SHAPING THE DIGITAL TRANSFORMATION IN EUROPE

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EXECUTIVE SUMMARY

The digital transformation of Europe's economies and societies is accelerating. It is entering a next phase, fuelled by a fusion of technologies that gradually blur the lines between the physical, digital, and biological spheres and push the frontier of what computers are capable of doing. These new technologies – and the new business models they create, building on the use of data – are progressively coming to maturity for at-scale deployment, and will increasingly impact all sectors of the economy. In section 2 of this report, we discuss a set of such high-impact technologies and applications, for example, artificial intelligence, high-performance computing, advanced robotics, virtual and augmented reality, and their potential impact on Europe's economy, the labour market, and wider society.

The potential value of these technologies is substantial, as described in section 3. Following macroeconomic simulations conducted for this report, by 2030, **the cumulative additional GDP contribution of new digital technologies could amount to €2.2 trillion in the EU**, a 14.1 per cent increase from 2017. This figure offsets all technological investment needed and is a direct positive return to the EU economy. In the simulation of labour market effects, the average employment effect of technology by 2030 is -2.9 per cent; however, this effect may be offset by a decline in the European labour force projected for the same period, due to demographic effects. This results in a need for higher labour productivity, which digitalisation can provide.

Raising the investment level in digital technologies and digital skills is essential. This investment need is unlikely to be covered by the private sector alone, either because the business case is lacking (e.g. connectivity investments in rural areas), because there are information barriers or risks to be mitigated (e.g. in industrial transformation) or because the scale is such that investments exceed the capacity of any individual company or sector (e.g. HPC, quantum, data spaces). Public funding is needed to leverage the capital required for the digital transformation.

As discussed in section 6 below, **European institutions and governments may need to contribute approximately €75 billion per year for ICT investment** in the coming decade to close the digital gap in Europe compared to the most digitally advanced Member States, and to keep up a high ambition level for capturing the value of high-impact technologies. Additionally, **education, upskilling and reskilling of the labour force to manage the digital transition, may require total investments of €42 billion per year**.

Without public intervention, both economic and labour effects are likely to impact countries and regions unevenly, favouring the economies that are already most advanced, and hence risking to exacerbate existing inequalities. On the other hand, measures that effectively promote the development, adoption, and diffusion of new technologies can help capture digital's potential to the benefit of all citizens, in an inclusive and sustainable manner. This, however, requires pro-actively managing the challenges that arise in the transition, including distribution effects within and between regions.

In this context, and building on the European Commission's strategy *Shaping Europe's Digital Future* of February 2020, section 5 discusses how this transformation can be guided by four objectives for a human-centric digital path for Europe:

- *building and deploying digital solutions for societal challenges and climate;*
- *reinvigorating democracy, trust and diversity;*
- *securing Europe's digital technological sovereignty and cybersecurity;* and
- *boosting the economy and competitiveness.*

A holistic perspective is needed at a pivotal moment for European decision making, as the Member States are struggling to manage, and eventually fully recover from the devastating COVID-19 pandemic; and as the European institutions and Member States are reaching a final agreement on the Multiannual Financial Framework for 2021-2027, as well as the Next Generation EU economic recovery instrument. The European Commission's proposals included initiatives and investments to promote the green and digital transition – two closely linked priority areas, and where investments are much needed.

Strategic initiatives and investments are needed on all levels. As discussed in section 4, Europe is lagging behind other leading regions in some areas of digital technology development and adoption, pertaining to both basic digital technologies and the emerging high-impact technologies highlighted in this report. Large differences remain within and between EU Member States, and fragmentation itself is a barrier for development and adoption at scale of European digital solutions, which often require a large critical mass – of data, users or connected nodes – to be viable. Therefore, some digital investments and interventions are likely most effective on the European level, where the world's largest single market can achieve a value larger than the sum of its parts.

This report outlines nine potential *signature initiatives* for Europe (summarized on next page): bold actions that set a high bar and that directly address the four objectives for Europe's digital transformation, discussed above. Briefly summarized below, the options and opportunities for launching these initiatives are discussed in section 7.

This report summarises the outcome of the study *Shaping the digital transformation in Europe* performed by McKinsey for the Directorate-General of Communications Networks, Content and Technology (DG CONNECT).

RÉSUMÉ EN FRANÇAIS

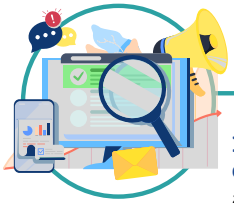
Les technologies digitales ont un impact profond sur les économies et les sociétés européennes. Dans ce rapport, nous discutons comment cette transformation peut être guidée par quatre principes pour un futur numérique européen centré sur l'humain : économie et compétitivité ; défis sociétaux et climat ; démocratie, confiance et diversité ; et souveraineté et sécurité. L'Europe peut se préparer pour bénéficier de cette transformation numérique, de manière inclusive et durable, au profit de tous les Européens. D'ici 2030, la contribution supplémentaire cumulée des nouvelles technologies digitales au PIB pourrait s'élever à 2,2 mille milliards d'euros dans l'UE, soit 14,1% plus par rapport à 2017. Cependant, sans une gestion proactive, la valeur sera répartie de manière inégale et pourrait avoir un impact négatif net sur l'emploi et l'égalité.

Dans certains domaines, l'Europe reste en retrait par rapport à d'autres régions, et de grandes différences subsistent au sein des États membres et entre ceux-ci. Des actions proactives seront nécessaires pour stimuler le développement et l'adoption de ces technologies, tout en gérant prudemment la transition et ses risques.

Ce rapport présente neuf initiatives potentielles d'action européenne : *développer les écosystèmes technologiques de l'UE pour en tant que leader mondiaux ; créer un instrument de leadership digital ; créer des plateformes de données européennes pour les secteurs stratégiques interentreprises ; montrer la voie vers une IA fiable dans le monde entier ; dynamiser les villes et communautés en Europe ; lever un bouclier de cybersécurité pour l'Europe ; améliorer le contrôle des citoyens sur leurs données personnelles ; promouvoir des solutions digitales durables; soutenir l'apprentissage tout au long de la vie pour l'avenir du travail*. Ensemble, ces actions peuvent améliorer la position de l'Europe pour adopter de nouvelles technologies digitales avancées au profit de tous les Européens.

Ce rapport résume les résultats de l'étude *"Shaping the digital transformation in Europe"* réalisée par McKinsey & Company pour la direction générale des réseaux de communication, contenu et technologies (DG CONNECT).

NINE SIGNATURE INITIATIVES TO LEAD THE WAY



1. Developing and scaling EU tech ecosystems to match the global best and position Europe as a leader in key new frontier digital technologies around Centres of Excellence enabled by the collaboration between Super-Universities, Public Authorities, established Industries and vibrant Start-ups

2. Creating a Digital leadership instrument for innovation procurement of digital technologies of European strategic importance, combining innovation funding and public procurement

4. Leading the way towards trustworthy AI worldwide by both promoting AI-based innovation to fuel economic growth and social innovations while ensuring transparency and a positive social impact, which can include social measures to counter potential adverse effects. This would differentiate European AI solution as ethical and trustworthy

3. Building EU data platforms for strategic B2B sectors, enabling as an example, the Europe-wide sharing of health data (or similarly utilities or transport data) to improve healthcare outcomes, research and fuel innovation while respecting privacy and citizen trust

5. Empowering cities and communities across Europe by promoting and enabling development and equal access to citizen-centric smart city technologies for better public and private services across transport, health, energy, social and community services for the EU's ~100.000 municipalities

6. Raising a cybersecurity shield for Europe to protect EU citizens, businesses and Member States from attacks on their data and data systems. This entails protecting end-to-end technology supply chains including foreign technology and increasing strategic autonomy for key technologies

8. Promoting digital solutions for climate risks by both promoting the positive potential of digital technologies to reduce CO2 emissions and resource use in other industries as well as reducing the growing contribution of ICT to CO2 emissions and material use (particularly rare metals) due to both infrastructure (e.g. data centres) and ICT devices

7. Advancing citizen control of their personal data, building on the General Data Protection Regulation, to improve understanding, user-centricity, control and effective enforcement of citizens' data rights and enable innovation and new business models based on data portability

9. Supporting lifelong learning for the future of work, to enable at-scale reskilling of citizens (particularly populations at risk of unemployment) and equip all citizens with the digital and cognitive skills they need to succeed in a future of work context

Dimensions addressed by the initiative

- Economy and competitiveness
- Societal challenges and climate
- Democracy, trust and diversity
- Sovereignty and security

1 INTRODUCTION

Digital technologies are profoundly impacting our economies and societies. While the previous three industrial revolutions were fostered by water and steam power, electric power, and more recently electronics and information technologies, the coming wave of high-impact, digital technologies (e.g. AI and quantum computing) are characterised by use of data in a fusion of technologies blurring the lines between the physical, digital, and biological spheres, and by their general purpose[1]. They are impacting all sectors, and pushing the frontier of what computers are capable of doing in all facets of business and the economy[2]. We are only seeing the beginning of this transformation. As technologies are increasingly maturing, their impact is accelerating, carrying a promise of increased prosperity and solutions to some of our most pressing societal problems, but also the risk of social disruptions and increased inequality.

Europe is well-positioned to capture the value of the next wave of digital transformation, inclusively and sustainably, to the benefit for all Europeans. But proactive actions will be needed on all levels to boost the development and adoption of high-potential technologies, while prudentially managing the transition and its risks. The European Commission laid the groundwork for shaping the digital transformation through the Digital Single Market strategy of 2015-2019 and its broad array of policies and funds to build a solid foundation for a digital economy and society, a level playing field for digital enterprises and innovations and better access to digital goods and services for all Europeans.

Europe now stands at a pivotal moment, with large strategic and investment decisions setting the direction for the coming years. In the new strategy *Shaping Europe's Digital Future*, launched in February 2020, the Commission once again voiced its commitment to taking an active role in the digital transformation[3]. As the EU enters into a new Multiannual Financial Framework (MFF) period in 2021, the European Commission has made investments that promote the digital transformation a top priority. The proposed new Digital Europe programme, with a proposed allocation of €9.2 billion for the 2021-2017 MFF period, aims at boosting high-performance computing and data, artificial intelligence, cybersecurity and advanced digital skills; the Connecting Europe Facility would add another €3 billion for digital infrastructure; and in the proposed €100 billion Horizon Europe programme, advanced digital research and innovation are prioritized cornerstones[4]. The InvestEU programme aims at triggering €650 billion in additional investment, targeting areas that include digitalisation, skills and SMEs. Moreover, in light of the COVID-19 crisis, the European Commission has put forward the Next Generation EU instrument, a proposed €750 billion fund to support the resilience and recovery of the Union – with a large emphasis on green and digital infrastructure investments[5]. Together, these funds and programmes target all stages of digital development and will raise the digital standard of the Union's Member States, closing digital gaps within and between Member States, and preparing Europe for the next wave of digital transformation. Funding at the European level, combined with national funding, can act as a catalyst for the private sector, showing that investing in digital is worthwhile. Leveraging multiple sources of public funding and blending it with private investment could provide the necessary capital required for the successful deployment of large scale, European-wide digital projects.

As reflected in the proposed MFF and the Next Generation EU instrument, the digital transformation is one of two large-scale challenges of our times for Europe along with the green transformation. The two are linked: digital solutions have a critical role to play in helping Europe transition to a more sustainable economy and society. At the same time, the green transformation can boost the future of digital technologies, with reduced resource usage, waste, and greenhouse gas emissions.

This report builds on a study[6] carried out by McKinsey on behalf of the Commission, Directorate-General of Communications Networks, Content and Technology. It builds on a broad review of literature and policy documents; on the McKinsey Global Institute's (MGI) methodology for macroeconomic simulations; and on extensive input from a wide range of academics, technology experts, policy experts, and business leaders, in interviews, workshops and in an executive (CxO) survey (see section 7). The report analyses the potential impact of new high-impact, digital technologies for Europe, assesses the position of the EU in digital and reviews the past and ongoing actions of the Commission, mainly related to the Digital Single Market strategy. It then discusses nine potential signature initiatives for European action that together can proactively improve Europe's readiness to embrace new high-impact technologies for the benefit of all Europeans.

1.1 The COVID-19 pandemic's effect on digital transformation

The global COVID-19 pandemic and the ensuing economic crisis have put digital technologies into the spotlight and highlighted the need for action. The need for social distancing has accelerated the development and uptake of digital services at an unprecedented pace. According to one analysis, digital adoption for consumers and businesses vaulted five years forward in a matter of weeks at the height of the crisis[7]; a large share of the workforce across Europe shifted to working remotely, e-commerce and use of delivery apps skyrocketed, millions of pupils and students continued their studies through online education, and governments rapidly developed new digital services to be able to serve citizens in times of social distancing. Much of this change, and many of these new services, experiences and digital skills will stay in place after the pandemic. Digital solutions have also played an essential role in the public health response. High-performance computing and innovative data sharing approaches are already being used for researching treatments and the development of vaccines at record pace[8] and AI solutions are used for lung scan analyses[9]

At the same time, the pandemic is responsible for the deepest economic crisis in post-war times, as businesses had to temporarily pause or slow their operations and private consumption as well as investment experienced a sharp drop. Millions of workers lost or are at risk of losing their jobs and Member States are forced into large budget deficits[10]. At a time when the need for digital transformation is larger than ever, without interventions, funds for the necessary investment may run short.

Policies and interventions that boost the digital transformation can hence also be an engine for recovery, growth and increased global competitiveness: while in all cases, social and economic consequences of the crisis will need to be alleviated, the regions that will take action sooner may recover faster and better by establishing leadership in digital value chains. This can help Europe spring back to prosperity, but could also lead to further divide between Member States. Hence, prudent action coordinated at European level is relevant.

2 EMERGING TECHNOLOGIES SHAPING EUROPE'S ECONOMY AND SOCIETY

The digital transformation is fuelled by a broad set of technologies, ranging from everyday products such as mobile phones, personal computers, the infrastructure and connectivity that support them, to cutting-edge solutions that blur the borders between technology areas and open up previously unimaginable possibilities for what machines and humans can do together. This new set of technologies is progressively coming to maturity for at-scale deployment in the coming years and decades. Taken together, they have the potential to profoundly reshape our daily lives.

While not disregarding the importance of basic information and communication technologies (ICT) and applications – without them, the next levels of advanced digitisation are impossible – this report has a forward-looking focus on a set of high-impact technologies, applications and solutions of specific relevance for Europe's digital transformation grouped in two clusters: enabling technologies and infrastructure, and high-impact, applied technologies

- *Enabling technologies and infrastructure* are the underlying technology groups, structures or models that enable transformative digital applications. They can include general-purpose technologies such as AI, big data analytics or high-performance computing, and support a wide range of applications across most sectors of the economy and society by providing the digital infrastructure for other high-impact applications, e.g. platforms and cloud.
- *High-impact, applied technologies* are applications of technologies that could have a transformative impact on a specific sector, area or function. They make use of one or a set of technologies to create concrete value, and can partly overlap with enabling technologies and each other (e.g. smart cities is a combination of IoT and AI applied to urban systems; autonomous mobility is an application of combined AI, IoT and other technologies).

Key technologies in these clusters have a high potential for social and economic impact

Most of these technologies share advanced data processing and applications as a common theme, while others represent new business models and reinvent value chains through digital applications. They will impact all aspects of the economy and society, they will change and improve the way we do business in many fields, and they can contribute to solving some of the most pressing issues that Europe and the world are facing by managing epidemic diseases, improving medical diagnostics, reducing traffic and workplace accidents and increasing system-wide energy efficiency[11]. But their impact can also be negative, especially on the social dimension and with regard to equality and cohesion. For example:

AI and *AI applications*, such as *autonomous vehicles* both have a high potential for social and economic impact. AI systems are designed to be able to perform tasks in complex environments without constant human guidance (autonomy), while also being able to improve performance by learning from experience (adaptivity) in those environments. As AI systems could play a significant role in society, it is important that those systems are trustworthy. Trustworthy AI should be lawful, ethical and robust (from a technical perspective while taking into account its social environment)[12].

Advanced robotics, 3D printing and advanced materials will very concretely change industrial processes, supply chains and value chains, unlocking the potential for growth in industrial sectors where the EU has been traditionally strong. They can reshuffle traditional value chains and supply chains by making many manufacturing processes more available, and further accelerate the transformation of labour markets within and between regions. New industrial processes and materials also hold a promise of

THE NEW DIGITAL REVOLUTION: High-impact technologies that will shape the European economy and society

Enabling technologies and infrastructure

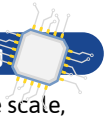
Artificial intelligence

Intelligent machines that work and react in a similar fashion to humans (incl. machine learning, natural language processing, computer vision, virtual assistants, AI robotics)

Big data analytics

Use of large and varied data sets to uncover information incl. hidden patterns, unknown correlations, market trends and customer preferences

Quantum & high-performance computing



Supercomputers with capacity to solve large scale, complex analytical tasks; use of quantum mechanics (via qbits) to increase computing power

IoT (incl. edge computing)

Multi-layer technology that enables management, and automation of connected devices

NextGen internet & infrastructure

Infrastructure enabling next generation of technology: e.g. 5G and beyond, digital twin, highspeed WLAN

Cloud computing

On-demand computing resources ran on distant computers, connected to users via the internet

Digital platforms

Digital platforms on which outside firms can develop their own activity or develop their own technologies

Distributed ledger technology

Peer-to-peer network with unique member digital signatures: all transactions are recorded by the entire network, notifying the network of a breach

High-impact applied technologies

Advanced robotics

Advanced robots capable of complex, previously non-automatable, tasks

Autonomous mobility (CAVs)

Autonomous and near-autonomous vehicles, incl. UAVs (drones)

Smart cities

Cities which incorporate ICT to enhance efficiency, quality of life, the economy and other performance metrics

Additive manufacturing

Creating 3D, solid objects from a digital file by adding layer-upon-layer of material

Virtual & augmented reality

Software-created, fully artificial environments/technology that superimposes a computer-generated image on a user's view of the real world

Digital energy innovation & sustainability

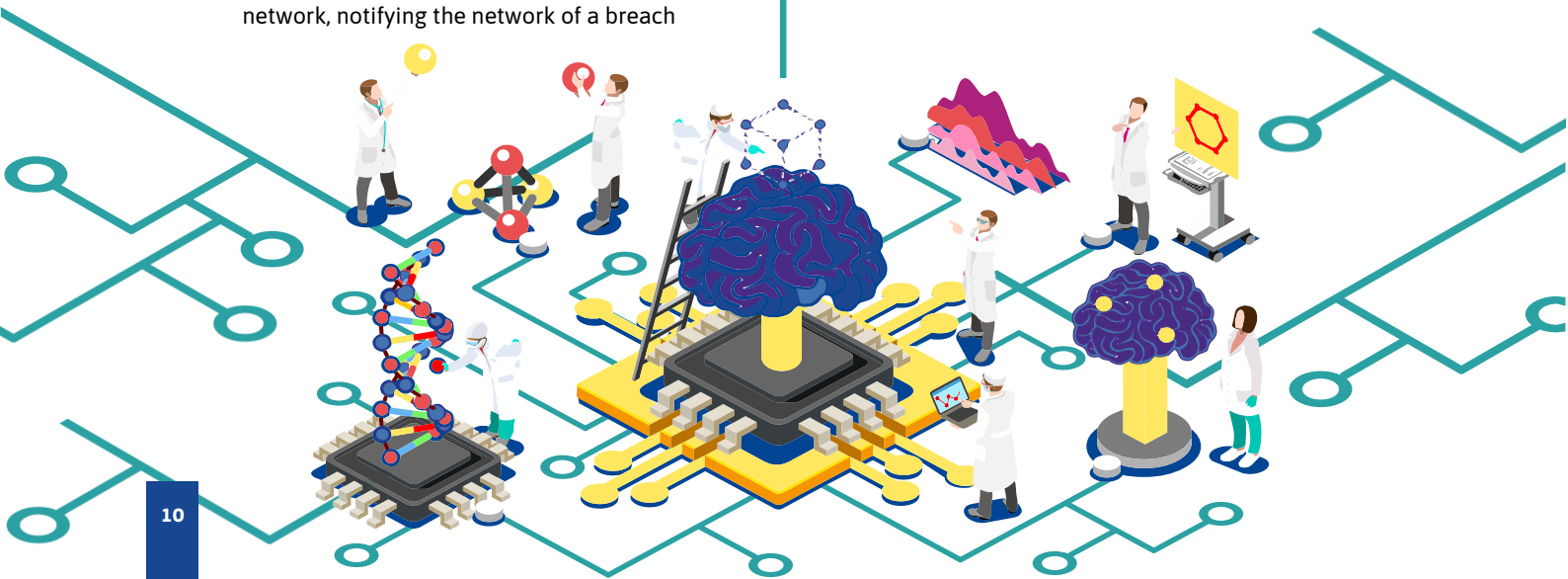
New digital technologies enabling innovative energy applications: storage, smart grids, renewables

Digitally enabled biotechnologies

Group of technologies enabling new applications of biological innovation (e.g. biohacking, next-gen genomics)

Advanced materials

New materials developed to obtain superior performance (e.g. graphene) power



more sustainable products and important contributions to Europe's green transformation.

High-performance computing (HPC), and emerging quantum computing have both a high economic impact as enablers of other disruptive technology application and a social impact, by providing unprecedented computing power to solve complex problems. But they also come with challenges: quantum computing – still early in its development – would render all current cybersecurity obsolete, with potentially far-reaching implications on sovereignty and security.

Cloud computing, digital platforms and related infrastructure technologies have already disrupted technology business models. They are characterised by a global 'winner takes all dynamic'[13] and are currently dominated by foreign businesses. As such technologies mature and continue disrupting existing industries, establishing local leadership in those would have a significant economic and strategic and security impact, e.g. to avoid EU sensitive data being hosted abroad or by foreign-owned entities.

Smart cities technologies translate digital technologies into better public services for citizens, better use of resources and less impact on the environment. Smart cities technologies have the potential for broad improvement in citizens' quality of life through better healthcare, better mobility, reduced crime, reduced emissions and lower water consumption, among other improvements[14]. However, left unchecked, the misuse of certain technologies could also lead to the invasion of citizens' privacy and neglect for their rights (e.g. mass surveillance).

These technologies are at varying stages of maturity. Many still require substantial research and innovation investments to be widely adopted and generate most of their economic or social values. Moreover, economies of scale are an inherent characteristic of digital technologies and business models – favouring or requiring large amounts of data, users or connected nodes – making any kind of market fragmentation an import barrier for such technologies. As discussed in section 4 below, few companies, or even European Member States, are large enough to alone achieve the critical mass needed for effective development and diffusion of, for example, high performance (or quantum) computing, advanced AI applications or globally competitive digital platform or cloud services. In such areas, joint investments or actions at the European level – and a truly integrated digital market – can create this critical mass, and help Europe capture the potential of high-impact technologies.

3 THE POTENTIAL OF DIGITAL TECHNOLOGIES IN EUROPE

3.1. Digital high-impact technologies – a powerful growth engine

Managed well, these technologies hold the promise for a more prosperous future Europe: a macroeconomic simulation developed by the McKinsey Global Institute, refined and adapted for this study shows, in its base scenario, that digital and new high-impact technologies could contribute 1.1 per cent additional annual growth compared to baseline growth projections in the coming ten years. By 2030, the cumulative additional GDP contribution of new digital technologies could amount to €2.2 trillion in the EU-28 (EU-27 and the United Kingdom), or 14.1 per cent growth compared to 2017, the base year of our model[15]. This potential is bigger than what has been achieved by early technology diffusion, including early ICT[16].

By 2030, the cumulative additional GDP contribution of new digital technologies could amount to €2.2 trillion in the EU, or 14.1 per cent growth compared to 2017.

This calculated value is the *net effect*, including investment and accounting for both positive and negative growth effects of disruptive digital technologies. In the base scenario simulation, the positive economic impact of productivity improvements, increased economic activity and spill-over effects outweigh implementation costs and negative externalities such as higher unemployment cost.

Importantly, the simulation shows a positive growth effect for all Member States, regardless of the starting point. However, without proactive convergence measures, the effects of digital innovation would likely be distributed unevenly between Member States, due to their industries' varying readiness to adopt disruptive technologies, and to supply it domestically. The most advanced economies ('digital front runners'[17]) would capture a larger share of the value, with an annual average GDP growth effect of 1.4 per cent, or 18.5 per cent in 2030 compared to 2017. The less advanced ('catch-up') countries are only projected to see a 4.8 per cent total GDP impact in the same period, or 0.4 per cent per year on average. The middle group lies close to the EU-28 total growth impact at 1.1 per cent per year, or 13.5 per cent over the entire simulation period.

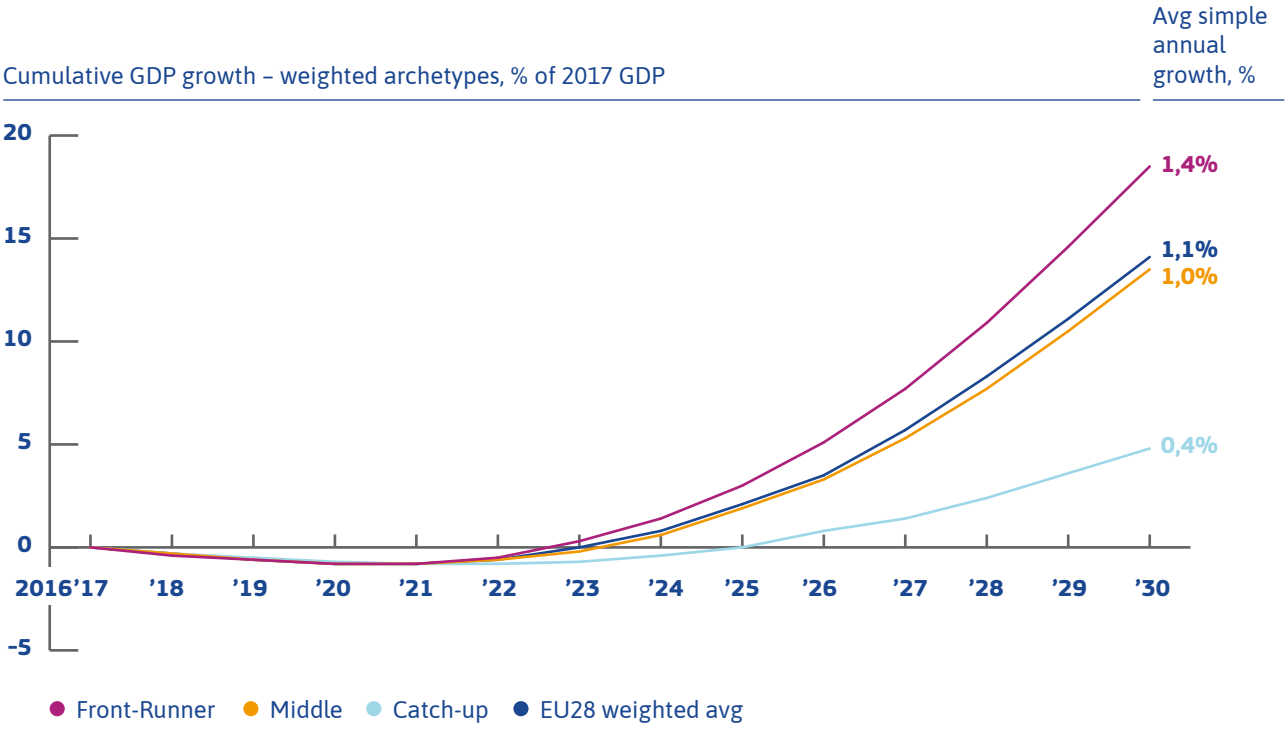
Furthermore, the expected growth effect in the simulation is not linear over time: until 2023, the effect is somewhat negative, driven by investment and transition costs that initially exceed the benefits. After that, the net value is captured at an accelerating pace. The simulations do not account for the COVID-19 pandemic, and a severe economic crisis may delay some of the investment necessary to capture the value. However, the crisis has also accelerated digitisation in many areas and may indeed serve as an impetus to also pursue emerging technologies at a more ambitious pace.

The simulation also shows that early, effective efforts to increase the technological maturity of a region or state can result in significant economic pay-offs. For example, in a simulated scenario where the EU-28 Member States achieve a 10 per cent improvement to their technology readiness[18] by 2023 compared to base scenario, the cumulative additional growth effect by 2030 is 3.3 percentage points (an additional 17.4 per cent GDP by 2030, versus 14.1 per cent in the base scenario). Likewise, early actions can help close the gap between more and less technologically advanced Member States and regions.

3.2. Social impact and inequality risks

Similar to previous technology revolutions, this wave of digitisation is set to pose significant challenges, on top of current

Exhibit 1: Estimated GDP impact of technology per country archetype, 2017-2013



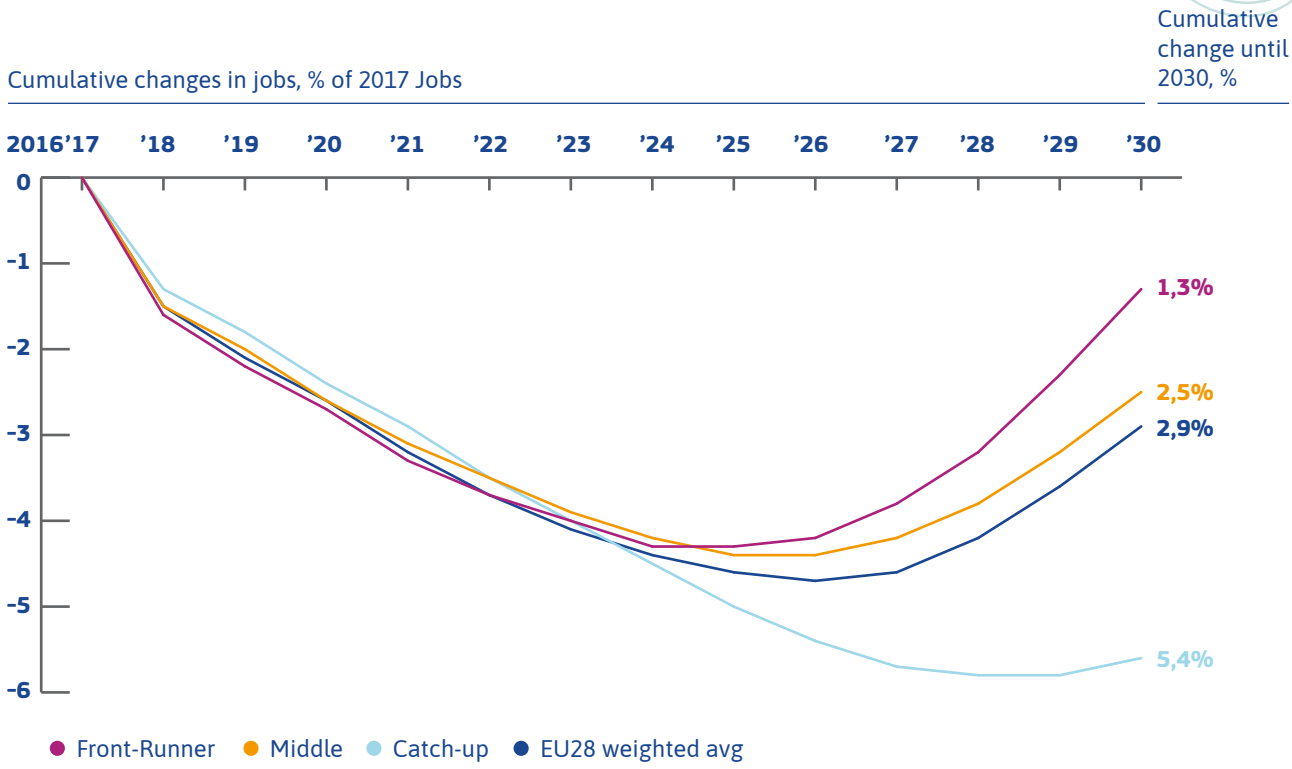
Source: macro-economic simulation

issues surrounding data privacy and control, security or access to digital service. Unless inclusion and cohesion aspects are actively managed, technology may contribute to higher inequality between citizens, companies and regions. As shown above, without specific interventions, Member States and regions that are the most advanced already today could also enjoy the highest levels of technology-driven growth going forward, widening the gap with less-advanced regions.

A similar pattern can be expected regarding labour markets. Automation and replacement of jobs have been an ongoing process since the advent of the industrial revolution, but faster adoption of digital technology is accelerating these trends. All workers will be impacted as tasks are taken over or supplemented by technology. There will be demand for new skills and new jobs will be created, likely requiring large-scale education and reskilling efforts on a scale previously unseen. Moreover, as productivity increases and generates new wealth, consumption also increases in the non-digital economy, notably in local service sectors; this spill-over effect generates new jobs in traditional sectors, offsetting part of the displacement effect. The degree to which the net effect on employment is positive or negative depends on the local economy's overall ability to capture the value of technology, but also specifically on the workforce's education and skill level, and workers' ability to transition to new, digitally advanced jobs. McKinsey Global Institute projects that 22 per cent of European jobs are at risk of becoming automated. While a large share of potential job losses (if not all) would be compensated by job creation and a shrinking workforce (due to ageing populations), this job creation could be concentrated geographically, leading to local labour market disruptions. Additionally, 94 million workers are expected to need digital upskilling as technology becomes a growing part of their occupation, while an estimated 21 million workers may need to completely change occupation[19].

In our model's base scenario, illustrated in Exhibit 2, the net employment effect of disruptive technologies is negative throughout the simulation period in all country archetype groups – although some

Exhibit 2: Estimated employment impact of technology per country archetype, 2017-2013



Source: macro-economic simulation

individual Member States may experience increased employment. In the catch-up states with less digitally advanced economies, the overall employment effect of technology is projected to -5.4 per cent by 2030. This compares to -2.5 per cent in the middle group and -1.3 per cent in front-runner economies, which are best prepared to generate new digital jobs - including as suppliers of technology - and which will experience larger spill-over effects. The weighted average employment effect on EU-28 by 2030 is -2.9 per cent in the base case scenario. Importantly, *these effects only refer to the contribution of the technology to employment and do not represent a forecast of future employment levels. Similarly, these effects are simulated in the scenario where no measures to stimulate the labour market are taken.* Rather, as Europe's population is ageing, and the working age share of the population is steadily decreasing, productivity enhancing technology will be needed to sustain a high standard of living for all Europeans: Eurostat projects that the old-age dependency ratio – the relative size of the older (non-working) population compared with the working age population – will increase from 30% in 2020 to ~40% in 2030; and around 50% in 2050[20]. This might in itself compensate part or all of the estimated impact of digital technologies on the employment rate of the active population.

The social and economic disruptions following the COVID-19 pandemic further complicate these issues. Depending on the scenarios, European GDP could only reach pre-pandemic levels by 2021 to 2023, resulting in negative social effects and putting increased financial pressure on citizens, businesses and Member States. McKinsey Global Institute projects that 59 million European jobs are at risk in the short term through reductions in hours or pay, temporary furloughs, or permanent lay-offs. The impact will be unevenly distributed, with significant differences among sectors and occupations and, as a consequence, among demographic groups and local labour markets.

Three occupational groups account for about half of all jobs at risk in Europe: customer service and sales, food services, and building occupations. The jobs most at risk from pandemic job losses

overlap to some extent with those most vulnerable to displacement through automation. Around 24 million jobs, almost 50 per cent of the number of jobs displaced through automation, are at risk of displacement though both COVID-19 and automation[21] (Exhibit 3).

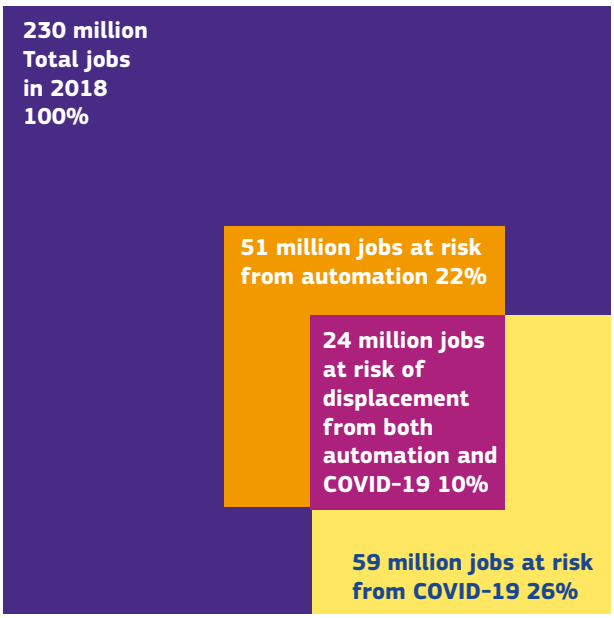
3.3. A need for decisive action to manage the transition

These challenges, however, do not mean that Europe should not pursue digitisation or try to delay it. On the contrary, denying the forces of transition rather than actively managing them carries much larger risks for Europe: with potential economic stagnation, rising inequality, and growth in welfare costs[22]. As other regions in the world are advancing, inaction would pose risks to Europe's competitiveness and employment in sectors where it has been traditionally strong. Embracing and supporting the diffusion of technology should thus be a priority for Europe, with the risk of seeing fewer benefits while fully experiencing adverse effect if no action is taken. The COVID-19 impact on jobs and GDP in Europe in the short term only increases the urgency for European action[23].

Successfully navigating this challenge will therefore be a balancing act for Europe and its Member States: capturing the full potential of new digital technologies will not only require specific policies to stimulate their diffusion and adoption, but also proactive action to tackle transition costs affecting citizen welfare, cohesion and inequality on all levels.

Exhibit 3: There is a large overlap between jobs at risk due to COVID-19 in the short term and jobs displaced by automation in the longer term

Breakdown of European employment



Note: includes EU-27 countries plus United Kingdom; jobs displaced are based on midpoint automation scenario. Analysis of long-term labor market trends and implact of automation was conducted before COVID-19 pandemic; we define "jobs at risk due to COVID-19"as a reduction in hours or pay, temporary furloughs, or permanent layoffs; analysis determines jobs at risk as related to physical-distancing policies and their short-term knock-on economic consequences.
Source: David Chinn, Julia Kier, Sebastian Stern, and Sahil Tesfu, Safeguarding lives and livelihoods: Mitigating the employment impact of COVID-19, McKinsey & Company, April 2020; Eurostat; Oxford Economicsl US Bureau of Labor Statistics, McKinsey Global Institute analysis

4 THE STARTING POINT FOR DIGITISATION IN EUROPE

In order to harness these technologies and reap their economic and social benefits, Europe can leverage its strengths as a large, well-educated industrial block. However, in some areas, Europe is still lagging behind other leading regions, and large differences remain within and between EU Member States. The Commission started addressing this with the Digital Single Market initiative, and is well positioned to build on the foundation it has created to take the important next steps into the digital age.

4.1. Underlying structural strengths and weaknesses

Europe has many strengths to build on to succeed. It has a large set of strong incumbent industries; many companies and SMEs are leaders in their field and Europe enjoys an increasingly vibrant start-up scene. Its economy is innovation and knowledge-based[24], with high-quality education and research, strong public services, the world's largest single market area and an overall predictable framework of rules. In many industries – including in several digital sector niches – European companies and researchers are world leading. The EU remains the largest single market in the world and the biggest trader of manufactured goods and services. Coupled with its capacity to deliver innovative pieces of legislation, this has allowed the EU to promote new global standards, for instance through the General Data Protection Regulation (GDPR).

However, challenges persist. In spite of the single market and a historically unprecedented success story of market integration, fragmentation within Europe remains in many areas, not least due to language barriers, but also due different regulatory and taxation regimes. Cross-border businesses are still in a minority, including in the physically borderless digital sector. For technologies that require large scale investments – either for the technology to mature, or for adoption at the company level to be worthwhile – acting at Member State level could be detrimental to cross-border roll-out, while the funds attracted could be insufficient. Furthermore, a skills gap is widening across Europe: between the emerging demands of the future, digital labour market and the present skills of workers, but also between workers with and without the right education and skill set[25].

4.2. Europe's global position in digital innovation

Digital solutions are inherently borderless, the market is global and the competition is intense. Even more than traditional goods and services, many digital business models, such as platforms or cloud services, benefit from, or require a critical mass of users and operating at a large scale – they are global 'winner-takes-all' business models. Capturing the full value of the digital transformation hence does not only require adopting and implementing digital solutions, but also establishing a strong international position in the digital value chain through world-leading digital research and companies.

Europe has a strong starting point in many areas, but is also lagging behind other regions, notably the world's two largest national economies, the US and China, which both heavily invest in their digital future. The two economies appear to have a head start in digital uptake as well as investment. Europe only attracted 13 per cent of global venture capital and corporate funding in 2019[26]. China is now attracting almost half of the global venture capital investment into AI start-ups, ahead of the United States,[27]. Both regions are expected to significantly increase overall private and public spending for digital technologies and AI in the near term, well beyond similar targets for Europe[28,29,30].

There are also substantial differences between countries' readiness to absorb digital technologies, and these differences are best shown through the case of AI, with the US and China emerging as active global leaders. Currently, corporate AI market adoption in the EU is 16 per cent lower than in the US[31]. Over time, these differ-

ences in AI and digital absorption will translate into differences in economic gains.

EU companies, researchers and inventors in the last five years filed about 79,000 ICT-related patents under the international Patent Cooperation Treaty – fewer than Japan alone (97,000), and only half the number of ICT patents filed by US and Chinese applicants (160,000 and 158,000, respectively) [32].

4.3. The work so far: Europe's digital policy

Recognising the crucial importance of the digital economy, and of need for action at the European level to strengthen the position of the Union on a wide range of digital dimensions, the Commission has, as of 2015, put forward an ambitious digital policy aimed at breaking down digital barriers within Europe and establishing Europe as a world leader in the digital economy. The 2015 Digital Single Market strategy was structured around three objectives: (1) better access for consumers and business to online goods; (2) the right environment for digital networks and services to flourish; and (3) maximising the growth potential of the digital economy. The 2020 *Shaping Europe's Digital Future* strategy's vision further states that (1) people must have the opportunity to develop personally, to choose freely and safely, to engage in society, regardless of their age, gender or professional background; (2) businesses need a framework that allows them to start up, scale up, pool and use data, to innovate and compete or cooperate on fair terms; and (3) Europe needs to have the choice to pursue the digital transformation in its own way.

To achieve these overarching goals, the Commission put forward over 60 initiatives, half of which consist of legislative proposals adopted by the co-legislators.

The Digital Single Market Strategy has targeted a reduction in market fragmentation[33], increased data flows[34] and updated existing rules to the digital age. It has sought to improve consumer access through the ban on unjustified geo-blocking, portability of content, the end of roaming, and WiFi4EU. Market framework conditions have been targeted through the new telecom code, the Directive on Audio-visual and Media Services, the updated copyright regime and the regulation on platforms. Actions addressing digital skills and digitising industry and the public sector, combined with the future Digital Europe Programme, may also contribute significantly to the digitisation of the economy. The implementation of the rules adopted over the last five years is still under way and enforcing the new rules remains a priority for the EU. The proposed MFF and Next Generation Europe instrument will add additional investments and actions to what has already been done.

4.4. Identified gaps in the Digital Single Market

Despite its achievements, if the EU is to achieve its ambitious targets for the digital economy and society, several gaps remain to be addressed, as identified in a comprehensive review of the Digital Single Market strategy performed within the scope of this study [35]. It will remain a priority to accelerate market integration and harmonisation, continuing with a strong focus on creating a level playing field and building a true single market for digital products and services, and building on existing policies.

In our analysis, four areas emerge as requiring additional attention. Firstly, there is a lack of common standards for data and interoperability, as well as a lag in next-generation digital infrastructure. Secondly, regulation pertaining to the digital sector is not fully harmonised across the Member States (especially for emerging, high-impact technologies), which risks hindering the Digital Single Market in the EU. Some pieces of regulation can risk stifling early innovation if not adapted to the specific technology context. Thirdly, the EU is facing a skills gap, particularly in digital skills, both for citizens (basic skills for the general population and workforce) and for advanced digital practitioners. Fourthly and finally, Europe is behind on innovation for new high-impact technologies, both in terms of funding and in terms of worldwide centres of excellence (CoEs) around specific technologies.

Specifically, and as a first step, decision-makers could consider what the most critical to scale or expand, to address some of the noted remaining gaps:

- operationalisation of the European cloud initiative (scale and implement);
- putting in place the right policy framework for AI, including through the implementation of the ethics guidelines (develop and operationalise building on the Ethics Guidelines for Trustworthy AI of April 2019);
- adequate funding, combined with the timely spectrum allocation and assignment of forthcoming broader-band infrastructures (e.g. 5G – scale the technology diffusion as fast as possible and maintain);
- further scaling up the funding allocated to building the digital skills in Europe.

5

CAPTURING THE VALUE AND PROMOTING VALUES – FOUR PRINCIPLES TO GUIDE EUROPE IN THE DIGITAL AGE

Successfully tackling the digital challenge for the benefit of European citizens will require more than regulation and investment. Europe's digital transformation must also be guided by a set of European values that will serve as a compass and guardrails for the Fourth Industrial Revolution.

Building on the achievements of the DSM, the EU could strive for a European way of doing digital policy that is human-centric and founded on respect for fundamental rights and European values, one that constitutes a "third way", balances between state-led development and laissez faire. This set of defining principles would enhance trust and privacy while promoting an inclusive digital society and sustainable economy as a basis to build the next competitive advantage for European companies acting worldwide in the digital age.

European initiatives could build on four societal objectives that can benefit from digital technologies and guide their development and adoption.

Building and deploying digital solutions for societal challenges
Digital technology can be a key lever to improve European quality of life and tackle some of our most pressing societal challenges. For example, connectivity will be a key enabler for many, if not most, climate solutions, by creating new and sustainable value chains and reducing the amount of natural resources used in the production process. Many solutions already exist in energy, buildings, transport, security, agriculture and food. Europe can now promote and accelerate the deployment of these solutions at a global scale.

At the same time, the ICT sector itself must recognise its own role in societal challenges and contribute to addressing them. For example, the ICT sector should act in order to reduce its footprint in terms of the resources it consumes, whether energy or rare materials.

Reinvigorating democracy, trust and cultural diversity
Technology has reduced the distance between people and decision makers and given everyone the tools to share their opinions instantly. However, left unchecked it can weaken the fabric of society, for example by allowing the rapid spread of disinformation, interfering in election processes or leading to cultural uniformity.

The EU can respond to this trend by promoting a human-centric approach to digital, for example by encouraging transparency of and trust in public institutions through easily accessible and intuitive digital public services, offering citizens equal access to digital technology and credible information, promoting high-quality EU digital media content or digital tools and services that enable EU citizens to participate in politics.

Securing digital technological sovereignty and cybersecurity
Digital technologies and data are becoming strategic societal assets whose control could become a condition for both prosperity and sovereignty. Europe is currently dependent on foreign-developed and owned technology assets for a significant part of its digital economy. As all sectors are on the point of being radical-

ly reshaped by the combination of connectivity and data, and as digital technology is at the heart of this transformation, Europe may want to reduce its dependency on foreign technology.

To reverse the trend, the EU can take immediate steps to increase its support for key enablers of the digital economy (e.g. connectivity, semiconductors, hardware, data access and sharing, AI, cybersecurity), particularly where its place in the supply chain is weak or fragile.

Boosting Europe's competitiveness

Digitisation is a unique opportunity for European industries to create the next generation of innovative products and services, retain jobs and create new ones.

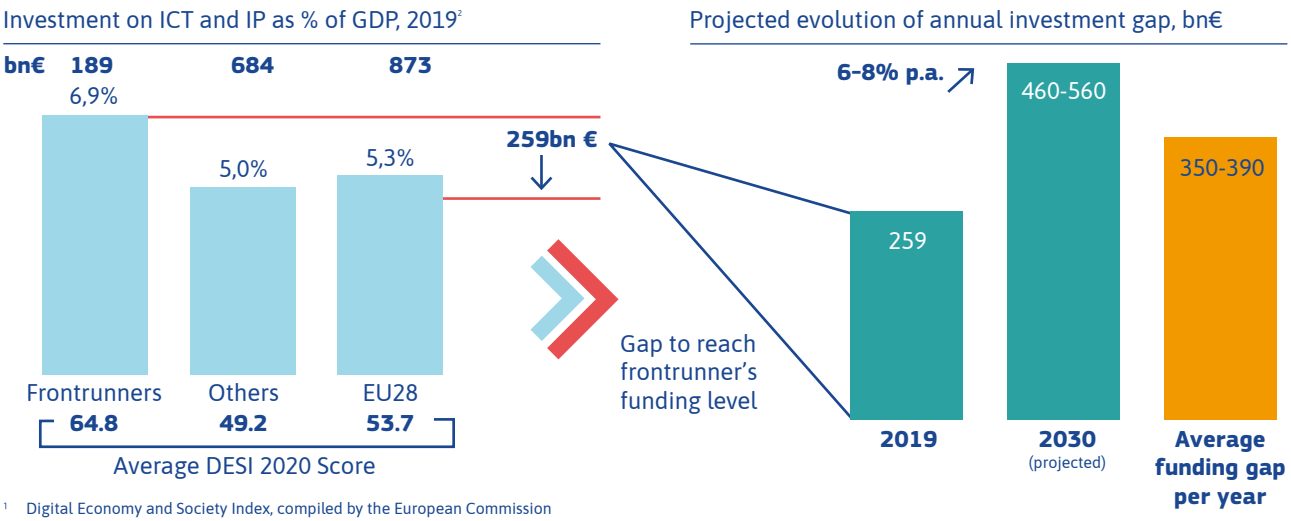
To capture this potential, the overall objective should be to create a strong digital ecosystem in Europe that starts with high-quality education, world-class research facilities, an innovative legislative framework that encourages entrepreneurship, experimentation and innovation, start-up and scale-up support across the entire EU, and financing and promoting industrial clusters for growth. Fuelling this competitiveness is data, with much of the economic potential for innovation and the development of new business services depending on the availability of large amounts of quality data and the necessary infrastructure and know-how to curate and process it.

6 INVESTMENT TO FUEL THE TRANSFORMATION

Ensuring Europe's leadership in the new high-impact, digital technologies will require bold and comprehensive actions – and ambitious investment on all levels. Building the digital infrastructure needed for the Gigabit society, whose objective is to make Europe the best connected continent in the world, is a priority, and large investments are needed to achieve the European Commission's connectivity objectives for 2025, including 100 Mbps connectivity for all European households uninterrupted 5G coverage in all urban areas and all major terrestrial transport paths. Investments are also necessary to fund the research, development and commercialisation of European-led next-generation digital technologies (including for support to EU initiatives such as cloud federation, the pan-European Blockchain Services Infrastructure, EuroHPC, the Quantum Communication Infrastructure), to build the digital skills and capabilities of the labour force, and to implement existing and new digital solutions in companies, authorities and in society on all levels.

Public and private actors in EU Member States in 2019 – before the COVID-19 crisis – invested €875 billion per year in ICT equipment and intellectual property (IP), including software, licences and patent acquisition[36]. Over the last five years, this investment already grew at 5 per cent per year, a testament to the rapidly increasing importance of digital technology and innovation. The Member States that invested most are also those that are most digitally advanced; indeed, leading EU Member States such as the Nordic countries, Benelux, Estonia and Ireland – Europe's eight 'digital front runners' or 'DF8' – are globally competitive and leading in many areas of digital technologies, and they already capture a large share of the digital value . These Member States invest on average 6.9 per cent of GDP in ICT and IP every year, compared to 5.0 per cent in the other Member States. If Europe raises the level of ambition to invest as much in digital innovation as these most digitally advanced countries do, and keeps up the pace of investment growth of previous years[38], then **an additional €350 to 400 billion** (depending on annual growth rate) would be needed every year over the coming ten years, as illustrated below.

Exhibit 4: Investment gap and DESI[1] scores of EU digital frontrunners vs. EU average



[1] Digital Economy and Society Index, compiled by the European Commission
[2] Eurostat, nama_10_an6 dataset, Gross fixed capital formation

Closing today's investment gap and lifting the entire Union to the level of its front runners will not happen without significant actions and contributions through public funds – on all levels. But public funding also attracts private investment, and under the right conditions, a minor public investment can act as a catalyst to fill the full gap from other sources. It is likely that the best results could be achieved via a blending of European, national and private resources.

The public funding multiplier effect varies depending on the risk and type of investment: leverage ratios of 2-10+ times are commonly discussed in the literature[39], by comparison, the InvestEU fund aims for a co-funding ratio of 13.7 times its investment, though this can include other public funding[40]. As a calculation example based on these typical ranges, a private co-funding rate of five times could be assumed. In this calculation example, and based on a total investment gap of €370 billion (mid-point of €350 to 390 billion), **European governments would need to contribute approximately €75 billion per year for ICT investment** in the coming years. This figure may still be at the lower end as frontrunner countries might also need to step up their investments to accelerate the digital transformation. European Funds from the MFF 2021-2027 and the Recovery and Resilience Facility could be mobilized to increase further public investments in digital, in areas that are characterized by the presence of services of general public interest or a more pronounced need for public support due to market failures (e.g. for digital infrastructures, skills, digitalisation of companies, joint technology capacities).

On top of that, **investment in education, re- and upskilling** stand out as the largest and most prioritised investment for Europe: as discussed and under the assumptions used in section 7.9. below, the needs stand at €350 to 490 billion over the next ten years or, in a mid-point cost calculation, **€42 billion** per year in Europe. Some parts of these costs could be covered by existing national education budgets, but new funding will likely be needed from employers and employees, and public sources on all levels.

Closing the digital investment gap to bring the entire Union to the level of its front runners, and investing in skills and education to manage the transition, would hence cost approximately **€117 billion per year for European governments in the coming years**. This encompasses investments in research and innovation, connectivity, physical and digital infrastructure and cybersecurity - all necessary enablers to capture the potential in all parts of Europe. Such investment needs to be accurate and accompanied by other actions. As these are large-scale projects, some of the digital investments are likely most effective if executed or coordinated at EU level, as no Member State acting alone could achieve the necessary critical mass. However, there is no a direct causal link between spending more money and achieving the full value. Since structural reforms may be needed in the Member States to enable effective use and value capture of investments, including simplification of administrative processes and permits, education system modernisation, training of civil servants and strengthening of government institutions. As a reminder, **The potential of €2.2 trillion value of technology by 2030, discussed above is section 3.1, is a net benefit to the economy after offsetting investment and other costs**.

The nine signature initiatives discussed below provide examples of some areas where this investment could be made with promising potential for Europe.

7 NINE SIGNATURE INITIATIVES TO LEAD THE WAY

Capturing the value of high-impact, digital technologies and then managing the digital transition and its effects on society will require a broad set of actions and policies on all levels. Within the framework of its digital strategy, and previously under the Digital Single Market, the Commission is attempting to deliver a broad set of ambitious policies to create the right market conditions for the digital economy and society, supporting innovation and infrastructure investments while protecting the rights of consumers. The Commission believes it will be critical to continue the course of these policies with renewed energy going forward, not least in the area of continued market integration and removal of barriers – whether specifically digital or not – to Europe-wide digital business.

On top of renewed commitment to a strong digital policy and further reinforcement of its previous actions, the Commission could take new, bold action to support the principles and four objectives of a human-centric digital path for Europe: *economy and competitiveness; societal challenges and climate; democracy, trust and diversity; and sovereignty and security*.

Nine signature initiatives are presented and discussed below. They outline ambitious actions in different priority areas that directly address the four objectives mentioned above. These areas and actions were selected and gradually developed over the course of this study: they represent views and needs uncovered by research and expressed by stakeholders from across the digital spectrum in surveys and expert workshops; they complement existing policies and to some extent fill gaps therein; they require collaboration or joint action at the European level to be most effective; and they individually show large economic and social potential. While insufficient to manage the digital transition in Europe alone, together these signature initiatives would set a high bar and could act as catalysts for change.

This report contains a high-level summary of the nine initiatives and as such should not be understood as final or as offering detailed policy recommendations. The following section provides the outlines of the most important aspects of each signature initiative. It includes:

- A summary **description of each initiative and the strategic objectives it addresses**.
- A rationale for why European action is needed, based on Europe's starting point or the potential impact the initiative could have.
- A summary of **what stakeholders say** about the initiative or area it addresses: in the process of developing these initiatives, 247 CEOs and senior business executives representing a wide range of industries in all parts of Europe were surveyed[41]. Relevant results are presented for each initiative.
- A discussion on **potential options** for implementation at the European level, and the different components these options could entail. These options are high level and exploratory, and do not constitute specific policy recommendations.
- **Examination of these options**, opportunities and risks they may carry, feasibility or challenges to implementation, and how different stakeholders may by impacted economically and socially, including with a view to inclusion and cohesion. Where relevant, potential implementation **investment needs** are also analysed.

7.1. Developing and scaling EU technology ecosystems to match the global best

European institutions can strengthen European technology ecosystems by helping to create leading, technology-specific Centres of Excellence (CoEs) that aim to spur innovation and commercialisation, attract talent and investment, and build on close cooperation between research and industry. This could entail creating European science, technology, engineering, and mathematics (STEM) 'super universities', focused R&D funding efforts and specific regulatory regimes for CoEs.

Potential rationale for European action

Technology ecosystems tend to flourish in regional clusters with cross-sector collaboration between corporates, start-ups, academia and government agencies, including regulators. Such clusters,

NINE SIGNATURE INITIATIVES TO LEAD THE WAY

1. Developing and scaling EU tech ecosystems to match the global best and position Europe as a leader in key new frontier digital technologies around Centres of Excellence enabled by the collaboration between Super-Universities, Public Authorities, established Industries and vibrant Start-ups

2. Creating a Digital leadership instrument for innovation procurement of digital technologies of European strategic importance, combining innovation funding and public procurement

4. Leading the way towards trustworthy AI worldwide by both promoting AI-based innovation to fuel economic growth and social innovations while ensuring transparency and a positive social impact, which can include social measures to counter potential adverse effects. This would differentiate European AI solution as ethical and trustworthy

3. Building EU data platforms for strategic B2B sectors, enabling as an example, the Europe-wide sharing of health data (or similarly utilities or transport data) to improve healthcare outcomes, research and fuel innovation while respecting privacy and citizen trust

5. Empowering cities and communities across Europe by promoting and enabling development and equal access to citizen-centric smart city technologies for better public and private services across transport, health, energy, social and community services for the EU's ~100.000 municipalities

6. Raising a cybersecurity shield for Europe to protect EU citizens, businesses and Member States from attacks on their data and data systems. This entails protecting end-to-end technology supply chains including foreign technology and increasing strategic autonomy for key technologies

8. Promoting digital solutions for climate risks by both promoting the positive potential of digital technologies to reduce CO2 emissions and resource use in other industries as well as reducing the growing contribution of ICT to CO2 emissions and material use (particularly rare metals) due to both infrastructure (e.g. data centres) and ICT devices

7. Advancing citizen control of their personal data, building on the General Data Protection Regulation, to improve understanding, user-centricity, control and effective enforcement of citizens' data rights and enable innovation and new business models based on data portability

9. Supporting lifelong learning for the future of work, to enable at-scale reskilling of citizens (particularly populations at risk of unemployment) and equip all citizens with the digital and cognitive skills they need to succeed in a future of work context

Dimensions addressed by the initiative

- Economy and competitiveness
- Societal challenges and climate
- Democracy, trust and diversity
- Sovereignty and security

and most famously Silicon Valley, account for an outsized proportion of R&I, new company creation and economic growth[42]. In spite of its strengths in research and technology, most leading technology clusters are found outside of Europe, as are many of the leading technical universities that ecosystems often form around[43,44]. Venture capital levels are also lower in Europe than in, e.g. the US and China, regions that attract and retain more foreign researchers and entrepreneurs – including from Europe[45]. Europe, however, shows continued growth in venture capital invested (approximately €30 billion in 2019 versus €14 billion in 2016)[46]. European institutions could play an important role in accelerating, developing and scaling European technology ecosystems, and strengthening the strategic talent pool through investment and actions targeted at strategic technology clusters.

In the executive survey (see section outline above and Section 7.10. for a summary of the survey) 50 per cent of respondents said 'better cooperation between universities, research institutions, start-ups, corporates, regulators and other government entities' would be the most important enabler for a leading technology ecosystem in Europe. 37 per cent believed that 'coordination of public, private, academic actors to collaborate more and promote innovation and commercialisation' would most effectively support the digital transformation in Europe, and 30 per cent pointed to the lack of world-class (STEM) universities in Europe.

Potential options for European action*

This objective can be promoted through a broad set of concrete initiatives, many of which would build on existing European programmes and policies. Three potential thematic options include:

Building and scaling up EU CoEs – The EU could coordinate the construction of a number of designated, localised European CoEs focused on technology commercialisation by:

- focusing topical R&D funding in CoE locations, including high-risk R&D, strategic R&D and incentives to private R&D;
- fostering cooperation between governments, universities, corporations and SMEs (e.g. funding of joint facilities for important infrastructure);
- creating regulatory sandboxes (e.g. tax, data rules) to foster commercialisation;
- using and scaling Digital Innovation Hubs for tech dissemination.

Attracting and retaining top talent in the EU – The EU could coordinate Member State action to attract and retain top talent in the EU by:

- further breaking down barriers to talent mobility within and into the EU (e.g. work permit after studying in the EU, 'EU Einstein visa', giving working rights to spouses, easing the transfer of working rights between EU countries, adapt pension systems);
- adapting taxation (e.g. on stock options for start-ups to attract founders);
- increasing grants for EU/non-EU students with a potential obligation or incentive to work in the EU for a period of time.

Developing and promoting EU super universities – The EU could enable the development of EU super universities that aim to be world-leading, in particular in STEM subjects, by:

- funding targeted institutions for cutting-edge research and best-in-class teaching (e.g. by attracting superstar professors);
- coordinating those institutions to foster entrepreneurship and technology commercialisation (e.g. venture capital funding, coaching, ease of spinning off);
- creating EU-wide venture capital competitions that increases visibility of innovative technologies and business models, and promotes funding of commercialisation and scaling.

Each of these themes come with advantages and challenges. Focusing resources and investment on targeted sectors and areas makes additional demands on decision-making processes and governance, and risks undesired redistribution effects if concentrating resources in areas, which are already best off. All of the themes affect domains that are partly within the competencies of the EU (such as research funding) and partly within the competencies of the Member States (such as taxation and education policy).

Likewise, **investment needs** for these themes would vary. Building out existing institutions to establish super universities with 10,000 students graduating per year could cost €2 billion annually[47]; a wider and broader reach would require proportionally higher investment. The distribution and size of investment in innovation and commercialisation is a political and commercial choice; a 'right' level cannot be calculated. However, by way of illustration, bringing European technology venture capital investment levels to the same level as in the US would require an additional €85 billion[48]. A significant part of these funds would likely be directed to technology clusters or CoEs.

* indicative and non-exhaustive

The case for digital transformation in two European ecosystems

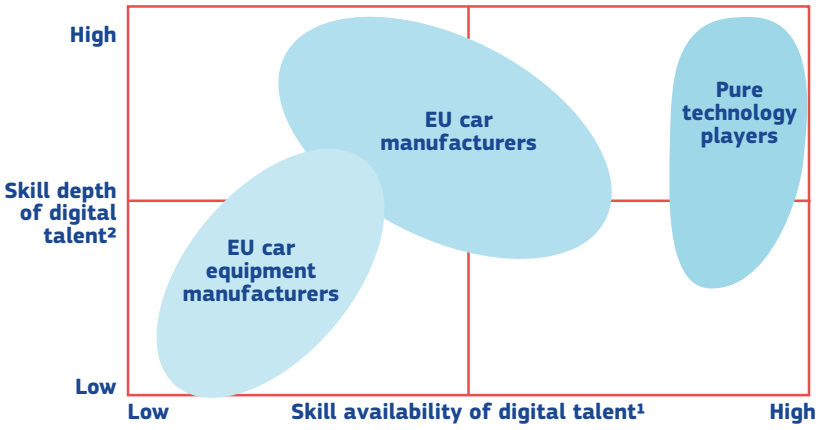
The case for concerted action on a European level can be illustrated by two essential and complex ecosystems: automotive and health. While both are critical to Europe's economy, sustainability and welfare, the challenges that they are facing, which include intense pressure to reform, are different. Fierce global competition, regulatory pressure and accelerated technology development are all putting the automotive industry under considerable external pressure to transform, while the health sector faces a long-term fiscal sustainability challenge as (public) costs consistently increase more than GDP[49] – at the same time that underlying needs and the expectations of citizens are increasing. The health ecosystem has been under increased pressure during the COVID-19 pandemic. Different digital technologies are crucial parts of the solution for these sectors, yet there are barriers to large-scale adoption at speed.

Automotive and mobility

Automotive and mobility is one of the most important sectors of European competitiveness, representing approximately 5 per cent of EU GDP and approximately 12.6 million jobs[50]. Four trends are shaping the industry in the long term: autonomous, connected, electric, smart and shared mobility (ACES). These trends are the result of technology development, the external pressures of changing user demands and the global imperative to create a sustainable – emission free – transport system.

These trends and technology areas are the focus of most innovation in the ecosystem and generate large investment – but only a small part of it is in Europe. Out of more than €270 billion disclosed venture capital and financing of companies developing ACES technology in the last ten years, only approximately 5 per cent is in Europe[51]. Moreover, while the European automotive industry has world-leading expertise in many traditional technology areas, it risks falling behind in the race for digital talent – especially as pure technology players, such as Google, or digitally native challengers such as Tesla, have begun to compete on the global automotive market. Indeed, an analysis of approximately 300,000 profiles at European car manufacturers and suppliers and US tech companies (illustrated below) showed that many EU car manufacturers had access to similar digital skill depth as the technology players, but lagged behind in breadth and availability of such talent. European car parts suppliers, who are crucial players in the ecosystem, to a large extent lacked both depth and breadth of digital knowledge among their workforce.

Exhibit 5: Analysis of the depth and availability of digital talent in the European automotive ecosystem



Note: Sample size ~300,000 anonymized LinkedIn profiles

[1] Average availability across 6 DnA capabilities. Availability measured as proportion of employees with at least one relevant skill on their LinkedIn profile.

[2] Average depth across 6 digital capabilities. Depth measured as average number of relevant skills on their LinkedIn profile.

Defending its world-leading position in automotive and achieving a leadership position across emerging technology areas requires large investment and scalability for European automotive and technology players in all parts of the ecosystem. To achieve this scale and help accelerate the transformation, European institutions could play an important role, together with Member States and the industry, by: fostering and fuelling industry collaboration; improving data access and cross-industry data sharing; building out connectivity and charging infrastructure; and further accelerating research in high-impact technology areas, in particular for autonomous and electric vehicles. While such initiatives would require reform and investment, the pay-offs for European industry's global competitiveness could be huge, if a truly collaborative automotive ecosystem was achieved. For example, in a calculation example involving five European manufacturers, effective collaboration on some of the most costly autonomous vehicle technology development could render efficiency gains of approximately €25 billion by sharing R&D costs and innovation outcomes[52].

Health

The health sector, including pharmaceutical and medical device development and manufacturing, is a critical ecosystem for the well-being of all Europeans as well as for the economy (it represents 11 per cent of employment and approximately 6 per cent of value added in the economy)[53]. While many of Europe's health systems count among the best in the world, they are facing challenges because public health spending is steadily increasing faster than GDP[54]. This is driven by the development of new – effective but costly – drugs and treatments, demographic change, and increasing citizen demands. In the long term, without productivity increases cost development in Europe is bound to become unsustainable.

Digital solutions can address this emerging productivity gap. An analysis of France and Germany, which account for 47 per cent of the EU-27 public healthcare spend, shows that five digital technology groups could achieve efficiencies of up to €55 billion (€120 billion if extrapolated for the entire EU-27). The five groups (online interactions and monitoring, paperless data, workflow automation, decision support, and appropriate patient self-care) encompass 25 specific, high-impact digital use cases. The three most important, teleconsultation, remote monitoring of chronic diseases and unified electronic health records (EHR), account for €21 billion, or 40 per cent of the total potential.

The pharmaceutical sector could also vastly benefit from digital technology, not least through better use of data in drug and treatment research and development, which could increase the probability of success for new treatments by 10 to 20 per cent[55].

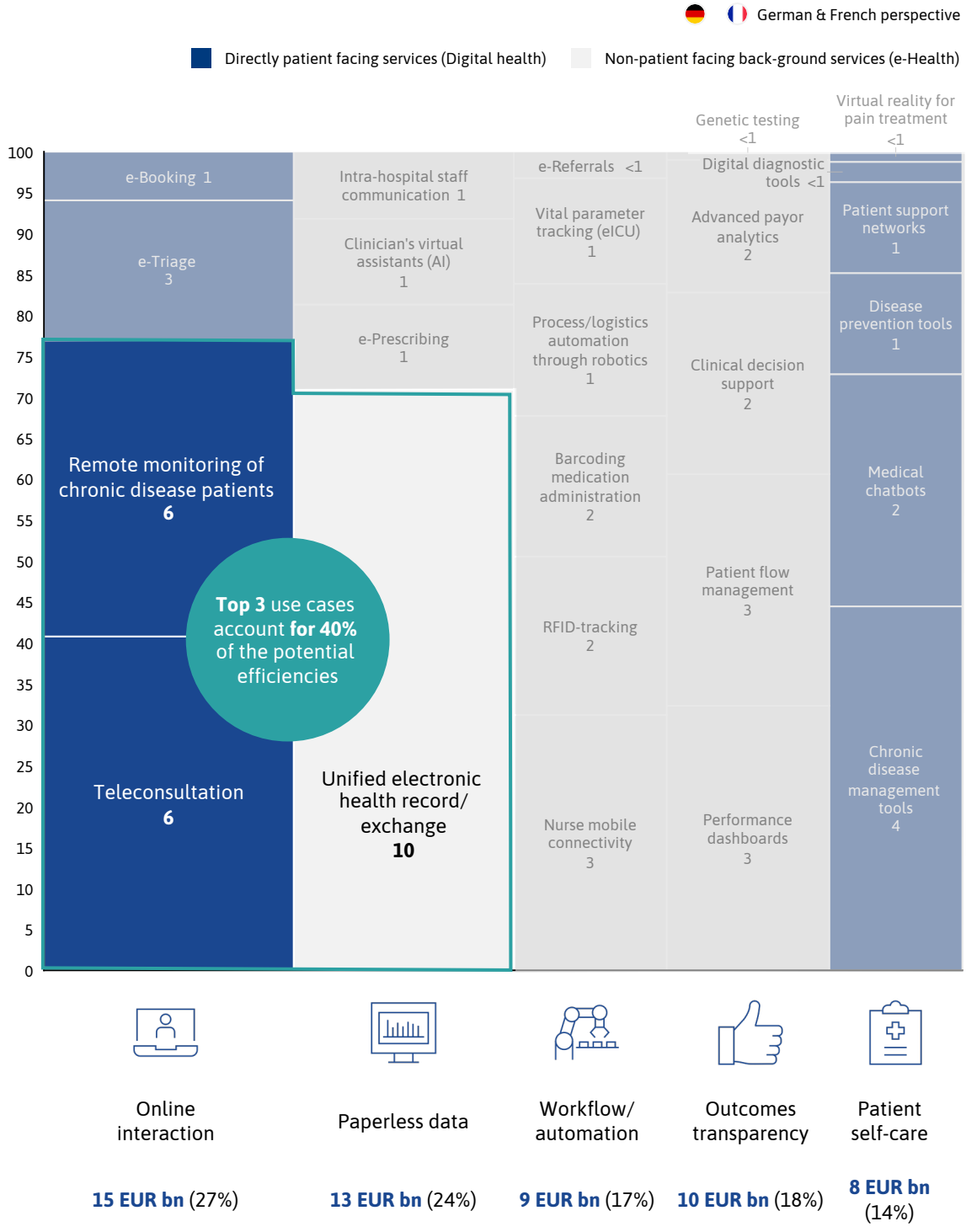
In spite of the considerable potential that could be released by embracing digital capabilities, health and pharmaceuticals remain among the least digitised sectors[56]. Large barriers to digital adoption persist, including a lack of unified data and digital infrastructure, lack of skills and funds, and regulatory barriers related to health and patient data. To overcome these barriers and capture the value of digital, European institutions could, in close collaboration with national and regional authorities and the ecosystem, foster the adoption of shared standards for EHR systems to ensure interoperability of unified EHR/exchange (and e-prescribing), and fund the necessary adaptation of physical/digital infrastructure. This would not only unlock efficiencies potentially exceeding €30 billion in Europe (based on the example of France and Germany) but also be a crucial enabler for many other digital health applications. Moreover, patient outcomes would directly improve due to health professionals' access to complete and accurate health information.

Furthermore, European institutions could accelerate the creation of a common European health data space, as already initiated by the Commission, by setting up a partnership to develop and deploy both digital and physical confidential computing infrastructure to be used for health research and development. This would enable both effective scaling of a long list of health solutions reliant on access to secure, standardised and high quality data and the development of new digital health innovations. A move towards a dedicated EU approval process for smart health products (e.g. with a specialised approval authority similar to British NIA, German DVG) or mutual recognition of national approvals would also boost the ecosystem, as would a built out physical infrastructure to support digital health services, including access to the European HPC network, to support digital use cases in pharmaceuticals and precision medicine.

For both sectors, forming truly integrated European ecosystems, with collaboration across industry borders as well as national borders, would help to accelerate the digital transformation. No company, institution or organisation alone can solve the complexities of large-scale digital adoption, but by acting together they can all capture the benefits.

Exhibit 6: In France and Germany alone, digital health solutions could generate a value of €55 billion to society, with three use cases accounting for 40% of the value

Benefit potential[2] of digital health solutions by use case, *EUR bn, 2017/18, sum for FR and DE[3]*



1. Unified electronic health record/exchange | 2. Benefit potential for 26 use cases across 5 digital domains; benefit potential captures reductions in the cost of delivery and/or direct decreases in activity | 3. Note: Figures may not add up due to rounding; benefit potential captures reductions in the cost of delivery and/or direct decreases in activity (compared to combined German and French 2018 baseline)

Source: German Federal Ministry of the Interior, German Federal Statistical Bureau,French Ministry of Social Affairs and Health (based on 2017 data)

7.2. Creating a digital leadership instrument

European institutions could accelerate technology innovation and the development and commercialisation of strategic new products by creating a mechanism that links research funding to public procurement. One potential option is to establish a European strategic funding agency, an instrument where Member States can join efforts to jointly fund and procure large-scale, high-risk development projects tied to critical global challenges – e.g. climate change, security or health – and coordinate Europe-wide procurement of innovation to support commercialisation and strengthen European value chains.

Potential rationale for European action

Enhancing the capacity to research, develop and commercialise new technology is key for Europe to remain competitive and reduce dependence on foreign imports for key hardware and infrastructure components. Despite Europe's ambitious joint research programme, Horizon 2020, efforts remain fragmented in many strategic research areas, and most companies or Member States do not have the scale to develop the most costly technology innovations. One of the issues hindering the commercialisation of strategic research is the lack of connection between breakthrough but high-risk research and the market. European governments procure goods and services worth approximately €2 trillion every year, with 10 to 15 per cent of these being digital-related[57]. Together, European governments have the purchasing power to commission new products that do not yet exist – and also have the opportunity to share development risks. There are promising efforts to address this topic under the European Innovation Council and the European Research Council. These mark important steps from the Commission on the innovation side[58], albeit at this point without a large-scale, joint strategic procurement element.

In the US, the Defence Advanced Research Projects Agency (DARPA) has helped bridge this gap for high-tech defence products, which in turn have been instrumental to the development and commercialisation of silicon chips, the internet, voice recognition, touch screen and GPS, as examples[59]. The EuroHPC Joint Undertaking demonstrated how the pooling of EU and Member States' resources can steer innovation and support the research and deployment of next-generation technologies. European institutions could build on this experience and extend it to other areas, e.g. blockchain, quantum technology, low-power microprocessors, or AI applications.

In the executive survey, approximately 63 per cent of executives stated that they would invest more in R&D for new products/services if they were ensured a public buyer for those products/¬services, and approximately 60 per cent stated that they believe pooling resources at an EU level would increase the effectiveness of large-scale innovation.

Potential options for European action*

Extending and expanding the mandate of an existing instrument for all/participating Member States – The Commission could tie funding to public procurement for strategic, large-scale EU innovation projects by:

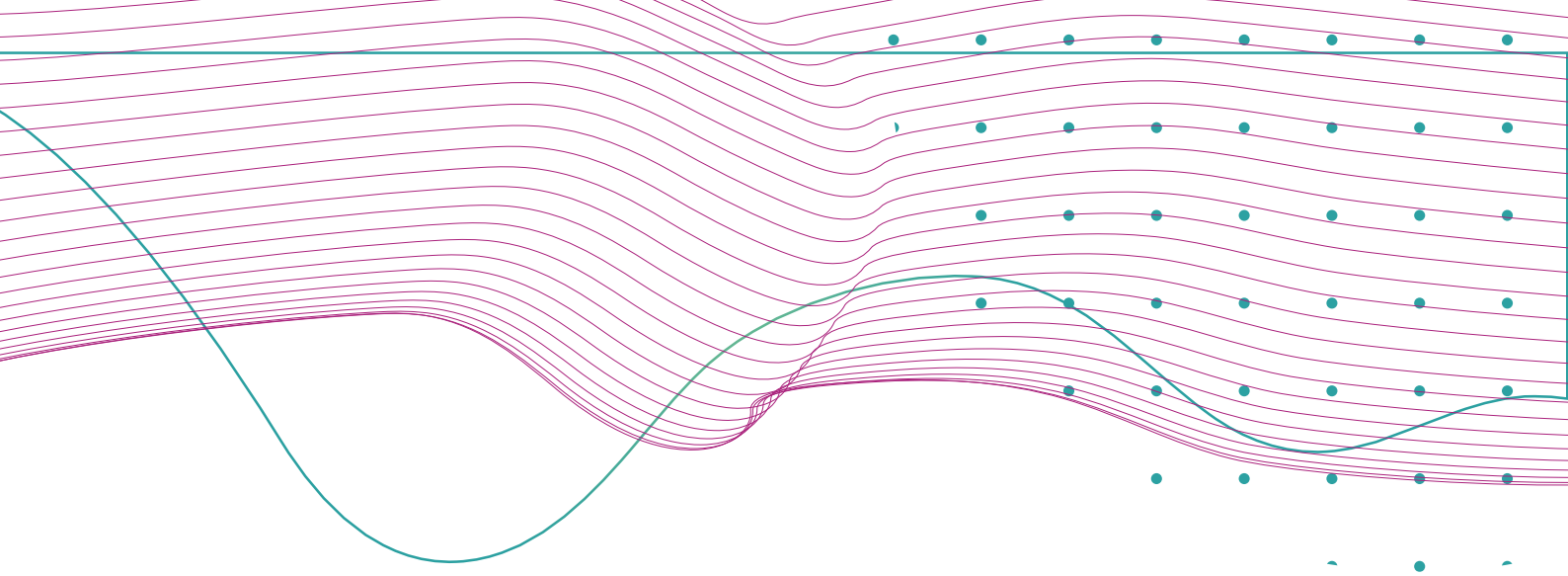
- creating a standing body for the EuroHPC Joint Undertaking to tackle other strategic innovation topics on behalf of all Member States and the Commission;
- expanding the Important Projects of Common European Interest (IPCEI) to include a public procurement instrument in the framework and create a governance body for sub-groups of Member States or the Commission to mobilise for strategic innovation topics.

Creating a new instrument for all/participating Member States – The Commission could tie funding to public procurement for strategic, large-scale EU innovation projects by:

- creating a new body or framework for large-scale strategic innovation procurement, thereby allowing the Commission to mobilise and pool Member States' resources for strategic innovation projects of various sizes. This would include joint procurement and grants. Alternatively, this framework could be used for Member States to voluntarily pool resources for common strategic innovation projects.

Pooling resources would drive the commercialisation at scale of strategic technologies, whose development or procurement costs are still prohibitively high for individual actors. The main difference between a voluntary and an EU-wide scheme is that a voluntary scheme could leave some Member States behind, potentially widening gaps. While it is beyond the current competencies of the European Commission to establish a EU-wide joint procurement body, the example of the EuroHPC joint undertaking shows that Member States can be widely willing to participate in strategic

* indicative and non-exhaustive



development programs under the right conditions. However, R&D investment inherently bear the risk of not being fruitful, and that large-scale strategic procurements could concentrate funding on the companies or institutions that are already best resourced, risking the exacerbation of existing resources imbalances unless specific attention is given to the matter.

The necessary **investment level** is a function of the ambition level and scope of technologies that will be developed – but large-scale innovations need to be supported by significant funds. As an example, setting aside 1 per cent of Europe's total digital procurement[60] funds would give the leadership instrument €2 to 3 billion every year for joint investment in future technologies: similar levels to DARPA (approximately €3 billion annual budget). In comparison, the EuroHPC budget was approximately €1 billion over 8 years[61].

7.3. Building EU data platforms for strategic B2B sectors

European institutions could promote secure access to high-quality data for business and government use and strengthen Europe's position in the digital value chain. One important component could be supporting the development of B2B data platforms in key sectors, for example healthcare and energy. This could entail regulatory, funding and coordinating actions.

Potential rationale for European action

Although Europe is the most trusted territory for collecting, storing and accessing data, the fragmentation of European data sets across value chains, with diverse rights and incentives to access to them, is an obstacle for enabling technological innovation, adoption and scaling. Data sharing for innovation in public goods services can have a significant social and equality impact by improving, e.g. healthcare or energy systems throughout Europe and reducing gaps between geographies. Additionally, the healthcare and energy sectors are largely public and produce large amounts of data, which means that they are in a good position to be piloted before rolling out benefits to other sectors.

Since data is an essential raw material for most high-impact technologies, data availability is at the heart of reaping the benefits of digital innovation. Notably, data availability is a critical enabler for the adoption of AI and related technologies based on big data. Additionally, access to data supports a level playing field for competition by allowing market players of all sizes to innovate. However, this data often resides in different stakeholder groups, with diverse rights and incentives on how to use the data as well as different Member States' interpretations of GDPR rules when personal data is used (e.g. health)[62].

There is untapped potential to strengthen Europe's leadership in its core industries through data sharing. To rise to this challenge, Europe will need to help its key industries build the core infrastructure and know-how in data science, as well as put in place the necessary regulatory frameworks to enable and promote B2B data sharing while maintaining data security and privacy.

The Commission is well placed to play a coordinating role, as it did when launching the COVID-19 data-sharing platform for research[63]. While the structural challenges mentioned above remain relevant, COVID-19 has brought an increased will to collaborate between health players (e.g. pharmaceutical companies[64]) that could be leveraged to lay the foundation of an EU approach to health data sharing. The COVID-19 pandemic has also highlighted the importance of EU health data sharing and presented a window of opportunity to address gaps exposed by the crisis[65]. *In Shaping Europe's Digital Future*, the Commission recognises the need for shared European data spaces, notably in health, and important first steps have been taken in the European Data Strategy[66].

93 per cent of the EU executives surveyed believe that better access to sector-specific data would be important to their organisation (with approximately 40 per cent designating this as very important). More than 50 per cent would be willing to share their data if they either (1) received access to similar data from competitors in return or (2) were paid for the data. In the Eurobarometer[67], 43 per cent of citizens expressed that they would be willing to share data for improvement in medical research and care.

Potential options for European action*

Standardising B2B sectorial data sharing – The Commission could play a standardising role to enable sectorial data sharing in the EU by:

- first, co-developing standards with industry;
- then, promoting data standards and laying out regulations for data exchange (for selected and suitable sectors, imposing standards could be a viable option, applying methodologies similar to those in the PSD2 directive[68]);
- reviewing potential regulatory barriers to cross-industry data sharing related to competition law, whereby the common good of innovation is weighed against the risk of anticompetitive practices related to data sharing.

* indicative and non-exhaustive

Organising the exchange of B2B sectorial data – Going even further, the Commission could play an active role in organising or operating data exchange platforms by:

- funding or operating the infrastructure for sector-specific platforms for data sharing where the EU can potentially play the role of a trusted third party to facilitate and control use of the platform, as well as setting up a framework to safeguard IP rights while sharing data;
- requiring data sharing on the platform (this could be limited to some strategic sectors and to companies above a certain size).

Currently, companies hold on to their data because it is a valuable asset. Indeed, in some circumstances, data sharing between competing companies may be considered an anticompetitive practice. To function on a large scale, data may be seen as a pre-commercial, precompetitive common asset, whose value is greater for all when scaled up and widely available. This requires a larger shift than the simple provision of data-sharing infrastructure.

Standardisation is the first step towards any large-scale data sharing that the Commission can carry out in a short time frame, with limited investment. The Commission's ability to co-create and enforce standards has been shown with the PSD2 regulation for the banking sector. However, while standards are a requirement, they might not suffice to ensure effective data sharing. The sector must see the value, and be willing to organise data exchanges. On the other hand, organising and directly providing the infrastructure data sharing is more costly and complex than regulatory and coordination measures, but could have a more immediate impact for sectors.

The willingness of industry to cooperate and share data is a precondition for data sharing even in the case of EU infrastructure, and especially in competitive markets. However, for public goods sectors the Commission could incentivise or mandate the sharing of important data. For instance in healthcare, starting with targeted pilots could be a first step to tackling the complexity of data and underlying healthcare systems that could be significant barriers to standardisation and sharing. EU action could also ensure that data shared can be used by all relevant actors in the market and not incumbent players alone.

7.4. Leading the way towards trustworthy AI worldwide

Europe can assume global leadership in supplying ethical and human-centric technology, especially AI. To foster the supply and development of AI, European Institutions could coordinate public and private funding in Europe to ensure internationally competitive levels. This could be accompanied by a regulatory framework setting ethical and legal standards, creating the legal certainty necessary for the development of human-centric AI. For example, a pan-European certification scheme could be developed based on the guidelines for trustworthy AI put forward by an expert group, and a supervisory body for critical, data-driven applications could be established.

Potential rationale for European action

AI and related high-impact technologies play a key role in the development of our future industry and society, and thus have become an area of strategic importance for the Commission[69]. As a general-purpose technology, like steam or electricity, AI can serve and revolutionise numerous sectors, and be a main contributor to the digital transformation of Europe. In addition, the use of AI promises contributions to many societal challenges, from treating complicated diseases to predicting extreme weather events.

There are already substantial differences between countries' readiness to absorb AI, with the US and China emerging as active global leaders. Currently, corporate AI market adoption in the EU is 16 per cent lower than in the US[70]. To ensure Europe captures its fair share of the value generated from such solutions, Europe will need to supply – not just consume – AI technologies. For example, the US has seen approximately €60 billion of annual investment in AI/big data companies in 2018-2019, compared to approximately €5 billion spent in Europe and approximately €17 billion in China[71].

However, for AI to be a positive force in European societies, it should be used ethically and machine decision making should be transparent. Most Member States are, or will be, grappling with these questions and risk producing fragmented regulatory approaches. A common framework on European AI ethics and transparency would create a true single market for trusted AI applications

58 per cent of EU executives surveyed see 'support[ing] universities and research institutions to build leading AI knowledge' as part of the most important policy to promote AI to the benefit of Europe. 45 per cent also see 'support[ing] European industry broadly to ensure adoption of existing AI technologies' and 42 per cent see 'guidelines or regulations to safeguard ethical and transparent use of AI' as part of such policy. Additionally, 75 per cent of EU executives surveyed do not consider that AI transparency regulation would affect their business negatively, with 36 per cent believing that it would have a positive impact.

COVID-19 has pushed many businesses and consumers towards online and remote services, which has the effect of creating new and more diversified data sets in specific areas (online shopping, remote working, and collaboration) that could be used as a basis for new AI applications.

Potential options for European action*

Investing to build European AI capabilities – The Commission could build on and expand its Coordinated Plan on Artificial Intelligence[72], and ensure sufficient investment in building European AI capabilities by:

- funding (1) research and innovation into and, (2) teaching and building AI talent and (3) common infrastructure and facilities (see section 7.1 above);
- creating an EU strategic innovation procurement instrument for AI (see section 7.2 above);
- incentivising private R&D, fostering commercialisation (e.g. AI venture capital) and funding the dissemination of AI tech through Digital Innovation Hubs.

Regulating and creating trust in AI – The Commission could regulate AI to avoid misuse and create trust while avoiding any stifling of innovation by:

- establishing a multi-level certification scheme, with certification depending on the risk level of applications and being tied to liability of the manufacturer, to protect both users and certified manufacturers;
- working to improve the perception of AI by creating transparency and awareness of the benefits;
- promoting the roll-out of AI for government by building a centre of competence to provide guidance on AI ethics and peer learning on AI for government.

The options presented above are complementary and both need to happen to capture AI benefits by addressing both AI uptake and AI trust. A certification scheme has the advantage of addressing the trustworthiness and transparency of AI systematically, but there is an inherent difficulty in controlling and certifying a product that is, by design, constantly changing. There is an added risk of hampering innovation, especially for small players, with certification costs and bureaucracy.

In addition, AI is expected to widen inequalities between Member States and companies, which could be subject to coordinated action by the Commission to ensure a fair repartition of the benefits of AI across the EU. As an example, by 2030, front-runner companies are predicted to gain about 122 per cent in economic value (economic output minus AI-related investment and transition costs)[73]. In contrast, laggard companies could lose around 23 per cent of cash flow compared with today[74].

Venture capital and other financing (public and private) of AI companies are at relatively low levels in Europe. To close this financing gap between the EU and the US, additional investment of approximately €55 billion annually would be needed, whereas closing the financing gap with China would require approximately €12 billion[75].

7.5. Empowering cities and communities across Europe

To empower European cities and communities through the use of digital technology, European institutions can support the development of interoperable and scalable smart city technology platforms through the coordination of technology standards and architecture. Furthermore, the EU could accelerate the funding of pilots and lead innovation procurement of such platforms, which are developed on the free market but are applicable across European cities.

Potential rationale for European action

Smart cities translate digital technologies into better public services for citizens, better use of resources and less impact on the environment. This means, among others, smarter urban transport networks, upgraded water supply and waste disposal facilities, more energy-efficient buildings, safer public spaces, and meeting the needs of an ageing population. Smart city technologies have been found to have potential for 15 to 20 per cent less time in traffic; up to 40 per cent less crime; 10 to 15 per cent lower carbon dioxide emissions; and 20 per cent lower water consumption, among other improvements[76].

There has been significant investment to date. In Europe, an estimated €17 billion related to smart cities was spent in 2018[77]. However, funding alone is insufficient to scale up the market.

While the core technologies are sufficiently mature, the first challenge for smart city solutions to reach broad adoption at scale across Europe, is to orchestrate city ecosystems to align on standards and concepts for scalability. Lack of standards leads to risk on both the supply and demand sides: developers bear a significant risk that solutions developed will not comply with future standards,

* indicative and non-exhaustive

while cities run the risk of vendor lock-in if solutions are not interoperable. Additionally, there is little clarity for procurement officers around Europe, e.g. on what services and solutions are available on the market, what has worked, what has failed, and which vendors offer the best service.

The top three elements, crucial for benefitting from advanced digital services at a city/local level, cited by EU executives, are (1) more investment by locality in digital services (cited by 50 per cent), (2) more technological capability building inside their own business (cited by 35 per cent), and (3) more engagement from public authorities with private actors (cited by 34 per cent). In the Eurobarometer[78], 60 per cent of citizens declared themselves willing to share data for improved public services.

COVID-19 has leapfrogged digital adoption by both citizens and public authorities to provide services to their community during the pandemic; this could be a window of opportunity for increasing connectivity in municipalities. This could also have the additional benefit of building more resilient communities and services, as the long-term progression of the pandemic (e.g. for senior citizens) and possible resurgences or other crises are unknown.

Potential options for European action*

Boosting the supply side of EU standard-compliant smart city technologies – The Commission could foster the development of interoperable, sustainable, citizen-centric smart city solutions on a large scale by:

- promoting interoperability and standards for scalable smart city platforms, e.g. through EU guidance, to incentivise the development of a scalable standard-compliant solution offering;
- developing an EU data platform for cross-border/cross-city services, on which companies can build services at reduced marginal cost;
- building knowledge and R&D for citizen centricity into smart city technology.

Boosting the demand side of EU standard-compliant smart city technologies – The Commission could put in place the right conditions for the adoption of sustainable smart city solution at scale in the EU by:

- creating a certified vendor marketplace, to build trust on the buying side and avoid vendor lock-in;
- co-funding the launch of smart city technology locally (e.g. match funding up to a certain amount per locality);
- offering training and experience sharing of local procurement staff in smart city applications to build trust.

For any effective action to promote the development and at-scale adoption of smart city technologies as a means to empowering cities and communities, a prerequisite is to establish and promote standards (e.g. interoperability) for smart city technologies.

The standardisation approach unlocks great potential value at-scale for all citizens if it succeeds, but would have to focus on a narrow scope of application that can be common to all cities or municipalities. There would be inherent difficulties in the standardisation of Europe-wide solutions for solutions that are intrinsically local and often application-specific.

From an **investment** perspective, platform standards development can build on previous action (e.g. the SynchroniCity programme[79]) and public procurement tied to these standards will incentivise development. Additionally, to foster uptake, a budget of €1 to 5 billion[80] could serve to co-fund platforms (following Minimal Interoperability Mechanism principles (MIMS), developed by the Open & Agile Smart Cities (OASC) network) and co-fund local investment in standard-compliant smart city technologies.

* indicative and non-exhaustive

Digitising the European construction ecosystem

Developing Europe's cities and built environment is tightly linked to developing the construction sector. One of the largest sectors in the economy, construction employs 7 per cent of the European workforce[81] and has a direct impact on our daily lives – and on those of future generations: directly and indirectly, the buildings and construction sector accounted for 39 per cent of global energy and process-related carbon dioxide emissions in 2018[82].

The construction sector struggles with low productivity, in Europe and elsewhere. No other major sector has had lower productivity development in the last 20 years[83], and as a result construction activities are becoming more and more expensive relative to other goods and services, at a time when upgrading infrastructure and housing at scale is more critical than ever to meet sustainability and social objectives.

The sector takes these challenges seriously: in a 2020 survey of 400 construction executives, 90 per cent said that the industry needs to change now, and that the need is more acute than five years ago. In the same survey, the vast majority of respondents – about 70 per cent – pointed at new production technologies and digitisation as the disruptions that would make the change happen[84]. Digital technologies have the potential to boost the productivity, sustainability and effectiveness of the sector in all parts of the value chain and across the life cycle of the assets it builds. Numerous use cases, ranging from analytics-supported procurement, 5D building information modelling (BIM) and project level data sharing to advanced construction robotics, new materials and modular prefabrication techniques could together directly render, or indirectly enable, productivity gains of up to 50 per cent in the industry[85].

Most high-impact digital use cases in the sector rely on basic and readily available software and systems rather than highly advanced technology. Yet construction remains one of the least digitised sectors in Europe[86]. In a highly fragmented industry, consisting mainly of SMEs with small financial margins and relatively low skill levels, most companies cannot – or lack the interest to – build a business case for investing even in basic digital technology; moreover, the technology landscape is equally fragmented, with few joint industry standards to ensure interoperability of different systems even within one construction project. Furthermore, building regulations can differ even between neighbouring municipalities, making it difficult to scale up standardised solutions. In many parts of Europe, poor network connection at construction sites makes digital tools difficult to use for those who have access to them, creating further barriers to the large-scale adoption of technology.

In this setting, European Institutions, Member States and the construction ecosystem can work together to create the right market conditions and capabilities in all parts of the sector and increase the pace of technology adoption. Companies and public buyers can be supported with training and financing to invest in systems and connectivity, and public procurement can be used as a tool to either promote or make modern, effective construction techniques a requirement. Following Helsinki's example[87] and digitally mapping the built environment of Europe's cities would put in place an important piece of digital infrastructure to use for other applications in the sector and could further boost development. Finally, working with the ecosystem and regulators on all levels to continue building a truly integrated single European market for construction services, and addressing fragmentation – regulatory and technological – remain important levers for capturing the potential of digital in the construction sector.

Table 1: Basic and advanced digital applications can play an important role across all steps of the cosntruction value chain

Non-exhaustive

	Value chain elements						
	Concept & feasibility	Design & engineering	Pre-construction	Construction & commissioning	Operation & maintenance	Overarching	
Basic digital construction use cases[1]	Portfolio planning & management Risk management Capital financing	Process simulation software Design software 3D modelling Productivity management Value engineering Safety software	Estimating Project scheduling Resource planning CRM Equipment market place Materials market place Labour & professionals market place Bidding process	Design management Quality control On-site scheduling Contract management Document management Compliance Remote equipment management Off-site fabrication Manpower optimization Progress tracking & performance dashboards System testing and training As-built documentation (incl. insurance) Immersive digital twins	Predictive asset performance	Design simulation BIM Bluetooth connectivity Design/ construction quality control	Most high impact use cases build on **basic hardware, software and connectivity** which are readily available in the market
Advanced digital construction use cases[2]		Laser scanning	Supply chain tracker	Drone-enabled yard inspection Remote materials management VR/AR3 on site	Real-time facility management AR[3] inspection and management	Virtual learning Machine learning Deep learning Robotics/ automation 3D printing AI[4] design optimisation	**Advanced technologies** could drive high impact Pursuing such use cases require long-term **R&D investments, e.g. AI, robotics, 3D printing, AR** Scalable only in **longer term**

1. Defined as digital use cases that are already available today at competitive performance and cost structure, and do not require specific technological advancement
2. Defined as digital use cases that are not available today at expected performance and with sustainable cost structure due to technological limitations
3. Augmented Reality
4. Artificial intelligence

Note: Contains additional use cases identified through expert interviews.

Source: 'Seizing opportunity in today's construction technology ecosystems' (McKinsey, 2018); McKinsey Construction Technology Ecosystem Mapping; expert interviews

7.6. Raising a cybersecurity shield for Europe

European institutions could, building on the agreement of the Cybersecurity Act, strengthen the cybersecurity of critical infrastructure, hardware and software. This could entail regulation of mandatory EU security standards for both hardware and software imported into the EU. Mandatory insurance coverage for critical infrastructure sectors could be part of such a scheme. ENISA or a new agency could obtain a broader mandate to audit compliance.

Furthermore, European institutions could address the advent of quantum by developing a secure quantum communication infrastructure.

Potential rationale for European action

Cybersecurity is a high priority for European citizens and two out of three do not believe that current policies in data protection are sufficiently effective[88]. It is estimated that IPR (Intellectual Property Rights) theft in the United States alone accounts for about $400 billion in losses each year[89]. Personal data safety is no different, with numerous examples of customer data breaches at consumer-facing institutions in recent years[90,91,92]. As the frequency of cyberattacks increases[93], cybersecurity is likely to become an essential element in attracting and maintaining investment.

In addition to economic and privacy concerns, cybersecurity is a domain with strong strategic autonomy rationale that is already recognised by the Commission[94]. With a significant portion of ICT technology imported into Europe, the challenge is twofold for critical technologies : (1) establish and build on what can be done locally in Europe and (2) limit vulnerabilities related to what must be imported as the need to import critical technologies securely is likely to endure. Moreover, as quantum technologies mature, they could potentially render most current encryption systems obsolete, posing new cybersecurity challenges calling for public action to support the development of new secure solutions.

71 per cent of EU executives surveyed believe mandatory software and hardware cybersecurity standards on imported technology would positively affect the long-term security of their business.

The COVID-19 pandemic has precipitated digital adoption by citizens and businesses resulting in a wave of new users could be less educated about cybersecurity and could therefore make systems weaker. Additionally, businesses moving online during the pandemic may have accelerated reliance on foreign-designed/operated infrastructures, thereby posing a risk to the stability of European business operations.

The Commission has acknowledged the need to adopt procurement standards to provide such protection. Despite this call to action, many businesses are not actively pursuing cybersecurity as a top priority[95]. A greater focus on cybersecurity is required in the coming years.

Potential options for European action*

Protecting technology supply chains – the Commission could regulate or provide guidelines to protect technology supply chains by:

- enhancing the sovereignty of critical infrastructure by building on the NIS and, e.g. expanding it to rule on ownership of service providers for critical infrastructure;
- creating an EU certification scheme that would limit liability for the manufacturer in case of cybersecurity failure, or enforce a set of minimal cybersecurity requirements for all connected products/services;
- promoting or mandating installation of a middleware/library encryption layer via security APIs on certain strategic imported digital technologies that are exposed to enhanced cybersecurity risks, or that are part of vulnerable or critical infrastructure.

Organising EU cyber defence – The Commission could mobilise common resources to increase capabilities for cyber defence by:

- strengthening the mandate of ENISA by adding a EU Cyber Defence rapid response unit to support Member States in real time in case of attack and for forensics after an attack. This support could take the form of technical support or more holistic cyber defence support against foreign threats;
- creating a forum and legal framework for critical infrastructure providers to share threat intelligence across borders (currently this could be blocked by national security rules).

Preparing for post-quantum cybersecurity – The Commission could sponsor the development of EU-led, quantum-resistant algorithms to strengthen Europe's technological sovereignty.

Actions on supply chains and on cyber defence are complementary but have different targets. Acting on technology supply chains through regulation and certification directly addresses risks related to digital hardware and could become a security imperative for the EU. This can, however, be complex, expensive and have significant implications for the global trade of digital goods (including consumer devices). Enforcing certification will come at a cost, either for the Commission or for manufacturers. One way to mitigate this cost and ensure it does not become a hurdle for smaller players could be to leverage EU universities and research institutes to establish certification centres throughout the EU.

Cyber defence is a Member State competence; however, the Commission could build joint capabilities to support Member States in case of attack. Alternatively, Member States could join forces on cybersecurity and establish a joint corps to defend EU Member States against foreign threats. This would have the advantage of centralising top EU cybersecurity capabilities while maintaining effectiveness, due to the remote nature of cyber defence operations.

* indicative and non-exhaustive

7.7. Advancing citizen control of their own personal data

European institutions can take the next step in reinforcing citizens' rights to, and control of, their own personal data, making it easier for them to access new services and providers, while promoting innovation in data-driven business models and more competition in the platform economy. Such a policy could entail the establishment and effective enforcement of data interoperability and portability standards.

Potential rationale for European action

GDPR has placed the EU at the forefront of data regulation with global ramifications. It introduced a common set of rules across Member States on the treatment and protection of personal data, modernised fundamental principles and reinforced individuals' rights to control their data and made it easier to access it. Specifically, on access to data, the right to data portability (as introduced in Article 20 of the GDPR) gives individuals a general claim to move personal data between data controllers, e.g. to a competing company the individual wants to use. This right not only strengthens the individual's control over their own data, it could also simplify service delivery for individuals. This could create opportunities for new business models and increase competition between digital service providers, which today follows a strict winner-takes-all logic and has a highly asymmetric relationship between providers and consumers.

However, barriers to implementation remain. True portability of data not only requires a legal claim but also the 'technical feasibility' to do so. In practice, this means that the current data controller and recipient need to use the same data formats, which is often not the case. In addition, the trade of personal data between data brokers and solution providers is opaque: increasing the transparency for individuals' data transactions would be a core element to allowing meaningful control of data.

46 per cent of surveyed European citizens[96] want to take a more active role in controlling their personal data, while 12 per cent declared that they do not want to share any personal data. Additionally, according to surveyed executives, the two main obstacles for citizens to move personal data between service providers are (1) lack of standards/interoperability for transferring data between service providers (cited by 62 per cent) and (2) lack of knowledge about the right to data portability (cited by 42 per cent). Furthermore, the COVID 19 pandemic has put a spotlight on key data privacy issues relating to contact tracing apps and patient personal data sharing with the authorities, which might require a special regime for limited use for the public good in times of crisis while ensuring that citizens trust that the systems will not be abused.

Potential options for European action*

Enforcing effective portability of personal data – The Commission could extend GDPR to effectively enforce one-click, user-friendly data portability by:

- co-developing, by sector, interoperability data standards for the most common/relevant types of data, then enforcing these;
- extending PSD2-style legislation for additional types of personal data or services beyond financial services[97].

Extending transparency and control over personal data use – The EU could ensure the use of citizen data can be transparently understood and controlled in a user-friendly way by:

- labelling types of data collection and uses on websites and ICT services (e.g. with standardised icons);
- offering or promoting awareness education on the value of personal data;
- creating a personal data dashboard containing central reporting for each citizen, where they can see who has their data, what type of data they have and what they use it for, and remove consent.

The main difference between the options (which are complementary) is the level of involvement that the Commission could have on the next layer of GDPR. The advantage of the standardisation approach is that it leaves businesses the freedom to implement standards in the way that best suits them, but limits control over the end product and how citizens would interact with their data between services.

The option to increase transparency would see the Commission take a more active role in educating and informing citizens (e.g. where the Commission could design user-friendly icons to label data uses on digital services). The advantage of a personal data dashboard for all EU citizens is guaranteed unprecedented control over their data, but this would require more Commission resources for design and operations (e.g. to avoid data breaches).

A key consideration must be to weigh the potential value of such a service (for citizens, trust, fair competition) against the added cost and bureaucracy for European digital companies.

7.8. Promoting digital solutions for climate risks

European institutions can adopt ambitious policies that ensure that the digital transformation in Europe is climate neutral and sustainable.

The Commission could take action to promote the reduction of emission and material waste from ICT. For products and services, this could include labelling and standards on longevity or repairability. For data centre infrastructure, the Commission could put forward an Emission-Free Data Centres policy, which ensures that the expansion of data centres is carbon neutral. This policy could mandate gradually increasing energy efficiency and share of renewable power sources for data centres. Supporting information infrastructure could create Europe-wide transparency on energy consumption, greenhouse gas (GHG) emissions and prices.

* indicative and non-exhaustive

Potential rationale for European action

There is little doubt that climate change is the most pressing challenge the world as a whole is facing, and that ambitious and immediate action is needed. Its adverse effects are increasingly evident already today, with disproportionately many and severe heat waves, droughts, floods, wildfires and other extreme weather events. If the trend is not dramatically reversed in the coming decade, the long-term ecological, economic and social damage to Europe and the world will be catastrophic.

Digital technologies can make important contributions to reducing GHG (Greenhouse Gas) emissions across sectors, e.g. by making industrial processes more effective and efficient, reducing the need for transportation, monitoring data on waste and emissions, and sharing data that is useful for reducing environmental footprints. According to some estimates, digital solutions can help in cutting 20 per cent of global GHG by 2030, mainly in transport, agriculture, manufacturing and energy[98].

However, the negative climate and environmental effects of the ICT sector itself are rapidly growing, and risk partly offsetting the positive effects of digital innovation. A recent study found that the ICT sector's GHG emissions could grow from roughly 1 to 2 per cent in 2007 to exceeding 14 per cent of the 2016-level worldwide GHG by 2040, accounting for more than half of the current relative contribution of the whole transportation sector[99]. In terms of material waste, with more than 12 million tonnes of waste generated in 2019, Europe ranks first worldwide for electronic waste per capita. Beyond this, only about 42.5 per cent of electronic waste is recycled in the EU, despite the total raw material value in it being estimated at approximately €13 billion[100]. Circular economy actions have the potential to address this through recycling and increasing the longevity of ICT products. As an example, according to the European Environmental Bureau, a one-year lifetime extension for EU smartphones could reduce carbon dioxide emissions by 2.1 megatonnes per year (roughly equivalent to 1 million cars)[101].

A European digital strategy that promotes the growth of the ICT industry and large-scale adoption of digital technologies should therefore include comprehensive policies that address these downsides.

64 per cent of EU citizens surveyed in the Eurobarometer[102] want to keep using their current digital devices for at least five years, and 80 per cent think manufacturers should be required to make it easier to repair these devices. 24 per cent would be willing to pay more for this. EU executives cite a reduction of both energy consumption (cited by 67 per cent) and material waste (cited by 50 per cent) of ICT devices and infrastructure as the two most impactful measures to address the ICT sector's effect on the environment. Other impactful measures would be to increase the lifespan and repairability of devices as well as supplying all ICT infrastructure and devices with renewable energy. 54 per cent of EU executives would also consider changing to a greener ICT provider, even if the cost was higher, providing that these have certification or a significantly higher environmental performance.

Additionally, the COVID-19 crisis increases both the opportunity and the urgency of climate action through and within ICT. As digital adoption has rapidly increased during the crisis, the ICT sector's impact, through the use of consumer hardware and data centres, threatens to spike and needs to be addressed. As governments across the world are devising ambitious economic support programmes, many see an opportunity to make green transition investment an integral part of these.

Potential options for European action*

Creating transparency on the impact of ICT – The EU could ensure visibility over the impact of ICT devices on the environment by:

- extending the labelling of ICT devices to services for resource/energy/emission efficiency;
- ensuring transparency over the environmental impact of goods and services for purchase/procurement in B2C, B2B and B2G transactions (e.g. ratings, procurement guidelines).

Building on the above, scaling up the adoption of clean ICT – The EU could ensure scaling up and adoption of clean ICT by:

- developing and promoting (or, in specific cases, imposing) hardware standards (modularity, durability, repairability, recyclability, etc.);
- imposing data centre targets in terms of emissions or efficiency while protecting competitivity, as outlined in *Shaping Europe's Digital Future*.

Both options have advantages and build on one another. Transparency measures such as labelling better informs consumers/purchasers about the impact on the environment of their choices. With approximately 70 per cent of consumers declaring themselves willing to pay roughly 5 per cent extra for a green product or service[103], this has potential to impact the green offering. However, a labelling scheme with broad coverage comes with costs and complications for manufacturers and importers, and needs to be carefully designed to be effective.

Going beyond this, developing and promoting ambitious standards for both material waste and energy efficiency/emissions truly has the power to fast-track systemic changes in the industry. As speed matters for the environment, this is an important consideration. For data centres, a policy could mandate gradually increasing energy efficiency and share of renewable power sources for data centres.

* indicative and non-exhaustive

7.9. Supporting lifelong learning for the future of work

European institutions can play a larger role in supporting the crucial transformation of the labour market, building the skills that underpin a more knowledge-intensive economy and supporting workers to adapt to new requirements. This could be done for example by coordinating and co-funding a 'at scale' reskilling across countries and employers. The digital platform to coordinate such an account could open opportunities to offer additional services, for example, AI-enabled career counselling, data aggregation and access, and direct access to Massive Open Online Courses (MOOC).

With new technologies, three issues will be compounded. Firstly, the digital skills gap is bound to increase in 2030 unless drastic measures are taken, as nine out of ten new jobs will require digital skills[104]. Already today, 30 per cent of companies say that candidates' lack of digital skills prevents them from filling entry-level positions[105]. Secondly, a new skill set, emphasising highly cognitive and social skills, will increasingly be needed in Europe to fit the new type of production function and workflow attached to new technologies.

Thirdly, AI and automation will inevitably accelerate the displacement of manual workers and change the nature of most professions. McKinsey Global Institute scenarios suggest that by 2030, 94 million European workers might need to upskill to handle a growing share of digital activities in their daily work, and an additional 21 million may need to switch occupational categories[106]. People are aware of this shift. 40 per cent of Europeans believe that the company they work for will disappear from the market in 10 years if it does not come up with a quick and decisive response to these changes[107].

Additionally, this transition might be accelerated by the COVID-19 pandemic, with companies possibly accelerating automation to react to the difficult economic environment and to make their business more resilient in a post-COVID-19 world (e.g. social distancing between employees). Regarding reskilling, the pandemic has forced educational institutions worldwide online for a significant period of time, and these capabilities for online education might be reused to reach a broader audience for reskilling purposes.

The transformation of the labour market may require broad social and economic action to manage the transition and alleviate negative effects. One of these elements is reskilling and supporting lifelong learning at greater scale and speed than those of previous technological revolutions, as already emphasised in 2016 in the Digitising European Industry Report[108].

73 per cent of EU executives surveyed as part of this study cite on-the-job training as the most effective way to re/upskill their workforce, followed by in-person/online training (42 per cent). 61 per cent think a mandatory personal training account, co-funded by employers, employees and governments, would positively impact their business.

Potential options for European action*

At-scale digital education / reskilling – The Commission could coordinate or sponsor the provision of digital upskilling programmes for EU citizens by:

- launching an EU online reskilling platform that would serve as a one-stop shop for all online reskilling resources in the EU, including career guidance;
- enabling the breaking up of a university/professional curriculum into a lifelong learning model by supporting pioneering educational institutions as well as ensuring societies can accommodate the lifelong learning model (e.g. tax, pension, temporary income);
- ensuring the necessary skills are developed throughout initial education to thrive in a Future of Work context. Such a learning journey would span from a reinvention of early childhood education (to learn flexibility, tolerance for uncertainty, a growth mindset, etc.) all the way to the continuous teaching of basic digital skills as part of all primary, secondary and tertiary education.

Career transition guidance – The Commission could fund regional Future of Work centres for proactive career counselling, re-/upskilling, and employment services at Member State/regional level for at-risk populations

Funding at-scale reskilling – The Commission could explore new financing mechanisms for at-scale investment in education and reskilling (e.g. social impact bonds or other innovative financial instruments).

As executives cite in the survey, online learning will be an important part of the solution, providing the opportunity for mass access to reskilling content. However, it is cited as only part of the solution and both in-person training and on-the job learning are at least as important.

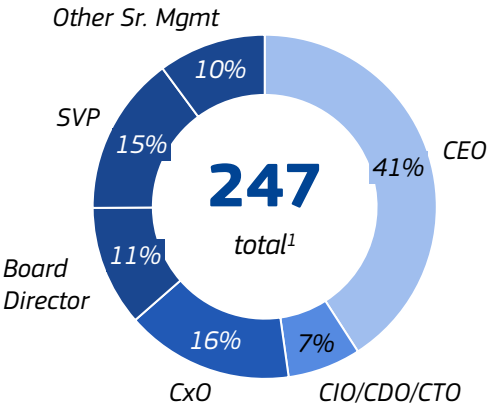
Education is primarily a Member State competence. However, in light of the pressure on government budgets, an apparent gap between and within Member States, and the critical priority of the question, there is a role for the European level to support education innovation, contribute necessary funds and infrastructure, and coordinate Member States to ensure the right conditions are in place for citizens to embrace lifelong learning.

Significant funding will be needed over the coming ten years to meet the demands of the future labour market in Europe. Reskilling 21 million workers and upskilling 94 million could represent a cost of €350 to 490 billion, a significant portion of which would likely require new funds beyond existing education and training budgets. The cost would likely be shared between employer, employees and public funds[109].

* indicative and non-exhaustive

7.10 Executive Survey Summary

Survey demographics



Number of respondents

Higher

Lower

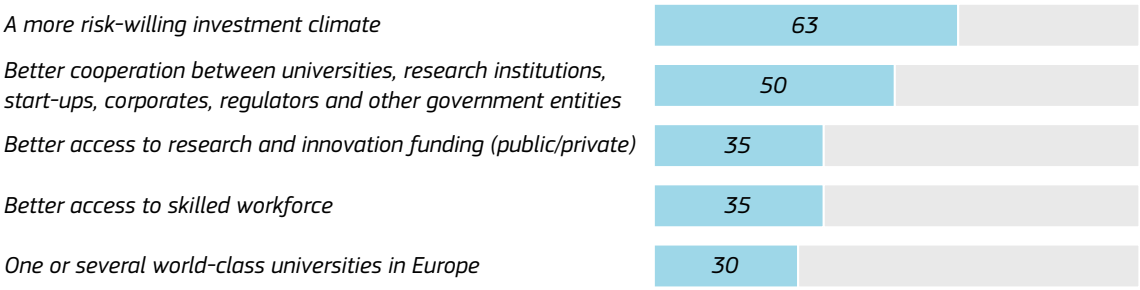
Countries represented in the survey

*52% of respondents say that **technology** is an important or core part of their responsibilities*

Responses[2]

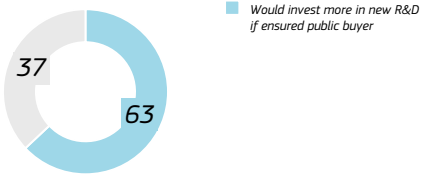
Most important enabler(s) for a leading technology ecosystem in Europe

Top 5 answers in a multiple choice list, % of respondents

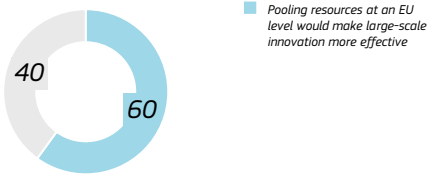


Willingness to invest in strategic technologies and view on resource-pooling

% of respondents - aggregated

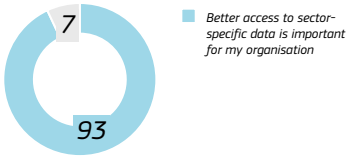


% of respondents - aggregated



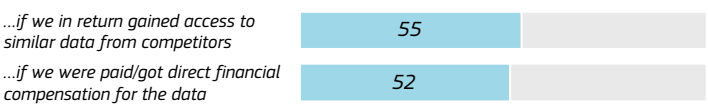
Importance of data access and willingness to share data

% of respondents - aggregated



Top 2 answers in a multiple choice list, % of respondents

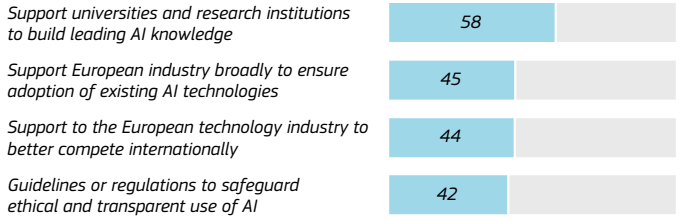
I'm willing to share my company data...



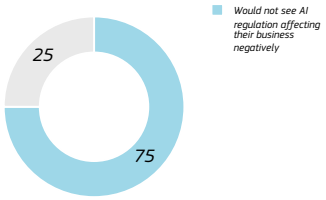
1 The response rate to the survey was ~5%
2 Selected questions

Most important policy elements to promote AI to benefit Europe and view of AI regulation

Top 4 answers in a multiple choice list, % of respondents

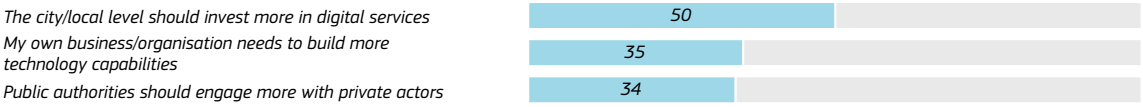


% of respondents - aggregated



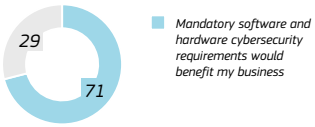
Elements needed for companies to benefit from advanced digital services at local level

Top 4 answers in a multiple choice list, % of respondents



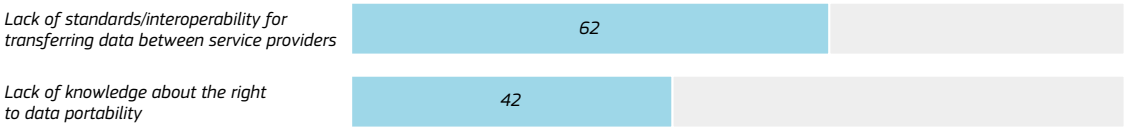
View of mandatory cybersecurity standards

% of respondents - aggregated



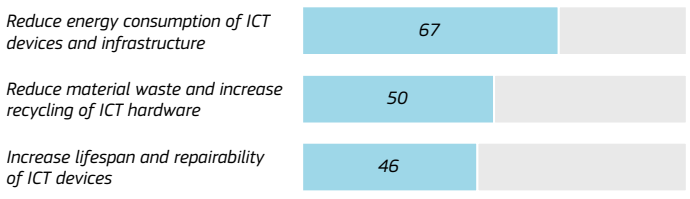
Hurdles for citizens to move data between services

Top 2 answers in a multiple choice list, % of respondents

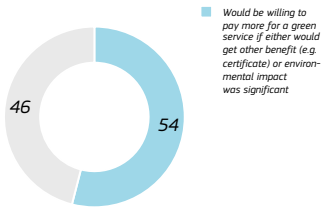


Levers to reduce ICT environmental impact and price elasticity for green services

Top 3 answers in a multiple choice list, % of respondents

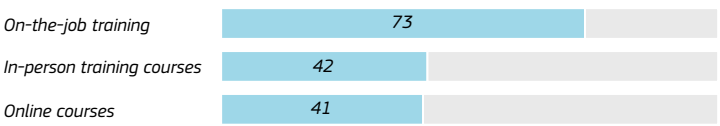


% of respondents - aggregated

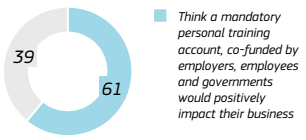


Most effective reskilling methods and view on a co-funded mandatory learning account

Top 3 answers in a multiple choice list, % of respondents



% of respondents - aggregated



8 A CALL TO ACTION

The identified signature initiatives will require actions, reforms and significant investment, across all of Europe. Investment and action will be needed at all levels: to a large extent driven by the private sector, through individual enterprises and with private investment, and by the Member States. The European level is, however, more important than ever: as digital technologies benefit from scale, the value of data can only be captured when it is shared and interoperable, as tomorrow's technologies can only be developed and fairly diffused through cooperation and – in light of the COVID-19 crisis – as local and national economies are under severe pressure.

Adding to this: speed matters. Several of the high-impact technologies and business models have early advantages[110]. Those advantages not only affect the ability to generate productivity growth, but also the ability to generate social benefits beyond GDP, such as improved healthy longevity[111]. Therefore, actions should be taken swiftly into the tenure of the next Commission to maximise their impact.

Action must also be taken to lift the least digitally advanced Member States while enabling the front runners to pull the pack along. At all levels, European decision makers should wholeheartedly embrace and promote the potential of the digital while – with equal commitment – supporting the groups that risk falling behind in the transition.

The initiatives discussed in this report would require innovative policy processes and new cooperation models within and between European institutions, Member States, companies, citizens and civil society organisations. They would by no means be sufficient in themselves, nor would they alone address all the challenges and objectives of the next European strategy. But they could act as flagship projects from which Member States, citizens, business and organisations could benefit directly, which would inspire all stakeholders to step up their own actions and initiatives.

There are many reason to be optimistic about the digital transformation potential of Europe. Europe has unique resources in its diversity of skills and ideas, held together by common values and mechanisms for cooperation towards a common goal. Digital innovation is a European idea at heart and Europeans are credited with fundamental discoveries like that of electromagnetism, and inventions like the World Wide Web. Standing on the shoulders of previous generations of Europeans, decision makers can accelerate now to capture the value of digital innovation in line with European values.

9 TECHNICAL APPENDIX

The McKinsey Global Institute (MGI) has done extensive work modelling the impacts of disruptive technologies through a series of models and articles with the themes *Future of Work* and *AI: The Next Digital Frontier*. The simulation in this report leverages this work and builds upon it to simulate the incremental economic impact of disruptive technologies (including AI and related advanced analytics technologies, 5G and next-generation networks, advanced robotics, IoT, and industrial platforms) on top of baseline economic performance in the EU-28 Member States through 2030.

The specific impact model updated for this work used three proprietary surveys with approximately 5,000 executive-level respondents globally and in the EU, representing all sectors and regions, interviews with leading economists, and an extensive library of proven use cases of technologies expected to reach more than 50 per cent average adoption by 2030 to estimate the potential employment, gross domestic product (GDP) and wage effects of impending disruptive, digital technologies on the EU-28 Member States. This was done by breaking down the effects of digital adoption into eight channels (e.g. substitution, negative externalities), estimating the total impact potential within these channels by country and applying an adoption rate by country to the channels to simulate annual impact through 2030.

The net base case assumes a weighted average adoption of approximately 51 per cent for these technologies in Europe by 2030. This was derived by assessing the adoption trend of relevant disruptive technologies through 2018 of corporate and SME firms, based on the technology adoption surveys referenced above. An average linear adoption trend was calculated based on the findings and was varied by Member States based on scoring of macro-econometric factors. These factors were derived based on over 20 existing data sources for markers of basic (e.g. use of internet and other services[112]) and advanced digital skills (e.g. science research and innovation outputs[113]), indicators of ICT supply readiness (e.g. developers per capita and venture capital spending by region[114]), and indicators of adoption readiness (e.g. ICT enabling new business models[115]).

Table 2: Estimated cumulative growth impact of digital innovation by 2030 in the eu-28

	Use case channels	Description	Est. GDP impact (€ trillions)
Production channels	1 Augmentation	Through emerging new technologies there will be an increased use of capital and labour	0.6
	2 Substitution	One major impact of digitisation lies in substitution of current jobs. Theoretically half of various tasks could be automated, driving greater productivity	2.3
	3 Innovation	Innovation tends to create new economic value through new products and services. However, a part of today's existing products will be substituted	1.2
Externality channels	4 Global data flows and connectedness	As earlier MGI studies indicate global data and innovation flows boost the global GDP	0.4
	5 Wealth creation/ reinvestment	The increased output from new technologies can be passed to workers and entrepreneurs. This could create spill-over effects in the economy	0.5
	6 Transition/ imple-ment-ation costs	While transitioning to new technologies, different costs are likely to be incurred	(1.0)
	7 Negative externalities	Technological innovations could create additional costs, e.g. when individuals need to be retrained	(1.1)
	8 Inequality and ICT supply	Inequality: additional concentration of wages reduces average consumption supply: estimate of ICT supplied from competing regions, based on supply development indicators	(0.5)
		TOTAL: (numbers do not add up due to rounding)	2.2

The simulation assesses economic impact of technologies through eight mechanisms ('channels'), as described in Table 1 above. A detailed description of the underlying methodology is provided in the 2018 report from the McKinsey Global Institute, *Notes from the AI frontier: Modeling the impact of AI on the world economy*[116]. Note that our results build on this methodology and therefore closely relate the findings from this report but do not tie directly to the figures presented.

The detailed description and methodology of channel 8 is described in detail in the two sections below.

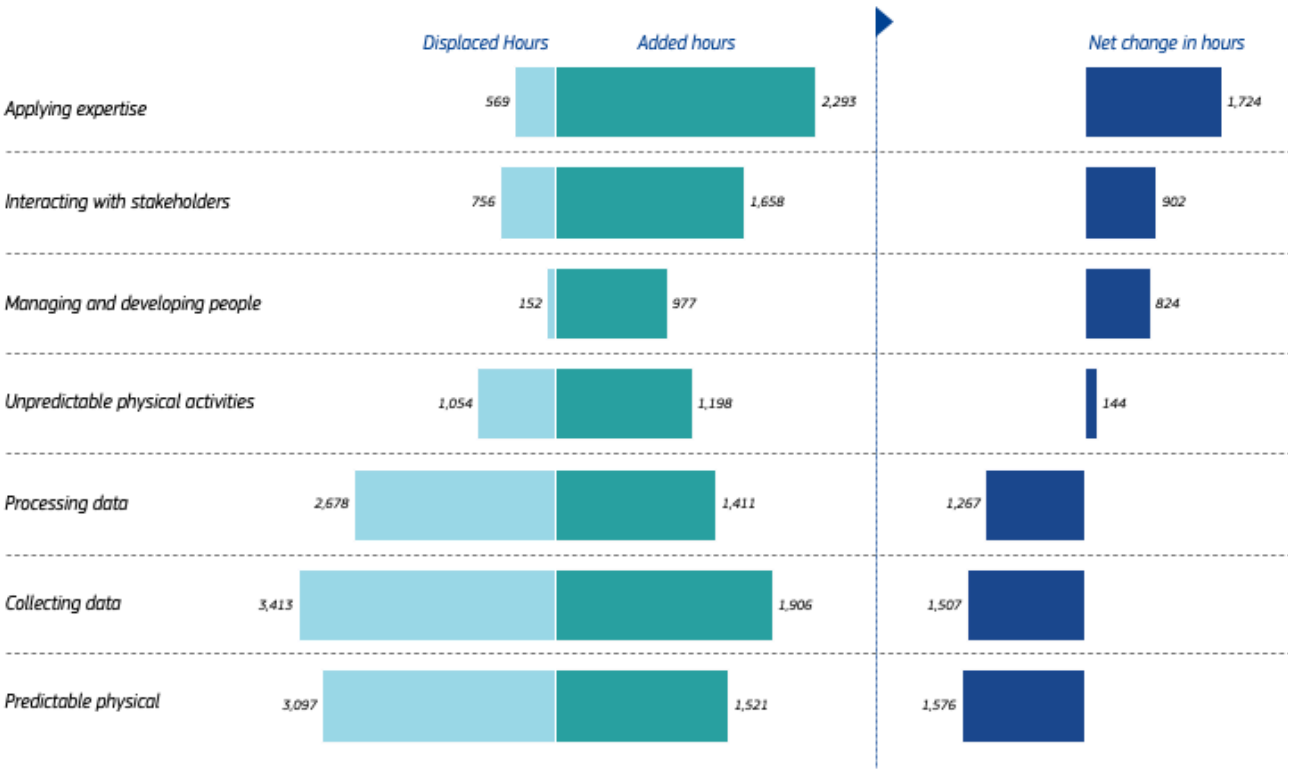
Incremental impact of disruptive technologies on jobs

The updated simulation provides estimates on the incremental impact of disruptive technologies on full time equivalent (FTE) in the EU-28 Member States by 2030. This estimate leverages findings from a recent MGI report[117], which provides fundamental assumptions for the future of work, such as the share of routine versus non-routine work by job type, and compositions of job type by sector. To model this incremental effect, three distinct categories of trends were considered at a country level: substitution, new jobs, and spill-over effects.

- **Substitution:** digital solutions can be applied to achieve productivity through substitution of labour. To estimate this effect, the MGI report cited above broke down the composition of labour into a series of tasks for which an automation potential is assumed, based on the results of previous case studies. Of note, this trend considers both the reduction and increase of time spent on certain tasks, based on how digital is expected to change the nature of work. The net impact of this shift was applied to job categories within incumbent industries to estimate the substitution effect of digital solutions at a country level. For an example of this shift, see **Exhibit 1**.
- **New jobs created:** as digital solutions are set to substitute some existing jobs, they are also expected to create new job categories in incumbent and developing industries, such as data scientist and translator roles. An estimate of this trend is done by Member States based on the incremental GDP calculated from the first four channels in the model and applying factors such as predicted capital-to-labour ratio.
- **Spill-over jobs:** the widespread use of technologies may lead to spill-over effects (for example, network effects) that boost global productivity, as wealth from wages and capital are captured into local economies and are spent on local products and services. This effect is expected to spur growth in local industry, growing existing jobs across categories. An ITU study performed in 2018 estimated that a positive spill-over impact of 1 to 5 per cent in domestic economies could be enjoyed in the Member States, (based on propensity to consume and investment capacity). This trend is estimated based on the incremental GDP generated in channel 5 and 8, wealth creation and local capture of ICT supply.

Exhibit 7: illustrative example[119] Net growth in work will involve more application of expertise, interaction, and management: Germany example

Total work hours by activity type, 2016-30 (Midpoint automation, step-up demand) (million)



SOURCE: MGI 2017

10. END NOTES

[1] General purpose technologies are technologies capable of affecting the entire economy through their impact on pre-existing economic and social structures. Past examples include the steam engine and the internet. For more details, see: Richard G. Lipsey, Kenneth I. Carlaw, and Clifford T. Bekar, Economic Transformations General Purpose Technologies and Long-Term Economic Growth, 2005.

[2] For an overview of AI technologies and use cases, see 'The age of analytics: Competing in a data-driven world', December 2016 and 'What's now and next in analytics', AI, and automation, McKinsey Global Institute, May 2017.

[3] Shaping Europe's Digital Future, European Commission, 2020. https://ec.europa.eu/info/sites/info/files/communication-shaping-europes-digital-future-feb2020_en_4.pdf

4 At the time of writing this report, the European Commission had put forward a proposed revised Multi-Annual Financial Framework for 2021-2027 (COM(2020) 442 final) to be negotiated and adopted by the co-legislators by December 2020

[5] Recovery plan for Europe, European Commission, June 2020. https://ec.europa.eu/info/live-work-travel-eu/health/coronavirus-response/recovery-plan-europe_en

[6] Shaping the digital transformation in Europe, European Commission, DG CONNECT contract SMART 2017/0094,

[7] The COVID-19 recovery will be digital: A plan for the first 90 days, McKinsey, 2020 https://www.mckinsey.com/business-functions/mckinsey-digital/our-insights/the-covid-19-recovery-will-be-digital-a-plan-for-the-first-90-days

8 Why share scientific data during a pandemic?, UK Research and Innovation, 15 May 2020. https://coronavirusexplained.ukri.org/en/article/vdt0011/

[9] The groundbreaking way to search lungs for signs of Covid-19, BBC, 5 May 2020. https://www.bbc.com/news/business-52483082

[10] Paying for coronavirus will have to be like war debt – spread over generations, The Conversation, 11 June 2020. https://theconversation.com/paying-for-coronavirus-will-have-to-be-like-war-debt-spread-over-generations-140406); and France's budget deficit could skyrocket to 7% of GDP in COVID-19 aftermath, Euractiv, 2020 (https://www.euractiv.com/section/economy-jobs/news/frances-budget-deficit-could-skyrocket-to-7-of-gdp-in-covid-19-aftermath/

[11] 'Tech for Good': Using technology to smooth disruption and improve well-being, McKinsey Global Institute, 2019. https://www.mckinsey.com/featured-insights/future-of-work/tech-for-good-using-technology-to-smooth-disruption-and-improve-well-being

[12] Ethics guidelines for trustworthy AI, European Commission, 2019. https://ec.europa.eu/digital-single-market/en/news/ethics-guidelines-trustworthy-ai

[13] Why Some Platforms Thrive and Others Don't, Harvard Business Review, January-February 2019 issue. https://hbr.org/2019/01/why-some-platforms-thrive-and-others-dont

[14] Smart Cities: Digital Solutions for a More Liveable Future, McKinsey Global Institute, June 2018. https://www.mckinsey.com/~/media/mckinsey/industries/capital%20projects%20and%20infrastructure/our%20insights/smart%20cities%20digital%20solutions%20for%20a%20more%20livable%20future/mgi-smart-cities-full-report.ashx

[15] The GDP simulation covers the period 2017-2030 and EU-28, including the United Kingdom. It does not take into account the potential impact of the COVID-19 crisis.

[16] 'Tech for Good': Using technology to smooth disruption and improve well-being, McKinsey Global Institute, 2019. https://www.mckinsey.com/featured-insights/future-of-work/tech-for-good-using-technology-to-smooth-disruption-and-improve-well-being

[17] Countries were separated in 3 archetypes (Front-runners, Middle adopters, and Catch up) based on a composite index calculated in 2017, the beginning of the simulation, using markers of disruptive technology adoption readiness (e.g. developers per capita, R&D expenditure in ICT), skills (e.g. PISA scores, STEM graduates per capita and social indicators (e.g. unemployment benefit % of annual wages, periodicity of skill training programs for employees) – Front-runners: FI, SE, DK, NK, UK, EE, DE. Middle adopters: AT, FR, BL, SL, MT, LT, ES, PT. Catch-up: LV, CZ, CY, HR, BG, PL, HU, IT, GR, RO

[18] The scenario builds on a 10 per cent improvement to a country technology readiness index, developed for the purposes of this study, consisting of 19 indicators, including human and social capital, R&D and venture financing, ICT sector size and innovation.

[19] The Future of Work in Europe, MGI, 2020. https://www.mckinsey.com/~/media/mckinsey/featured%20insights/future%20of%20organizations/the%20future%20of%20work%20in%20europe/mgi-the-future-of-work-in-europe-discussion-paper.pdf

[20] Ageing Europe - Looking at the lives of older people in the EU, Eurostat, 2019, https://ec.europa.eu/eurostat/en/web/products-statistical-books/-/KS-02-19-681

[21] The Future of Work in Europe, MGI, 2020. https://www.mckinsey.com/~/media/mckinsey/featured%20insights/future%20of%20organizations/the%20future%20of%20work%20in%20europe/mgi-the-future-of-work-in-europe-discussion-paper.pdf

[22] Testing the resilience of Europe's inclusive growth model, McKinsey Global Institute, 2018

[23] Ibid.

[24] The state of European tech, Atomico, 2017. https://2017.stateofeuropeantech.com/

[25] For a deeper discussion on the transition of the labour market and emerging skills gap, see: The future of work in Europe: Automation, workforce transitions, and the shifting geography of employment, McKinsey Global Institute, 2020 https://www.mckinsey.com/~/media/mckinsey/featured%20insights/future%20of%20organizations/the%20future%20of%20work%20in%20europe/mgi-the-future-of-work-in-europe-discussion-paper.pdf

[26] Pitchbook Database, 2019.

[27] Artificial Intelligence Trends To Watch In 2018, CB Insights, 2018. https://www.cbinsights.com/research/report/artificial-intelligence-trends-2018/

[28] What critics get wrong about the 'American AI Initiative', TechCrunch, 4 March 2019. https://techcrunch.com/2019/03/04/what-critics-get-wrong-about-the-american-ai-initiative/

[29] Artificial Intelligence (AI) in the United States: $36 Billion Business Opportunities & Outlook, 2025 - AI Spending/Market Size & Forecast Across 140+ Application Areas in 18 Industries, Globe Newswire, 27 March 2019. https://www.globenewswire.com/news-release/2019/03/27/1773947/0/en/Artificial-Intelligence-AI-in-the-United-States-36-Billion-Business-Opportunities-Outlook-2025-AI-Spending-Market-Size-Forecast-Across-140-Application-Areas-in-18-Industries.html

[30] Factsheet on Artificial Intelligence in Europe, European Commission, 2019. https://ec.europa.eu/digital-single-market/en/news/factsheet-artificial-intelligence-europe

[31] Notes from the AI Frontier: Tackling Europe's Gap in Digital and AI, McKinsey Global Institute, 2019. https://www.mckinsey.com/~/media/mckinsey/featured%20insights/artificial%20intelligence/tackling%20europes%20gap%20in%20digital%20and%20ai/mgi-tackling-europes-gap-in-digital-and-ai-feb-2019-vf.ashx

[32] Patent counts by technology, OECD statistics. Data extracted on 26 June 2020 10:53 UTC (GMT) from https://stats.oecd.org/

[33] Communication on the Mid-Term review on the implementation of the Digital Single Market Strategy, European Commission, May 2017. https://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1496330315823&uri=CELEX:52017DC0228

[34] Free flow of non-personal data, European Commission, 28 May 2019. https://ec.europa.eu/digital-single-market/en/news/free-flow-non-personal-data

[35] The review was performed as part of the project, based on an extensive review of academic literature, reports and previous evaluations, and a series of expert workshops with iterative voting, based on the Delphi method, with representatives for academia, government, the digital sector and various industries from across Europe.

[36] Eurostat, nama_10_an6 dataset, Gross fixed capital formation, Sum of ICT equipment (gross), including computer hardware and telecommunications equipment, and Intellectual property products (gross), including computer software and databases. While these variables are the most relevant indicators for total public and private investment in digital products captured in official, Europe-wide statistics, they are not providing a complete view of such investments. Relevant investments may be classified in other categories, such as other machinery, and non-financial digitization efforts such as education or process development is not captured. Reversely, not all included investments, e.g. in intellectual property, may be relevant for digitalization. https://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=nama_10_an6&lang=en

[37] For an analysis of the value of digital in the most advanced European countries, see: Shaping the future of work in Europe's digital front-runners, McKinsey Global Institute, 2017. https://www.mckinsey.com/~/media/mckinsey/featured%20insights/europe/shaping%20the%20future%20of%20work%20in%20europes%20nine%20digital%20front%20runner%20countries/shaping-the-future-of-work-in-europes-digital-front-runners.ashx

[38] In the calculation example, an average growth rate for the EU of 6-8 per cent in the 2020-2030 period is assumed, an increase from 5 per cent the previous 5-year period. Reference values are from before the COVID-19 crisis. Aggregate effects of COVID-19 on digital investment levels were not available at the time of writing, and the effect may go in both directions: on the one hand the use of digital solutions increased rapidly, as discussed in section 1.1., on the other hand the ensuing financial crisis reduced the financial scope for investments for companies across Europe.

[39] See e.g. Leveraging private investment: the role of public sector climate finance, Overseas Development Institute, 2011, for a discussion on public instruments to leverage private investment

[40] What is the InvestEU programme? European Commission, 2019. https://ec.europa.eu/commission/sites/beta-political/files/what_is_investeu_mff_032019.pdf

[41] Executive survey responses from 247 CEOs and other senior business leaders from 21 European countries – these insights and findings are only valid for the respondent group. Whereas a high number of CxOs participated, representing a broad range of sectors, company types and regions, the respondents may not be representative of all business leaders in Europe.

[42] Global Startup Ecosystem Report 2019, Startup Genome, 2019. https://startupgenome.com/reports/global-startup-ecosystem-report-2019

[43] Impact: Stanford University's Economic Impact via Innovation and Entrepreneurship, Charles E. Eesley and William F. Miller, Foundations and Trends in Entrepreneurship, vol. 14, no. 2, pp. 130–278, 2018.

[44] Global Startup Ecosystem Report 2019, Startup Genome, 2019. https://startupgenome.com/reports/global-startup-ecosystem-report-2019

[45] The global race for STEM skills, The Observatory on Borderless Higher Education, January 2013. http://www.obhe.ac.uk/newsletters/borderless_report_january_2013/global_race_for_stem_skills

[46] State of European tech, Atomico and dealroom.co, 2019. https://2019.stateofeuropeantech.com/chapter/investments/article/investment-snapshot/

[47] Based on the comparison of 2018 university yearly budget (excluding hospital) divided by the number of students for the Massachusetts Institute of Technology and Stanford University, and the Delft University of Technology and the Technical University of Munich.

[48] Pitchbook database, 2019.

[49] Health Spending Projections to 2030: New results based on a revised OECD methodology, Lorenzoni, L., et al., 2019; OECD Health Working Papers, No. 110, OECD Publishing. https://doi.org/10.1787/5667f23d-en

[50] Annual national accounts, detailed breakdowns, Eurostat (namna_10_ a64) using NACE codes C29, C30, G45, H49

[51] McKinsey Growth Analytics – Horizon Scan; CapitalIQ; Pitchbook

[52] Based on calculation assumptions: cooperation will allow players to not spend €5 to 10 billion on the development of AV per player (assumption: five OEMs collaborate and thus save 4x €7 billion); Waymo has so far spend €3.5 billion and is expected to need the same amount to complete the project.

[53] Annual national accounts, detailed breakdowns, Eurostat (namna_10_ a64) using NACE codes C21, C32.5 and Q.

[54] Health Spending Projections to 2030: New results based on a revised OECD methodology, Lorenzoni, L., et al., 2019; OECD Health Working Papers, No. 110, OECD Publishing. https://doi.org/10.1787/5667f23d-en

[55] How pharma can accelerate business impact from advanced analytics, McKinsey & Company, 2018. https://www.mckinsey.com/industries/pharmaceuticals-and-medical-products/our-insights/how-pharma-can-accelerate-business-impact-from-advanced-analytics

[56] Metric for the digital/analytical maturity of a company, including strategy, capability, organisation, and culture, McKinsey Digital Quotient database, April 2020; proprietary assessment tool developed by McKinsey, based on an in-depth diagnostic survey and benchmarked against 550 companies around the world (20,000 participants in 18 industry sectors).

[57] Based on data from the TED database, estimating the share of digital spending per sector.

[58] On artificial Intelligence – A European approach to excellence and trust, European Commission, 2020. https://ec.europa.eu/info/sites/info/files/commission-white-paper-artificial-intelligence-feb2020_en.pdf

[59] How to bring Macron's vision of a European innovation agency to life, Science Business, 14 December 2017. https://sciencebusiness.net/framework-programmes/viewpoint/how-bring-macrons-vision-european-innovation-agency-life.

[60] Based on a public procurement market of approximately €2 trillion in the EU and 10 to 15 per cent being digital related.

[61] From November 2018 until end of 2026.

[62] GDPR Fragmentation May Appear More Significant than Intended, Alston Privacy, 26 June 2018. https://www.alstonprivacy.com/gdpr-fragmentation-may-appear-more-significant-than-intended/

[63] EU Project : COVID-19 Data Portal, European Science Media Hub, European Parliament, 2020. https://sciencemediahub.eu/2020/04/23/eu-project-covid-19-data-portal/

[64] How big pharma firms are quietly collaborating on new coronavirus antivirals, Chemical and Engineering News, 1 May 2020. https://cen.acs.org/biological-chemistry/infectious-disease/How-big-pharma-firms-quietly-collaborating-on-new-coronavirus-antivirals/98/i18

[65] Coronavirus exposes lack of common data approach, EUobserver, 6 April 2020. https://euobserver.com/coronavirus/147982

[66] Shaping Europe's Digital Future, European Commission, 2020. https://ec.europa.eu/info/sites/info/files/communication-shaping-europes-digital-future-feb2020_en_4.pdf

[67] Special Eurobarometer 503: Attitudes towards the impact of digitalisation on daily lives. https://data.europa.eu/euodp/en/data/dataset/S2228_92_4_503_ENG

[68] Payment services (PSD 2) - Directive (EU) 2015/2366, mandating the sharing of customer data with external parties at the request of the customer and defines the standard format of the data sharing.

[69] A Union that strives for more - My agenda for Europe, political guidelines for the next European Commission 2019-2024, European Commission, 2019. https://ec.europa.eu/commission/sites/beta-political/files/political-guidelines-next-commission_en.pdf

[70] Notes from the AI Frontier: Tackling Europe's Gap in Digital and AI, McKinsey Global Institute, 2019. https://www.mckinsey.com/~/media/mckinsey/featured%20insights/artificial%20intelligence/tackling%20europes%20gap%20in%20digital%20and%20ai/mgi-tackling-europes-gap-in-digital-and-ai-feb-2019-vf.ashx

[71] Pitchbook VC, PE and M&A investments in AI and big data companies.

[72] Coordinated Plan on Artificial Intelligence, communication from the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee and the Committee of the Regions, 2018.

[73] Notes from the AI Frontier: Modeling the Impact of AI on the World Economy, McKinsey Global Institute, 2018. https://www.mckinsey.com/~/media/McKinsey/Featured%20Insights/Artificial%20Intelligence/Notes%20from%20the%20frontier%20Modeling%20the%20impact%20of%20AI%20on%20the%20world%20economy/MGI-Notes-from-the-AI-frontier-Modeling-the-impact-of-AI-on-the-world-economy-September-2018.ashx

[74] ibid.

[75] Pitchbook VC, PE and M&A investments in AI and big data companies.

[76] Smart Cities: Digital Solutions for a More Liveable Future, MGI, 2018. https://www.mckinsey.com/~/media/mckinsey/industries/capital%20projects%20and%20infrastructure/our%20insights/smart%20cities%20digital%20solutions%20for%20a%20more%20livable%20future/mgi-smart-cities-full-report.ashx

[77] Worldwide Smart Cities Spending Guide, IDC, May 2020. https://www.idc.com/getdoc.jsp?containerId=IDC_P37477

[78] Special Eurobarometer 503: Attitudes towards the impact of digitalisation on daily lives. https://data.europa.eu/euodp/en/data/dataset/S2228_92_4_503_ENG

[79] SynchroniCity is a Horizon 2020 project aiming to help cities simplify the adoption of new services that tackle urban challenges using IoT and data technologies; see: https://futurecities.catapult.org.uk/project/synchronicity/

[80] Assuming similar participation to Wifi4EU (6,000 to 8,000 municipalities), 50,000 to 100,000 of co-investment, and 50 per cent administrative costs on top for communication campaigns, procurement support etc.

[81] Annual national accounts, detailed breakdowns, Eurostat, (namna_10_ a64) using NACE codes 41-43, 71.

[82] Global Status Report for Buildings and Construction, IEA, 2019. https://www.iea.org/reports/global-status-report-for-buildings-and-construction-2019

[83] Reinventing construction: A route to higher productivity, McKinsey Global Institute, 2017. https://www.mckinsey.com/industries/capital-projects-and-infrastructure/our-insights/reinventing-construction-through-a-productivity-revolution

[84] The next normal in construction: How disruption is reshaping the world's largest ecosystem, McKinsey, 2020. https://www.mckinsey.com/industries/capital-projects-and-infrastructure/our-insights/the-next-normal-in-construction-how-disruption-is-reshaping-the-worlds-largest-ecosystem

[85] Reinventing construction: A route to higher productivity, McKinsey Global Institute, 2017. https://www.mckinsey.com/industries/capital-projects-and-infrastructure/our-insights/reinventing-construction-through-a-productivity-revolution

[86] Digital Europe: pushing the frontier, capturing the benefits, McKinsey Global Institute, 2016.

[87] Helsinki's 3D city models, City of Helsinki, 2019 https://www.hel.fi/helsinki/en/administration/information/general/3d/3d

[88] Special Eurobarometer 487a: The General Data Protection Regulation, https://ec.europa.eu/commfrontoffice/publicopinion/index.cfm/ResultDoc/download/DocumentKy/86881

[89] The Theft of American Intellectual Property, Office of the US Director of National Intelligence, 2015. http://www.ipcommission.org/report/IP_Commission_Report_Update_2017.pdf

[90] Equifax hack: Visa and Mastercard flag 200k compromised credit cards, FinExtra, 15 September 2017. https://www.finextra.com/newsarticle/31073/equifax-hack-visa-and-mastercard-flag-200k-compromised-credit-cards

[91] Bitpoint Exchange Hacked for $32 Million in Cryptocurrency, Coindesk, 12 July 2019. https://www.coindesk.com/japanese-exchange-bitpoint-hacked-by-32-million-worth-in-cryptocurrencies

[92] These Small-Town Hackers Are Making a Living Showing Companies How Insecure Their Sites Really Are, Vice, 15 October 2018. https://www.vice.com/en_asia/article/evwkyk/these-small-town-hackers-are-making-a-living-showing-companies-how-insecure-their-sites-really-are

[93] Cyberattacks Skyrocketed in 2018. Are You Ready for 2019? Industry Week, 2019. https://www.industryweek.com/technology-and-iiot/cyberattacks-skyrocketed-2018-are-you-ready-2019

[94] Resilience, Deterrence and Defence: Building strong cybersecurity for the EU, European Commission, 2017. https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52017JC0450&from=EN

[95] Two in three CEE companies don't have any cybersecurity strategy, according to "Cyber Threat CEE Region 2018" report, CyberSec Hub, 2018. https://cybersechub.eu/two-in-three-cee-companies-dont-have-any-cybersecurity-strategy-according-to-cyber-threat-cee-region-2018-report/

[96] Special Eurobarometer 503: Attitudes towards the impact of digitalisation on daily lives. https://data.europa.eu/euodp/en/data/dataset/S2228_92_4_503_ENG

[97] See note 64

[98] Digitalisation As Key For A Sustainable Europe, Digital Europe, 2019. https://www.digitaleurope.org/wp/wp-content/uploads/2019/06/Narrative_Sustainability_0620_WEB.pdf

[99] Assessing ICT global emissions footprint: Trends to 2040 & recommendations, Journal of Cleaner Production, 2017.

[100] Global E-waste Monitor 2017, ITU, 2017. https://www.itu.int/en/ITU-D/Environment/Pages/Spotlight/Global-Ewaste-Monitor-2020.aspx

[101] Coolproducts don't cost the Earth, European Environmental Bureau, 2019. https://eeb.org/library/coolproducts-report/

[102] Special Eurobarometer 503.

[103] How much will consumers pay to go green?, McKinsey, 2012 https://www.mckinsey.com/business-functions/sustainability/our-insights/how-much-will-consumers-pay-to-go-green

[104] Factsheet – The Digital Skills Gap in Europe, European Commission, 2017. https://ec.europa.eu/digital-single-market/en/news/digital-skills-gap-europe

[105] Education to Employment: Designing a System that Works, McKinsey, 2013. https://www.mckinsey.com/industries/social-sector/our-insights/education-to-employment-designing-a-system-that-works

[106] The Future of Work in Europe, McKinsey Global Institute, 2020. https://www.mckinsey.com/~/media/mckinsey/featured%20insights/future%20of%20organizations/the%20future%20of%20work%20in%20europe/mgi-the-future-of-work-in-europe-discussion-paper.pdf

[107] Jobs lost, jobs gained: Workforce transitions in a time of automation, McKinsey Global Institute, 2017. https://www.mckinsey.com/~/media/mckinsey/featured%20insights/Future%20of%20Organizations/What%20the%20future%20of%20work%20will%20mean%20for%20jobs%20skills%20and%20wages/MGI-Jobs-Lost-Jobs-Gained-Report-December-6-2017.ashx

[108] Communication: Digitising European Industry, European Commission, 2016. https://ec.europa.eu/digital-single-market/news-redirect/30288

[109] Assuming approximately five months and a cost of €10,000/person for reskilling; one to two months and a cost of €1,500-3,000/person for upskilling

[110] Over 2,000 European AI experts join hands to challenge US, China in artificial intelligence, SCMP, 21 September 2018. https://www.scmp.com/news/china/science/article/2165004/european-artificial-intelligence-experts-unite-bid-challenge-us

[111] Artificial intelligence (AI) in healthcare and research, Nuffield Council on Bioethics, 2018. (http://nuffieldbioethics.org/wp-content/uploads/Artificial-Intelligence-AI-in-healthcare-and-research.pdf)

[112] Digital Economy and Society Index (DESI) 2017, European Commission, 2017. https://ec.europa.eu/digital-single-market/en/news/digital-economy-and-society-index-desi-2017

[113] Artificial Intelligence, A European Perspective, Joint Research Centre, 2018. http://publications.jrc.ec.europa.eu/repository/bitstream/JRC113826/ai-flagship-report-online.pdf

[114] The State of European Tech, Atomico, 2017. https://2017.stateofeuropeantech.com/

[115] The Global Innovation Index (GII) 2018: Global Innovation Index, 2018. https://www.globalinnovationindex.org/gii-2018-report

[116] Notes from the AI frontier: Modeling the impact of AI on the world economy, McKinsey Global Institute, 2017.

[117] Jobs lost, jobs gained: Workforce transitions in a time of automation, McKinsey Global Institute, 2017. https://www.mckinsey.com/~/media/mckinsey/featured%20insights/future%20of%20organizations/what%20the%20future%20of%20work%20will%20mean%20for%20jobs%20skills%20and%20wages/mgi-jobs-lost-jobs-gained-report-december-6-2017.ashx

[118] Assessing the Economic Impact of Artificial Intelligence, ITU, 2018. https://www.itu.int/pub/S-GEN-ISSUEPAPER-2018-1

[119] Jobs lost, jobs gained: Workforce transitions in a time of automation, McKinsey Global Institute, 2017. https://www.mckinsey.com/~/media/mckinsey/featured%20insights/future%20of%20organizations/what%20the%20future%20of%20work%20will%20mean%20for%20jobs%20skills%20and%20wages/mgi-jobs-lost-jobs-gained-report-december-6-2017.ashx

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