacompany.com/en/news-articles/iot-speeds-up-effort-to-reduce-energy-consumption-in-challenging-times
[129] Emify (2020), 'Narrowband IoT (NB-IoT) Explained'. Available at: https://www.emnify.com/iot-glossary/narrowband-iot
[130] Telia (2020), 'Telia IoT to connect one million E.On customers'. Available at: https://business.teliacompany.com/blog/telia-iot-to-connect-one-million-e.on-customers-

Box 7. Altice's Live!Green platform for agriculture

Developed by Altice Labs in Portugal, Live!Green is a specialised data platform for agriculture. Thanks to specialised sensors connected to a data analysis platform, the solution allows for the monitoring and analysis of weather conditions, of the soil, and of the plants. The relationship between these three elements (soil, weather, and plants) can also be explored, also through the retrieval of historical data.

This type of solution is particularly helpful as climate change pushes producers towards precision agriculture, which aims to improve efficiency and sustainability of resource use. A trial of the project, called The BASE Project – "BAnana SEnsing", has been conducted in Funchal, Madeira, on a banana cultivation. The Banana Sector Management Company (GESBA) was the main promoter of this project, which was co-financed by PRODERAM 2020 and had Altice Labs, the Regional Agency for the Development of Research, Technology and Innovation (ARDITI) and the University of Madeira as partners.

Source: Visionary Analytics, based on inputs collected during the First Roundtable on disruptive technologies and on Altice Labs (2023), 'Altice Labs participates in "BAnana SEnsing" seminar', available at: https://www.alticelabs.com/blog/altice-labs-participates-in-banana-sensing-seminar/

Projected social impact

The advent of IoT also holds numerous implications for the organization and operation of telcos. First, IoT will reshape job demands, emphasising skills in architecture, system diversification, and standardization. **Technical expertise in managing evolving IoT networks** and configurations will be increasingly sought after, reflecting the evolving landscape of telecommunications[131].

The integration of IoT also offers opportunities to **streamline administrative and bureaucratic tasks**. However, **security and privacy** remain significant concerns. The internet connectivity of IoT devices makes them susceptible to cyber-attacks: many current IoT devices lack the computing power to interface with modern firewalls and antivirus solutions, heightening security challenges. Moreover, IoT devices can collect a large volume of employee data, including location, communication habits, and even biometric information. While this data can be useful for informed decision-making and efficiency improvements, it also raises questions about the potential for misuse[132]. Thus, telcos must enforce robust security measures to protect both the network infrastructure and sensitive data transmitted through IoT devices.

Box 8. Flyaps' solution to streamline British Telecom Group's processes

British Telecom (BT) Group, a UK-based multinational telecom operator, sought a customized IoT platform for effective SIM card management, traffic tracking, and billing. So, they turned to Nextgen Clearing, a telecom business intelligence provider. Nextgen Clearing later partnered with Flyaps – a software product development company to develop the IoT. For its part, Flyaps developed a system targeting four modules:

- SIM card management module: Enables BT Group to monitor and assign unique numbers to all distributed SIM cards.
- Rate plans module: A specialized engine that autonomously selects the optimal plan for each customer by comparing different options.
- Billing module: This component automates invoicing, ensuring real-time tracking of traffic usage for accurate billing.
- Account management module: Provides customers with a user-friendly interface for easy sign-up, bill viewing, and inviting other businesses to use the services.

Flyaps' development of a fully customized IoT portal has empowered BT Group with enhanced decision-making capabilities through readily accessible data[133]

Source: Visionary Analytics, based on sources cited in the text.

[131] EURES (2020), 'The future of work: ICT professionals'. Available at: https://eures.europa.eu/future-work-ict-professionals-2020-09-25_en#:~:text=Employment%20for%20IT%20professionals%20is,filled%20between%202018%20and%202030

[132] Sievers, F. (2021), 'Empowering employees in industrial organizations with IoT in their daily operations'. Available at: https://www.sciencedirect.com/science/article/pii/S016636152100052X

[133] Flyaps (2023), 'IoT in Telecom: How it's impacting the industry'. Available at: https://flyaps.com/blog/iot-in-telecom-how-its-impacting-the-industry/

Finally, IoT devices hold the potential to improve working conditions: an area in which IoT holds considerable potential is safety. Wearable IoT devices can be employed in a variety of industrial sectors, among which telecommunications, and can be employed to maximise safety in the following areas[134]:

- By warning employees of potential risks tied to machinery or their surroundings (e.g., air quality, weather conditions);
- By tracking workers' biometrics, such as stress and fatigue, and mandating appropriate rest periods;
- By keeping workers from involuntarily performing dangerous tasks (e.g., lifting material that is heavier than the recommended weight);
- By reducing risks connected to driving, which is one of the lead causes of accidents on the workplace, through smart and connected vehicles.

In telcos, more specifically, IoT can be used to increase safety of maintenance tasks and data centres operations. For instance, TIM – Telecom Italia is employing IoT sensors on its network of copper cable poles, which are present in rural areas of the network. The sensors are attached to each pole and can alert the company if any of them constitutes a safety hazard, requiring replacement or maintenance[135]. Such an application of IoT enhances workers' safety, because they do not have to personally survey potentially faulty poles, but also the broader society, as the infrastructure is monitored more accurately.

From an employer's point of view, IoT can enhance data transparency and provide opportunities to monitor processes, enabling employees and managers to achieve a better understanding of their work activities. This possibility can lead to increased productivity and the availability of process-related data collected through connected devices may lead managers to make more informed choices[136]. Furthermore, employees can benefit from more opportunities to share operational knowledge and get support where needed[137]. An example is the use of IoT devices for sensor-based monitoring of employees' mental workload, which are showing promise for employees' well-being and workplace design[138]. Nevertheless, some problems have been identified regarding the switch to IoT-based work environments. Primarily, workers' privacy and right to data sovereignty are a prominent concern: in this direction, IoT implementation must be paired with adequate regulatory frameworks that specify the employer's use of the data, to ensure that personal information is not used to take disciplinary action, or to make personnel cuts or changes[139].

Moreover, according to a recent study, the implementation of IoT-based solutions has been the most successful in companies that provided adequate training and support to their employees throughout the introduction process, fostering a sense of empowerment[140]. On the other hand, where this care was not taken, the **changing nature of work activities** and increased complexity contributed to workers' stress and a sense of being overwhelmed by new tasks. A successful implementation of IoT therefore requires an assessment of the potential negative impacts, emphasizing the importance of empowering workers and promoting social dialogue to mitigate risks[141].

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[134] Wheelwright, G. (2017), 'IoT-linked wearables will help workers stay safe'. *Financial Times*, available at: https://www.ft.com/content/944e6efe-96cb-11e7-8c5c-c8d8fa6961bb
[135] Interview with a TIM representative, 05/03/2024.
[136] Cornish, C. (2017), 'Digital eyes and ears on: the internet of things takes off'. Financial Times, available at: https://www.ft.com/content/94ccaac2-962a-11e7-8c5c-c8d8fa6961bb
[137] Sievers, F. (2021), 'Empowering employees in industrial organizations with IoT in their daily operations'. Available at: https://www.sciencedirect.com/science/article/pii/S016636152100052X
[138] Pütz,S., Rick, V., Mertens A., Nitsch, V. (2022), 'Using IoT devices for sensor-based monitoring of employees' mental workload: Investigating managers' expectations and concerns'. Applied Ergonomics, 102, available at: https://doi.org/10.1016/j.apergo.2022.103739
[139] Ibid.
[140] Sievers (2022), 'Empowering employees in industrial organizations with IoT in their daily operations'. Available at: https://www.sciencedirect.com/science/article/pii/S016636152100052X
[141] Ibid.

2.5. Artificial intelligence

Since the inception of the term artificial intelligence (AI) in 1955, AI has consistently captured the attention of scientists, policymakers, the general public, and businesses. While lacking a universally agreed-upon definition, AI is defined by the European Parliament as: '**the ability of a machine to display human-like capabilities such as reasoning, learning, planning, and creativity**. AI enables technical systems to perceive their environment, deal with what they perceive, solve problems and act to achieve a specific goal'[142].

This definition encompasses a wide spectrum of technologies, ranging from automatic spam filters and chatbots to systems used for social scoring. Despite its potential, AI also entails various risks, particularly **ethical and privacy concerns**[143]. For example, the possibility of machine error in delicate fields of application, such as AI-led surgery. The varied landscape of AI technologies has prompted the European Union to adopt a **risk-based approach** in categorizing and regulating AI through the EU AI Act, the world's very first comprehensive legal framework to regulate AI. This has been lauded as a landmark development in the history of AI in Europe and beyond[144], demonstrating the significant implications that AI may have on different sectors of society.

A term closely related to AI is **machine learning (ML)**. According to the School of Engineering and Applied Science, at Columbia University, AI and ML are sometimes used interchangeably, but ML is a subset of AI. In essence, AI is the umbrella term that refers to all computers and systems emulating human thought and tasks, while ML *specifically* involves technologies and algorithms enabling systems to identify patterns, make decisions, and 'learn' by themselves through experience and data[145][146]. For instance:

- AI-driven tax applications like Taxfix[147] assist users in evaluating and filing tax returns using human-programmed rules and knowledge. However, these applications lack the autonomous learning ability and are often referred to as 'expert systems AI'.
- In contrast, facial recognition, such as the one used by Facebook, uses machine learning techniques. Through user inputs like name suggestions and tagging in photos, the algorithms autonomously learn and adeptly recognize faces.

In telecoms, some AI applications and uses may be referred to more correctly as ML, therefore, while the two terms will be considered jointly under this chapter, the term 'machine learning' will also be used in this report where appropriate.

AI is now widely integrated across diverse societal domains, spanning both public and private sectors (DiMatteo, 2022). Its benefits have become increasingly apparent in fields like healthcare, industrial operations, and consumer marketing (ibid). The **telecommunications industry** has also experienced significant AI adoption, with numerous global academic studies and reports underscoring the positive impacts of AI on key aspects, such as **optimizing network roll-out and network operation, enhancing customer service, and improving performance in billing, contracts, sales, and marketing**[148].

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[142] European Parliament (n.d), 'What is artificial intelligence and how is it used?'. Available at: https://www.europarl.europa.eu/news/en/headlines/society/20200827STO85804/what-is-artificial-intelligence-and-how-is-it-used

[143] McKinsey (2019), 'Confronting the risk of artificial intelligence'. Available at: https://www.sipotra.it/wp-content/uploads/2019/05/Confronting-the-risks-of-artificial-intelligence.pdf

[144] Reuters (2023), 'Europe agrees landmark AI regulation deal'. Available at: https://www.reuters.com/technology/stalled-eu-ai-act-talks-set-resume-2023-12-08/

[145] Columbia University (n.d.), 'Artificial Intelligence (AI) vs. Machine Learning'. Available at: https://ai.engineering.columbia.edu/ai-vs-machine-learning/

[146] Manheim, K. & Kaplan, L. (2019), 'Artificial Intelligence: Risks to Privacy and Democracy'. Available at: https://edisciplinas.usp.br/pluginfile.php/6502070/mod_folder/content/0/Manheim-AI%2C%20risks%20to%20privacy%20and%20democracy%2C%202019.pdf

[147] Taxfix. Available at: https://taxfix.de/

[148] Balmer, R., et al. (2020), 'Artificial Intelligence Applications in Telecommunications and other network industries'. Available at: https://www.sciencedirect.com/science/article/abs/pii/S0308596120300690

In this context, we can identify several concrete AI applications in telecoms. These include:

- **AI for network roll-out and operation**: the use of AI systems and techniques that support the network deployment process, from planning and design to implementing infrastructural changes. Once the network is in place, AI can be used to improve operations through management of network performance that aims to improve user experience quality.
- **Back-office** AI: AI systems and techniques that support back-office tasks (e.g., HR, accounting, compliance, etc.).
- **Front-office** AI: AI systems and techniques that support front-office tasks (e.g., customer service, sales, marketing, etc.).
- **AI for products and services**: AI systems and techniques that telcos are currently offering.

The subsequent discussion will provide a comprehensive analysis of the effects and potential risks associated with each category.

Box 9. AI for network sustainability: the case of Elisa

A good example of a telco application of AI comes from **Elisa**, a Finnish telecommunication company[149]. Elisa is implementing AI applications to optimise energy storage and distribution. In this case, the company employs intelligent algorithms and special algorithms to optimise the performance of the electrical grid, a solution that was originally applied by Elisa on its telecom networks. The Distributed Energy Storage solution works with Transmission Service Operators to adapt energy supply to its demand, thanks to three layers of control through AI and Machine Learning: the top-level planner determines the capacity needed within the system to balance the grid or reallocate resources, through the use of simulations; the middle-level ensures optimal use of assets (including battery longevity) by supervising electricity flow and conditions of the equipment; and lastly, the lowest layer selects the specific units within the grid that should respond to the changes suggested by the above levels. This solution can provide energy savings and increase efficiencies in capacity use and energy consumption in power and data plants, by reducing telcos' carbon footprint and increasing system resilience.

Source: Visionary Analytics, based on sources cited in the text

2.5.1. AI for network roll-out and operation

Network roll-out entails introducing a new product distribution method while maintaining consistent sales during infrastructural changes and transformations[150]. In this context, **AI for network roll-out and operation** encompasses techniques and systems that assist in the network roll-out process, covering not only the design and planning but also the actual implementation of infrastructural change. The integration of AI can boost efficiency in network rollouts by fine-tuning various processes; in particular, AI and ML applications are key to **network automation**, together with cloud and edge technologies. This optimization is a key driver in enhancing the overall profitability of telcos by curtailing operational costs and implementing more streamlined deployment strategies, as well as energy-saving systems. Indeed, European telcos are already widely leveraging AI and ML technologies to automate their Radio Access Networks (RAN): *Figure 6* below illustrates the extent of this effort, and future predictions, while *Box 10* illustrates a practical use case example of network roll-out and operations with integrated AI systems. The key ways in which AI can support network automation are[151]:

- **Automation of equipment installation and maintenance** on towers using AI and drone inspections can increase the reliability of services, reduce downtime and support predictive maintenance. Operators including BT and Orange have trialled such services, claiming potential reduction in site visits and inspection costs of about 50%, with reduced outages.
- **Transition to 'dark network operations centres'** enabled by AI, according to exponents such as BT and Swisscom, which will use AI for network planning to reduce cost and increase accuracy.

[149] Source: Elisa, 'Distributed Energy Storage'. Available at: https://elisa.com/des/
[150] Kepler (n.d.), 'Network Rollout – Definition'. Available at: https://www.kepler-consulting.com/en/solutions/what-is-network-rollout/
[151] ETNO (2024), 'The State of Digital Communications 2024'. Chapter 3.3. Available at: https://etno.eu/library/reports/117-state-of-digital-2024.html

- **Automation of traffic steering** and allocation to support differentiated quality of experience, and achieve optimal cost and energy efficiency through load balancing.
- **Automation of base station waking and sleeping** to reduce energy consumption (refer to 'potential for sustainability' for more information)

Figure 6. Degree of automation in the RAN in 2023, and targeted by 2027, by percentage of functions, European operators (28 respondents)

Source: ETNO (2024), 'State of Digital Communications'. Based on Analysys Mason, 2023.

Box 10. TIM: Artificial Intelligence for energy saving in power plants

TIM, one of the leading telecommunication companies in Italy, is looking to reduce its energy consumption, which constitutes the second largest in the country after railways. To do so, the company is implementing technological solutions that integrate AI-led automation with data and cloud applications in order to monitor and optimise energy use. To plan and implement the solution, a working group was formed, drawing on internal and external expertise (the Energy Centre of the Polytechnic of Turin and the Industrial Engineering department of the University of Salerno).

These insights were made possible by the use of a great volume of **energy data**, which was collected as part of TIM's data efforts. TIM's personnel worked on developing a cloud-based solution, to provide on-demand computing power, immediate scalability, and support for iterative and dynamic algorithms on large data sets, as well as monitoring tools for optimising costs and consumption. The first output of the project was the development of a dashboard for visualisation of energy consumption, **EVA (Energy Visual Analytics)**. The dashboard (illustrated on the right) has functions to visualise consumption broken down by hours, days, months and load index. Data can also be filtered by year, region, municipality, or point of delivery.

This was instrumental to the creation of a **machine learning platform capable of developing predictive models**: following calculations, the working group determined that the network component requiring the most optimisation was the network cooling system, deemed over-reliant on external temperature and fluctuating energy consumption. The ML platform was then programmed to identify patterns of energy consumption vis-à-vis external temperature and time of the year; following the analysis of this data, the platforms detect any anomalies in energy consumption by learning from previous years' behaviour. This allowed the company to identify a number of sites with anomalous energy consumption patterns, which revealed problems in the cooling systems installed (then solved through ordinary maintenance).

The application and development of big data and ML to networks also enriched the company's know-how, and there are plans in place to extend this kind of solution to other industrial processes in order to further the company's energy saving plans and further optimise operations.

Source: Visionary Analytics, based on interview with a TIM representative, 05/03/2024, and TIM Technical Magazine, 2/2023: Green Networks. Available at: https://www.gruppotim.it/it/innovazione/news-innovazione/notiziario-tecnico-green-networks.html

The incorporation of AI into network rollouts, while offering numerous advantages, also presents inherent risks that can impact the sustainability of telcos and other stakeholders. The reliance on AI technologies introduces the **potential risk of over-dependence**, wherein technical failures or disruptions in AI systems could result in significant operational challenges[152]. Furthermore, the integration of AI may require a reconfiguration of organizational structures, introducing potential uncertainties. Notably, experts discussing AI adoption in telcos highlight a significant challenge: effectively **transitioning employees and processes from manual operations to automated ones** necessitates a considerable investment of time and capital[153]. Additionally, as AI deployment involves multiple players, unclear accountability for unexpected outcomes and technical errors is a prominent concern, according to a report by the Body of European Regulators for Electronic Communications (BEREC)[154]. These risks are inherent in technology use, and while risk cannot be entirely avoided, a few carefully implemented measures can greatly reduce it. For this reason, planning of AI-integrated network must consider the introduction of the following measures[155]:

- On the **managerial side**, the time and costs of the implementation project should be accurately estimated to ensure a clear vision of the process at all times. This also helps to manage risk reduction through thorough knowledge of the state of operations. The organisational structure should also have clear accountability and liability in case of incidents.
- On the **technical side**, design flaws should be avoided as much as possible. Furthermore, a thorough quality assurance process, as well as thorough testing of the system, will help avoid incidents. A contingency plan for possible faults should also be in place.
- On the **sociocultural side**, employees should be adequately trained and have effective communication channels in place. Keeping an eye on the employees' mental and physical state can also help ensure that they are able to comply effectively with contingency plans and regulations.

Potential for sustainability

The telecommunications industry is known for its high energy consumption, accounting for approx. 2-3% of the world's total energy supply[156]. Telecom networks are also estimated to take up to 51% of ICT-related energy consumption by 2025[157]. Thus, here AI can step in to automate tasks, reducing the probability of errors, cutting costs and lessening fuel usage and gas emissions. For example, the Radio Access Network (RAN) is the most significant source of telcos' electricity consumption, accounting for 70% of energy utilization (for further information, refer to *Box 11*)[158]. RAN is a critical component of a mobile telecommunications system. It is the part of the network responsible for connecting individual devices, such

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[152] Wong, E. R., et al. (2017), 'Be more familiar with our enemies and pave the way forward: A review of the roles bugs played in software failures'. Available at: https://www.sciencedirect.com/science/article/abs/pii/S0164121217301334

[153] Tech Republic (2020), 'Telecoms have unique challenges in adopting AI'. Available at: https://www.techrepublic.com/article/telecoms-have-unique-challenges-in-adopting-ai/

[154] Body of European Regulators for Electronic Communications (2023), 'BEREC Report on the impact of Artificial Intelligence (AI) solutions in the telecommunications sector on regulation'. Available at: https://www.berec.europa.eu/system/files/2023-06/BoR%20%2823%29%2093%20BEREC%20Report%20on%20impact%20of%20AI%20solutions%20in%20telecom%20sector%20on%20regulation.pdf

[155] Ibid.

[156] Orange (2023), 'Greening the telecoms network'. Available at: https://www.orange-business.com/en/blogs/greening-telecoms-network

[157] Utilities One (2023), 'The impact of energy-efficient construction on telecommunication infrastructure'. Available at: https://utilitiesone.com/the-impact-of-energy-efficient-construction-on-telecommunication-infrastructure

[158] Orange (2023), 'Greening the telecoms network'. Available at: https://www.orange-business.com/en/blogs/greening-telecoms-network

as mobile phones or other wireless terminals to the core network (see section 2.11). Deploying AI for roll-out and operation at RAN sites can help reduce the need for human workers and their movement, and in turn, carbon footprint. AI tools for operation can also reduce RAN power consumption by 5-7%[159]. Nokia reports that 78% of telcos are now relying on AI energy solutions to effectively trim down network energy[160]. An example is the use of AI to determine 'waking' and 'sleeping' times of base stations in order to save energy when the network is not needed by users[161]. This underscores the significant contribution of integrating AI into network rollouts to enhance **environmental sustainability**[162].

Box 11. AI for data centres sustainability: a perspective from India

Within the National eGovernance Plan (NeGP), the Government of India has launched initiatives to improve the quantity and quality of innovation of its data centres, which are a key infrastructure for the digital and social innovation of the country. A key goal is to reduce the data centres' power consumption to increase sustainability, without compromising efficiency. One pilot example will be the Smart Data Centres in Hyderabad and Chennai, set to be built by the National Payments Corporation of India (NPCI). Through targeted policies, India plans to integrate AI and ML in data centres to make them more sustainable, in the following ways:

- Digital twins with AI and ML platforms can track the data centres' components to make energy and data supply adjustments in real-time. This can also translate to predictive maintenance, through automated surveillance of the facilities, which saves costs as well as energy.
- Intelligent cooling systems based on ML and sensors can optimise energy expenses and minimise the need for human supervision and intervention. This system is guided by intelligent software that adjusts the cooling system in real-time, according to the data transmitted by sensors; this and similar AI-based solutions for cooling can save telcos up to 40% of the power dedicated to this task.
- The monitoring of server performance, network congestions, and disk utilisation can also be performed by AI, which minimises downtimes.
- The use of AI combined with digital twins technology can help the operations of bigger data centres, by tracking all the components in the facility, predicting their behaviour and making real-time adjustments. For instance, these technologies would be able to predict data outages before they occur, saving companies time, energy and money.

Source: EY and ASSOCHAM (2022), 'India smart data centres & cloud infrastructure summit 2022: Making India a global hub for data centre and cloud solutions'. Available at: https://www.ey.com/en_in/technology/how-ai-and-automation-make-data-centers-greener-and-more-sustainable

Projected social impact

The integration of AI in network rollouts brings forth a spectrum of social impacts in the workplace. In terms of working conditions, the implementation of AI technologies can potentially redefine the nature of tasks performed by technicians and workers involved in network deployment. In particular, automation of repetitive and physically demanding tasks may lead to **improved working conditions, reducing physical strain and minimizing occupational hazards**. For example, AI-enabled drones can conduct aerial surveys for network planning, minimizing manual labour. It has been reported that the use of drones reduces infrastructure deployment time by up to 50%[163]. Another example is Meta's aerial fibre deployment solution that uses a robot designed to safely deploy a specialized fibre-optic cable on medium-voltage power lines[164]. On the other hand, concerns around **job displacement** grow, as certain manual tasks become automated, necessitating a careful balance between technological advancement and preservation of employment

[159] Ibid.
[160] Nokia (n.d), 'AVA – Energy efficiency'. Available at: https://www.nokia.com/networks/bss-oss/ava/energy-efficiency/?did=D000000007BR&gad_source=1
[161] Interview with TIM representative, 05/03/2024.
[162] Inveniam (2023), 'AI – A Key Driver of Sustainability in Telco Companies'. Available at: https://www.inveniam.fr/en/blog/ai-key-driver-of-sustainability-in-telco-companies
[163] Utilities One (2023), 'How Drones are Revolutionizing Communication Infrastructure Development'. Available at: https://utilitiesone.com/how-drones-are-revolutionizing-communication-infrastructure-development
[164] Meta (2020), 'Making aerial fiber deployment faster and more efficient'. Available at: https://engineering.fb.com/2020/07/13/connectivity/aerial-fiber-deployment/

opportunities[165]. Indeed, statistics show that the 20 largest telcos in North America and Western Europe have reduced their headcount by 384,000 jobs since 2015[166].

Box 12. Drones take over heavy machinery in Ericsson's 5G network deployment

The automation of labour-intensive tasks through AI may result in an **enhancement of working conditions** for employees, as hazardous tasks are taken over by machinery. For example, Ericsson states that the use of drones improves safety and efficiency in network deployment. Traditional site surveys can be delayed by weather and safety regulations, requiring in some cases that employees climb the towers to carry out site documentation. While this is done in full compliance with occupational health and safety regulation, risks for the employees remain. Conversely, Ericsson's use of drones allows quick and thorough tower inspections, capturing complete images in just 30 minutes, without involving heavy human labour[167]. Once the images have been collected by drones, a dedicated AI software is able to reconstruct the site virtually, enabling engineers to make decisions (e.g., on material required) remotely, reducing times and potentially hazardous site visits.

Source: Ericsson (2020), 'Afraid of heights? Drones, AI and digitalization to the rescue! Available at: https://www.ericsson.com/en/blog/2020/3/intelligent-site-engineering

As AI becomes integral to network rollouts, the impact on job content and skills is substantial. The changing landscape necessitates a workforce proficient in operating and managing AI-driven systems. On the flipside, the integration of AI also presents opportunities for job creation, opening avenues for **skill enhancement and career development** among the workforce. While some traditional roles may become redundant, demanding a shift in job content and skills, other roles within telcos can be complemented by new AI-related knowledge through ad-hoc training programs, transforming employees to respond to the new AI environment. The most sought-after skills in this field belong to the technical side of operation, and are related to generative AI engineering, and data engineering[168]. The implementation of AI also requires expert figures able to orchestrate data collection and system management (data experts and automation experts). Nevertheless, upskilling can involve all categories of employees, including managers, and does not only involve technical knowledge on AI deployment but also, for example, training on risks related to the diffusion of proprietary data through AI training[169].

Furthermore, AI in network rollouts provides wide-reaching benefits to society by **enhancing connectivity and accessibility**. The positive impact on consumers and society stems from improved network connectivity facilitated by AI applications[170]. This may foster societal interconnectivity and development, thereby alleviating the so-called digital divide that puts those in remote and rural areas at a disadvantage compared to their urban counterparts[171]. Effective deployment and operation of telecom networks through AI, including 5G, also play a crucial role in fostering **socio-economic growth** in the serviced regions, resulting in positive overall social impact. A comprehensive report by the World Economic Forum extensively explores and advocates for the positive impact of 5G on economic and social values across diverse sectors such as manufacturing, mobility, healthcare, finance, retail, media, and energy[172]. Moreover, as previously discussed, AI has the potential to reduce the environmental footprint of telecom infrastructure. These advantages collectively contribute to a positive impact on the twin transition.

[165] English, J. (2018), 'The growing ties between networking roles and automation'. Available at: https://www.techtarget.com/searchnetworking/opinion/The-growing-ties-between-networking-roles-and-automation

[166] Morris, I. (2023), 'Big telcos cut another 85k jobs in 2022 as gen AI loomed'. Available at: https://www.lightreading.com/ai-machine-learning/big-telcos-cut-another-85k-jobs-in-2022-as-gen-ai-loomed#close-modal

[167] Ericsson (2020), 'Afraid of heights? Drones, AI and digitalization to the rescue!'. Available at: https://www.ericsson.com/en/blog/2020/3/intelligent-site-engineering

[168] McKinsey (2024), 'How generative AI could revitalize profitability for telcos'. Available at: https://www.mckinsey.com/industries/technology-media-and-telecommunications/our-insights/how-generative-ai-could-revitalize-profitability-for-telcos

[169] Ibid.

[170] Supercharge Lab (2023), 'AI and 5G: Enhancing Telecommunication Networks for a Smarter World'. Available at: https://superchargelab.com/ai-and-5g-enhancing-telecommunication-networks-for-a-smarter-world/

[171] Utilities One (2023), 'Unequal Connections Investigating the Digital Divide in Telecommunications Networks'. Available at: https://utilitiesone.com/unequal-connections-investigating-the-digital-divide-in-telecommunications-networks

[172] World Economic Forum (2020), 'The Impact of 5G: Creating New Value across Industries and Society'. Available at: https://www3.weforum.org/docs/WEF_The_Impact_of_5G_Report.pdf

2.5.2. Back-office AI

The **back-office** serves as the backbone for administrative functions, crucial to the daily operations of a business. Operating behind the scenes, it encompasses essential departments like **compliance, human resources, accounting, and operations management**. From recruiting new talent to maintaining computer systems, databases, and financial oversight, the back office ensures the seamless execution of company operations[173]. In this context, **back-office AI** refers to the integration of AI technical systems to optimize and streamline these behind-the-scenes activities.

An area of AI use in back-office operations that has attracted much attention (and controversy) is the realm of **algorithmic management (AM)**. This is defined as 'the use of computer-programmed procedures for the coordination of labour input in an organisation'[174]. Algorithmic management translates in the use of algorithms to solve organisational problems through the collection and analysis of data, which may be pertinent to workers' efficiency, time taken to perform tasks, task sequence and workers' biometrics[175]. This data is then fed to the AM system, which may elaborate strategies to make operations faster and/or more efficient. Naturally, this kind of system raises ethical questions surrounding workers' rights. At present, there is evidence that systems of this kind are being implemented without workers' knowledge of what data is collected, how it is used, and how it influencing decisions affecting them (such as employment termination or changes)[176]. Furthermore, automated task assignment and extracting aggregate knowledge from personal data can have powerful effects on power relations at work. Bargaining power of employees on wages might decrease, as well as their power over organising tasks surrounding individual physical and mental capabilities[177]. As previously discussed in chapters *2.5.1* and *2.4*, algorithmic management, and of any other form of employee monitoring, must be accompanied by social dialogue, clear chains of responsibility, and solid company-level plans for algorithmic transparency, as well as broader national and EU-level regulations[178].

Box 13. Use cases of AI in A1's offices

As part of a company-wide effort of AI implementation and employee engagement (previously detailed in *section 2*), A1 has rolled out a number of use cases of AI, predominantly related to back-office and front-office tasks. Some examples of back-office applications are:

- **AI for document intelligence** – use of AI to collect specific information from unstructured documents, for instance, to extract information from stored contracts in the company's business area.
- **Connecting AI to knowledge bases** and operational information sources to generate answers to content-based queries faster than manual document consultation.
- **Supporting employees in the development of code** through AI-based solutions.

Some instances have also involved front-office AI applications (see section 2.5.3 for further details on front-office AI):

- **Intent and sentiment analysis** through AI, used in customer interactions.
- **Customer interaction** applications, that see AI interact with customers through chat, mail, SMS, or voice services. So far, AI has been integrated in A1's chatbot.
- AI support for the **marketing department**. This use case sees generative AI produce material that can be used to market or advertise products, such as text or pictures.

Source: First Roundtable on disruptive technologies, 09/04/2024.

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[173] Sonatafy (n.d), 'Front Office vs Back Office'. Available at: https://sonatafy.com/about-front-office-vs-back-office-2/

[174] Baiocco et al. (2022), 'The Algorithmic Management of work and its implications in different contexts'. Background paper for ILO and the European Commission, available at: https://www.ilo.org/wcmsp5/groups/public/---ed_emp/documents/publication/wcms_849220.pdf

[175] Ibid.

[176] UNI Europa (2022), 'Algorithmic Management: 1 in 3 workers left in the dark'. Available at: https://www.uni-europa.org/news/algorithmic-management-1-in-3-workers-left-in-the-dark/

[177] Wolfie Christl (2023), 'Monitoring, streamlining and reorganising work with digital technology'. Report for UNI Europa ICTs, available at: https://www.uni-europa.org/news/new-report-monitoring-streamlining-and-reorganizing-work-with-digital-technology/

[178] Visionary Analytics and Tallinn University of Technology for OSHA (2022), 'Artificial intelligence for worker management: an overview'. Available at: https://osha.europa.eu/sites/default/files/artificial-inteligence-worker-management_en.pdf

Potential for Sustainability

Generally speaking, back-office AI applications are concerned with customer experience and service delivery[179]. Nevertheless, the adoption of back-office AI in telecoms presents a range of indirect benefits for the sustainability of telcos and other stakeholders. Its main advantages are[180]:

- **Streamlining administrative processes:** Back-office AI automates tasks like invoice processing, payroll management, and compliance checks, reducing manual workload and cutting operational costs.
- **Error reduction and financial sustainability:** AI's ability to detect billing discrepancies contributes to error reduction and dispute prevention, enhancing the financial sustainability of telcos.
- **Energy consumption reduction:** AI-driven systems in the back office reduce energy consumption, particularly through automated server management, aligning with environmental sustainability goals.
- **Enhanced compliance:** Back-office AI automates compliance checks, ensuring telcos adhere to regulations and potentially strengthening overall sustainability.

Projected social impact

The integration of back-office AI has many impacts on working conditions, work organization, and job content and skills. First, back-office AI significantly transforms **working conditions** by automating routine tasks traditionally handled manually. EY suggests that robots can be coded to execute identical tasks as humans but at a significantly faster pace, at a speed increase of approximately 300%-400%, and with heightened precision and consistency[181]. For example, some technology partners now leverage robotic process automation (RPA) and Microsoft Power Apps to upgrade back-office operations of telcos, aiming to enhance the speed of calculations and deliver a more efficient platform for sales and account managers[182]. One example comes from Telekom Romania, which is using AI chatbots to streamline internal HR processes for more than 4000 employees. The chatbots automate tasks like approving leave requests, handling specific HR inquiries (like medical or employee certificates), showing available leave days, and updating personal data using OCR technology[183]. The implementation of AI in the back-office can thus reduce the burden of repetitive and time-consuming responsibilities on employees. This has the potential to enhance the overall work environment, minimizing stress associated with mundane tasks and fostering more convenient working conditions. However, the use of back-office AI may pose certain **challenges in terms of working conditions**. For example, employees accustomed to traditional methods may experience difficulties or potential job displacement due to the automation of tasks, impacting their overall job satisfaction. Furthermore, while not peculiar to the telecom industry, a survey by Real Research shows that employees' overreliance on AI might lead to issues such as complacency, or reduced creativity and critical thinking[184]. This can negatively impact their working experience.

Secondly, the integration of back-office AI can also lead to changes in **work organization**. The efficient utilization of AI algorithms for tasks such as compliance, human resources, and operations management enhances workflow, potentially shortening project timelines and improving overall efficiency. A report indicates widespread anticipation among HR professionals regarding the impact of AI on recruitment and overall productivity. Specifically, 73% of respondents foresee AI accelerating recruitment processes, while

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[179] EY (2021),'Why RPA is the smart way to begin your process transformation'. Available at: https://www.ey.com/en_it/tmt/why-rpa-is-the-smart-way-to-begin-your-process-transformation
[180] Lopes, J. (2024), 'Supercharge your business with back-office automation: The ultimate guide'. Available at: https://www.pipefy.com/blog/back-office-automation/
[181] EY (2022), 'Adapting operations as fast as your markets are changing'. Available at: https://www.ey.com/en_us/tmt/adapting-operations-as-fast-as-your-markets-are-changing
[182] Intellias (n.d), 'Optimizing Telecom Back-Office Systems'. Available at: https://intellias.com/optimizing-telecom-back-office-systems/
[183] DRUID (2021), 'Telekom deploys DRUID AI chatbots to automate HR processes for 4000 employees'. Available at: https://www.druidai.com/chatbots-in-the-press/druid-ai-chatbot-uipath-rpa-hr-automation-telekom
[184] Real Research Media (2023), 'Survey on Dependence of Artificial Intelligence at Workplace'. Available at: https://realresearcher.com/media/survey-on-dependence-of-artificial-intelligence-at-workplace/

53% expect increased productivity across HR roles in various sectors, including telecommunications[185]. AI can aid in recording and summarizing calls and meetings, as well as automate ticket management tasks such as creating and routing tickets. For instance, technologies like Augmented Reality (AR) or Virtual Reality (VR) can facilitate virtual meetings and product demonstrations, improving communication and collaboration[186]. Another example concerns **regulatory compliance processes**: AI-driven systems are capable of monitoring network operations, identifying potential breaches, and automating the reporting process. This functionality enables companies to efficiently meet regulatory requirements. This proactive approach enhances the industry's ability to stay compliant with constantly evolving regulations[187]. Given its potential for compliance, the Telecom Regulatory Authority of India has instructed telcos in India to implement an AI-based system for detecting and taking action against unregistered telemarketers to tackle unsolicited commercial communication[188]. That said, organizational restructuring may be required to accommodate the integration of AI, leading to uncertainties and potential disruptions in work organization.

Third, as traditional back-office roles may see a shift as AI systems take on routine responsibilities, there is a need for a **workforce proficient in managing and utilizing back-office AI systems**. This highlights the importance of upskilling and adapting to technological advancements. Nevertheless, the rapid adoption of AI may create a skills gap between the abilities employees possess and those required to effectively work with AI systems. This gap can result in challenges related to job content and performance. Moreover, as mentioned several times earlier, the automation of certain tasks may render some traditional job roles redundant, necessitating employees to adapt their job content and skills to remain relevant in the evolving workplace. These potential risks underscore the importance of thoughtful implementation and management strategies to mitigate negative impacts on working conditions and organization, health and safety, and job content and skills.

In particular, several risks are connected to the implementation of back-office AI, including the unregulated use of algorithmic management and automation in the workplace:

- **Operational disruption:** Back-office AI introduces the risk of operational disruption due to system failures or technical glitches. For example, a serious scandal took place in the Netherlands in 2021 due to failures in the Dutch Government's AI system for assessing child benefits. A flaw in the system design led to an algorithm that caused devastating financial problems for those affected[189]. Similar cases might also occur in the telecoms industry.
- **Data security and privacy concerns:** Managing sensitive data in the back office presents notable concerns regarding data security and privacy. On the customer side, insufficient security measures may result in data breaches, jeopardizing customer trust and regulatory compliance. On the workers side, excessive surveillance from algorithmic management applications may present significant concerns around human rights issues, such as dehumanising forms of workers' tracking and management in the workplace, resulting in a loss of autonomy[190].
- **Ethical and bias concerns:** The use of AI algorithms for back-office tasks raises ethical considerations, and biases in decision-making processes may lead to unfair treatment. A very prominent example from another industry is the failure of Amazon's AI recruitment tool which showed bias against women: simply

[185] iQuasar (2023), 'Enhancing Efficiency: How AI is Revolutionizing Telecom Staffing'. Available at: https://iquasar.com/blog/enhancing-efficiency-how-ai-is-revolutionizing-telecom-staffing/
[186] Yo Telekom (2023), 'Artificial Intelligence & Telecoms'. Available at: https://yotelecom.co.uk/artificial-intelligence-telecoms/
[187] TUPL (2023), 'Should Telcos Be Worried About AI and Its Evolution?'. Available at: https://www.tupl.com/blog/should-telcos-be-worried-about-ai-and-its-evolution/
[188] CNBC (2023), 'Telecom regulatory body orders telcos to use AI for call filtering, seeks compliance report within 30 days'. Available at: https://www.cnbctv18.com/telecom/telecom-regulatory-body-orders-telcos-to-use-ai-for-call-filtering-seeks-compliance-report-within-30-days-16922551.htm
[189] Amnesty International (2021), 'Dutch childcare benefit scandal an urgent wake-up call to ban racist algorithms'. Available at: https://www.amnesty.org/en/latest/news/2021/10/xenophobic-machines-dutch-child-benefit-scandal/
[190] Baiocco et al. (2022), 'The Algorithmic Management of work and its implications in different contexts'. Background paper for ILO and the European Commission, available at: https://www.ilo.org/wcmsp5/groups/public/---ed_emp/documents/publication/wcms_849220.pdf

put, Amazon's AI had taught itself that male candidates are preferable to women[191]. Moreover, undue automated management of employees and bias may lead to stress and anxiety. Addressing these concerns through appropriate safeguards is essential for responsible back-office operations.

Transparency and accountability need to be regarded as paramount in the use of all AI systems, to avoid risks specifically related to data privacy, worker's human rights, ethics, and health and safety[192]. Ethical frameworks at the company level should promote transparency on employees' data usage in compliance with European regulations and promote a 'humans-in-command' approach to AI, in which humans remain in control of automated systems at all times. Furthermore, AI applications should be transparent, meaning that employees must have knowledge of how the system processes their data, and have the right to know how decisions affecting them may be taken. Important to note is also the issue of possible algorithmic biases, which must be avoided through thorough supervision of algorithms. Where possible, ways to avoid bias by design should be explored by developers.

2.5.3. Front-office AI

While the back-office focuses on day-to-day administrative tasks and ensuring the smooth operation of a business, the front-office is recognized as the division responsible for generating revenue. Front-office responsibilities encompass a range of functions, including marketing, sales, public relations, customer services, and call centre operations. Teams within the front office, such as those in sales and marketing, develop promotional activities aimed at selling products or services. **Front-office AI** refers to technical systems supporting these front-office functions.

Potential for sustainability

In terms of sustainable impact, front-office applications of AI can generate opportunities to reduce costs and save energy. In terms of **operational efficiency and cost reduction,** the adoption of front-office AI in marketing, sales, and customer services can streamline operations, reduce manual efforts, and cut operational costs. For example, Vodafone introduced TOBi, the first live AI-based chatbot in the U.K., resulting in faster customer services and the handling of over 70% of customer queries. Similarly, China Mobile launched its customer service bot Yiwa, engaging in more than 200 million interactions with customers in a month and saving over 110 million yuan in labour costs[193]. Improved efficiency contributes to the financial sustainability of telcos, enabling them to invest in sustainable innovation and infrastructure. Moreover, digital assistants may reduce the need for maintaining large customer contact centres, resulting in energy savings.

Nevertheless**,** the **energy usage and emissions** associated with the development, production, and deployment of front-office AI may also lead to negative effects on the environment[194]. As already mentioned in section *2.5.1*, the energy required to train an AI model is significant[195], and any AI application must consider the net balance between energy use and benefit for the environment that may derive from its implementation.

[191] Reuters (2018), 'Insight – Amazon scraps secret AI recruiting tool that showed bias against women'. Available at: https://www.reuters.com/article/idUSKCN1MK0AG/
[192] ETNO and UNI Europa ICTs (2020), 'The Telecom Social Dialogue Committee Joint Declaration on Artificial Intelligence'. Available at: https://etno.eu/downloads/news/ue-etno%20declaration%20ai.pdf
[193] Chen, H. (2019), 'Success factors impacting Artificial Intelligence adoption – Perspective from the telecom industry in China'. Available at: https://digitalcommons.odu.edu/cgi/viewcontent.cgi?article=1101&context=businessadministration_etds
[194] Cornor, C. (2023), 'Artificial intelligence in marketing: fiend or foe of sustainable consumption'. Available at: https://link.springer.com/article/10.1007/s00146-021-01227-8
[195] Earth.org (2023), 'The Green Dilemma: Can AI fulfil its potential without harming the environment'. Available at: https://earth.org/the-green-dilemma-can-ai-fulfil-its-potential-without-harming-the-environment/

Projected social impact

Front-office AI has the potential to enhance **working conditions** by automating routine tasks in marketing, sales, public relations, customer services, and call centre operations. This automation effectively reduces the workload on employees, enabling frontline staff to concentrate on more strategic and intricate aspects of their roles, while abandoning repetitive tasks. Indeed, a global survey involving 34,000 respondents worldwide demonstrates that automation can create more favourable working conditions by eliminating tedious tasks and allowing humans to engage in more stimulating and meaningful activities[196]. Research based on data from a Belgian telco indicates that the use of front-office AI can save more than 10 minutes per customer interaction[197].

In addition, the integration of front-office AI can also optimize **work organization**. For example, in marketing and sales, AI provides a competitive edge by enabling targeted campaigns through data-driven insights from millions of customers, offering real-time understanding of user experiences and critical marketing knowledge[198]. Additionally, AI-driven chatbots efficiently handle customer inquiries, alleviating the workload on frontline employees. A McKinsey case study highlighted an Asian telco's launch of a 5G virtual retail assistant, streamlining customer interactions and transactions, ultimately contributing to more manageable workloads and heightened job satisfaction among customer service teams.[199] In North America, almost half of customer contacts initiated by telecoms are currently managed by machines, including AI. According to McKinsey, there is an additional potential for AI to further reduce the volume of contacts serviced by humans by up to 50%[200]. Particularly, with the advent of generative AI applications such as ChatGPT, telcos can now swiftly create engaging responses to customer queries. AI can also create more personalized recommendations for customers and faster speed of answers in call centres.

Front-office AI introduces the risk of **operational disruptions**. Technical glitches, system failures, or AI-related issues may disrupt the smooth workflow in marketing, sales, and customer services, impacting overall work organization. Additionally, since front-office AI involves handling large amounts of customer data, the risks of data breaches, privacy concerns, or biases pose a threat to the work organization. An instance is ChatGPT, developed by OpenAI, a US-based company, which has raised privacy concerns among telco employees. This prompted a major telco to develop its own generative AI application[201]. On a different note, the adoption of front-office AI requires front-office employees to develop both AI and analytical skills. Analysing AI-generated insights, understanding customer behaviours, and interpreting data trends will become essential competencies, fostering the need for continuous **skill development** among the workforce.

On the flipside, front-office AI also carries certain risks. First, task automation may raise concerns about job displacement among frontline staff, impacting working conditions and causing stress. The potential of job loss disproportionately affects low-skilled workers, such as clerical support workers, while managers are less likely to be impacted by task automation[202]. Secondly, an overreliance on AI for tasks requiring human interaction, like customer service, may depersonalize interactions, affecting the quality of customer relationships. A study indicates that 66% of European customers of a major international telco gave a

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[196] Forbes (2019), 'Automation and AI actually relieve workplace stress, and customers will notice'. Available at: https://www.forbes.com/sites/joemckendrick/2019/07/29/automation-and-ai-actually-relieve-workplace-stress-and-customers-will-notice/
[197] Sinch (n.d), 'How a leading telco increases client & employee satisfaction with Conversational AI'. Available at: https://www.sinch.com/insights/customer-stories/telco-increases-client-employee-satisfaction-conversational-ai/
[198] Johnson, J. (2022), 'How AI-Based Marketing is Transforming Telecom Companies'. Available at: https://www.spiceworks.com/tech/artificial-intelligence/guest-article/ai-based-marketing-transforming-telecom-companies/
[199] McKinsey (2023), 'The AI-native telco: Radical transformation to thrive in turbulent times'. Available at: https://www.mckinsey.com/industries/technology-media-and-telecommunications/our-insights/the-ai-native-telco-radical-transformation-to-thrive-in-turbulent-times
[200] McKinsey (2023), 'The economic potential of generative AI'. Available at: https://www.mckinsey.de/~/media/mckinsey/locations/europe%20and%20middle%20east/deutschland/news/presse/2023/2023-06-14%20mgi%20genai%20report%2023/the-economic-potential-of-generative-ai-the-next-productivity-frontier-vf.pdf
[201] FTP Software (2023), 'Talk to Experts Ep 6: Creating Tomorrow: Generative AI and the Future of Work'. Available at: https://fptsoftware.com/resource-center/blogs/talk-to-experts-ep-6-creating-tomorrow-generative-ai-and-the-future-of-work
[202] Gymrek et al. (2023), 'Generative AI and jobs: A global analysis of potential effects on job quantity and quality'. ILO Working Paper, available at: https://www.ilo.org/static/english/intserv/working-papers/wp096/index.html#ID0EC2AG

customer service chatbot a low satisfaction rating of 1 out of 5[203]. Thirdly, AI front-office applications that include algorithmic management in customer service areas (e.g., call centres) can induce worrying working conditions. For instance, automated call distribution and worker monitoring applications can significantly increase stress and impact the psychological wellbeing of workers, constituting a potential health and safety hazard[204]. Aside from the aforementioned need for industry-wide plans and regulation, there is evidence that social dialogue efforts can be helpful in mitigating the impact of AI on workers, giving them agency over the design of AI features and the organisation of work through algorithmic management[205].

2.5.4. AI for products and services

Besides the benefits that AI can (potentially) bring to telcos, telcos are now also offering a wide range of products and services that make use of AI technologies:

- **Smart homes**: Telcos are incorporating AI-driven technologies, like voice assistants, into smart home devices and services. This allows customers to manage different aspects of their homes, including security systems and smart appliances, through simple voice commands. For instance, KPN, a prominent Dutch telco, in collaboration with Deutsche Telekom, provides the QIVICON Smart Home service, which integrates the virtual assistant Alexa[206].
- **AI integration for manufacturers:** Deutsche Telekom offers services to integrate AI platforms and solutions to help manufacturers optimize their operations[207].
- **AI-driven data analysis solution:** Orange France offers an AI-driven large-scale data analysis solution to the Port of Antwerp to help monitor vessel traffic and optimize their operations[208].
- **'Self-fix' solutions:** Cellnex Telecom offers AI-driven applications for asset and workforce management[209].
- **Private networks enabling robotics for patient monitoring:** Cellnex Telecom also offers services to deploy private networks suitable for the use of technologies such as robotics, and AR/VR in the healthcare industry[210].

Potential for sustainability

The integration of AI into the products and services offered by telcos holds great potential for promoting sustainability across various applications. AI systems used for smart homes together with other technologies like IoT (see section 2.4) enable customers to manage different aspects of their homes. The potential sustainability impact lies in the efficient management of home devices, potentially reducing energy consumption and promoting eco-friendly practices. Indeed, it has been estimated that implementing smart home devices and load monitoring systems in conventional homes leads to energy conservation of approximately 12% to 20%[211]. Likewise, AI products and services provided by telcos, which help businesses

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[203] Crolic, C. (2021), 'Blame the Bot: Anthropomorphism and Anger in Customer-Chatbot Interactions'. Available at: https://journals.sagepub.com/doi/10.1177/00222429211045687
[204] Doellgast, V. and O'Brady, S. (2023), 'AI in contact centers: Artificial intelligence and algorithmic management in frontline service workplaces'. Available at: https://www.researchgate.net/publication/375922335_AI_in_contact_centers_Artificial_intelligence_and_algorithmic_management_in_frontline_service_workplaces
[205] Ibid.
[206] Telekom (2016), 'Smart Home platform QIVICON now also available in the Netherlands'. Available at: https://www.telekom.com/en/media/media-information/detail/smart-home-platform-qivicon-now-also-available-in-the-netherlands-363268
[207] Telekom (n.d), 'Services for the industries of the future'. Available at: https://b2b-europe.telekom.com/enterprise-it-solutions/manufacturing-it-solutions
[208] Orange (2022), 'Artificial Intelligence'. Available at: https://www.orange.com/sites/orangecom/files/documents/2022-02/IA-EN%20-%20FINAL.pdf
[209] Cellnex (n.d), 'Transforming Energy and Utilities with 5G Connectivity'. Available at: https://www.cellnex.com/gb-en/solutions/energy-utilities/
[210] Cellnex (n.d), 'Healthcare'. Available at: https://www.cellnex.com/gb-en/solutions/healthcare/
[211] Kim, H., et al. (2021), 'A systematic review of the smart energy conservation system: From smart homes to sustainable smart cities'. Available at: https://www.sciencedirect.com/science/article/pii/S1364032121000502?casa_token=LOSQ0oLnD7gAAAAA:CiyOiV6UP8ckMwebY49iQI4GcUsOEhNgp_D9y35WGUVuyO0jnOsQDWur6d-KkDm1rT57HNQiUg

streamline their operations, can also play a role in enhancing financial sustainability and reducing energy consumption in other sectors[212].

Projected social impact

AI-driven services offered by telcos can also influence the work structure and conditions of various sectors. In terms of workers' performance, these services can contribute to increased efficiency and effectiveness. For instance, the deployment of private networks and technologies like robotics in healthcare enables remote patient monitoring. These 'telehealth' innovations are particularly beneficial in underserved regions, allowing healthcare specialists to operate remotely. As a consequence, it can alleviate the issue of medical staff shortage, reduce costs, and prevent unnecessary exposure to contagious illnesses. Telehealth technology is also pertinent in developing countries with expanding healthcare systems, allowing infrastructure design to meet current needs efficiently. Telcos play a crucial role in enabling these advancements, providing the connectivity and technologies necessary for telehealth[213].

Regarding **skills**, telcos' AI-driven services are creating a demand for technical proficiency in AI platforms and solutions. This trend requires ongoing upskilling or reskilling programs for existing employees or the hiring of individuals with expertise in both telecommunication and AI technologies. An example of the synergy between these two types of expertise comes from the field of healthcare. Medical telerobotic systems can carry out necessary tasks from a remote location, leveraging the inherent benefits of medical robots such as steady-hand precision, accuracy, motion scaling, and biomotion compensation. However, remote operations such as telesurgery require specialized training in operating advanced telerobotic systems and adaptability to remote collaboration[214].

2.6. Quantum technology

Quantum computing is widely regarded as one of the most important future evolutions of computing technology. The term 'quantum technologies' refers to **transistors, lasers, microprocessors and computers based on applied quantum mechanics** – the interactions between molecules, atoms and their constitutive particles[215]. These particles' mechanical properties can be exploited to create extremely powerful machines, capable of solving ever more complex problems that are currently out of reach of standard computers.

While applications of quantum technology go far beyond telecommunications, this sector sees a lot of potential in a quantum revolution, as countries all over the world work to make quantum communication a reality. In the EU, a Quantum Technology Flagship Initiative was launched in 2018 with the long-term objective of developing a Quantum Internet, sustained by quantum communication networks[216]. At present, quantum efforts for the creation of communication networks have been tied to national governments and agencies (see for example the 2019 Declaration of Cooperation on Quantum Communications signed by 9 EU countries[217]). Nevertheless, the telecommunication industry might see a profound impact on their operations driven by quantum applications. In particular, the **computational power harnessed by quantum-based machines will likely be essential to the optimal functioning of many technological solutions** requiring a high capacity for complex data analysis or optimisation:

[212] Telekom (n.d), 'Services for the industries of the future'. Available at: https://b2b-europe.telekom.com/enterprise-it-solutions/manufacturing-it-solutions
[213] Bohr, A., & Memarzadeh, K. (2020), 'The rise of artificial intelligence in healthcare applications'. Available at: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7325854/
[214] Avgousti, S., et al. (2016), 'Medical telerobotic systems: current status and future trends'. Available at: https://biomedical-engineering-online.biomedcentral.com/articles/10.1186/s12938-016-0217-7
[215] European Commission (n.d.), Shaping Europe's Digital Future: Quantum. Available at: https://digital-strategy.ec.europa.eu/en/policies/quantum
[216] See https://digital-strategy.ec.europa.eu/en/policies/quantum-technologies-flagship
[217] Available through https://digital-strategy.ec.europa.eu/en/news/future-quantum-eu-countries-plan-ultra-secure-communication-network

- The speed of calculation of quantum computers will likely be beneficial to the creation and management of **6G networks**, specifically by managing network congestion, scheduling, and resource allocation.
- Quantum will likely power solutions based on **AI and ML**, especially when they are based on hard optimisation problems (e.g., fault management or network optimisation)[218].
- Traditional sensors in IoT solutions can be replaced by **quantum sensors**, which are characterised by superior sensitivity, in tasks such as signal processing and network optimisation[219].
- Various applications of quantum technologies will be instrumental to enhance cybersecurity in telcos (see *section 2.7* for further details). In particular, quantum technologies such as quantum key distribution, together with complementary classical technology in the form of **post-quantum cryptography** will be necessary to ensure data protection, as current encryption system would not be sufficient if faced with a quantum cyberattack. The telco ecosystem is taking steps to address this and develop quantum-safe encryption models, through the development of post-quantum plans and standards[220].

Box 14. A commercial use case of quantum technologies in telcos

The first commercial trial of a quantum-based network infrastructure was launched in 2022 by telecommunication operator BT, in partnership with Toshiba and EY. In the trial phase, the project connects two EY offices in London in an end-to-end solution that will protect the data shared through Quantum Key Distribution (a secure method of data communication that encrypts data using quantum technology). The project has also been extended to create a network able to connect customers in the London metropolitan area through the same solution, starting from enterprise customers who need a solution to deal with particularly sensitive data. To implement the project, BT provides encrypted connectivity through a private fibre network, as well as a range of quantum-secured services to ensure data security and encryption along the whole network. Toshiba will provide the software and hardware required; importantly, the solution uses a shared quantum network core, reducing the amount of physical infrastructure required to deliver both quantum key distribution and secure, encrypted high bandwidth communication links between customer sites.

Source: interview with a BT researcher (05/04/2024) and BT (2022), 'BT and Toshiba to build world's first commercial quantum-secured metro network across London'. Available at: https://newsroom.bt.com/bt-and-toshiba-to-build-worlds-first-commercial-quantum-secured-metro-network-across-london/

Potential for sustainability

Like other technologies discussed, quantum presents both opportunities and challenges regarding its potential for sustainability. What sets it apart from other technologies, however, is its yet scarce availability in European industries. Many discussions centred around quantum sustainability are thus predictive in character, but merit our consideration given the potentially very broad changes they might induce in telcos, or enable in other sectors:

- **Reduced needs for infrastructure**: quantum technologies (such as quantum sensing of wireless communications) might enable long-distance communication, connecting remote locations with reduced need for additional physical infrastructure (costly for people and the planet)[221].
- **New materials discovery**: One of the greatest hopes for quantum computing is that it will enable better simulation of materials and semiconductor devices, including organic semiconductors. This could help us address design challenges such as better solar cells, longer lasting materials, understanding how materials will degrade sustainably, understanding recycling processes, designing semiconductors that will operate at higher temperatures and so do not need active cooling (an energy intensive process)[222].

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[218] Phillipson, F. (2023). "Quantum Computing in Telecommunication—A Survey" Mathematics 11, no. 15: 3423. https://doi.org/10.3390/math11153423
[219] Utilities One (2023), 'Telecommunications Infrastructure and the Future of Quantum Communication'. Available at: https://utilitiesone.com/telecommunications-infrastructure-and-the-future-of-quantum-communication
[220] For more information, see GSM Association (2023), *Post Quantum Telco Network Impact Assessment* – Whitepaper, available at: https://www.gsma.com/newsroom/wp-content/uploads//PQ.1-Post-Quantum-Telco-Network-Impact-Assessment-Whitepaper-Version1.0.pdf
[221] Ibid.
[222] Input from a BT researcher, 24/04/2024.

- **Driving progress in device physics**: The quantum industry is developing capabilities to sense, control and manipulate light and matter on robust platforms such as hybrid integrated circuits suitable for use in real world environments. This technological progress increases our capabilities to build smaller and lower power devices, for classical as well as quantum applications[223].
- **Reduced need for cooling**: some forms of quantum technology do not require significant, or any, active cooling. This is because of the nature of photonic light, which is not as susceptible to noise (heat, in this case) and can run hotter than traditional quantum computational solutions. This characteristic is important, as cooling equipment is one of the largest factors in energy consumptions in today's data centres (see also *Box 6* for an example of technical solution for equipment cooling)[224].
- **Network and logistics optimisation** – it is hoped that logistics and network management can be greatly enhanced thanks to quantum computer applications to network and logistics simulation and modelling, helping telcos save resources and energy by optimising processes. Concerning other advanced technologies paired with traditional computing, quantum would create even greater benefits in terms of energy savings[225].

Critics of quantum technologies highlight the possibility that the **environmental costs** of quantum might outweigh its environmental benefits: importantly, the manufacture of dedicated hardware in non-ethical or non-sustainable ways, and problems related to the scale of data used. Indeed, quantum technologies might exacerbate the need for data storage, which would in turn increase energy consumption and resources for data centre building[226]. The energy required to run quantum solution is, at the moment, considerable; however, recent research is emerging that possibly counters this belief, highlighting that quantum can be feasible from a cost/power perspective, through future predictions of hardware improvements[227]. Additionally, researchers note how company-specific value considerations and approaches to this technology might make the difference in making quantum environmentally friendly or potentially hazardous[228].

Projected social impact

As a technology with a potentially revolutionary impact on all sectors and industries, quantum will certainly impact the world of work, both in terms of skills and work organisation and safety. While the novelty of the technology leaves much to discover, we can identify some of the projected scenarios of impact:

- Regarding job skills, recent research shows that the **number of quantum-related job openings outstrips the skills offered** by almost three to one; however, the number of recent graduates with relevant skills is growing[229].
- Universities across the world are working on creating employees with **quantum engineering skills**, which are in high demand across sectors, including the public sector which is developing its R&D programs[230].

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[223] Ibid.
[224] Interview with a BT researcher, 05/04/2024.
[225] EY (2022), 'How can your quantum vision be transformed into a sustainable reality?'. https://www.ey.com/en_uk/emerging-technologies/how-can-your-quantum-vision-be-transformed-into-a-sustainable-reality
[226] Ibid.
[227] Kasi, S. et al. (2023), 'A Cost and Power Feasibility Analysis of Quantum Annealing for NextG Cellular Wireless Networks'. *IEEE Transactions on Quantum Engineering*, available at: https://discovery.ucl.ac.uk/id/eprint/10180192/1/A_Cost_and_Power_Feasibility_Analysis_of_Quantum_Annealing_for_NextG_Cellular_Wireless_Networks.pdf
[228] Ibid.
[229] Mohr, N. et al. (2022), 'Five lessons from AI on closing quantum's talent gap—before it's too late'. McKinsey Digital, available at: https://www.mckinsey.com/capabilities/mckinsey-digital/our-insights/five-lessons-from-ai-on-closing-quantums-talent-gap-before-its-too-late
[230] See Chen, S. (2023), 'The future is quantum: universities look to train engineers for an emerging industry'. Nature, available at: https://www.nature.com/articles/d41586-023-03511-7
See also Hilton, J. (2019), 'Building The Quantum Workforce Of The Future'. Forbes, available at: https://www.forbes.com/sites/forbestechcouncil/2019/06/19/building-the-quantum-workforce-of-the-future/?sh=5078bac4fa47

- In the private sector, programs of **employee upskilling** might be needed, as expert personnel will be required to oversee the quantum roll-out. This will affect IT employees especially, which are also projected to increase in number[231].
- Workplaces might require **enhanced cybersecurity infrastructure and protocols** to meet the demand for new quantum computers, regulations which may be mandated by legislation as the technology progresses[232].

2.7. Optic fibre and GPON technologies

One important technology in the world of telecommunication, which is being rolled out all over Europe, is **optic fibre**, developed and now used by telcos to provide fast internet connections to their customers[233]. Technically speaking, optic fibre is **a type of cable for data transmission made of glass or plastic fibre, able to transmit light from one point to another (including UV and infrared radiation)**[234]. This method of transmission presents numerous advantages against metallic cable systems, among which we find increased bandwidth (the transmission speed increases by a factor of tens of thousands, according to conservative estimates) and various practical advantages (such as electrical isolation, future-proofness, and signal security)[235]. Fibre is also a key building block of **Very High-Capacity Networks (VHCN)**, widely regarded as key to digitalisation across sectors[236], and fundamental to the implementation of nearly all advanced technologies discussed in this report. A VHCN can be defined as: 'either an electronic communications network which consists wholly of optical fibre elements at least up to the distribution point at the serving location, or an electronic communications network which is capable of delivering, under usual peak-time conditions, similar network performance in terms of available downlink and uplink bandwidth, resilience, error-related parameters, and latency and its variation'[237].

The deployment of fibre optic in fixed networks across Europe is a requirement of one of the targets of the EU's Digital Decade Programme, 'Gigabit connectivity for all by 2030'. This target aims to provide Gigabit networks to all European households by 2030, and the deployment of fibre is a necessary condition to fulfil this ambition[238]. To achieve this target, a substantial amount of public and private funds will be needed; as of July 2023, the **investment gap** between necessary and available investments stands at €174 bn, and investment needs are expected to increase as technologically advanced solutions are implemented across industries. The investment gap is likely to also create problems of competitiveness at the global scale in the future. Moreover, the substitution of all copper cables in networks is a difficult and costly task, and in many cases, customers still do not enjoy fibre connectivity up to their premises[239]. Nevertheless, telcos are working to cover as much of the network as possible with fibre technology: when optic fibre covers the distance from the distribution point to the customer's home or other premises, this is indicated as '**fibre to the premise' (FTTP) or 'fibre to the home' (FTTH)**, and is considered the ideal solution to enjoy the bandwidth benefits of fibre connectivity, as the data journey occurs entirely through optic cables. To develop last-mile network access solutions (among which FTTH and FTTP), telcos have created and deployed innovative technologies,

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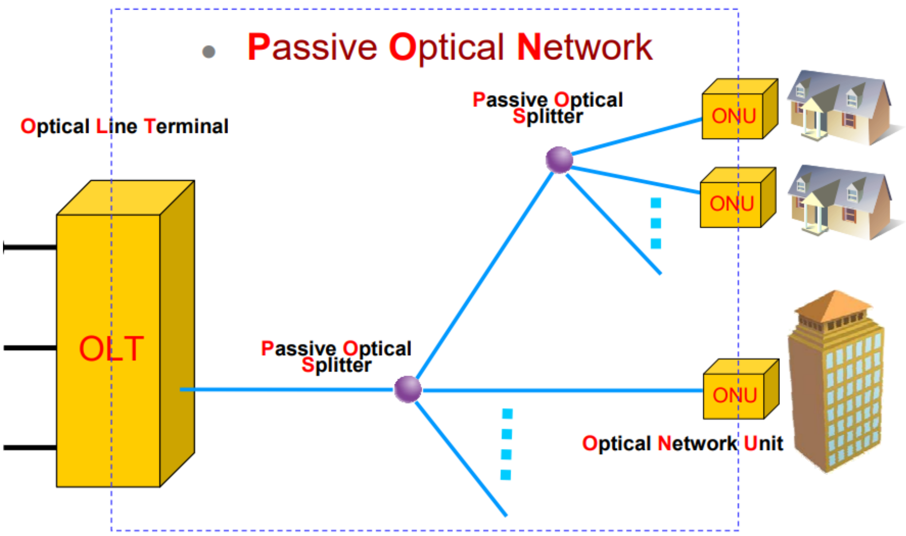
[231] Davies, N. (2023), 'Here's what quantum computing is—and how it's going to impact the future of work, according to a software engineer'. Fast Company, available at: https://www.fastcompany.com/90925065/heres-what-quantum-computing-is-and-how-its-going-to-impact-the-future-of-work-according-to-a-software-engineer
[232] Ibid.
[233] Yeh, C. (2012), *Applied Photonics*. Elsevier. Available at: https://shop.elsevier.com/books/applied-photonics/yeh/978-0-08-049926-0
[234] Senior, John M.; Jamro, M. Yousif (2009). *Optical fiber communications: principles and practice*. Pearson Education.
[235] Ibid.
[236] ETNO (2022), 'Shaping Policies to Support Investment in Very High Capacity Networks'. Available at: https://etno.eu/library/reports/103-investment-vhcn-2022.html
[237] European Electronic Communications Code (EU) 2018/1972 (EECC), Article 2(2). https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32018L1972
[238] European Commission (2023), *Broadband Coverage in Europe 2022: Mapping progress towards the coverage objectives of the Digital Decade*. Luxembourg: Publications Office of the European Union. Available at: https://digital-strategy.ec.europa.eu/en/library/broadband-coverage-europe-2022
[239] To explore the difficulties of telcos switching to FTTP networks, see: https://ifgconsultingeurope.com/the-hidden-challenges-of-moving-to-fibre%EF%BF%BC

the most popular of which is **gigabit passive optical networks (GPON)**, which are now widely used in the sector[240].

GPON concerns **last-mile connectivity**, and in GPON systems the delivery of connections ends at a passive optical splitter, which breaks the signal and divides it among a set number of customers (see *Figure 7* below)[241]. Signal-splitting in optic fibre has much fewer repercussions on the strength of the signal due to the properties of optic fibre, which does not allow the signal to deteriorate over long distances as copper would[242]. Nevertheless, PON technologies can come in different configurations, and the ongoing effort within the ecosystem seeks to establish which configuration can provide the maximum bandwidth to customers. The latest standard created for the next generation of PON is **Higher Speed PON**, approved by the International Telecommunications Union (ITU), which would boost the speed of VHCNs to up to 50 Gbit/s per wavelength (per user), from the current 10 Gbit/s of its most-used predecessors (XGPON)[243].

Figure 7. Configuration of a passive optical network



Source: Huawei, 'GPON Fundamentals'. Available at: http://jm.telecoms.free.fr/QCM_Fibre/GPON-Fundamentals_Huawei.pdf

Potential for sustainability

Optic fibre, photonics, and PON technologies have numerous advantages related to sustainability that are generated throughout the network and can impact the telco providers as well as the final users:

- **Energy consumption**. Optic fibre networks have been shown to increase network speed drastically while slashing carbon emissions in several European telcos: in particular, the power consumption of network maintenance can be reduced significantly (up to 75%) by upgrading networks to FTTH technology[244].
- **Carbon footprint**. GPON technologies are also more advantageous than VDSL and cable HFC (their predecessors), registering an emission footprint of respectively 28–41% and 12–29% less CO_2 (at average access rates higher than ~50Mbps)[245]. Newer generations of PON, such as XGS-PON, have an even lesser

[240] ITU (2021), 'New ITU standards to boost Fibre to the Home from 10G to 50G'. Available at: https://www.itu.int/hub/2021/06/new-itu-standards-to-boost-fibre-to-the-home-from-10g-to-50g/
[241] European Investment Bank (2020), 'How it works: GPON fibre to the home'. Available at: https://www.eib.org/en/stories/what-is-gpon
[242] Ibid.
[243] ITU (2021), 'New ITU standards to boost Fibre to the Home from 10G to 50G'. Available at: https://www.itu.int/hub/2021/06/new-itu-standards-to-boost-fibre-to-the-home-from-10g-to-50g/
[244] World Broadband Association, https://worldbroadbandassociation.com/wp-content/uploads/2022/09/The-Importance-of-Environmental-Sustainability-in-Telecom-Service-Providers-Strategy-World-Broadband-Association-White-Paper.pdf
[245] Ibid.

impact on the environment, which is an incentive to develop faster and more efficient PON solutions (such as higher-speed PON)[246].

- **Efficiency**. FTTH networks are more reliable and have no active network elements in the field, making them easier and less costly to operate. This translates into less staff needed, fewer repairs, and fewer trips needed to manage the network, which all represent a sustainability advantage[247].
- **Durability**. Fibre is considered 'future-proof', as the speed of connection is not limited by the material itself, but by terminal equipment[248]. This would limit the possibility of future substitution, making fibre a sustainable choice.
- **Enables other technologies**. VHCNs make sustainable high-connectivity solutions feasible and constitute, together with 5G, a key enabler for advanced technologies, including those that are key for sustainability in all sectors (some of which are discussed in this report)[249]. Advanced studies in photonics have the potential to develop powerful yet sustainable optical technologies for ground and satellite communications[250], data storage and processing, and intra-system connections[251]. Businesses of all kinds can benefit from these solutions, wherever there is a need to handle data.

Box 15. Telefònica: the place of fibre optic technology within a telco sustainability strategy

Spanish Telco Telefònica has included responsible network roll-out and operations in its broader sustainability strategy, which led the company to significantly cut back on its emissions and energy consumption while increasing its use of renewable energies. A key part of the plan has been the responsible management of network infrastructure, which entailed both network transformation (from copper to optic fibre) and an Energy Efficiency Programme. The solutions implemented at the network level do not stop at roll-out, however: to maintain network sustainability in the face of a steadily growing demand for connectivity (which would normally translate into higher energy consumption), Telefonica has implemented an all-encompassing management strategy. This included:

- The optimisation of power plants and heating,
- Projects for the renovation of ventilation and air conditioning (HVAC) equipment;
- Implementation of solutions to cool equipment by using air from outside;
- Projects to permanently shut down and decommission legacy networks;
- implementation of power-saving features in the access network; and
- A reduction in fuel consumption by the implementation of hybrid stations.

Interestingly, according to Telefònica's calculations, the impact of their sustainable practices has reflected in important sustainability gains for their customers: for each tonne of CO2 emitted by Telefónica, they estimate a saving of 1.2 tonnes at the customer level. Part of these gains stems from the technological solutions that connectivity enabled for end users.

Source: Telefònica, available at: https://www.telefonica.com/en/communication-room/blog/a-telcos-take-on-sustainability/

Projected social impact

The social impact of fibre technology is mainly tied to the **possibilities it can offer to customers**, which consist of higher speeds of connectivity and the possibility to use the newest technologies without restrictions. Indeed, in Europe, policymakers at all levels are looking to switch to fibre as part of their digitalisation strategies, which concern digital skills and infrastructure. For instance, the European Commission's Broadband Strategy aims to provide VHCN connectivity to European businesses and private customers, to **promote a more digital society and reduce the digital divide**[252]. If accomplished, the

[246] Ibid.
[247] Ibid.
[248] European Investment Bank, 'How it works'.
[249] Frontier Economics (2021), 'Shaping Policies to Support Investments in Very High-Capacity Networks'. Report for ETNO, available at: https://www.etno.eu/component/attachments/attachments.html?task=download&id=8164
[250] https://cordis.europa.eu/project/id/730149
[251] Testa, F., Bianchi, A., Stracca, S., Sabella, R. (2016). Silicon Photonics for Telecom and Datacom Applications. In: Pavesi, L., Lockwood, D. (eds) Silicon Photonics III. Topics in Applied Physics, vol 122. Springer, Berlin, Heidelberg. Available at: https://doi.org/10.1007/978-3-642-10503-6_15
[252] European Commission (n.d.), 'Support for Broadband rollout'. https://digital-strategy.ec.europa.eu/en/policies/broadband-support

complete switch to VHCNs should enable public administrations to provide technology-powered services to industries and citizens and open a wide array of digital possibilities for the private sector[253].

In the labour market, some technologies enabled by VHCNs have the potential to alter working conditions and organisation, as well as have implications for health and safety. Some of these are discussed in previous chapters of this report (see sections *2.1*- *2.5*, *2.8*). In terms of direct impacts on the labour market, fibre rollout to remote or unserved locations can have positive effects on rural economies and teleworking practices. One example of this is reported in the box below.

Box 16. The Case of rural Poland: How Fibre rollout can Bridge the Digital/regional divide

Światłowód Inwestycje (S.I.) and Nexera, two Polish companies, have recently obtained funding from the European Investment Bank for two projects aimed at bringing high-speed fibre connectivity to rural areas of Poland. The projects are financed through the European Fund for Strategic Investments as it represents a huge opportunity for the digital advancement of the regional areas of the country, which are among the least digitalised in Europe. In these contexts, fast connectivity will have a broad impact on public services such as education and healthcare, as well as on business applications, communication and entertainment. According to Anders Bohlin, a senior sector specialist at the European Investment Bank, the fibre switch will bring to rural areas a 'regional digital shift', and it will allow citizens to access new job skills and job opportunities. Furthermore, well-connected areas have the potential to attract investment and (tele)workers, possibly leading to a change in demographics as well.

Source: European Investment Bank (2021) 'Dare to Connect'. Available at: https://www.eib.org/en/stories/polish-fibre-projects?recommendation=1

2.8. Blockchain and technologies for cybersecurity

With the development of new technologies, faster internet speeds and more far-reaching networks, the concern of telcos with cybersecurity grows. In particular, 5G deployment, the Internet of Things, and cloud technologies can expose telcos to new and additional cybersecurity risks, due to intrinsic vulnerabilities that require to be addressed with technology and strategy[254]. Moreover, in the future, the possible development of industrial-scale quantum computers will require cybersecurity measures to be completely restructured and modelled around the quantum threat (see *Box 17* below for details). To address these challenges, the industry needs new technological solutions to maintain its data security while ensuring that the objectives tied to the twin transition are respected. In particular, new technologies that show potential to address telcos' cybersecurity concerns include **blockchain, defensive AI and behavioural analytics**. While the latter two technologies are specific applications of technologies we have already discussed (respectively, AI and big data), blockchain is a technology that originated in the world of cryptocurrencies and is now finding applications across various sectors, particularly in the realm of cybersecurity. Other process-based measures that are being employed in the telecom industry include DevSecOps[255] and strategies for API security[256].

Among the technologies showing potential to enhance telco cybersecurity:

- **Blockchain** is defined as a public ledger consisting of all transactions taking place across a peer-to-peer network. It is a data structure consisting of linked blocks of data, e.g. confirmed financial transactions with each block pointing/referring to the previous one forming a chain in linear and chronological order'[257]. Blockchain can enhance the security of transactions, which can involve contracts, payments,

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[253] Ibid.
[254] EY (2020), 'Aligning cybersecurity to enable the Telco metamorphosis in a post-COVID-19 era'.
[255] DevSecOps is a methodology for team organization in software development. It foresees the integration of security measures at all stages of work, in opposition to older methods of development in which security was a concern only addressed at the end of the software development process. DevSecOps does not only make software more secure, but it also ensures cost-effectiveness and efficiency. More information available at https://www.ibm.com/topics/devsecops
[256] APIs constitute the backend framework of mobile and web applications. Their security is a rising concern, especially with the implementation of IoT: in fact, IoT applications gather and process data, and often information inserted by users gets processed within the same environment housing the API. This exchange of sensitive information between APIs, users, and applications/websites exposes data to vulnerabilities. More information on mitigating strategies available at https://www.fortinet.com/resources/cyberglossary/api-security
[257] ENISA (n.d.), 'Blockchain'. Available at: https://www.enisa.europa.eu/topics/incident-response/glossary/blockchain

records, or other sensitive information, enhancing trust and security in networks (see Figure 8). While in Europe blockchain has not yet been adopted at a large scale by telcos, examples from overseas and experiments within our continent are showing promise and a growing demand for skills in this sector[258]. Within telcos, blockchain is being used:

  - As a tool to prevent frauds, such as roaming frauds;
  - To optimise ID management, using processes based on smart contracts;
  - To enable access technology selection mechanisms required by 5G networks;
  - To optimise supply chains;
  - To improve the cost-efficiency of IoT connectivity.

- **Defensive AI** is an application of AI or ML for cybersecurity purposes. Although these applications are still not widely used, some use cases exist, and experts predict that their importance will continue to grow in the future[259]. Importantly, their use can in turn create new vulnerabilities tied to ML-specific cyber-attacks, for which new defences are being developed[260]. It is used in telcos for the following cybersecurity applications[261]:
  - Detection of fraudulent usage of mobile subscriptions;
  - Detection of misbehaving IoT devices, which is also a feature in the 3GPP Network Data Analytics Function;
  - Detecting false base stations;
  - Detecting malicious workloads in cloud-native environments.
- **Behavioural analytics** combines big data with applied analytics, most of which are now AI-powered, to analyse user behaviour in real-time and identify potentially suspicious patterns of use. This helps prevent fraudulent activity, and strengthen data security, by blocking attacks before they occur[262]. This technology may also detect 'insider' threats, that are (or are masked as) inside the organisation's network[263].

Big issues surrounding cybersecurity solutions that track employees and users' behaviour (such as behavioural and predictive analytics, but also certain uses of AI and ML algorithms) are privacy, use transparency, and the **respect of individual rights** more broadly. This perspective follows European efforts to regulate AI applications to ensure their safety and compliance with European values and regulations, such as the Artificial Intelligence Act[264]. These concerns are also in line with the General Data Protection Regulation (GDPR)[265], stating that European citizens have the right 'not to be subject to automated decision making, including profiling, which produces legal effects or otherwise significantly affects them and/or their personal interests'[266]. In this sense, behavioural analytics or similar AI or big data applications may develop unfair biases or discrimination of users, which would harm the citizens' rights to non-discrimination. At the same time, extensive data profiling may go beyond the lawful scope of personal data usage, putting citizens (and employees, in this case) at risk of personal information exposure[267]. Recent data shows that in many workplaces, behavioural analytics are already being used in many companies, not only for cybersecurity

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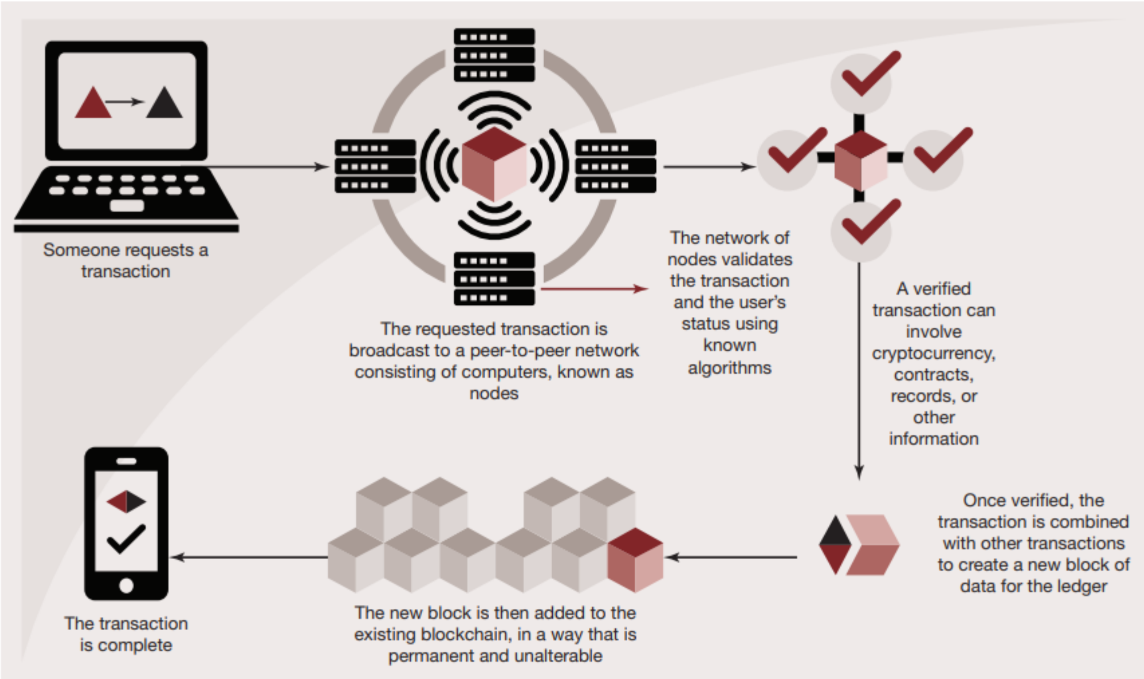
[258] Telefònica Tech (2021), 'Growing impact and future potential of blockchain for telcos: A Game Changer?' Available at: https://telefonicatech.com/en/blog/growing-impact-and-future-potential-of-blockchain-for-telcos-a-game-changer
[259] Ericsson (2020), 'On the relationship between AI and security in mobile networks'. Available at: https://www.ericsson.com/en/blog/2020/10/ai-security-mobile-networks
[260] Ibid.
[261] Ibid.
[262] Ericsson (2022), 'Research on adversarial security modelling in RAN: User Behaviour Analytics and Deception'. Available at https://www.ericsson.com/en/blog/2022/6/research-adversarial-security-modeling-in-ran
[263] Ibid.
[264] Available at: https://artificialintelligenceact.eu/the-act/
[265] Regulation (EU) 2016/679 of the European Parliament and of the Council of 27 April 2016 on the protection of natural persons with regard to the processing of personal data and on the free movement of such data, and repealing Directive 95/46/EC (General Data Protection Regulation). Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32016R0679
[266] Ronchi, A. (2022), 'Big Data & Machine Learning Data Analytics & New Trends'. In Pavan Duggal (ed.), *Cybercrime, cyberlaws, cybersecurity*, New Delhi: ICCC Academy. Available at: https://re.public.polimi.it/handle/11311/1234898?mode=complete
[267] Ibid.

purposes, often without the knowledge of employees[268]. Naturally, these uses of the technology are highly problematic from a rights perspective. Technological applications that track uses for any purpose should always be duly justified, and their use should be negotiated through social dialogue in a transparent manner, to ensure workers' rights are fully respected[269]

Figure 8. How Blockchain works



Source: https://www.strategyand.pwc.com/m1/en/reports/blockchain-for-mena-telecom-operators.pdf

Box 17. Quantum technologies: risks for telco cybersecurity

Quantum computers, and more precisely Cryptographically Ready Quantum Computers (CRQC) represent an enormous potential for technological advancements for telcos (see *section 2.5*). However, when discussing cybersecurity implications, quantum can represent a risk as well as an opportunity. The computational power of quantum computers will give them the ability to break into most cryptographic systems used today, exposing massive quantities of data to leaks. That is why governments and businesses across sectors are preparing to transition to quantum-safe cryptography, through the development of standards and solutions[270]. According to GSMA, the world's largest telecommunications association, telcos should be prepared for the advent of quantum and its security risks by preparing for attacks that may originate in the future from CRQCs, but also by preparing for present cyberattacks from (potentially) quantum-capable actors, that aim to steal information with the intent to decrypt it later, when they will have acquired or developed the necessary CRQCs[271]. Official guidelines have been developed by GSMA to avert these risks[272]. These include increased planning and awareness of the quantum risk, through risk frameworks, risk assessment plans, and the creation of a transition plan towards quantum-ready cryptographic systems.

Source: Visionary Analytics, based on sources indicated in the text.

Potential for sustainability

The technologies discussed above, while they are tied to cybersecurity, also have the potential to contribute to the sustainability of telcos. While the environmental implications of AI and big data have already been

[268] UNI Europa (2021), 'A Workers' perspective on Artificial Intelligence (AI) and Surveillance'. Available at: https://www.uni-europa.org/news/a-workers-perspective-on-artificial-intelligence-ai-and-surveillance/
[269] Ibid.
[270] IBM (2023), 'Securing telecoms networks for the post-quantum era'. Available at: https://research.ibm.com/blog/quantum-safe-telecoms-ibm
[271] GSMA (2023), 'Guidelines for Quantum Risk Management for Telco'. Available at: https://www.gsma.com/get-involved/working-groups/gsma_resources/guidelines-for-quantum-risk-management-for-telco
[272] Available at: https://www.gsma.com/get-involved/working-groups/gsma_resources/guidelines-for-quantum-risk-management-for-telco

discussed in the relative sections (*2.4* and *2.1* respectively), blockchain stands out as a technology having multiple applications, some of which are related to sustainability. A recent publication[273] shows that applications of blockchain technologies can help increase sustainability across sectors; some solutions can also apply to telcos, for instance:

- **Using blockchain to improve the carbon credits market**. The carbon market is being employed as a solution to compensate for or reduce emissions across sectors, including telecommunications. This solution entails the view of carbon as a 'commodity', transformed into positive credits (carbon offsets) or certificates of reduced emissions that can be traded with heavier emitters[274]. Unfortunately, the carbon credit industry suffers from various problems, including a lack of transparency and fragmented implementation. These issues could reflect on the final users and on companies relying on this system to lower their carbon footprint. Blockchain could help solve this, by creating a token-based system in which buyers and sellers can use a platform on blockchain to trade carbon credits[275]. Such a solution would also entail smart contracts, transparently registered on the same platform[276]. A positive example of this mechanism comes from the Climate Action Data Trust, which has started to offer blockchain-based carbon credits[277].
- **Implementing blockchain-based proximity energy grids**. Some European telcos have entered the energy market, as they turn to renewable energy generation to fulfil their considerable power needs, or even provide solutions for customers who wish to depend on renewable energy[278]. Blockchain platforms have the potential to make this easier by providing a trusted and secure environment in which peer-to-peer renewable energy transactions can be conducted without the need for third-party energy brokers[279]. This solution represents a service provision opportunity for telcos dealing in renewables, or depending on them, which would also increase the sustainability of their customers.
- **Tracking supply chains**. Other sectors, such as retail, are experimenting with blockchain to ensure trustworthiness and transparency in their supply chains, making use of smart contracts (contracts that are translated into code and stored on a blockchain) and registering, validating and sharing all transactions among partner companies involved in supply chains, thanks to a single, efficient blockchain platform[280].

Projected social impact

Regarding the social impacts of cybersecurity technologies in the labour market, these have already been discussed in chapters *2.4* and *2.1* for AI and data analytics (respectively). We will then turn to focus on the implications of blockchain solutions.

It is important to note how telcos will require **specific skill profiles** to implement blockchain solutions; the most requested employee profile related to this technology is blockchain developer, a figure able to build and manage blockchain systems. It is likely, however, that telcos already employ developers capable of providing such solutions[281]. Moreover, telcos are uniquely positioned in the ecosystem to be able to develop and scale blockchain solutions, as most of them would probably have a large database of partners, which could be able to help acquire the relevant skills and/or provide expertise through ad-hoc partnerships[282].

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[273] Elshin, L.A., Burganov, and Abdukaeva (2022), 'Assessing the Impact of Blockchain Technologies on Environmental Sustainability'. *Procedia Environmental Science, Engineering and Management,* 9(1), pp. 1-6. Available at: https://www.procedia-esem.eu/pdf/issues/2022/no1/1_Elshin_22.pdf
[274] Saraji, S. and Borowczak, M. (2021), 'White Paper A Blockchain-based Carbon Credit Ecosystem'. Available at: https://arxiv.org/ftp/arxiv/papers/2107/2107.00185.pdf
[275] Ibid.
[276] Ibid.
[277] More information can be found at https://climateactiondata.org/the-role-of-blockchain-technology-and-robust-digital-infrastructure-in-shaping-the-future-of-carbon-markets/
[278] See https://www.oliverwyman.com/our-expertise/insights/2021/may/next-level-of-emission.html
[279] See https://www.monash.edu/news/articles/blockchain-technology-enables-secure-energy-trading-between-neighbours
[280] See https://www2.deloitte.com/us/en/pages/operations/articles/blockchain-supply-chain-innovation.html
[281] PwC (2019), Blockchain for MENA telecom operators: seizing the opportunity'. Available at: https://www.strategyand.pwc.com/m1/en/reports/blockchain-for-mena-telecom-operators.pdf
[282] Ibid.

This could even lead to telcos commercialising their blockchain solutions, as they can typically count on close relationships with customers, especially in the technology and public sector[283].

Another possible area of impact of blockchain technology is their potential **impact on work organisation**. Some applications of blockchain could simplify company procedures: primarily, the implementation of smart contracts, which employ blockchain to verify customer identity digitally, enhancing data security and privacy (although methods of this kind would have to be supported by digital ID initiatives at the institutional level)[284]. This kind of application of blockchain could potentially remove the need for external services for identity verification, which would be substituted by the trustworthiness and security of smart contracts; moreover, telcos wouldn't need to store customers' private data[285]. In the second instance, the security coming from blockchain implementation at the company level can make telcos safer workplaces. Telecom networks manage vast amounts of sensitive data, from employees' information to network configurations. Blockchain offers a more secure way of managing and protecting this data through its decentralized and cryptographic features[286].

Helping to **secure employee and customer data** through blockchain, and preventing the risk of breaches, are important issues that reach beyond the violation of privacy regulations. Indeed, new evidence has emerged from the European Agency for Safety and Health at Work that cybersecurity threats may impact workers' health and safety directly[287]. More specifically, the following impacts of cybersecurity breaches can be felt on workers' health and safety[288]:

- Physical injuries (such as loss of lives deriving from a failure of a cyber-physical system)
- Mental health injuries (such as anxiety or frustration)
- Impact on personal rights (privacy violation deriving from data breaches)
- Personal economic damage.

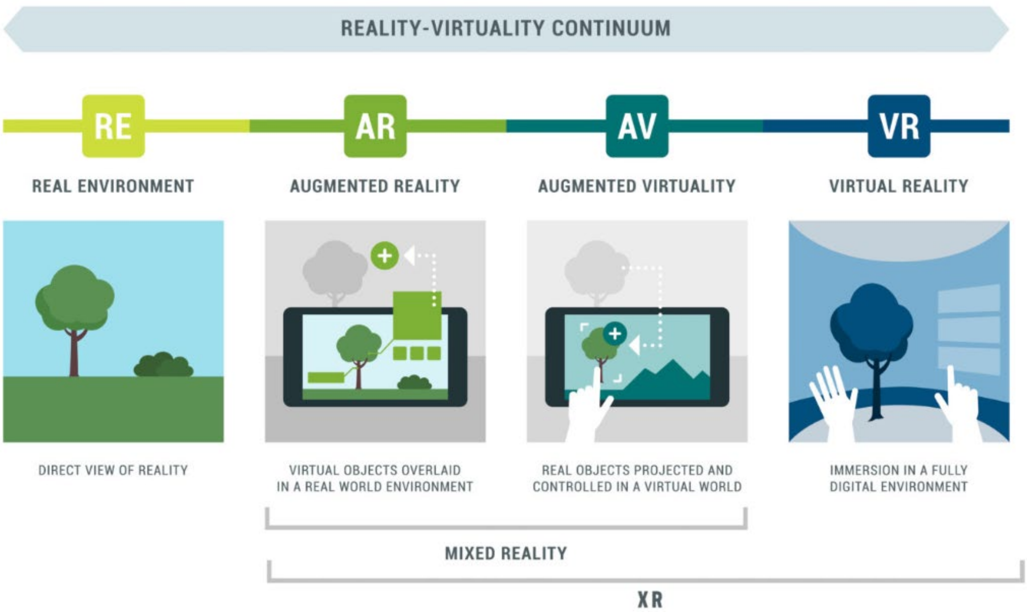
In this context, it becomes then paramount to adopt mechanisms and technologies that improve workers' awareness of possible cybersecurity threats, as well as adopting technologies (such as blockchain) which may help telcos make the cyber workspace more cyber secure.

2.9. Extended reality

The term 'extended reality' is an umbrella term including virtual reality (VR), augmented reality (AR) and mixed reality (MR), as well as any potential digital reality[289]. These technologies use a combination of software, hardware, and/or additional technologies (e.g., cloud computing, 5G/6G connections, haptic sensors, and so on) to enrich reality (e.g., with the overlap of images, sounds and digital elements) or to immerse the user into a digital reality which aims to simulate a virtual world[290]. The technologies belonging to this realm exist in various stages of a spectrum, which contemplates the real environment (i.e., unaltered by technology) on one end, and the virtual world (i.e., fully digital) on the other end (see figure below). Following this logic, XR technologies can incorporate more or less elements that are fully virtual, and according to this, they are defined differently.

[283] Ibid.
[284] Weaver Labs (2023), 'Blockchain: The Future of the Telecoms Industry'. Available at: https://medium.com/weaver-labs/blockchain-the-future-of-the-telecoms-industry-b12cf9ca203e
[285] Ibid.
[286] Reintech (2023), 'Blockchain in Telecommunications: Use Cases and Applications'. Available at: https://reintech.io/blog/blockchain-in-telecommunications-use-cases-applications
[287] Corradini, I., for OSHA (2022), 'Incorporating occupational safety and health in the assessment of cybersecurity risks'. Available at: https://osha.europa.eu/en/publications/incorporating-occupational-safety-and-health-assessment-cybersecurity-risks
[288] Ibid.
[289] Visionary Analytics for DG-CNCT (forthcoming), 'Zero-distance XR applications and services'.
[290] Ibid.

Figure 9. The reality-virtuality continuum



Source: CreatXR, available at: https://creatxr.com/the-virtuality-spectrum-understanding-ar-mr-vr-and-xr/

In particular, the concerned XR applications have produced various definitions. We present the most common below:

- **Virtual Reality** (VR) is a 3D environment in which a person can become immersed, using a dedicated headset, powered by a computer, game console or smartphone.'[291]. Famously used for gaming applications, this technology has found a wide range of applications, for instance in the education and training sectors (learning through simulation and situational learning), or applications in the fields of advertising, marketing, cultural exhibitions and festivals.
- **Augmented Reality** (AR) 'refers to the real-time digital overlay of information over physical elements'[292]. It consists of applications aimed at overlaying information on the physical reality, for example by displaying information on a particular work of art when this is framed by a smartphone camera.
- **Mixed reality** (MR) is an umbrella term to indicate the continuum between digital and physical entities, that can be combined in various solutions in virtual or physical worlds.
- **Digital twins** are a virtual replica of a physical product, process or system'[293] that can be used to re-create products or environments or simulate scenarios in various contexts. For instance, in industrial settings, digital twins of a production system can be used to predict when or under which circumstances a machine will fail, through simulation and data analysis[294]. Digital twins are generally not considered part of XR technologies, but they can, in particular cases, be integrated into XR solutions. For instance, the user can experience, or control, the reality of a digital twin through VR hardware, in situations in which real decision-making must be simulated, or for educational purposes (situational training)[295].

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[291] Ecorys (2017), 'Virtual Reality and its potential for Europe'. Available at: https://ec.europa.eu/futurium/en/system/files/ged/vr_ecosystem_eu_report_0.pdf

[292] European Commission Digital Transformation Monitor (2017), 'Augmented and Virtual Reality'. Available at: https://ati.ec.europa.eu/sites/default/files/2020-05/Augmented%20and%20Virtual%20Reality%20vf.pdf

[293] European Commission (2020), 'ELISE - European Location Interoperability Solutions for e-Government – Glossary'. Available at: https://joinup.ec.europa.eu/collection/elise-european-location-interoperability-solutions-e-government/glossary/term/digital-twin#:~:text=Digital%20twins%20create%20a%20virtual,increase%20productivity%20through%20predictive%20maintenance.

[294] Ibid.

[295] See for example: Kaarlela, Tero, Paulo Padrao, Tomi Pitkäaho, Sakari Pieskä, and Leonardo Bobadilla. 2023. "Digital Twins Utilizing XR-Technology as Robotic Training Tools" Machines 11, no. 1: 13. https://doi.org/10.3390/machines11010013

These technologies are both enabled by telcos and directly applied within the value chain. As potential and current uses of XR and digital twins in telecommunications, we have identified the following[296]:

- Broadcast of augmented reality holograms and transmissions, e.g. sports events[297];
- Use as a tool for technical assistance: service technicians could get aid in AR from senior technicians, reducing travel and increasing efficiency;
- Use as a training tool for employees;
- Front-office applications, as customer service applications and as marketing tools[298];
- Network design and migration (see box below);
- There is potential for telecoms to create and market software and services for the Metaverse, which could represent a new market and/or investment opportunity for the sector[299]. This application is particularly important for telcos that plan to become key service providers in the AI ecosystem, as artificial intelligence is projected to intersect with metaverse use and applications[300].

Box 18. Use case: digital twins for network design

Finnish telco giant Nokia has designed its new **5G radio access sites** thanks to digital twin technology. From one site visit, Nokia's engineers have been able to build a complete 3D model of the site, and to make it available to site designers and involved personnel whenever required, without the need to travel. This was done by storing the data (including installation height, antenna tilt, azimuth angles and other measurements) in a cloud infrastructure, where it could be retrieved remotely. In parallel, a full virtual digital twin of the site helped engineers simulate and study the site's projected characteristics, such as the behaviour of bearing structures, antennas, radios, baseband units, and all the equipment planned for the site. The increased availability of site-related data and mappings reduced the number of site visits by 30% in the design phase and made the overall process 20 per cent faster than manual methods for site design.

As well as efficiency, this use case highlights the potential of this technology to increase sustainability and work safety:

- **Sustainability** is increased thanks to the reduced travel required to plan and study the network site, as well as through efficient optimisation of the resources required to build and power the site, which can be studied in greater detail thanks to the data available to workers.
- **Working conditions** are safer for the personnel involved, as simulation takes the place of hazardous site visits and in-person trials which could expose workers to potentially unsafe conditions (for instance, tower climbing for data collection is replaced once by drones, and afterwards by remote data retrieval).

Source: Nokia (2023), available at https://www.nokia.com/blog/transform-your-5g-network-design-with-a-digital-twin/

Potential for sustainability

The projected use cases in the telecommunication industry find potential for sustainability, both directly and in terms of enabling sustainable solutions for other sectors. In terms of direct applications, these technologies could be applied in:

- The field of telco **customer service**, which could implement remote troubleshooting for their network products, allowing technicians and support staff to help customers with product malfunctions remotely. This would save costs, and resources, and reduce carbon emissions (fewer physical journeys for staff mean a big cut in transport-related carbon emissions)[301].

[296] Cherukuri, N. (2023), 'How Augmented Reality (AR) And 5G Could Impact Telecommunications'. Forbes, available at: https://www.forbes.com/sites/forbestechcouncil/2023/04/06/how-augmented-reality-ar-and-5g-could-impact-telecommunications/

[297] See the use case piloted by BT in the UK: the BT Sports App will be able to literally 'immerse' its users into sports broadcasts thanks to AR/VR and 5G. Source: https://www.telcotitans.com/btwatch/bt-sport-app-enters-a-new-reality/2600.article#:~:text=BT%20has%20been%20collaborating%20with,(BTwatch%2C%20%23309).

[298] See for example EON's commercial solution for the provision of AR/VR applications to telcos: https://eonreality.com/wp-content/uploads/2020/06/8.2-Augmented-Virtual-Reality-for-Telco-Providers.pdf

[299] https://www.ey.com/en_au/telecommunications/seven-ways-telecom-operators-can-power-the-metaverse

[300] Taaffe, J. (2023), 'SK Telecom's bet on immersive experiences'. Available at: https://inform.tmforum.org/features-and-opinion/sk-telecoms-business-bet-on-immersive-experiences

[301] Waicberg, S. (2022), 'Augmented reality advances organisation ESG initiatives'. Sustainability, available at: https://sustainabilitymag.com/esg/augmented-reality-advances-organisation-esg-initiatives

- **Digital twins of data centres**, which would allow optimisation of energy resources, as well as streamlining of machine upkeep and fault prediction. Taking the manufacturing industry as a model, telecoms can create digital twins of networks to simulate downtime scenarios and predict failures, with positive consequences for energy consumption[302]. In this scenario, the intersection between digital twins and AI/ML applications can be fundamental to ensure optimal energy efficiency in data centre cooling systems, as well as data analysis for energy efficiency[303].

On the other hand, telcos can play a key role in sustainability by **enabling environmentally friendly XR applications in other sectors**. Fundamentally, XR technologies require stable, low-latency networks to function optimally, and the telecommunication sector will need to provide these to enable more sophisticated XR-based sustainability solutions. 6G networks in particular will enable a wider range of services, such as robotics-based solutions for industry, digital twins' development as a service, and/or VR entertainment as a service[304]. Many of these applications can also have crucial impacts on the sustainability of the target sector, although further data is needed as XR technology is employed in practice; for instance, the promise is great in the manufacturing sector, which would employ XR solutions for quality management, training, and maintenance support, with possible intersections with other emergent technologies, to improve the efficiency and environmental performance of factories[305].

Projected social impact

In the field of skills, there is already a consistent number of examples of XR technologies being used to **train telco employees.** The skills on offer from this kind of training simulation experience – that can be conducted in augmented, mixed, or virtual reality – vary widely. For instance, customer service employees can learn how to interact and communicate effectively with customers in a professional manner, without risks or repercussions for the employer[306]. Training can also be aimed at geographically distributed personnel who can be onboarded remotely and receive training to install and/or service hardware and products[307]. Other use cases include sales departments, logistics and technical support, as well as company-wide applications for health and safety training. Indeed, VR simulations have the added benefit of reducing work-related hazards when used company-wide, as employees can benefit from VR-based learning to deal with difficult and potentially hazardous situations, reducing their likelihood of getting injured while working in real life[308]. Some examples include malfunctioning equipment, power outages, live shooter situations (e.g., in retail branches), first aid scenarios, and more. From this point of view, XR applications can revolutionise the world of work by producing more aware and prepared workers.

Another potential area of impact for these technologies is the possibility of being used **remotely**. The use of XR hardware and software for meetings and employee training could encourage remote working and the provision of services such as remote maintenance of technical appliances[57]. VR could also be used to onboard new remote colleagues to the organisation, which could help boost employee retention[58]. As previously discussed, shifts to remote working entail a restructuring of work organisation, and the addition of XR technologies to the telework revolution could translate into a wider array of tasks that will be possible to perform remotely.

[302] Ericsson, 'The future of digital twins: what will they mean for mobile networks?' https://www.ericsson.com/en/blog/2021/7/future-digital-twins-in-mobile-networks
[303] Thomas, A. (2022), 'How AI and automation make data centers greener and more sustainable'. EY, available at: https://www.ey.com/en_in/technology/how-ai-and-automation-make-data-centers-greener-and-more-sustainable
[304] Ericsson, 'The future of digital twins'.
[305] Sebastian Thiede, Roy Damgrave, Eric Lutters (2022), 'Mixed reality towards environmentally sustainable manufacturing – overview, barriers and design recommendations'. Procedia CIRP, 105, pp. 308-313. Available at: https://doi.org/10.1016/j.procir.2022.02.051.
[306] See for example: https://www.gmetri.com/justaboutreal/xr-customer-interaction-training-for-a-telco-giant/
[307] Fromkin, S. (2020), 'How can extended reality improve employee performance and retention?' *Talespin*, available at: https://www.talespin.com/blog-post/how-can-extended-reality-training-improve-employee-performance-and-retention
[308] Ibid.

2.10.5G and 6G Networks

Mobile networks have undergone significant transformations approximately every decade since the advent of 1G. **Fifth-generation mobile network**, or **5G**, is the latest iteration of cellular technology. It is considered a pivotal technology for innovation and digital transformation by the European Commission[309]. Compared to its predecessor 4G, 5G boasts significantly faster speeds, lower latency, and enhanced connectivity, supporting up to 100 times as many devices[310]. For this reason, operators in Europe and the rest of the world are working to switch off their 2G and 3G networks, which will result in improved services, decreased maintenance costs, and energy savings (see the section on 'potential for sustainability' below for further details). As of December 2023, 5G coverage has reached 82% of EU coverage[311], with telecom leaders like Deutsche Telekom achieving a 94% coverage rate in Germany by 2022[312]. This shows a clear commitment by telcos to expand 5G networks in Europe.

As per findings from the European Startup Network, 5G holds the potential to generate 2.4 million jobs and contribute €1.2 trillion to the economy by 2025[313]. 5G technologies offer a wide range of use cases across multiple domains, leveraging their high-speed, low-latency, and massive connectivity capabilities. Some examples are:

- **Smart cities, smart homes, etc.:** together with technologies like IoT or AI, 5G enables the development of smart city and smart home solutions, including real-time monitoring of traffic, waste management, energy consumption, and other services. It facilitates efficient urban planning and resource management[314][315].
- **Telehealth:** 5G supports telemedicine applications, allowing for real-time remote patient monitoring, surgical assistance through augmented reality, and quick sharing of medical data between healthcare professionals[316].
- **Autonomous vehicles:** 5G's low latency is crucial for enabling communication between autonomous vehicles and their surrounding environment[317]. This is vital for ensuring quick responses and enhancing road safety.
- **Tele-education:** 5G supports advanced educational tools such as virtual classrooms, online collaborative learning environments, and immersive educational experiences through Augmented Reality (AR) and Virtual Reality (VR)[318].

However, although we are still navigating the era of 5G, conversations among researchers and practitioners have already shifted towards the future – **6G** technologies. According to a recent study, the next decade is poised to witness significant lifestyle and societal changes, reshaping the landscape of 6G networks. 6G presents significant improvements vis-à-vis 5G, and its potential use cases include[319]:

- **Immersive communications**: in the future, 6G might enable real-time communications through XR applications, holograms, multi-sensory telepresence and more. Such means of communication will

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[309] European Commission (n.d), '5G'. Available at: https://digital-strategy.ec.europa.eu/en/policies/5g
[310] Cisco (n.d), 'What is 5G vs 4G?'. Available at: https://www.cisco.com/c/en/us/solutions/what-is-5g/5g-vs-4g.html
[311] ETNO (2024), 'State of Digital'.
[312] Parcu, P. L., et al. (2023), 'The future of 5G and beyond: Leadership, deployment and European policies'. Available at: https://www.sciencedirect.com/science/article/pii/S0308596123001337
[313] EU Startup news (2023), '5G and Startups in the EU: Building a stronger digital future'. Available at: https://eustartup.news/5g-and-startups-in-the-eu-building-a-stronger-digital-future/
[314] Forbes (2022), 'Smart Cities and 5G: Taking it to the next level'. Available at: https://www.forbes.com/sites/deloitte/2022/11/15/smart-cities-and-5g-taking-it-to-the-next-level/
[315] Arjmandi, M. K. (2016), '5G Overview: Key technologies'. Available at: https://web.archive.org/web/20200709223338id_/http://www.ittoday.info/Excerpts/5G-Overview-Key-Technologies.pdf
[316] Georgiou, K. E., et al. (2021), '5G Use in Healthcare: The future is present'. Available at: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8764898/
[317] Telekom (n.d), '5G network as foundation for autonomous driving'. Available at: https://www.telekom.com/en/company/details/5g-network-as-foundation-for-autonomous-driving-561986
[318] World Bank (2021), 'How can 5G make a difference to education?'. Available at: https://blogs.worldbank.org/digital-development/how-can-5g-make-difference-education
[319] International Telecommunication Union (2023), *Recommendation ITU-R M.2160-0 (11/2023):* 'Framework and overall objectives for the development of IMT for 2030 and Beyond'. Available at: https://www.itu.int/dms_pubrec/itu-r/rec/m/R-REC-M.2160-0-202311-I!!PDF-E.pdf

require low latency and high reliability to simultaneously convey multi-sensorial information, and support interaction between virtual and real elements.

- **Hyper-reliable and low-latency communication**: 6G would extend the ultra-reliable and low-latency standards of 5G.
- **Connectivity for All Things**: the interconnectivity between different domains and everyday functions, such as water supplies, agriculture, continuous power, and transportation and logistics networks, will necessitate a robust network connection.
- **Ubiquitous connectivity**: this scenario involves making connectivity ubiquitous, including in those areas where the digital divide is still an issue.
- **AI and communication**: 6G could support distributed computing and AI applications such as autonomous cars, prediction on digital twins, AI in medicine, and more.
- **Integrated sensing and communication**: applications and services requiring sensing would become easier to operate, including high-precision positioning, including object detection, estimation of range, velocity, and angle estimation, and more.

These advancements highlight the need for updates in future networks. However, as 6G is still in the discussion/exploration stage, this report will primarily focus on the current state of 5G. One closer development in the field of mobile networks will be stand-alone 5G, discussed in the box below.

Box 19. Stand-alone 5G networks

'Stand-alone' or SA 5G is the technical way to refer to a network that does not require 4G core network infrastructure. The earliest implementations of 5G, in fact, relied on core 4G networks to handle connection; this allowed for a faster 5G deployment, but suffered from the limitations of 4G LTE latency (much higher than in 5G SA networks). European telcos are then looking to progress to SA networks where possible, but a staggering 93% of European 5G networks are still not stand-alone. Deutsche Telekom is one example: DT is gradually implementing a 5G rollout to fully transition to stand-alone 5G in the future. However, this is done while operating in tandem with 4G, strategically leveraging its existing 4G network infrastructure to maintain maximum efficiency and reduce costs, but with planned strategies to facilitate transition when possible. Indeed, this shift necessitates several developmental steps before a full-fledged switchover can be realized: SA technology will need to be improved in technical terms, and user hardware (such as smartphones) will have to support SA technology before a complete switch is justified. Indeed, at present, while SA does open up many possibilities in technology implementation, such an efficient and low-latency network may suffer by lack of user demand, as user technology uptake might be lagging behind what 5G SA can offer.

Source: ETNO (2024), 'State of Digital' and Deutsche Telekom (2021), '5G roll-out: Some stand alone, we stand together'. Available at: https://www.telekom.com/en/blog/group/article/5g-roll-out-we-stand-together-640602

Potential for sustainability

5G holds important implications for the sustainability of telcos, of companies within other sectors, and of the broader society. **Optimization of energy utilization, effective information sharing, and enhanced resource efficiency** are indeed among the primary objectives pursued by 5G[320]. On the one hand, 5G networks exhibit a 90% improvement in energy efficiency compared to their 4G counterparts when considering data bits per kilowatt. On the other hand, substantial **rises in density and traffic** are anticipated to offset these gains, resulting in a net 5G energy consumption that could be 4 to 5 times higher than that of 4G[321]. In some respects, this mirrors the challenge faced by the airline industry which is constantly reducing emissions per passenger mile travelled but also seeing an inexorable growth in volumes. The big difference, however, is that the airline industry is not enabling rapid transformation in other industries.

5G is a key enabler for other technologies, such as Edge computing, IoT, and AI, which in turn can support more sustainable solutions for people and businesses (see sections 2.3, 2.4, 2.5). For smartphones (by far the

[320] Palazzo, M., & Siano, A. (2021), 'Fifth-generation (5G) communication networks and sustainability: A research agenda'. Available at: https://journals.francoangeli.it/index.php/cgrds/article/view/10459

[321] Viavi Solutions (n.d), 'What is 5G energy consumption?'. Available at: https://www.viavisolutions.com/en-us/what-5g-energy-consumption

device category with the largest contribution to carbon emissions), 5G's higher frequencies will result in lower device energy consumption for the same applications. In practice, we can expect 5G to result in more energy and throughput-intensive applications being enjoyed for longer periods[60]. Furthermore, 5G substantially enhances connectivity, particularly for remote and rural areas with an unstable internet connection[322] (for example, see *Box 20* below). This, in turn, leads to more societal sustainability. Given these benefits, 5G has been argued to contribute to the achievement of the UN's Sustainable Development Goal 8, which concerns decent work and sustainable economic growth[323].

Box 20. Use cases - 5G improving sustainability of the telco ecosystem (TIM) and beyond (RuralDorset)

Direct environmental impact of 5G: TIM and 5G sustainability

TIM's 5G strategy seeks to implement 5G networks by balancing sustainability with technological and business performance indexes. To do so, the company is implementing the following solutions as part of their 5G transition:

- Maintaining an open network architecture, in order to benefit from present and future technological applications for energy saving, such as AI-based energy optimisation systems.
- Using the most efficient hardware elements, such as radio and baseband modules, and privileging intelligent software features (e.g., MIMO sleep) that may contribute to further energy consumption reduction.
- Switching off 3G networks and replacing it with 2G, 4G and 5G connectivity.
- By enabling sustainable solutions in industrial ecosystem: for instance, TIM offers personalised services aimed at optimising production processes and operations management. These services are varied and may concern advanced applications such as Autonomous Driving Vehicles (AGV), Drones, Video Analytics, Smart Monitoring, Smart Logistics, Smart Manufacturing, Smart City, Healthcare 4.0 , Smart (Air)Port, Agriculture 4.0.

Indirect environmental impact of 5G: RuralDorset

The 5G **RuralDorset** project in southern England shows how 5G can benefit rural areas. Led by Dorset Council and Qualcomm Technologies, the project used 5G to improve farming and community services. The results show that 5G can enhance farming by helping robots identify and treat weeds, potentially increasing crop yields by 200%. Additionally, it improved the transfer of drone images and helped quickly identify cattle health issues. The project demonstrated that 5G can provide reliable and affordable solutions for rural challenges, making farming more efficient and sustainable.

Sources: interview with a TIM representative, 05/03/2024), Castellani et al. (2023), '5G ed Efficientamento Energetico'. *Notiziario Tecnico TIM*, available at : https://www.gruppotim.it/it/newsroom/notiziario-tecnico-tim/Anno-2023/n2-2023/5G_ed_efficientamento_energetico.html
GSMA 5G Transformation Hub, available at : https://www.gsma.com/5ghub/ruralareas

Projected social impact

First, the deployment of 5G requires a shift in the **skill set** of telecom professionals[324]. Currently, there is a shortage of telecom workers with the skills to build and maintain 5G infrastructure. Additionally, there is a growing need for expertise in areas such as IoT, robotics, AI, cloud, and augmented reality[325]. Some telcos are addressing this by offering upskilling opportunities. For example, Nokia has launched a 5G certification program, covering topics like 5G Networking and Industrial Automation Networks[326].

Second, 5G's implementation can also optimize **work organization** within telecom companies. The technology allows for more efficient collaboration, automated processes, and enhanced real-time data analytics. This streamlining of operations not only improves productivity but also reshapes how teams collaborate. To be specific, 5G's near-zero latency facilitates seamless collaboration among team members located in different locations, ensuring efficient communication and productive cooperation. This also

[322] Ericsson (2021), 'The 5G future of work – on the road to a better new normal'. Available at: https://www.ericsson.com/en/blog/2021/2/5g-future-of-work
[323] Beltozar-Clemente, S., et al. (2023), 'Contributions of the 5G Network with Respoect to Decent Work and Economic Growth (Sustainable Development Goal 8): A Systematic Review of the Literature'. Available at: https://www.mdpi.com/2071-1050/15/22/15776
[324] McKinsey (2023), 'Tech talent in transition: Seven technology trends reshaping telcos'. Available at: https://www.mckinsey.com/industries/technology-media-and-telecommunications/our-insights/tech-talent-in-transition-seven-technology-trends-reshaping-telcos
[325] Chaker, N. (2021), 'Equipping Telecom Workers for the 5G Era'. Available at: https://beamery.com/resources/telecoms/equipping-telecom-workers-for-the-5g-era
[326] Nokia (n.d), 'Nokia Bell Labs 5G Certification Program'. Available at: https://www.nokia.com/networks/training/5g/bell-labs/

enables telcos to rapidly share information, monitor operations in real-time, adjust supply chains instantly, conduct prompt analytics, and make fast, informed decisions.

Third, 5G also contributes to improved **working conditions**. Especially in the context of remote work, 5G's accelerated speeds and heightened security protocols reduce the dependence on costly fixed networks, resulting in more independence and decreased expenses for remote workers and telecommuters. According to a survey conducted by the European Central Bank, approximately two-thirds of surveyed employees expressed a preference for teleworking at least one day per week. The improved connectivity and low latency provided by 5G enable seamless collaboration and communication for remote teams, fostering a flexible work environment. This not only reduces geographical constraints but also promotes the benefits connected to telework, such as a better work-life balance for professionals employed in telecommunications (see chapter *1.2* for a more extended discussion on telework)[327].

2.11.xRAN

Radio Access Networks (RAN) are a key component of the services offered by the telecommunication industry, as they connect user devices to other parts of the network through radio connections[328]. A RAN is typically made up of a base station and various antennas that are projected to cover a certain area. However, RAN networks have evolved, to allow for the connection of more complex devices (such as drones or IoT devices), and to support more and more evolved network generations (from 1G to 5G); 5G has restructured the layout of RANs, requiring radios and antennae to be separated from the base station[329]. Standard RANs typically include integrated proprietary software; new generations of RANs employ virtual platforms that are increasingly more standards-based and software-centric[330].

In this context, **xRAN** is an umbrella term defining new approaches to RAN, that display innovative configurations and/or non-proprietary characteristics[331]. The most commonly found types of xRAN are:

- **Centralised RAN (CRAN)**: an alternative to the most common DRAN (decentralised RAN) architecture. In DRAN, all signal processing for each antenna site is done locally within that site, in opposition to CRAN solutions which process the signal in common centralised CRAN hubs, which handle the incoming signal of multiple antenna sites[332]. Depending on network configuration, providers may want to consider switching to CRAN architectures to simplify antenna site management, as well as coordination and more efficient hardware use[333].
- **Virtualised RAN (vRAN)**: vRAN applies the principles of Network Function Virtualisation to RAN stations. This means that once hardware-based network functions are substituted with software-based network functions, they can easily be updated with software patches if changes are needed. This solution is fundamental in the era of 5G, which demands greater flexibility in terms of connected devices and ever-increasing needs for dynamic radio resources[334].
- **Cloud RAN, or Cloud-native RAN**: a virtualised network that allows for baseband RAN software to be deployed on different kinds of cloud infrastructure. These could be on-site cloud hardware, CSP-owned

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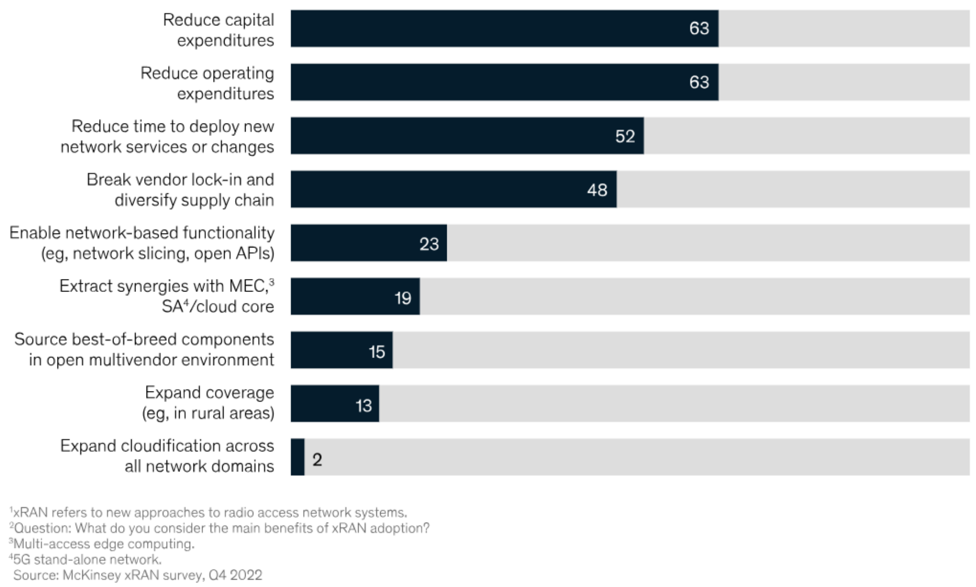
327 European Central Bank (2023), 'How people want to work – preferences for remote work after the pandemic'. Available at: https://www.ecb.europa.eu/pub/economic-bulletin/focus/2023/html/ecb.ebbox202301_04~1b73ef4872.en.html
328 Vodafone (n.d.), 'What is a radio access network (RAN)?'. Available at: https://www.vodafone.com/business/news-and-insights/glossary/what-is-a-radio-access-network-ran
329 TechTarget (n.d.), 'Radio Access Network (RAN)'.Available at: https://www.techtarget.com/searchnetworking/definition/radio-access-network-RAN?_ga=2.203974288.1847071535.1599037084-940098927.1599037084
330 Essing N.H. and Westcott, H. (2021), 'The next-generation radio access network: Open and virtualized RANs are the future of mobile networks'. Deloitte Insights, available at: https://www2.deloitte.com/xe/en/insights/industry/technology/technology-media-and-telecom-predictions/2021/radio-access-networks.html
331 De Geest G. et al. (2023), 'Telecom networks: Tracking the coming xRAN revolution'. McKinsey & Company, available at: https://www.mckinsey.com/industries/technology-media-and-telecommunications/our-insights/telecom-networks-tracking-the-coming-xran-revolution
332 De Geest et al., 'Telecom networks'.
333 Ibid.
334 Mangtani, A. (2023), 'What is vRAN?'. Medium, available at: https://ashley-mangtani.medium.com/what-is-vran-9307f39e13b6

data centres, or hyper-scaler public clouds. As long as the software component is hosted on a cloud, the term open RAN could refer to centralised or distributed RAN solutions, as well as RAN networks that are or are not purpose-built[335].

- **Open RAN (ORAN)** are virtualised RAN networks that, similarly to vRAN, seek to adopt software-based network functions; however, unlike vRAN, they strive to make RAN elements uniform and interoperable between each other. More specifically, they seek open-source solutions and a united interconnection standard, as well as cloud-native components, to develop RAN software and hardware that are not vendor-specific. For telcos, this solution would encourage technology development, increase flexibility, and reduce costs[336].

Depending on the type of RAN solution, the transition to xRAN can bring an array of benefits to telcos (see *Figure 10*). However, as examined above, different types of RAN suit different circumstances. In considering new avenues for RAN architecture and management, it is vital to consider the individual organisational needs of the network at hand, as well as the challenges faced by the organisation.

Figure 10. McKinsey survey on benefits of RAN adoption (2022; n of respondents = 52)



Source: McKinsey, available at: https://www.mckinsey.com/industries/technology-media-and-telecommunications/our-insights/telecom-networks-tracking-the-coming-xran-revolution

Potential for sustainability

New RAN approaches are being built and designed with sustainability in mind. In most of the explored solutions, this will be achieved by integrating other advanced technologies into xRAN, such as native AI and real-time monitoring of energy-intensive RAN components[337]. The most discussed examples of these synergies are:

- **Employment of MIMO** (multiple input, multiple output) technologies to multiply the capacity of radio links. MIMO transmitters are an innovative solution that can be deployed in radio sites at a large scale to

[335] Ericsson (2022), 'What's next for RAN?'. Full report available at: https://www.ericsson.com/4ab4fb/assets/local/reports-papers/further-insights/doc/whats-next-for-ran.pdf
[336] Mangtani, 'What is vRAN?'
[337] Deutsche Telekom, Orange, TIM, Telefònica and Vodafone (2022), 'Open RAN MoU progress update on maturity, security and energy efficiency'. Available at: https://telecominfraproject.com/wp-content/uploads/joint-mou-white-paper-mwc-2023.pdf

increase energy efficiency, as they represent 'the most energy-efficient technology there is when it comes to gigabytes per watt'[338].

- RAN components called **RIC (Ran Intelligent Controller)** can manage various aspects of the network, including energy efficiency; their latest generation is hosted in edge servers or telco clouds and allows to control of the network in near-real time. The energy savings can be achieved by switching channels on and off, controlling sleep mode, and more[339]. Some types of near-real-time RIC can be designed to operate through AI and ML, and according to experts, this could further maximise energy savings[340].
- **Telemetry** (employment of sensors to collect and transmit data from the network components) can represent a solution to gain insight into the energy consumption pattern of the RAN; together with AI and ML analysis, these will be fundamental to deploying energy-saving plans[341].

However, one xRAN solution -Open RAN – is proving controversial regarding its sustainability. Since its large-scale implementation would lead to an ecosystem of relatively small-scale suppliers, the main concern is fragmentation, which would make environmental targets harder to regulate and control from the telcos' side[342]. Another common concern is the initial immaturity that the ecosystem is likely to have, possibly resulting in not fully reliable solutions[343]. Nevertheless, considerable progress has been achieved, and investments are being made by operators to make xRAN a viable, sustainable, and interoperable solution. Some examples are:

- AT&T and Ericsson, in the US, are forming a partnership, planning to scale Open and Interoperable Radio Access Networks to cover 70% of AT&T's wireless network traffic by 2026. The solutions' non-proprietary interface will allow for management of mixed supplier hardware at each cell site[344].
- Nokia and Deutsche Telekom have begun deployment of a multi-vendor Open RAN network in Germany. The deal struck between the two companies highlights the level of maturity reached, and includes specific commitments to ensure that avenues for energy efficiency are explored[345].

At present, there are elements to determine that Open RAN could at least become as energy efficient as its predecessors, thanks to energy-efficient hardware and monitoring systems[346]. According to some, if the availability of the technologies discussed above increased (e.g., real-time AI/ML data analysis), the energy efficiency of Open RAN could surpass traditional RAN solutions[347]. Other commentators hypothesize that the creation of a diversified ORAN market could, in the long run, increase the sustainability of these solutions, as competition could incentivise the development of sustainable solutions on offer[348]. Another widespread view is that the open structure of ORAN could facilitate the integration and deployment of software applications for sustainability that might be deployed in the future by various actors, thanks to its flexible, non-proprietary character[349].

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[338] Kinney, S. (2024), 'How does RAN modernization foster sustainability?'. *RCRWirelessNews*, Available at: https://www.rcrwireless.com/20240103/fundamentals/how-does-ran-modernization-foster-sustainability
[339] Rakuten Symphony (2023), 'White Paper - Best Practice Approaches for Reducing System Level Energy Consumption in 5G Open RAN'. Available at: https://assets-global.website-files.com/6317e170a9eabbe0fbbf4519/651d5db527d1e4e4c956daa2_Energy%20Saving.pdf
[340] Ibid. ; see also Telecom Infra Project (2022), 'Automation and Optimisation for OpenRAN TIP White Paper'. Available at: https://cdn.mediavalet.com/usva/telecominfraproject/nW7oKPWc-EiGkZHPZnm-wA/PYEOHoNFmkqOPCkvNKZJyA/Original/AI-RAN-OPT-White-Paper-Jan-2022-For_Public_Release-FINAL_Format.pdf
[341] Rakuten, 'White Paper'.
[342] Oliver Wyman (2021), 'The next level of emission reductions in telecom operators'. Available at: https://www.oliverwyman.com/our-expertise/insights/2021/may/next-level-of-emission.html
[343] McKinsey (2023), 'Telecom Networks: tracking the coming xRAN Revolution'. Available at: https://www.mckinsey.com/industries/technology-media-and-telecommunications/our-insights/telecom-networks-tracking-the-coming-xran-revolution
[344] AT&T, 'AT&T to Accelerate Open and Interoperable Radio Access Networks (RAN) in the United States through new collaboration with Ericsson'. Available at: https://about.att.com/story/2023/commercial-scale-open-radio-access-network.html
[345] Nokia (2023), 'Nokia and Deutsche Telekom begin deployment of multi-vendor Open RAN network in Germany'. Available at: https://www.nokia.com/about-us/news/releases/2023/12/12/nokia-and-deutsche-telekom-begin-deployment-of-multi-vendor-open-ran-network-in-germany/
[346] Deutsche Telekom, Orange, et al., 'Open RAN MoU progress update'.
[347] Ibid.
[348] Fujitsu (2023), 'How Open RAN's sustainability advantages support net-zero carbon targets'. Available at: https://networkblog.global.fujitsu.com/2023/09/21/how-open-rans-sustainability-advantages-support-net-zero-carbon-targets/
[349] Deutsche Telekom, Orange, et al., 'Open RAN MoU progress update'.

Box 21. Efforts for a sustainable development of xRAN: the Telecom Infra Project

A good example of how the integration of advanced technologies into xRAN can be done in a coordinated manner is the **Telecom Infra Project**. The Telecom Infra Project defines itself as a global community of companies and organizations working together to accelerate the development and deployment of open, disaggregated, and standards-based technology solutions that deliver […] high-quality connectivity[350]. Within the organisation, different project groups aim to provide an accelerating force for some new technology applications that might facilitate a global increase in connectivity. One of these project groups is concerned with OpenRAN, and five European telecom operators forming the OpenRAN MoU have recently produced a report on the OpenRAN roadmap for technology maturity, security and energy efficiency[351]. The efforts of the group are focused on making OpenRAN at the very least as efficient as RAN, and possibly more energy-efficient by design. To achieve this, the solutions explored involve players of the cloud and AI ecosystems, to explore synergies for sustainability and achieve a better product outcome[352]. This joint effort is an example of virtuous cooperation to design more energy-efficient advanced technological applications in the field of telecoms.

Source: Visionary Analytics, based on sources cited in the text

Projected social impact

The transition to xRAN will require some internal restructuring of telcos' capabilities. Firstly, the **skills of currently employed personnel will have to be integrated and/or adapted to the new requirements** of xRAN. According to a McKinsey survey, telcos do not presently feel equipped for the xRAN revolution and lament a lack of skills related to system integration and network architecture. In general, telcos are likely to prioritise[353]:

- Talent skilled in agile working to enhance engineering practices and innovation deployment;
- Data engineering, to develop architecture;
- Cloud, to develop and test solutions that xRAN enables;
- Product management, to enable the evolution of xRAN; and
- DevOps, to build solutions and accelerate the transition to xRAN.

Specific needs also depend on the level of xRAN implementation, with telcos managing one or two vendors requiring more skills in the field of network integration, and telcos dealing with more than three vendors prioritizing the search for network architects[354].

Nevertheless, telcos agree that the organisational changes related to this technology will be comprehensive and may lead to **changes in organisational practices as well as sourcing of new skill profiles**. Particularly, solutions based on software (e.g., vRAN) and multivendor environments (e.g., ORAN) have the potential to encourage more agile methodologies in telcos, giving workers more methodological freedom to adapt better to the customers' requirements, perhaps through the creation of 'cross-functional 'tribes" around new xRAN capabilities[355]. Further, as previously mentioned, requirements for physical assets and hardware such as towers, antennas and cables, might decrease, increasing the extent of the **market competition** within the ecosystem, with repercussions on organisational practices and business plans[356]. Greater competition and choice of products could also improve **costs of ownership** for telcos, as it may lead to the marketisation of prices, and greater flexibility, as the trial of new technological solutions will not bring direct development costs[357].

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[350] Telecom Infra Project (n.d.), homepage, available at: https://telecominfraproject.com/
[351] Deutsche Telecom et al., 'Open RAN'.
[352] Ibid.
[353] McKinsey, 'Telecom Networks'.
[354] Ibid.
[355] Ibid.
[356] McKinsey (2023), 'Tech talent in transition: Seven technology trends reshaping telcos'. Available at: https://www.mckinsey.com/industries/technology-media-and-telecommunications/our-insights/tech-talent-in-transition-seven-technology-trends-reshaping-telcos
[357] Ibid.

Lastly, potential challenges could arise in ensuring **data security**. This is mainly due to the disaggregated multi-vendor environment, which can leave telcos more vulnerable in terms of cybersecurity at the intersections between the integrated technologies employed. For instance, patches and updates released by the respective vendors of software to address a particular vulnerability would need to be updated at the same time, to avoid leaving parts of the networks exposed[358]. These kinds of security challenges can be mitigated with the adoption of security standards by equipment manufacturers, software developers, integrators, and mobile network operators (these standards for Open RAN are currently being developed)[359].

3. Role of social partners in the twin transition

The European telecommunication sector is diverse and dynamic, creating jobs for over 1.1 million people in the EU[360]. The two main social partners in the sector are the European Telecommunications Network Operators' Association (ETNO; as employees' representatives) and UNI Europa ICTS (as workers' representatives). The ILO emphasises that '**social dialogue** plays an important role in shaping the future of work, taking into account particular trends of globalization, technology, demography and climate change.'[361] Active collaboration between **social partners** – employee and employer representatives – plays a pivotal role in achieving a just transition. Inevitably, jobs will be lost in the process, and social partners are in a unique position to ensure that, while the restructuring of the telco job market takes place, as many quality jobs as possible are preserved and/or created, and that workers can be efficiently reskilled or upskilled where necessary[362].

In the context of technology adoption, there are at least two major reasons why employee involvement in technology adoption is crucial. Firstly, **the level of employee involvement is related to how the technology impacts them**. How technology is developed and implemented in a workplace determines whether it will benefit or hurt workers (i.e. the same technology can lead to either gains or losses in terms of efficiency, autonomy, flexibility, job control, occupational safety and health, etc. depending on how it is deployed). The effects of digitalisation are addressed by collective bargaining through arrangements that relate to training, working time, work organisation, work-life balance, management of redundancies, or safety and health at work[363]. Therefore, well-functioning mechanisms that allow workers to participate in technology adoption give workers a chance to ensure that their needs and expectations are met, and that technology assists rather than hinders their work or leads to the deterioration of working conditions. Moreover**, employee involvement in technology adoption reduces the risk of worker resistance to digitalisation and change**. As workers are informed and consulted on adopting technologies, they are more likely to have more confidence in using technologies and accept changing work styles.[364]

Generally speaking, the efforts conducted for stakeholder engagement through this project suggest that the involvement of social dialogue should occur **very early in the process** of technology implementation, ideally

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[358] US National Security Agencyand CISA (2022), 'Open Radio Access Network Security Considerations'. Available at: https://www.cisa.gov/sites/default/files/publications/open-radio-access-network-security-considerations_508.pdf
[359] Ibid.
[360] European Commission (n.d.), 'Sectoral social dialogue – Telecommunications'. Available at: https://ec.europa.eu/social/main.jsp?catId=480&intPageId=1856&langId=en
[361] ILO (2018). Resolution concerning the second recurrent discussion on social dialogue and tripartism, p. 2, available at: https://www.ilo.org/ilc/ILCSessions/previous-sessions/107/reports/texts-adopted/WCMS_633143/lang--en/index.htm.
[362] CESI (2022), 'Towards Socially Fair Green-Digital Transitions in Europe'. Available at: https://www.cesi.org/wp-content/uploads/2022/06/CESI-Positionspapier-zum-sozial-fairen-gru%CC%88n-digitalen-Wandel-scr.pdf
[363] Eurofound (2021), 'Impact of digitalization on social dialogue and collective bargaining'. *Research digest*. Available at: https://www.eurofound.europa.eu/en/impact-digitalisation-social-dialogue-and-collective-bargaining
[364] Eurofound, Digitisation in the workplace.

before the project is announced to the public and/or employees[365]. Early engagement of social dialogue would ensure that employees are well-informed, and that there is sufficient time for unions to collect and form a position on the solution proposed. This could also lead to increased benefits for workers' health and safety, thanks to an increase in transparency between employers and employees and the establishment of an ongoing, open dialogue. Examples of ongoing dialogue can be represented by shared risk assessment policies and practices, as well as technology forum groups between social partners that can help share knowledge on technical issues related to technology implementation[366]. These efforts should be complemented by a willingness of social partners to adapt to new technologies and their applications, including their necessity for market reasons, while ensuring their safety and fairness towards workers[367].

We identify two major areas of impact management that can be effectively implemented through social dialogue, which will be discussed in the upcoming sections:

- The **change in skills required** by the labour market that can be managed through upskilling or reskilling programmes;
- The possible impact of the twin transition on **working conditions**, including employees' well-being, job stability, work-life balance, workers' engagement levels, and occupational health and safety.

3.1. Managing changing skills requirements

Active participation of employer representatives is particularly crucial in **ensuring the effective development and execution of upskilling and reskilling policies** in the context of the twin transition.[368][369] According to some of the stakeholders consulted, the role of social dialogue among the reshuffling of skills requirements should be to monitor these changes and mitigate their impact on workers, through voluntary exit packages and/or upskilling and reskilling programs[370]. Indeed, employers and their representatives are actively seeking adult learning systems designed to equip individuals with the precise skills necessary to maintain productivity, competitiveness, and innovation.[371] Simultaneously, they acknowledge the significance of training in sustaining worker engagement and motivation.[372]

Research shows that the participation of both social partners in the governance of adult learning systems yields beneficial outcomes, rendering these systems more resilient and ensuring the effective implementation of policies. For a successful twin transition, workers need skills to adapt to job changes or transition to new roles, and enterprises need skills for producing digitalized and sustainable products and services. Here, two main roles of social partners have been identified[373]:

- they directly participate in decision-making and management of re-skilling and upskilling systems, and
- they play a consultative role, sharing insights regarding their constituents' needs and conditions.

In numerous OECD countries, particularly in Europe, social partners directly influence adult learning systems by participating in decision-making and managing learning programs (see *Figure 11* below detailing the level of social partners' involvement in managing upskilling and reskilling systems). For instance, the Swedish Job Security Councils (JSCs), jointly operated by employers' organizations and trade unions independently of the

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[365] First Roundtable on disruptive technologies, 09/04/2024.
[366] Ibid.
[367] Ibid.
[368] OECD (2020), *Increasing Adult Learning Participation: Learning from Successful Reforms*. Paris: OECD Publishing. Available at: https://doi.org/10.1787/cf5d9c21-en.
[369] Global Deal (2020), 'Global Deal Flagship Report 2020: Social Dialogue, Skills and Covid-19'. Available at: https://www.theglobaldeal.com/resources/2020%20Global%20Deal%20Flagship%20Report.pdf
[370] First Roundtable on disruptive technologies, 09/04/2024.
[371] OECD (2021), *Training in Enterprises: New Evidence from 100 Case Studies*. Paris: OECD Publishing. Available at: https://doi.org/10.1787/7d63d210-en
[372] Ibid.
[373] Global Deal (2023), 'Upskilling and reskilling for the twin transition: The role of social dialogue'. Available at: https://www.theglobaldeal.com/resources/Upskilling-and-reskilling-for-the-twin-transition.pdf

government, manage various aspects of the system. They offer support and guidance to displaced workers during plant closures and mass redundancies, including counselling, career planning, job search assistance, outplacement services, and retraining[374]. Experiences from Nordic countries during the COVID-19 pandemic indicate that when social partners are actively engaged in skills governance, trust is built among stakeholders, and the system becomes more resilient in responding to unforeseen events[375]. Similarly, it is suggested that promoting employee involvement can mediate and mitigate various adverse consequences of the twin transition.[376] Therefore, the **involvement of social partners** at the macro (European Union and national), meso (sectoral), and micro (branch and company) levels **is crucial for shaping these transitions sustainably and inclusively**.[377]

Figure 11. Social partners' involvement in managing upskilling and reskilling systems in the OECD

Level of involvement	Country
Social partners are involved in decision-making and management	Austria, Denmark, Germany, Iceland, Italy, Netherlands, Sweden
Social partners contribute to decision-making	Belgium, Canada (AB), Canada (BC), Finland, France[1], Japan[2], Luxembourg, Mexico, Norway, Poland, Slovenia, Switzerland, Türkiye
Social partners play a consultative role	Canada (ON), Canada (QB), Czech Republic, Estonia, Greece, Ireland, Israel, Latvia, Lithuania, New Zealand, Portugal, Slovak Republic, Spain
Other	Australia, Hungary, United Kingdom, United States

Source: Global Deal (2023), 'Upskilling and reskilling for the twin transition: The role of social dialogue'. Available at: https://www.theglobaldeal.com/resources/Upskilling-and-reskilling-for-the-twin-transition.pdf

In this context, efforts to create sector-wide guidelines and projects for social dialogue can establish a solid base to ensure a supply of skilled workers, on the one hand, and satisfied employees, on the other. An example comes from ETNO's and UNI Europa ICTS' joint social dialogue project (2020-2022) '**Digital upskilling for all! (DUFA!)'**. The project has focused on encouraging digital upskilling in the telecommunications sector, with a particular focus on more inclusivity and diversity in the workforce in terms of gender equality, ageing, and groups which generally represent a minority among telco workers.[378] The DUFA working group has highlighted a low percentage of telco enterprises which have a strategic plan to include minorities in the workforce (only 19% of digital skills strategies identified included provisions to attract female workers, while none of them considered ageing workers)[379]. To promote these alternative employment strategies, ETNO and UNI Europa ICTS have created a toolkit for the industry, showcasing best practice examples and encouraging more social dialogue on the topic. The project thus aims at bridging the skills-diversity gap in inclusive ways, attentive to the needs of both workers and employers.

3.2. Managing the impact on working conditions

Another possible risk posed by the twin transition on the labour market is the **impact on working conditions**. This can refer to:

- The quality of jobs, which may deteriorate as workers' duties change and additionally influence job stability[380].
- The well-being of employees, in terms of occupational health and safety and productivity.

[374] Global Deal. (2023), 'Upskilling and reskilling for the twin transition: the role of social dialogue'. Available at: https://www.voced.edu.au/content/ngv:97232#
[375] Global Deal. (2023), 'Upskilling and reskilling for the twin transition: the role of social dialogue'. Available at: https://www.voced.edu.au/content/ngv:97232#
[376] Ibid.
[377] Ibid.
[378] ETNO (2022), 'ETNO and UNI Europa ICTS consolidate the findings of the 2-year social dialogue project on Digital Upskilling for All'. Available at: https://etno.eu/news/all-news/8-news/750-etno-and-uni-europa-icts-consolidate-the-findings-of-the-2-year-social-dialogue-projecton-digital-upskilling-for-all.html
[379] Ibid.
[380] CESI (2022), 'Towards Socially Fair Green-Digital Transitions in Europe'.

- Changes related to the social dialogue structure, which may need to change its practices to adapt to an evolving workforce.

One challenge that needs to be addressed by telcos during the twin transition is the possibility of a deteriorating quality of jobs. This means that workers who lose their jobs due to obsolescence may find themselves working for lower salaries in unskilled or unstable positions[381].

Organisations that highly involve workers in managerial decisions were found to offer a better work environment (including less physical risk, lower work intensity and greater job security)[382][383]. Employee involvement can impact **workplace well-being**, including working and employment conditions, employee motivation, worker retention, learning opportunities at work, and more, but it can also improve the **establishment's performance**, including profitability, changes in production volume, employment levels, and productivity gains[384]. This creates an advantageous situation for both parties. A Eurofound study found that the share of employees reporting high worker engagement in high-involvement organisations was almost double the share of those working in low-involvement organisations (47% compared to 24%)[385]. Finally, workers in high-involvement organisations had better access to formal and informal training, with a smaller difference in opportunities for skills development between high-skilled and lower-skilled employees.[386][387]

Workers' right to privacy is a particularly sensitive topic in those organisations implementing technological solutions that involve the **analysis of employee data** (for example, algorithmic management, discussed in section *2.5.2* and *2.5.3*). In this case, the violation of privacy and/or solutions that foresee employee surveillance can infringe workers' fundamental rights. In the telecommunications sector, there are already some examples of union involvement that have managed to improve and/or regulate the working conditions of employees subjected to data collection and/or analysis. *Box 22* collects two such examples, highlighting how early involvement of social dialogue can considerably improve working conditions and successfully uphold workers' rights, minimising the risk for unsafe or unhealthy working conditions.

Box 22. A social dialogue best practice: Syndicom and Swisscom

Syndicom is a Swiss trade union for the media and communication sectors. Syndicom has a long-standing tradition of social dialogue with Swisscom, the largest telecommunication company in Switzerland. The two parties regularly engage in discussions, resulting in collective agreements, and the topics of the latest discussions have increasingly been tied to the implementation of technological solutions. In particular, the use of employee data has been in the spotlight during the most recent negotiations. The challenge to be solved consisted in allowing the telco to implement an algorithmic solution, while involving the employees in the decisions that surrounded the use and analysis of their own data.

The two factors that made the difference in ensuring a fair and smooth social dialogue process were the tradition of mutual trust and understanding between the two partners, which led to early involvement of Syndicom, and the formation of ad-hoc working groups in opposition to the 'standard' process of periodic collective agreement negotiation. The formation of a working group allowed Syndicom to analyse the situation thoroughly, and facilitated the dialogue with the newly appointed Head of Data Governance at Swisscom. The negotiations of the working group led to agreements on the specific data policy, but also to the development of a shared policy on smart data principles, which represents a new development and will apply to all future decisions on technology implementation. This policy was made necessary by the fast pace of technology creation / implementation, and its goal is to ensure that workers' wishes are respected even in subsequent instances of technological change.

Lastly, one important insight from Syndicom was that the approach was never centred on opposing technological developments outright, as this would have proven unproductive for the company's competitiveness in an evolving world.

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[381] Ibid.
[382] Eurofound, 'How does employee involvement in decision-making benefit organisations?'
[383] Eurofound (2020), 'Workplace practices unlocking employee potential'. *European Company Survey 2019 series*, Luxembourg: Publications Office of the European Union. Available at: https://www.eurofound.europa.eu/sites/default/files/ef_publication/field_ef_document/ef20 001en.pdf.
[384] Eurofound and Cedefop (2020), 'European Company Survey 2019: Workplace practices unlocking employee potential'. *European Company Survey 2019 series*. Luxembourg: Publications Office of the European Union. Available at: https://www.cedefop.europa.eu/en/publications/2228
[385] Eurofound (n.d.), 'Work organisation'. Available at: https://www.eurofound.europa.eu/en/topic/work-organisation#policy-pointers
[386] Eurofound, 'How does employee involvement in decision-making benefit organisations?'
[387] Eurofound, 'Workplace practices'.

Rather, the union focused on understanding the impact on workers, mitigating the risks and challenges of the specific technology, while being attentive to the company's business needs. This benefitted the process of social dialogue, as well as the relationship between Syndicom and Swisscom.

Source: Interview with a Syndicom representative, 19/02/2024.

The most disruptive, and perhaps controversial, technology among those discussed is artificial intelligence. This technology has raised many questions in the world of social dialogue and spurred a lot of initiatives to try and manage its deployment from the organisational and labour perspectives. For example, the *European Social Partners Framework Agreement on Digitalisation*, which discusses opportunities and challenges of digital workplaces, poses an accent on the regulation of AI, and on what its **trustworthiness** should mean:

> - *it should be lawful, fair, transparent, safe, and secure, complying with all applicable laws and regulations as well as fundamental rights and non-discrimination rules,*
> - *it should follow agreed ethical standards, ensuring adherence to EU Fundamental/human rights, equality and other ethical principles and,*
> - *it should be robust and sustainable, both from a technical and social perspective since, even with good intentions, AI systems can cause unintentional harm.*[388]

As previously mentioned in *Chapter 2.5,* European regulations have also devoted attention to the ethical principles of this technology. Nevertheless, social dialogue remains important to monitor and coordinate the impacts that AI-led automation may bring on the workforce. In particular, some digital technologies, among which AI, may be implemented to monitor employees, to improve organisational performance and/or health and safety measures. While this could be beneficial from an employer's point of view, because of increased workers' performance, workers may be at risk of privacy and fundamental rights violations, as well as ethical risks[389]. Social partners have a strong role to play in this field, as their involvement has already laid a consolidated foundation in matters of respect for personal data and employees' privacy (as per Article 88 of the GDPR[390])[391]. As outlined in ETNO and UNI Europa ICTS' Joint Declaration on Artificial Intelligence, a more sustained involvement of social partners in the technological transition can ensure that workers' rights are respected, without undermining any of the benefits and opportunities that Artificial Intelligence can offer.

Importantly, the twin transition itself can pose **challenges to established social dialogue structures,** such as contributing to a reduction in collective bargaining coverage and representation[392]. Social partners, especially trade unions, may face significant structural challenges, ranging from unsupportive (and often deteriorating) institutional frameworks to insufficient internal capacity to manage change.[393] For instance, the transition to telework may negatively impact collective bargaining by challenging the traditional role of the workplace. The current trade union model is built on organizing workers at the workplace, fostering collective approaches to work and worker-representative relationships. Teleworking poses a risk of individualizing work, potentially isolating workers at home. This, in turn, may reduce employees' ability to shape the twin transition inclusively[394]. This is also a concern within the telecoms industry, leading to a Guidelines on Remote Work issued by ETNO and UNI Europa ICTS. According to the guidelines, for fair representation of teleworkers, employers should grant trade unions access to the remote workforce,

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[388] European Social Partners (2020), *European Social Partners Framework Agreement on Digitalisation.* Available at: https://www.etuc.org/system/files/document/file2020-06/Final%2022%2006%2020_Agreement%20on%20Digitalisation%202020.pdf

[389] ETNO and UNI Europa (2020), *The Telecom Social Dialogue Committee Joint Declaration on Artificial Intelligence*. Available at: https://www.uni-europa.org/old-uploads/2020/12/20201130_UE-ETNO-declaration-AI.pdf

[390] Full text available at: https://gdpr-info.eu/

[391] European Social Partners, *Framework Agreement*.

[392] Bednorz, J, Sadauskaitė, A, et al, 2022, Unionisation and the twin transition. Good practices in collective action and employee involvement, Publication for the committee on Employment and Social Affairs, Policy Department for Economic, Scientific and Quality of Life Policies, European Parliament, Luxembourg, available at: https://www.europarl.europa.eu/RegData/etudes/STUD/2022/733972/IPOL_STU(2022)733972_EN.pdf

[393] Ibid.

[394] IndustriALL (2021), 'Report: Why telework needs institutional regulation and collective bargaining'. Available at: https://www.industriall-union.org/report-why-telework-needs-institutional-regulation-and-collective-bargaining

following rules similar to those in a physical workplace. Tools provided to unions and employee representatives must be accessible in a remote/virtual context, including electronic communication, virtual bulletin boards, and inductions for new staff, all with full privacy and data protection guarantees[395].

Lastly, one important challenge stemming from digitalisation is the **rapid pace of technological change**. As we have seen throughout the technology analysis, telcos are attempting to implement and experiment with new technologies in order to keep up with external competition, and to optimise their operations to ensure productivity and sustainability. Additionally, the technologies implemented are in constant evolution, both regarding their features and their applications. For this reason, in best case scenarios where social dialogue is involved in technology implementation since its early stages, unions and their members may find that they lack the technical information required to make informed decisions regarding a technological solution[396]. This translates in a necessity of more (human) resources allocated to the social dialogue process, as well as a need to make social dialogue a constant occurrence, as opposed to 'traditional' models of negotiations which foresee technology approvals from workers after 'one-off' discussions about technology use[397][398]. In the new context of the twin transition, the challenge will be to restructure social dialogue to ensure continuous involvement in technology-based decisions, as well as to empower unions and workers with knowledge to make informed choices[399][400].

Box 23. Legal frameworks and technology implementation: the case of Austria

A possible opportunity for reflection on patterns of social dialogue comes from Austria. In Austria, the national legal framework allocates considerable weight to works councils. Works councils are employee bodies that grant their members special protection against dismissal and redundancy, and have the goal of monitoring the company's compliance with laws applicable to them. In addition, works councils have the right to make proposals regarding working conditions, and they have to be informed when company decisions are being taken, that would affect workers (for instance, changes in the processing and storage of employees' data). In such cases, the company would need the works council's permission to implement the solution.

One of the interviewees consulted mentioned that the inclusion of this process into national law facilitates the early stages of union involvement into technology implementation, and guarantees transparency between workers and companies. Moreover, it ensures that the attitude of unions is more geared towards mitigating risks, rather than seeking to ban specific technological applications, or refuse their implementation. Nevertheless, both unions and employees emphasize the existing scarcity of technical and specific knowledge from the unions' side, which may delay negotiations or hamper technological progress, even in cases when employees agree on the solutions proposed. Lastly, the process is reported as being rather slow by design, with possible effects on workflow and overall competitiveness of businesses; however, this may increase understanding from both parties, and have the ultimate effect of empowering workers with the necessary knowledge.

Sources: Visionary Analytics, based on: interviews with a Magenta representative (22/02/2024) and with an A1 representative (13/03/2024). Austrian Federal Ministry of Labour and Economy (2024), 'Works Council'. Available at: https://www.usp.gv.at/en/mitarbeiter-und-gesundheit/interessenvertretung/betriebsrat.html#:~:text=In%20every%20company%20employing%20at,a%20term%20of%20five%20years.

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[395] ETNO & UNI Europa ICTS (2023), 'The EU Telecom Social Partners' Guidelines on Remote Work'. Available at: https://www.uni-europa.org/wp-content/uploads/sites/3/2023/06/Telecom-Remote-Work-Guidelines.pdf

[396] Interview with a Magenta representative, 22/02/2024; interview with a Syndicom representative, 19/02/2024.

[397] Ibid.

[398] Bednorz, J, Sadauskaitė, A, et al. (2022), Unionisation and the twin transition. Good practices in collective action and employee involvement, Publication for the committee on Employment and Social Affairs, Policy Department for Economic, Scientific and Quality of Life Policies, European Parliament, Luxembourg, available at: https://www.europarl.europa.eu/RegData/etudes/STUD/2022/733972/IPOL_STU(2022)733972_EN.pdf

[399] Ibid.

[400] Interview with a Magenta representative, 22/02/2024.

4. Conclusions and lessons learned

The technologies examined and the issues raised in this report have highlighted the salience of the twin transition for the telecommunication sector. Many changes are in motion, thanks to the potentially **revolutionary impacts of new technologies**; but, as we have discussed, these changes can have a profound impact on workers and their occupational environment, and some of them need to be carefully managed to ensure that their implementation does not harm the environment, but rather promotes the social and environmental sustainability of the industry.

As discussed throughout Chapter 1, telcos are uniquely placed in their ecosystem because their environmental impact is not confined to their operations; rather, said impact can transfer to other sectors and actors in ICT and beyond. More specifically, the technologies employed by telcos and the solutions adopted have the potential to enable sustainable technological applications in all other economic sectors, especially when considering technologies with a broad range of implementations such as AI, big data, or IoT.

Broadly applicable technologies also show a considerable potential to alter the demand for skills in the sector, by potentially increasing the automation of some tasks and decreasing the demand for unspecialized and medium-skilled workers. This shift will also be accompanied by a higher number of teleworkable jobs, which will translate into new organisational practices as work will be increasingly likely to be performed from outside organisations' premises.

The technologies regarded as responsible for these developments have been highlighted in Chapter 2. For each of them, we highlighted their impacts on sustainability, as well as the potential impacts they could have on the organisation of work, occupational health and safety, and the skills market in the telecom sector.

The key impacts on the **sustainability** of the technologies discussed included:

- Energy-saving technologies (that inherently consume less energy than their predecessors).
- Possibilities to streamline operations (i.e. to save more energy through efficiency).
- Possibilities to gain insights on sustainability.
- Remote applications that can reduce travel and office costs.
- Avoidance of faults which would consume energy.

In parallel, the key impacts on the **working organisation** of the technologies discussed included:

- Telework, which will become more and more popular as some of the technologies discussed will make remote work easier.
- Demand for new skills tied to ICT, often specific to the technology application being rolled out.
- Potential automation of tasks, with possible repercussions on work organisation and skills (some jobs becoming obsolete).
- Risks and opportunities for cybersecurity.
- Streamlining operations through ad-hoc technology applications could translate into an improvement of organisational practices.

The **role of social partners** is pivotal among these vast, comprehensive changes, and can ensure that the twin transition occurs in a coordinated and safe manner, to the benefit of workers and the environment. Given the high potential of disruption of new technologies, workers should be involved at the early stages of the transition process, the most crucial aspect of which is the management of changing skills requirements. **Social dialogue will be crucial** to determine best practices on upskilling and reskilling that will have to satisfy a growing demand for ICT-related skills. The impacts of advanced technologies on working conditions will also need to be discussed with social partners as needed to ensure that jobs in the sector are not lost, nor do they deteriorate in quality or pay. Similarly, technology changes within organisations bear important implications on workers' privacy, and on the structure of social dialogue itself, and will need the involvement of all affected parties to ensure robust, socially sustainable twin transitions.

In light of the issues raised above, some preliminary recommendations can be formulated, based on challenges that social partners should consider when negotiating topics related to the twin transition.

Lesson learned #1: Social dialogue must adapt to the new environment. Given the clear evidence presented in Chapter 3 regarding workers' well-being and engagement through social dialogue, it is important to preserve the structures allowing negotiations at all levels in the digital era. This could mean adapting social dialogue to new working environments, such as distributed teams or teleworking, but also sharing (technical) knowledge among social partners, who will require more information on new technologies to make informed decisions. Lastly, the nature of social dialogue is likely to change, and should prioritise early and continuous involvement (e.g., through the development of policies and guidelines) over 'traditional' periodic consultations. This necessity comes from the rapid pace of technological change.

Lesson learned #2: Technologies can have very specific impacts. Since each technology presents vastly different impacts on social and environmental sustainability (sometimes leading to opposite concerns), technology implementation at the company level should carefully consider the predicted impact of each technology roll-out plan, avoiding blanket approaches and harnessing expertise within the respective organisations to utilise a technology-specific lens. Importantly, in many cases, the technology can have opposite effects on work organisation and/or company performance depending on the management approach. Best practice examples include the development of internal company working groups on fair AI.

Lesson learned #3: The twin transition offers opportunities for change of telcos' products and services*.* Telcos will change not only from a labour perspective but also from a market perspective – many technologies are likely to change the products that telcos will produce and distribute in the future, as some of the best practice examples confirm. Since the transition to different products and services will imply a change in skills required on the labour market, and an internal reshuffling of roles and job demands, social dialogue should be involved in the process as comprehensively as possible.

Lesson learned #4: Social partners should leverage their expertise in neighbouring topics. While the twin transition represents a new challenge, some of the issues raised in the realm of labour conditions mirror issues that have already been tackled by social partners. The latter may be able to offer valuable insights to companies and workers according to previous experience, for example, they would be in a position to guide standards on personal data protection in the context of AI and/or big data.

Lesson learned #5: Positive relationships build safer and fairer workplaces. Early engagement of social dialogue in the technology transition process, as well as the existence of mutual trust and long-standing relationships between unions and companies, may result in better outcomes for workers. In particular, stakeholders have underlined how proactive dialogue between social partners seeking to understand the potential of technologies for workers' rights and their health and safety, results in more productive discussion and outcomes, vis-à-vis attitudes aimed at rejecting new technologies and their applications.

Lesson learned #6: Legal frameworks have power*.* The stakeholders consulted highlighted how national and EU-level legislation influences the process of social dialogue. Companies need to be aware of the labour regulations in their country and consider how they will need to adapt internal processes following technological change. At the same time, unions can push for more adequate legal frameworks empowering workers in the digital age.

Annex 1. List of interviews conducted

As part of the study project, an interview program has been conducted focusing on best practice scenarios relative to the implementation of disruptive and advanced technologies in the European telecommunication industry. The aim was to collect information and good practices on the role of social dialogue at the various stages of technology uptake, focusing on the 11 technologies covered in this report. The respondents were employees of ETNO members or union representatives, with expertise in advanced technology strategies and/ or in the role of social dialogue. All interviews were conducted online through MS Teams. The table below lists the interviews conducted by the study team:

Company	Date
Syndicom	15/02/2024
Magenta	22/02/2024
TIM	05/03/2024
A1	13/03/2024
Altice Labs	04/04/2024
BT	05/04/2024

Annex 2. Bibliography

- Accenture (2020), 'The green behind the cloud'. Available at: https://www.accenture.com/us-en/insights/strategy/green-behind-cloud
- Ahmad, A., Khan, R.A., Khan, S.U. et al. (2023), 'Green cloud computing adoption challenges and practices: a client's perspective-based empirical investigation'. Cogn Tech Work 25, 427–446. Available at: https://doi.org/10.1007/s10111-023-00734-6
- Altice Labs (2023), 'Altice Labs participates in "BAnana SEnsing" seminar', available at: https://www.alticelabs.com/blog/altice-labs-participates-in-banana-sensing-seminar/
- Amnesty International (2021), 'Dutch childcare benefit scandal an urgent wake-up call to ban racist algorithms'. Available at: https://www.amnesty.org/en/latest/news/2021/10/xenophobic-machines-dutch-child-benefit-scandal/
- Arjmandi, M. K. (2016), '5G Overview: Key technologies'. Available at: https://web.archive.org/web/20200709223338id_/http://www.ittoday.info/Excerpts/5G-Overview-Key-Technologies.pdf
- AT&T, 'AT&T to Accelerate Open and Interoperable Radio Access Networks (RAN) in the United States through new collaboration with Ericsson'. Available at: https://about.att.com/story/2023/commercial-scale-open-radio-access-network.html
- Avgousti, S., et al. (2016), 'Medical telerobotic systems: current status and future trends'. Available at: https://biomedical-engineering-online.biomedcentral.com/articles/10.1186/s12938-016-0217-7
- Baiocco et al. (2022), 'The Algorithmic Management of work and its implications in different contexts'. Background paper for ILO and the European Commission, available at: https://www.ilo.org/wcmsp5/groups/public/---ed_emp/documents/publication/wcms_849220.pdf
- Balmer, R., et al. (2020), 'Artificial Intelligence Applications in Telecommunications and other network industries'. Available at: https://www.sciencedirect.com/science/article/abs/pii/S0308596120300690
- Bednorz, J, Sadauskaitė, A, et al, 2022, Unionisation and the twin transition. Good practices in collective action and employee involvement, Publication for the committee on Employment and Social Affairs, Policy Department for Economic, Scientific and Quality of Life Policies, European Parliament, Luxembourg, available at: https://www.europarl.europa.eu/RegData/etudes/STUD/2022/733972/IPOL_STU(2022)733972_EN.pdf
- Beltozar-Clemente, S., et al. (2023), 'Contributions of the 5G Network with Respoect to Decent Work and Economic Growth (Sustainable Development Goal 8): A Systematic Review of the Literature'. Available at: https://www.mdpi.com/2071-1050/15/22/15776
- Berg Insight (2022), 'Berg Insight says global cellular IoT connections grew 22 percent to reach 2.1 billion in 2021'. Available at: https://www.berginsight.com/berg-insight-says-global-cellular-iot-connections-grew-22-percent-to-reach-21-billion-in-2021
- Besfamilnyi, K. (2021), 'Overcoming crucial barriers to cloud adoption in the telecommunications sector'. Available at: https://www.rcrwireless.com/20211014/opinion/overcoming-crucial-barriers-to-cloud-adoption-in-the-telecommunications-sector-reader-forum
- Bisello (2022), 'Is telework really a 'green' choice?', *Eurofound*, available at: https://www.eurofound.europa.eu/en/blog/2022/telework-really-green-choice#:~:text=One%20of%20the%20most%20widely,and%20capitals%20most%20of%20all.
- BM (2022), 'How telcos can navigate their sustainability paradox'. https://www.ibm.com/downloads/cas/J6ZNBZ1W
- Body of European Regulators for Electronic Communications (2023), 'BEREC Report on the impact of Artificial Intelligence (AI) solutions in the telecommunications sector on regulation'. Available at: https://www.berec.europa.eu/system/files/2023-06/BoR%20%2823%29%2093%20BEREC%20Report%20on%20impact%20of%20AI%20solutions%20in%20telecom%20sector%20on%20regulation.pdf

- Bohr, A., & Memarzadeh, K. (2020), 'The rise of artificial intelligence in healthcare applications'. Available at: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7325854/
- Burge, A. (2023), 'Telcos, There's More to Sustainability Than 5G and Data Analytics'. *The Fast Mode*, available at: https://www.thefastmode.com/expert-opinion/32087-telcos-there-s-more-to-sustainability-than-5g-and-data-analytics
- CEDEFOP (2019), 'ICT professionals: skills opportunities and challenges (2019 update)'. Available at: https://www.cedefop.europa.eu/en/data-insights/ict-professionals-skills-opportunities-and-challenges-2019-update
- CEDEFOP (2020), 'Coronavirus, automation and the future of work'. Available at: https://www.cedefop.europa.eu/en/news/coronavirus-automation-and-future-work
- Cellnex (n.d), 'Healthcare'. Available at: https://www.cellnex.com/gb-en/solutions/healthcare/
- Cellnex (n.d), 'Transforming Energy and Utilities with 5G Connectivity'. Available at: https://www.cellnex.com/gb-en/solutions/energy-utilities/
- CESI (2022), 'Towards Socially Fair Green-Digital Transitions in Europe'. Available at: https://www.cesi.org/wp-content/uploads/2022/06/CESI-Positionspapier-zum-sozial-fairen-gru%CC%88n-digitalen-Wandel-scr.pdf
- Chaker, N. (2021), 'Equipping Telecom Workers for the 5G Era'. Available at: https://beamery.com/resources/telecoms/equipping-telecom-workers-for-the-5g-era
- Chen, C.M. (2016), 'Use cases and challenges in telecom big data analytics'. *APSIPA Transactions on Signal and Information Processing* , Volume 5 , e19. https://doi.org/10.1017/ATSIP.2016.20
- Chen, H. (2019), 'Success factors impacting Artificial Intelligence adoption – Perspective from the telecom industry in China'. Available at: https://digitalcommons.odu.edu/cgi/viewcontent.cgi?article=1101&context=businessadministration_etds
- Cherukuri, N. (2023), 'How Augmented Reality (AR) And 5G Could Impact Telecommunications'. Forbes, available at: https://www.forbes.com/sites/forbestechcouncil/2023/04/06/how-augmented-reality-ar-and-5g-could-impact-telecommunications/
- CISCO (2018), 'Cloud-Native Network Functions'. Available at: https://www.cisco.com/c/en/us/solutions/service-provider/industry/cable/cloud-native-network-functions.html
- Cisco (2024), 'Establishing the Edge'. Available at: https://www.cisco.com/c/en/us/solutions/service-provider/edge-computing/establishing-the-edge.html
- Cisco (n.d), 'What is 5G vs 4G?'. Available at: https://www.cisco.com/c/en/us/solutions/what-is-5g/5g-vs-4g.html
- CNBC (2023), 'Telecom regulatory body orders telcos to use AI for call filtering, seeks compliance report within 30 days'. Available at: https://www.cnbctv18.com/telecom-regulatory-body-orders-telcos-to-use-ai-for-call-filtering-seeks-compliance-report-within-30-days-16922551.htm
- Columbia University (n.d.), 'Artificial Intelligence (AI) vs. Machine Learning'. Available at: https://ai.engineering.columbia.edu/ai-vs-machine-learning/
- Corbo, A. (2023), 'What is Cloud Security?'. Available at: https://builtin.com/cybersecurity/cloud-security
- Cornish, C. (2017), 'Digital eyes and ears on: the internet of things takes off'. Financial Times, available at: https://www.ft.com/content/94ccaac2-962a-11e7-8c5c-c8d8fa6961bb
- Cornor, C. (2023), 'Artificial intelligence in marketing: friend or foe of sustainable consumption'. Available at: https://link.springer.com/article/10.1007/s00146-021-01227-8
- Corradini, I., for OSHA (2022), 'Incorporating occupational safety and health in the assessment of cybersecurity risks'. Available at: https://osha.europa.eu/en/publications/incorporating-occupational-safety-and-health-assessment-cybersecurity-risks
- Crolic, C. (2021), 'Blame the Bot: Anthropomorphism and Anger in Customer-Chatbot Interactions'. Available at: https://journals.sagepub.com/doi/10.1177/00222429211045687
- Datamation (2021), 'The Pros and cons of Edge computing'. Available at: https://www.datamation.com/edge-computing/pros-cons-edge-computing/

- Davies, N. (2023), 'Here's what quantum computing is—and how it's going to impact the future of work, according to a software engineer'. Fast Company, available at: https://www.fastcompany.com/90925065/heres-what-quantum-computing-is-and-how-its-going-to-impact-the-future-of-work-according-to-a-software-engineer
- de Paula, A.C.M., de Carneiro, G.d.F. (2016), 'A Systematic Literature Review on Cloud Computing Adoption and Migration'. In: Maciaszek, L., Filipe, J. (eds) Evaluation of Novel Approaches to Software Engineering. ENASE 2016. Communications in Computer and Information Science, vol 703. Springer, Cham. Availabe at: https://doi.org/10.1007/978-3-319-56390-9_11
- De Geest G. et al. (2023), 'Telecom networks: Tracking the coming xRAN revolution'. McKinsey & Company, available at: https://www.mckinsey.com/industries/technology-media-and-telecommunications/our-insights/telecom-networks-tracking-the-coming-xran-revolution
- Deloitte (2023), '2023 telecommunications industry outlook'. Available at: https://www.deloitte.com/global/en/Industries/tmt/perspectives/telecommunications-industry-outlook.html
- Deutsche Telekom, 'Big Data Analytics to Boost your Business in the Digital Age'. Available at: https://b2b-europe.telekom.com/digitalization/big-data-analytics
- Deutsche Telekom, Orange, TIM, Telefònica and Vodafone (2022), 'Open RAN MoU progress update on maturity, security and energy efficiency'. Available at: https://telecominfraproject.com/wp-content/uploads/joint-mou-white-paper-mwc-2023.pdf
- Doellgast, V. and O'Brady, S. (2023), 'AI in contact centres: Artificial intelligence and algorithmic management in frontline service workplaces'. Available at: https://www.researchgate.net/publication/375922335_AI_in_contact_centers_Artificial_intelligence_and_algorithmic_management_in_frontline_service_workplaces
- DRUID (2021), 'Telekom deploys DRUID AI chatbots to automate HR processes for 4000 employees'. Available at: https://www.druidai.com/chatbots-in-the-press/druid-ai-chatbot-uipath-rpa-hr-automation-telekom
- Earth.org (2023), 'The Green Dilemma: Can AI fulfil its potential without harming the environment'. Available at: https://earth.org/the-green-dilemma-can-ai-fulfil-its-potential-without-harming-the-environment/
- Ecorys (2017), 'Virtual Reality and its potential for Europe'. Available at: https://ec.europa.eu/futurium/en/system/files/ged/vr_ecosystem_eu_report_0.pdf
- EISMEA (2021), Skills for industry – Upskilling and reskilling in the post-covid era – Fostering new services and jobs creation – Three scenarios for 2030 – Final report. Luxembourg: Publications Office of the European Union. Available at: https://data.europa.eu/doi/10.2826/59135
- Elshin, L.A., Burganov, and Abdukaeva (2022), 'Assessing the Impact of Blockchain Technologies on Environmental Sustainability'. *Procedia Environmental Science, Engineering and Management,* 9(1), pp. 1-6. Available at: https://www.procedia-esem.eu/pdf/issues/2022/no1/1_Elshin_22.pdf
- Emify (2020), 'Narrowband IoT (NB-IoT) Explained'. Available at: https://www.emnify.com/iot-glossary/narrowband-iot
- English, J. (2018), 'The growing ties between networking roles and automation'. Available at: https://www.techtarget.com/searchnetworking/opinion/The-growing-ties-between-networking-roles-and-automation
- ENISA (n.d.), 'Blockchain'. Available at: https://www.enisa.europa.eu/topics/incident-response/glossary/blockchain
- Ericsson (2020), 'Afraid of heights? Drones, AI and digitalization to the rescue!'. Available at: https://www.ericsson.com/en/blog/2020/3/intelligent-site-engineering
- Ericsson (2020), 'On the relationship between AI and security in mobile networks'. Available at: https://www.ericsson.com/en/blog/2020/10/ai-security-mobile-networks
- Ericsson (2021), 'The 5G future of work – on the road to a better new normal'. Available at: https://www.ericsson.com/en/blog/2021/2/5g-future-of-work

- Ericsson (2022), 'Research on adversarial security modelling in RAN: User Behaviour Analytics and Deception'. Available at https://www.ericsson.com/en/blog/2022/6/research-adversarial-security-modeling-in-ran
- Ericsson (2022), 'What's next for RAN?'. Full report available at: https://www.ericsson.com/4ab4fb/assets/local/reports-papers/further-insights/doc/whats-next-for-ran.pdf
- Ericsson, 'The future of digital twins: what will they mean for mobile networks?' https://www.ericsson.com/en/blog/2021/7/future-digital-twins-in-mobile-networks
- Ericsson, Port Network Authority of the North Mediterranean Sea, cnit and FEEM (2020), 'Port of the future Addressing efficiency and sustainability at the Port of Livorno with 5G'. Available at: https://www.ericsson.com/4ac696/assets/local/cases/customer-cases/2020/ericsson_portofthefuture_report.pdf
- Essing N.H. and Westcott, H. (2021), 'The next-generation radio access network: Open and virtualized RANs are the future of mobile networks'. Deloitte Insights, available at: https://www2.deloitte.com/xe/en/insights/industry/technology/technology-media-and-telecom-predictions/2021/radio-access-networks.html
- ETNO & UNI Europa ICTS (2023), 'The EU Telecom Social Partners' Guidelines on Remote Work'. Available at: https://www.uni-europa.org/wp-content/uploads/sites/3/2023/06/Telecom-Remote-Work-Guidelines.pdf
- ETNO (2021), 'Why ICT is the real (green) deal for Europe'. Available at: https://etno.eu/news/8-news/709-ict-green-deal.html
- ETNO (2022), 'ETNO and UNI Europa ICTS consolidate the findings of the 2-year social dialogue project on Digital Upskilling for All'. Available at: https://etno.eu/news/all-news/8-news/750-etno-and-uni-europa-icts-consolidate-the-findings-of-the-2-year-social-dialogue-projecton-digital-upskilling-for-all.html
- ETNO (2022), 'Shaping Policies to Support Investment in Very High Capacity Networks'. Available at: https://etno.eu/library/reports/103-investment-vhcn-2022.html
- ETNO (2024), *State of Digital Communications 2024*. Available at: https://etno.eu//downloads/reports/etno%20state%20of%20digital%20communications%20-%202024.pdf
- ETNO and UNI Europa ICTS (2020), *Joint Declaration on Artificial Intelligence*. Available at: https://etno.eu/downloads/news/ue-etno%20declaration%20ai.pdf
- ETNO and UNI Europa ICTS (2020), *The Telecom Social Dialogue Committee Joint Declaration on Artificial Intelligence*. Available at: https://www.uni-europa.org/old-uploads/2020/12/20201130_UE-ETNO-declaration-AI.pdf
- ETNO and UNI Europa ICTS (2020), 'The Telecom Social Dialogue Committee Joint Declaration on Artificial Intelligence'. Available at: https://etno.eu/downloads/news/ue-etno%20declaration%20ai.pdf
- ETNO, 'EU Taxonomy and the European telecommunications sector'. Available at: https://etno.eu/library/482-eu-taxonomy-and-the-european-telecommunications-sector.html
- ETUI (2023), 'The future of remote work'. Available at: https://www.etui.org/sites/default/files/2023-05/The%20future%20of%20remote%20work_2023.pdf
- EU Startup news (2023), '5G and Startups in the EU: Building a stronger digital future'. Available at: https://eustartup.news/5g-and-startups-in-the-eu-building-a-stronger-digital-future/
- EURES (2020), 'The future of work: ICT Professionals'. Available at: https://eures.europa.eu/future-work-ict-professionals-2020-09-25_en#:~:text=Employment%20for%20IT%20professionals%20is,filled%20between%202018%20and%202030
- Eurofound (2020), 'Workplace practices unlocking employee potential'. *European Company Survey 2019 series*, Luxembourg: Publications Office of the European Union. Available at: https://www.eurofound.europa.eu/sites/default/files/ef_publication/field_ef_document/ef20 001en.pdf.

- Eurofound (2021), 'Impact of digitalization on social dialogue and collective bargaining'. *Research digest*. Available at: https://www.eurofound.europa.eu/en/impact-digitalisation-social-dialogue-and-collective-bargaining
- Eurofound (n.d.), 'What about skills in the digital age?'. Available at: https://www.eurofound.europa.eu/en/what-about-skills-digital-age
- Eurofound (n.d.), 'Work organisation'. Available at: https://www.eurofound.europa.eu/en/topic/work-organisation#policy-pointers
- Eurofound and Cedefop (2020), 'European Company Survey 2019: Workplace practices unlocking employee potential'. *European Company Survey 2019 series*. Luxembourg: Publications Office of the European Union. Available at: https://www.cedefop.europa.eu/en/publications/2228
- European Central Bank (2023), 'How people want to work – preferences for remote work after the pandemic'. Available at: https://www.ecb.europa.eu/pub/economic-bulletin/focus/2023/html/ecb.ebbox202301_04~1b73ef4872.en.html
- European Commission (2021), 'Next-Generation Internet of Things and Edge Computing'. Available at: https://digital-strategy.ec.europa.eu/en/library/next-generation-internet-things-and-edge-computing
- European Commission (2022), 'Shaping Europe's Digital Future: Big Data'. Available at: https://digital-strategy.ec.europa.eu/en/policies/big-data#:~:text=Big%20data%20refers%20to%20large,%2C%20GPS%20signals%2C%20and%20more. .
- European Commission (2022), 'Study on Greening Cloud Computing and Electronic Communications Services and Networks: Towards Climate Neutrality by 2050'. Available at: https://digital-strategy.ec.europa.eu/en/library/study-greening-cloud-computing-and-electronic-communications-services-and-networks-towards-climate
- European Commission (2023), '2023 Report on the state of the Digital Decade'. Available at: https://digital-strategy.ec.europa.eu/en/library/2023-report-state-digital-decade
- European Commission (2023), 'Global targets for renewables and energy efficiency'. Available at: https://energy.ec.europa.eu/topics/international-cooperation/global-targets-renewables-and-energy-efficiency_en
- European Commission (2023), 'Results of the exploratory consultation on the future of the electronic communications sector and its infrastructure'. Available at: https://digital-strategy.ec.europa.eu/en/library/results-exploratory-consultation-future-electronic-communications-sector-and-its-infrastructure
- European Commission (2023), *Broadband Coverage in Europe 2022: Mapping progress towards the coverage objectives of the Digital Decade*. Luxembourg: Publications Office of the European Union. Available at: https://digital-strategy.ec.europa.eu/en/library/broadband-coverage-europe-2022
- European Commission (2020), 'ELISE - European Location Interoperability Solutions for e-Government – Glossary'. Available at: https://joinup.ec.europa.eu/collection/elise-european-location-interoperability-solutions-e-government/glossary/term/digital-twin#:~:text=Digital%20twins%20create%20a%20virtual,increase%20productivity%20through%20predictive%20maintenance
- European Commission (n.d), '5G'. Available at: https://digital-strategy.ec.europa.eu/en/policies/5g
- European Commission (n.d.), 'Europe's Internet of Things Policy'. Available at: https://digital-strategy.ec.europa.eu/en/policies/internet-things-policy
- European Commission (n.d.), 'Sectoral social dialogue – Telecommunications'. Available at: https://ec.europa.eu/social/main.jsp?catId=480&intPageId=1856&langId=en
- European Commission (n.d.), 'Support for Broadband rollout'. https://digital-strategy.ec.europa.eu/en/policies/broadband-support
- European Commission (n.d.), Shaping Europe's Digital Future: Quantum. Available at: https://digital-strategy.ec.europa.eu/en/policies/quantum

- European Commission Digital Transformation Monitor (2017), 'Augmented and Virtual Reality'. Available at: https://ati.ec.europa.eu/sites/default/files/2020-05/Augmented%20and%20Virtual%20Reality%20vf.pdf
- European Electronic Communications Code (EU) 2018/1972 (EECC), Article 2(2). https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32018L1972
- European Investment Bank (2020), 'How it works: GPON fibre to the home'. Available at: https://www.eib.org/en/stories/what-is-gpon
- European Parliament (n.d), 'What is artificial intelligence and how is it used?'. Available at: https://www.europarl.europa.eu/news/en/headlines/society/20200827STO85804/what-is-artificial-intelligence-and-how-is-it-used
- European Parliamentary Research Service (EPRS) (2021), 'The future of work: Trends, challenges and potential initiatives'. *EPRS Ideas Paper* (briefing). Available at: https://www.europarl.europa.eu/RegData/etudes/BRIE/2021/679097/EPRS_BRI(2021)679097_EN.pdf
- European Social Partners (2020), *European Social Partners Framework Agreement on Digitalisation.* Available at: https://www.etuc.org/system/files/document/file2020-06/Final%2022%2006%2020_Agreement%20on%20Digitalisation%202020.pdf
- EY (2020), 'Aligning cybersecurity to enable the Telco metamorphosis in a post-COVID-19 era'.
- EY (2021),'Why RPA is the smart way to begin your process transformation'. Available at: https://www.ey.com/en_it/tmt/why-rpa-is-the-smart-way-to-begin-your-process-transformation
- EY (2022), 'Adapting operations as fast as your markets are changing'. Available at: https://www.ey.com/en_us/tmt/adapting-operations-as-fast-as-your-markets-are-changing
- EY (2022), 'How AI and automation make data centres greener and more sustainable'. https://www.ey.com/en_in/technology/how-ai-and-automation-make-data-centers-greener-and-more-sustainable
- EY (2022), 'How can your quantum vision be transformed into a sustainable reality?'. https://www.ey.com/en_uk/emerging-technologies/how-can-your-quantum-vision-be-transformed-into-a-sustainable-reality
- Fleisch, B. (2022), 'Cut your data centre's energy appetite and boost sustainability'. Available at: https://www.globalservices.bt.com/en/insights/blogs/cut-your-data-centres-energy-appetite-and-boost-sustainability
- Flyaps (2023), 'IoT in Telecom: How it's impacting the industry'. Available at: https://flyaps.com/blog/iot-in-telecom-how-its-impacting-the-industry/
- Forbes (2019), 'Automation and AI actually relieve workplace stress, and customers will notice'. Available at: https://www.forbes.com/sites/joemckendrick/2019/07/29/automation-and-ai-actually-relieve-workplace-stress-and-customers-will-notice/
- Forbes (2022), 'Smart Cities and 5G: Taking it to the next level'. Available at: https://www.forbes.com/sites/deloitte/2022/11/15/smart-cities-and-5g-taking-it-to-the-next-level/
- Frishberg, L. and Lambdin, C. (2015), 'Chapter 3 - PrD and an Agile Way of Business'. In Frishberg, L. and Lambdin, C., *Presumptive Design: Design Provocations for Innovation*. Elsevier.
- Fromkin, S. (2020), 'How can extended reality improve employee performance and retention?' *Talespin*, available at: https://www.talespin.com/blog-post/how-can-extended-reality-training-improve-employee-performance-and-retention
- Frontier Economics (2021), 'Shaping Policies to Support Investments in Very High-Capacity Networks'. Report for ETNO, available at: https://www.etno.eu/component/attachments/attachments.html?task=download&id=8164
- FTP Software (2023), 'Talk to Experts Ep 6: Creating Tomorrow: Generative AI and the Future of Work'. Available at: https://fptsoftware.com/resource-center/blogs/talk-to-experts-ep-6-creating-tomorrow-generative-ai-and-the-future-of-work

- Fujitsu (2023), 'How Open RAN's sustainability advantages support net-zero carbon targets'. Available at: https://networkblog.global.fujitsu.com/2023/09/21/how-open-rans-sustainability-advantages-support-net-zero-carbon-targets/
- Geeksforgeeks (2022), 'Advantages and Disadvantages of Edge Computing'. Available at: https://www.geeksforgeeks.org/advantage-and-disadvantage-of-edge-computing/
- Georgiou, K. E., et al. (2021), '5G Use in Healthcare: The future is present'. Available at: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8764898/
- Global Deal (2020), 'Global Deal Flagship Report 2020: Social Dialogue, Skills and Covid-19'. Available at: https://www.theglobaldeal.com/resources/2020%20Global%20Deal%20Flagship%20Report.pdf
- Global Deal (2023), 'Upskilling and reskilling for the twin transition: The role of social dialogue'. Available at: https://www.theglobaldeal.com/resources/Upskilling-and-reskilling-for-the-twin-transition.pdf
- Google Cloud (2023), 'Cloud network security'. Available at: https://cloud.google.com/learn/what-is-cloud-network-security
- GSMA (2023), *Post Quantum Telco Network Impact Assessment* – Whitepaper, available at: https://www.gsma.com/newsroom/wp-content/uploads//PQ.1-Post-Quantum-Telco-Network-Impact-Assessment-Whitepaper-Version1.0.pdf
- GSMA (2023), 'Guidelines for Quantum Risk Management for Telco'. Available at: https://www.gsma.com/get-involved/working-groups/gsma_resources/guidelines-for-quantum-risk-management-for-telco
- GSMA, 'Mobile Net Zero: State of the Industry on Climate Action 2022'. Available at: https://www.gsma.com/betterfuture/wp-content/uploads/2022/05/Moble-Net-Zero-State-of-the-Industry-on-Climate-Action-2022.pdf
- Gymrek et al. (2023), 'Generative AI and jobs: A global analysis of potential effects on job quantity and quality'. ILO Working Paper, available at: https://www.ilo.org/static/english/intserv/working-papers/wp096/index.html#ID0EC2AG
- Hilton, J. (2019), 'Building The Quantum Workforce Of The Future'. Forbes, available at: https://www.forbes.com/sites/forbestechcouncil/2019/06/19/building-the-quantum-workforce-of-the-future/?sh=5078bac4fa47
- IBM (2023), 'Securing telecoms networks for the post-quantum era'. Available at: https://research.ibm.com/blog/quantum-safe-telecoms-ibm
- IBM (2023), 'What is edge computing?'. Available at: https://www.ibm.com/topics/edge-computing
- IBM (2024), 'What is IT Infrastructure?'. Available at: https://www.ibm.com/topics/infrastructure
- ILO (2018). Resolution concerning the second recurrent discussion on social dialogue and tripartism, p. 2, available at: https://www.ilo.org/ilc/ILCSessions/previous-sessions/107/reports/texts-adopted/WCMS_633143/lang--en/index.htm.
- IndustriALL (2021), 'Report: Why telework needs institutional regulation and collective bargaining'. Available at: https://www.industriall-union.org/report-why-telework-needs-institutional-regulation-and-collective-bargaining
- Intellias (n.d), 'Optimizing Telecom Back-Office Systems'. Available at: https://intellias.com/optimizing-telecom-back-office-systems/
- International Telecommunication Union (2023), *Recommendation ITU-R M.2160-0 (11/2023):* 'Framework and overall objectives for the development of IMT for 2030 and Beyond'. Available at: https://www.itu.int/dms_pubrec/itu-r/rec/m/R-REC-M.2160-0-202311-I!!PDF-E.pdf
- Inveniam (2023), 'AI – A Key Driver of Sustainability in Telco Companies'. Available at: https://www.inveniam.fr/en/blog/ai-key-driver-of-sustainability-in-telco-companies
- iQuasar (2023), 'Enhancing Efficiency: How AI is Revolutionizing Telecom Staffing'. Available at: https://iquasar.com/blog/enhancing-efficiency-how-ai-is-revolutionizing-telecom-staffing/
- ITU (2021), 'New ITU standards to boost Fibre to the Home from 10G to 50G'. Available at: https://www.itu.int/hub/2021/06/new-itu-standards-to-boost-fibre-to-the-home-from-10g-to-50g/

- Johnson, J. (2022), 'How AI-Based Marketing is Transforming Telecom Companies'. Available at: https://www.spiceworks.com/tech/artificial-intelligence/guest-article/ai-based-marketing-transforming-telecom-companies/
- JRC (2019), *The changing nature of work and skills in the digital age*. Luxembourg: Publication Office of the European Union. Available at: https://publications.jrc.ec.europa.eu/repository/handle/JRC117505
- Kanerika Inc (2023), 'Data Analytics in Telecom Industry: A Comprehensive Guide'. Available at: https://medium.com/@kanerika/data-analytics-in-telecom-industry-a-comprehensive-guide-da9735565ae9
- Kasi, S. et al. (2023), 'A Cost and Power Feasibility Analysis of Quantum Annealing for NextG Cellular Wireless Networks'. *IEEE Transactions on Quantum Engineering*, available at: https://discovery.ucl.ac.uk/id/eprint/10180192/1/A_Cost_and_Power_Feasibility_Analysis_of_Quantum_Annealing_for_NextG_Cellular_Wireless_Networks.pdf
- Kastouni and Lahcen (2020), 'Big data analytics in telecommunications: Governance, architecture and use cases'. *Journal of King Saud University – Computer and Information Sciences*, 34, pp. 2758–2770. Available at: https://doi.org/10.1016/j.jksuci.2020.11.024 .
- Kepler (n.d.), 'Network Rollout – Definition'. Available at: https://www.kepler-consulting.com/en/solutions/what-is-network-rollout/
- Khan MJ, Ullah F, Imran M, Khan J, Khan A, AlGhamdi AS, Alshamrani SS. (2022), 'Identifying Challenges for Clients in Adopting Sustainable Public Cloud Computing'. Sustainability: 14(16). Available at: 9809. https://doi.org/10.3390/su14169809
- Kim, H., et al. (2021), 'A systematic review of the smart energy conservation system: From smart homes to sustainable smart cities'. Available at: https://www.sciencedirect.com/science/article/pii/S1364032121000502?casa_token=LOSQ0oLnD7gAAAAA:CiyOiV6UP8ckMwebY49iQI4GcUsOEhNgp_D9y35WGUVuyO0jnOsQDWur6d-KkDm1rT57HNQiUg
- Kinney, S. (2024), 'How does RAN modernization foster sustainability?'. *RCRWirelessNews*, Available at: https://www.rcrwireless.com/20240103/fundamentals/how-does-ran-modernization-foster-sustainability
- KPN (2019), 'Smart Cities in the Netherlands: what are they, benefits and areas for improvement'. Available at: https://www.kpn.com/zakelijk/blog/smart-cities-in-nederland-voorbeelden-voordelen-en-verbeterpunten.htm
- Lopes, J. (2024), 'Supercharge your business with back-office automation: The ultimate guide'. Available at: https://www.pipefy.com/blog/back-office-automation/
- Mangtani, A. (2023), 'What is vRAN?'. Medium, available at: https://ashley-mangtani.medium.com/what-is-vran-9307f39e13b6
- Manheim, K. & Kaplan, L. (2019), 'Artificial Intelligence: Risks to Privacy and Democracy'. Available at: https://edisciplinas.usp.br/pluginfile.php/6502070/mod_folder/content/0/Manheim-AI%2C%20risks%20to%20privacy%20and%20democracy%2C%202019.pdf
- McKinsey (2019), 'Confronting the risk of artificial intelligence'. Available at: https://www.sipotra.it/wp-content/uploads/2019/05/Confronting-the-risks-of-artificial-intelligence.pdf
- McKinsey (2023), 'Tech talent in transition: Seven technology trends reshaping telcos'. Available at: https://www.mckinsey.com/industries/technology-media-and-telecommunications/our-insights/tech-talent-in-transition-seven-technology-trends-reshaping-telcos
- McKinsey (2023), 'Telecom Networks: tracking the coming xRAN Revolution'. Available at: https://www.mckinsey.com/industries/technology-media-and-telecommunications/our-insights/telecom-networks-tracking-the-coming-xran-revolution
- McKinsey (2023), 'The AI-native telco: Radical transformation to thrive in turbulent times'. Available at: https://www.mckinsey.com/industries/technology-media-and-telecommunications/our-insights/the-ai-native-telco-radical-transformation-to-thrive-in-turbulent-times
- McKinsey (2023), 'The economic potential of generative AI'. Available at: https://www.mckinsey.de/~/media/mckinsey/locations/europe%20and%20middle%20east/deutschland/

news/presse/2023/2023-06-14%20mgi%20genai%20report%2023/the-economic-potential-of-generative-ai-the-next-productivity-frontier-vf.pdf

- McKinsey (2024), 'How generative AI could revitalize profitability for telcos'. Available at: https://www.mckinsey.com/industries/technology-media-and-telecommunications/our-insights/how-generative-ai-could-revitalize-profitability-for-telcos
- McKinsey Digital (2023), 'Cloud-powered technologies for sustainability'. Available at: https://www.mckinsey.com/capabilities/mckinsey-digital/our-insights/cloud-powered-technologies-for-sustainability
- Meta (2020), 'Making aerial fiber deployment faster and more efficient'. Available at: https://engineering.fb.com/2020/07/13/connectivity/aerial-fiber-deployment/
- Mohr, N. et al. (2022), 'Five lessons from AI on closing quantum's talent gap—before it's too late'. McKinsey Digital, available at: https://www.mckinsey.com/capabilities/mckinsey-digital/our-insights/five-lessons-from-ai-on-closing-quantums-talent-gap-before-its-too-late
- Morris, I. (2023), 'Big telcos cut another 85k jobs in 2022 as gen AI loomed'. Available at: https://www.lightreading.com/ai-machine-learning/big-telcos-cut-another-85k-jobs-in-2022-as-gen-ai-loomed#close-modal
- Nanos, I. (2023), 'Cloud Computing Adoption in Public Sector: A Literature Review about Issues, Models and Influencing Factors'. In: Matsatsinis, N.F., Kitsios, F.C., Madas, M.A., Kamariotou, M.I. (eds) Operational Research in the Era of Digital Transformation and Business Analytics. BALCOR 2020. Springer Proceedings in Business and Economics. Springer, Cham. https://doi.org/10.1007/978-3-031-24294-6_26
- Nikou, S.A. (2023), 'Digital Experts: a deep-dive'. *European Digital Skills & Jobs Platform*, available at: https://digital-skills-jobs.europa.eu/en/latest/briefs/digital-experts-deep-dive-0
- Nokia (2023), 'Nokia and Deutsche Telekom begin deployment of multi-vendor Open RAN network in Germany'. Available at: https://www.nokia.com/about-us/news/releases/2023/12/12/nokia-and-deutsche-telekom-begin-deployment-of-multi-vendor-open-ran-network-in-germany/
- Nokia (n.d), 'AVA – Energy efficiency'. Available at: https://www.nokia.com/networks/bss-oss/ava/energy-efficiency/?did=D000000007BR&gad_source=1
- Nokia (n.d), 'Nokia Bell Labs 5G Certification Program'. Available at: https://www.nokia.com/networks/training/5g/bell-labs/
- OECD (2020), *Increasing Adult Learning Participation: Learning from Successful Reforms*. Paris: OECD Publishing. Available at: https://doi.org/10.1787/cf5d9c21-en.
- OECD (2021), *Training in Enterprises: New Evidence from 100 Case Studies*. Paris: OECD Publishing. Available at: https://doi.org/10.1787/7d63d210-en
- Oliver Wyman (2021), 'The next level of emission reductions in telecom operators'. Available at: https://www.oliverwyman.com/our-expertise/insights/2021/may/next-level-of-emission.html
- Orange (2022), 'Artificial Intelligence'. Available at: https://www.orange.com/sites/orangecom/files/documents/2022-02/IA-EN%20-%20FINAL.pdf
- Orange (2023), 'Greening the telecoms network'. Available at: https://www.orange-business.com/en/blogs/greening-telecoms-network
- Orient (2024), 'When technologies collide: Exploring the powerful impact of IoT in Telecommunications'. Available at: https://www.orientsoftware.com/blog/iot-in-telecommunications/
- Palazzo, M., & Siano, A. (2021), 'Fifth-generation (5G) communication networks and sustainability: A research agenda'. Available at: https://journals.francoangeli.it/index.php/cgrds/article/view/10459
- Parcu, P. L., et al. (2023), 'The future of 5G and beyond: Leadership, deployment and European policies'. Available at: https://www.sciencedirect.com/science/article/pii/S0308596123001337
- Peruffo, E. (n.d.), 'Artificial intelligence and the world of work'. *Eurofound*, available at: https://www.eurofound.europa.eu/en/artificial-intelligence-and-world-work
- Phillipson, F. (2023). "Quantum Computing in Telecommunication—A Survey" Mathematics 11, no. 15: 3423. https://doi.org/10.3390/math11153423

- Pütz, S., Rick, V., Mertens A., Nitsch, V. (2022), 'Using IoT devices for sensor-based monitoring of employees' mental workload: Investigating managers' expectations and concerns'. Applied Ergonomics, 102, available at: https://doi.org/10.1016/j.apergo.2022.103739
- PwC (2019), Blockchain for MENA telecom operators: seizing the opportunity'. Available at: https://www.strategyand.pwc.com/m1/en/reports/blockchain-for-mena-telecom-operators.pdf
- Rakuten Symphony (2023), 'White Paper - Best Practice Approaches for Reducing System Level Energy Consumption in 5G Open RAN'. Available at: https://assets-global.website-files.com/6317e170a9eabbe0fbbf4519/651d5db527d1e4e4c956daa2_Energy%20Saving.pdf
- RCR Wireless News (2021), 'What is a Cloud native Network Function?'. Available at: https://www.rcrwireless.com/20211025/telco-cloud/what-is-a-cloud-native-network-function
- Real Research Media (2023), 'Survey on Dependence of Artificial Intelligence at Workplace'. Available at: https://realresearcher.com/media/survey-on-dependence-of-artificial-intelligence-at-workplace/
- RedHat (2021), 'Understanding edge computing for telecommunications'. Available at: https://www.redhat.com/en/topics/edge-computing/telecommunications
- Regulation (EU) 2016/679 of the European Parliament and of the Council of 27 April 2016 on the protection of natural persons with regard to the processing of personal data and on the free movement of such data, and repealing Directive 95/46/EC (General Data Protection Regulation). Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32016R0679
- Reintech (2023), 'Blockchain in Telecommunications: Use Cases and Applications'. Available at: https://reintech.io/blog/blockchain-in-telecommunications-use-cases-applications
- Reuters (2018), 'Insight – Amazon scraps secret AI recruiting tool that showed bias against women'. Available at: https://www.reuters.com/article/idUSKCN1MK0AG/
- Reuters (2023), 'Europe agrees landmark AI regulation deal'. Available at: https://www.reuters.com/technology/stalled-eu-ai-act-talks-set-resume-2023-12-08/
- Ronchi, A. (2022), 'Big Data & Machine Learning Data Analytics & New Trends'. In Pavan Duggal (ed.), *Cybercrime, cyberlaws, cybersecurity*, New Delhi: ICCC Academy. Available at: https://re.public.polimi.it/handle/11311/1234898?mode=complete
- Saraji, S. and Borowczak, M. (2021), 'White Paper A Blockchain-based Carbon Credit Ecosystem'. Available at: https://arxiv.org/ftp/arxiv/papers/2107/2107.00185.pdf
- SDx Central Studios (2020), 'What is Cloud Networking or Cloud-Based Networking?'. Available at: https://www.sdxcentral.com/networking/sdn/definitions/enterprise-data-center-networking/all-about-cloud-networking/
- Sebastian Thiede, Roy Damgrave, Eric Lutters (2022), 'Mixed reality towards environmentally sustainable manufacturing – overview, barriers and design recommendations'. Procedia CIRP, 105, pp. 308-313. Available at: https://doi.org/10.1016/j.procir.2022.02.051.
- See Chen, S. (2023), 'The future is quantum: universities look to train engineers for an emerging industry'. Nature, available at: https://www.nature.com/articles/d41586-023-03511-7
- See for example: Kaarlela, Tero, Paulo Padrao, Tomi Pitkäaho, Sakari Pieskä, and Leonardo Bobadilla. 2023. "Digital Twins Utilizing XR-Technology as Robotic Training Tools" Machines 11, no. 1: 13. https://doi.org/10.3390/machines11010013
- Senior, John M.; Jamro, M. Yousif (2009). *Optical fiber communications: principles and practice*. Pearson Education.
- Siddiqui, L. (2023), 'What is Cloud Security? Types, Risks & Benefits Defined'. Available at: https://www.splunk.com/en_us/blog/learn/cloud-security.html
- Sievers, F. (2021), 'Empowering employees in industrial organizations with IoT in their daily operations'. Available at: https://www.sciencedirect.com/science/article/pii/S016636152100052X
- Sinch (n.d), 'How a leading telco increases client & employee satisfaction with Conversational AI'. Available at: https://www.sinch.com/insights/customer-stories/telco-increases-client-employee-satisfaction-conversational-ai/

- Sonatafy (n.d), 'Front Office vs Back Office'. Available at: https://sonatafy.com/about-front-office-vs-back-office-2/
- Supercharge Lab (2023), 'AI and 5G: Enhancing Telecommunication Networks for a Smarter World'. Available at: https://superchargelab.com/ai-and-5g-enhancing-telecommunication-networks-for-a-smarter-world/
- Sustainability Success (2023), 'How can Edge computing Be Used To Improve sustainability?'. Available at: https://sustainability-success.com/how-can-edge-computing-be-used-to-improve-sustainability/
- Swisscom, 'Responsibility for the Environment', available at: https://www.swisscom.ch/en/about/sustainability/environment.html
- Swisscom, 'A pan-European player in the fleet management technology sector is born!' Available at: https://ventures.swisscom.com/a-pan-european-player-in-the-fleet-management-technology-sector-is-born/
- Taaffe, J. (2023), 'SK Telecom's bet on immersive experiences'. Available at: https://inform.tmforum.org/features-and-opinion/sk-telecoms-business-bet-on-immersive-experiences
- Tech Republic (2020), 'Telecoms have unique challenges in adopting AI'. Available at: https://www.techrepublic.com/article/telecoms-have-unique-challenges-in-adopting-ai/
- Techjockey (2023), 'Top 10 CRM in Telecom Industry: Its Roles & Benefits'. Available at: https://www.techjockey.com/blog/crm-in-telecom-industry
- TechTarget (n.d.), 'Radio Access Network (RAN)'.Available at: https://www.techtarget.com/searchnetworking/definition/radio-access-network-RAN?_ga=2.203974288.1847071535.1599037084-940098927.1599037084
- Telecom Infra Project (2022), 'Automation and Optimisation for OpenRAN TIP White Paper'. Available at: https://cdn.mediavalet.com/usva/telecominfraproject/nW7oKPWc-EiGkZHPZnm-wA/PYEOHoNFmkqOPCkvNKZJyA/Original/AI-RAN-OPT-White-Paper-Jan-2022-For_Public_Release-FINAL_Format.pdf
- Telecom Infra Project (n.d.), homepage, available at: https://telecominfraproject.com/
- Telefònica Tech (2021), 'Growing impact and future potential of blockchain for telcos: A Game Changer?' Available at: https://telefonicatech.com/en/blog/growing-impact-and-future-potential-of-blockchain-for-telcos-a-game-changer
- Telekom (2016), 'Smart Home platform QIVICON now also available in the Netherlands'. Available at: https://www.telekom.com/en/media/media-information/detail/smart-home-platform-qivicon-now-also-available-in-the-netherlands-363268
- Telekom (n.d), '5G network as foundation for autonomous driving'. Available at: https://www.telekom.com/en/company/details/5g-network-as-foundation-for-autonomous-driving-561986
- Telekom (n.d), 'Services for the industries of the future'. Available at: https://b2b-europe.telekom.com/enterprise-it-solutions/manufacturing-it-solutions
- Telia (2020), 'Telia IoT to connect one million E.On customers'. Available at: https://business.teliacompany.com/blog/telia-iot-to-connect-one-million-e.on-customers-
- Telia Company (2021), 'Robots go 5G: Telia and Ekobot in partnership for sustainable farming'. Available at: https://www.teliacompany.com/en/news-articles/robots-go-5g-telia-and-ekobot-in-partnership-for-sustainable-farming
- Telia Company (2023), 'IoT speeds up effort to reduce energy consumption in challenging times'. Available at: https://www.teliacompany.com/en/news-articles/iot-speeds-up-effort-to-reduce-energy-consumption-in-challenging-times
- Testa, F., Bianchi, A., Stracca, S., Sabella, R. (2016). Silicon Photonics for Telecom and Datacom Applications. In: Pavesi, L., Lockwood, D. (eds) Silicon Photonics III. Topics in Applied Physics, vol 122. Springer, Berlin, Heidelberg. Available at: https://doi.org/10.1007/978-3-642-10503-6_15

- Thomas, A. (2022), 'How AI and automation make data centers greener and more sustainable'. EY, available at: https://www.ey.com/en_in/technology/how-ai-and-automation-make-data-centers-greener-and-more-sustainable
- Tim, H.W. and Rana, M.E. (2023), 'A Review off Cloud computing on Sustainable Development'. Available at: https://ieeexplore.ieee.org/document/10041482
- Todosioska, A. (2020), 'The role of telecommunication companies in Internet of Things'. Available at: https://run.unl.pt/handle/10362/94883
- Tryson, M. (n.d), 'How High-Speed Connectivity is Enabling IoT'. Available at: https://www.te.com/usa-en/about-te/perspectives-on-technology/high-speed-connectivity-enabling-iot.html
- TUPL (2023), 'Should Telcos Be Worried About AI and Its Evolution?'. Available at: https://www.tupl.com/blog/should-telcos-be-worried-about-ai-and-its-evolution/
- UNI Europa (2021), 'A Workers' perspective on Artificial Intelligence (AI) and Surveillance'. Available at: https://www.uni-europa.org/news/a-workers-perspective-on-artificial-intelligence-ai-and-surveillance/
- UNI Europa (2022), 'Algorithmic Management: 1 in 3 workers left in the dark'. Available at: https://www.uni-europa.org/news/algorithmic-management-1-in-3-workers-left-in-the-dark/
- UNI Europa ICTS and ETNO (2023), 'The EU Telecom Social Partners' Guidelines on Remote Work'. Available at: https://etno.eu//downloads/news/telecom-remote-work-guidelines.pdf
- US National Security Agency and CISA (2022), 'Open Radio Access Network Security Considerations'. Available at: https://www.cisa.gov/sites/default/files/publications/open-radio-access-network-security-considerations_508.pdf
- Utilities One (2023), 'How Drones are Revolutionizing Communication Infrastructure Development'. Available at: https://utilitiesone.com/how-drones-are-revolutionizing-communication-infrastructure-development
- Utilities One (2023), 'Telecommunications Infrastructure and the Future of Quantum Communication'. Available at: https://utilitiesone.com/telecommunications-infrastructure-and-the-future-of-quantum-communication
- Utilities One (2023), 'The impact of energy-efficient construction on telecommunication infrastructure'. Available at: https://utilitiesone.com/the-impact-of-energy-efficient-construction-on-telecommunication-infrastructure
- Utilities One (2023), 'Unequal Connections Investigating the Digital Divide in Telecommunications Networks'. Available at: https://utilitiesone.com/unequal-connections-investigating-the-digital-divide-in-telecommunications-networks
- Vella, H. (2024), 'Edge computing and the future of telecommunications'. Available at: https://www.verizon.com/business/resources/articles/s/edge-computing-and-the-future-of-telecommunications/
- Viavi Solutions (n.d), 'What is 5G energy consumption?'. Available at: https://www.viavisolutions.com/en-us/what-5g-energy-consumption
- Visionary Analytics for DG CNECT (forthcoming), 'Zero-distance XR applications and services'.
- Visionary Analytics and Notus (2023), 'Study exploring the social, economic and legal context and trends of telework and the right to disconnect, in the context of digitalisation and the future of work, during and beyond the Covid-19 pandemic'. Report for the European Commission, DG EMPL. Available at: https://ec.europa.eu/social/main.jsp?catId=738&langId=en&pubId=8595&furtherPubs=yes
- Visionary Analytics and Tallinn University of Technology for OSHA (2022), 'Artificial intelligence for worker management: an overview'. Available at: https://osha.europa.eu/sites/default/files/artificial-inteligence-worker-management_en.pdf
- Vodafone (n.d.), 'What is a radio access network (RAN)?'. Available at: https://www.vodafone.com/business/news-and-insights/glossary/what-is-a-radio-access-network-ran
- Waicberg, S. (2022), 'Augmented reality advances organisation ESG initiatives'. Sustainability, available at: https://sustainabilitymag.com/esg/augmented-reality-advances-organisation-esg-initiatives

- Weaver Labs (2023), 'Blockchain: The Future of the Telecoms Industry'. Available at: https://medium.com/weaver-labs/blockchain-the-future-of-the-telecoms-industry-b12cf9ca203e
- Wheelwright, G. (2017), 'IoT-linked wearables will help workers stay safe'. *Financial Times*, available at: https://www.ft.com/content/944e6efe-96cb-11e7-8c5c-c8d8fa6961bb
- Wolfie Christl (2023), 'Monitoring, streamlining and reorganising work with digital technology'. Report for UNI Europa ICTs, available at: https://www.uni-europa.org/news/new-report-monitoring-streamlining-and-reorganizing-work-with-digital-technology/
- Wong, E. R., et al. (2017), 'Be more familiar with our enemies and pave the way forward: A review of the roles bugs played in software failures'. Available at: https://www.sciencedirect.com/science/article/abs/pii/S0164121217301334
- World Bank (2021), 'How can 5G make a differene to education?'. Available at: https://blogs.worldbank.org/digital-development/how-can-5g-make-difference-education
- World Broadband Association (2022), 'The Importance of Environmental Sustainability in Telecom Service Providers' Strategy'. Available at: https://worldbroadbandassociation.com/wp-content/uploads/2022/09/The-Importance-of-Environmental-Sustainability-in-Telecom-Service-Providers-Strategy-World-Broadband-Association-White-Paper.pdf
- World Economic Forum (2020), 'The Impact of 5G: Creating New Value across Industries and Society'. Available at: https://www3.weforum.org/docs/WEF_The_Impact_of_5G_Report.pdf
- Yeh, C. (2012), *Applied Photonics*. Elsevier. Available at: https://shop.elsevier.com/books/applied-photonics/yeh/978-0-08-049926-0
- Yo Telekom (2023), 'Artificial Intelligence & Telecoms'. Available at: https://yotelecom.co.uk/artificial-intelligence-telecoms/