European Commission

Study on the EU's critical digital capacities deployment beyond 2027

Final Report

Internal identification

Contract number: LC-03442173
VIGIE number: STUDY 2024-034 under FWC EAC/2021/OP/0004

EUROPEAN COMMISSION

Directorate-General for Communications Networks, Content and Technology

Unit DDG1.01 — Research and Deployment Strategy and Programme Coordination

Contact: CNECT-DDG1-01@*ec.europa.eu*

European Commission
B-1049 Brussels

Study on the EU's critical digital capacities deployment beyond 2027

Final Report

Edited by: Kincsö Izsak, Paul Simmonds, Matthias Ploeg, Sophie Viscido, Alexandre Lotito, Carmen Moreno and Rania Alasghar (Technopolis Group)

Data team: Carmen Moreno, Chiel Scholten, David Rosenfeld, Paresa Markianidou, Micha Arnoldus (Technopolis Group)

Technology team: Adebisi Adewusi, Rania Alasghar, Emma Coroler, Elmar Cloosterman, Todd Cook, Anna Denais, Alessia Iannacci, Jennifer Hönicke, Lizahn van Gend, Laura Lopez, Aphra Murray, Jonathan Puerta Pereira, Morten Rasmussen, Patricia Scheiber, Lennart Stoy, Elizabeth Storer, Tjerk Timan, Orestas Strauka, Théophile Cassignol, Eleonora Zoboli (Technopolis Group)

Directorate-General for Communications Networks, Content and Technology
2026 EN

LEGAL NOTICE

PDF	ISBN 978-92-68-40079-1	doi: 10.2759/0673677	KK-01-26-087-EN-N

Manuscript completed in May 2026

1st edition

Luxembourg: Publications Office of the European Union, 2026

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

Abbreviations used in the study

AAS = Asset Administration Shell

AGI = Artificial General Intelligence

AI = Artificial Intelligence

AIGF = Artificial Intelligence Gigafactories

AIOD = AI-on-demand platform

AIoT = Artificial Intelligence of Things

API = Application Programming Interface

AR = Augmented Reality

ASIC = Application-Specific Integrated Circuit

BaaS = Backend as a Service

BERD = Business Expenditure on R&D

CAGR = Compound Annual Growth Rate

CAPEX = Capital Expenditure

CATI = Computer-Assisted Telephone Interviewing

CBA = Cost-Benefit Analysis

CCI = Cultural and Creative Industries

CEF = Connecting Europe Facility

CMOS = Complementary Metal Oxide Semiconductor

CPU = Central Processing Unit

CS = Computer Science

DIGITAL = Digital Europe Programme

DESI = Digital Economy and Society Index

DDPP = Digital Decade Policy Programme

DLT = Distributed Ledger Technology

EBSI = European Blockchain Services Infrastructure

EC = European Commission

ECCC = European Cybersecurity Competence Centre

ECF = European Competitiveness Fund

EDA = Electronic Design Automation

EDF = European Defence Fund

EEA = European Economic Area

eHDSI = eHealth Digital Service Infrastructure

EDIC = European Digital Infrastructure Consortium

EDIH = European Digital Innovation Hub

EDR = Endpoint Detection and Response

EIB = European Investment Bank

EIC = European Innovation Council

EIF = European Interoperability Framework

ENISA = European Union Agency for Cybersecurity

EOSC = European OPEN Science Cloud

EPO = European Patent Organisation

ERA = European Research Area

ERC = European Research Council

ERDF = European Regional Development Fund

ESCI = European Student Card Initiative

ESG = Environmental, Social and Governance

ESIA = European Semiconductor Industry Association

ETSI = European Telecommunications Standards Institute

EU-LISA = European Union Agency for the Operational Management of Large-Scale IT Systems in the Area of Freedom, Security and Justice

FPGA = Field Programmable Gate Arrays

FTQC = Fault-Tolerant Quantum Computing

FTTH = Fibre to the Home

GaN = Gallium Nitride

GDPR = General Data Protection Regulation

GovTech = Government Technology

GPU = Graphics Processing Unit

GVA = Gross Value Added

HBM = High Bandwidth Memory

HCF = Hollow Core Fiber

HMI = Human Machine Interface

HPC = High Performance Computing

ICT = Information and Communication Technology

IPCEI = Important Project of Common European Interest

IoT = Internet of Things

IP = Intellectual Property

ISA = Instruction Set Architecture

ISAC = Integrated Sensing and Communication

JCAS = Joint Communications and Sensing

JU = Joint Undertaking

LEO = Low Earth Orbit

LPU = Language Processing Unit

MEMS = Micro-Electromechanical Systems

MFF = Multiannual Financial Framework

MiCA = Markets in Crypto-Assets Regulation

ML = Machine Learning

MQTT = Message Queuing Telemetry Transport

MS = Member State

MSA = Modular Supercomputing Architecture

NCC = National Competence Centre

NGI = Next Generation Internet

NISQ = Noisy Intermediate-Scale Quantum

NLP = Natural Language Processing

NVM = Non-Volatile Memory

OPC UA = Open Platform Communications Unified Architecture

OPEX = Operational Expenditure

PDK = Process Design Kit

PIC = Photonic Integrated Circuit

QaaS = Quantum as a Service

QKD = Quantum Key Distribution

QRNG = Quantum Random Number Generation

RDI = Research, Development, and Innovation

RF = Radio Frequency

RISC-V = Reduced Instruction Set Computer Five

ROI = Return on Investment

RRF = Recovery and Resilience Facility

RSA = Rivest-Shamir-Adleman

RTO = Research and Technology Organisation

R&D = Research and Development

R&I = Research and Innovation

SiC = Silicon Carbide

SME = Small and Medium-Sized Enterprises

SOAR = Security Orchestration, Automation, and Response

SRIA = Strategic Research and Innovation Agenda

STEM = Science, Technology, Engineering, and Mathematics

STEP = Strategic Technologies for Europe Platform

STI = Science, Technology, and Innovation

SSI = Self-Sovereign Identity

TEF = Testing and Experimentation Facility

TPU = Tensor Processing Unit

TRL = Technology Readiness Level

UAV = Unmanned Aerial Vehicle

UGV = Unmanned Ground Vehicle

UMV = Unmanned Marine Vehicle

UX = User Experience

VC = Venture Capital

VET = Vocational Education and Training

VR = Virtual Reality

XAI = Explainable Artificial Intelligence

XR = Extended Reality

ZKP = Zero-Knowledge Proof

Executive Summary

This study, commissioned by the European Commission's Directorate-General for Communications Networks, Content and Technology (DG CNECT), aims to enhance understanding on the deployment of strategic digital technologies in the European Union. It identifies digital areas where funding to support digital capacity building, deployment, skills and infrastructure development is critical under the next Multiannual Financial Framework (MFF) (2028-2034). The key findings of the research are presented below.

Market state of play of critical digital technologies

There is a strong European start-up landscape underpinning technology deployment which has shown remarkable progress over the past decade, marked by a rise in entrepreneurship and increased mobilisation of venture capital. In 2025, the EU boasted 20,720 advanced digital tech start-ups, out of which 728 scaled up (3.5%) and are still operational and 40 reached unicorn status (0.2%).

Europe's challenge revolves around not only accelerating the scaling of tech start-ups but fostering their growth-stage coupled with a stronger demand-pull focus that can enable the emergence of unicorns, while simultaneously maintaining a strong pipeline of new start-ups amid the slowdown in early-stage financing.

Technology deployment in Europe faces critical challenges, as research and innovation are often misaligned with practical application, and commercialisation efforts still struggle to meet market demand or translate into profit and productivity. As emphasised, the key question is not only how to lead in developing AI, but how to be more effective at applying and integrating it across the economy.

The digital technologies most often adopted include Artificial Intelligence, Data Analytics, Cybersecurity and Cloud, but less so Next Generation Internet (NGI) and Extended Reality (XR), Quantum or Photonics. The uneven adoption of advanced digital technologies is an important issue to address as it can undermine the productivity and competitiveness of certain industries and regions relative to the world's leading innovators.

The pace of digital technology deployment varies significantly across EU countries and sectors, and particularly across EU regions and in sub-sectors, affecting both Europe's digital-technology developers and those that apply these technologies.

Europe has a critical underinvestment in advanced digital technologies in the private sector. On average, European companies invest less than €50,000 annually in critical digital technologies. In particular, in areas such as Artificial Intelligence, Data Analytics, Advanced Connectivity, Cybersecurity, and Cloud–Edge–IoT, company spending is generally modest.

The strongest spenders are medium-sized enterprises that show an engagement in advanced digital technologies relative to their size. They demonstrate agility in adopting digital solutions more often than smaller firms or larger corporations.

Future private investments are projected to grow across all technologies most rapidly in the area of Artificial Intelligence. The deployment of Photonics, Quantum are also expected to be a future investment target by companies, but less so for High Performance Computing (HPC) and NGI and XR.

Another key challenge is related to profit generation as for example the costs of AI are extremely high while their ability to charge enough revenue currently is limited. Training and running large models requires massive spending on compute infrastructure, data centres, and energy, which often outpaces what firms can earn from subscriptions or usage fees.

Policy programmes supporting technology deployment

Under the current MFF (2021-2027) significant investments were made across several EU funding programmes The total amount of targeted contribution from the EU for DIGITAL and CEF Digital together totals €9.8 bn, with €7.93 bn for DIGITAL and €1.89 bn for CEF Digital. CEF Digital is mostly supporting digital infrastructures and to a lesser extent testing facilities in the areas of Advanced Connectivity, AI, Quantum and HPC, whereas the Digital Europe Programme is heavily investing in deployment, ecosystem activities, testing facilities and skills in the areas of AI, HPC, Microelectronics, NGI, Data, Interoperability and Crosscutting issues. Overall, areas such as Photonics, Blockchain, XR and Robotics receive comparably less support.

The EU's Recovery and Resilience Facility (RRF) has been one of the sources for the national roadmaps as the central financial instrument of NextGenerationEU. A core requirement of the RFF has been that each national plan allocates at least 20% to digital transformation, funding projects that enhance connectivity (e.g., 5G, broadband), digitise public administration, support SME digitalisation, develop digital skills and education, and promote advanced technologies like AI, cybersecurity, and quantum computing. According to estimates, €149 bn has been dedicated from the RRF to digital decade targets.

Beyond Digital Europe and CEF Digital, there are another 30 EU programmes providing support to technology deployment such as Horizon Europe or the European Defence Fund (EDF).

At the level of EU Member States, the overall level of projected funding in the period up to 2030 is estimated to reach €110 bn, which is a significant total investment, many times greater than the current Digital Europe Programme and underlines the need for future EU programmes to build on, coordinate and pursue synergies with Member State efforts. National programmes target mostly the deployment of Artificial Intelligence and cybersecurity technologies, and high public funding is also dedicated to microelectronics and advanced connectivity in line with their strategic priorities.

Total investment in future digital technologies varies significantly across EU Member States, beyond what structural factors alone explain. This unevenness may widen regional performance gaps, highlighting the need for support of pan-EU and multi-country projects.

Key challenges of technology deployment

Insufficient investment is identified as the most significant barrier to digital transformation for both large companies and SMEs, largely due to high upfront costs for infrastructure, software, and skills, combined with delayed or hard-to-measure returns and limited access to finance, especially for start-ups and SMEs. This is compounded by limited access to finance via banks or other financial sources. On the technical side, many companies struggle with legacy IT, the difficulty of integrating new advanced digital technologies across multiple platforms, immature AI applications, and cybersecurity threats.

While both SMEs and large firms prioritise investment constraints, SMEs are particularly affected by complex public procurement and administrative burdens, whereas large companies are more concerned about market fragmentation.

Market fragmentation is a key challenge where divergent national markets and related regulatory systems, but also differences in consumer preferences and economic conditions hinder technology deployment. For digital businesses, these variations present substantial obstacles to expanding and operating seamlessly across multiple EU Member States.

Companies also point to the need to better demonstrate the value of digital products and services to clients, as well as to manage rapid changes in client expectations. The lack of understanding what technology can do can hinder digitisation efforts and is causing a slow adoption of new technologies despite their technical maturity.

In the public sector, organisations see the limited availability of public funding, the legal uncertainty and regulatory complexity combined with limited support for implementation (in particular in the case of AI) and the shortage of advanced digital skills in the workforce as the most important barriers limiting the uptake of advanced technologies. Public organisations face barriers in terms of technical reliance on legacy systems that are costly to change and often resistant to change. This problem is amplified by a lack of funding and limited private investment, which makes it difficult to replace outdated infrastructure with modern, interoperable platforms.

EU's global position, dependencies and reverse dependencies

The EU's global position is suboptimal in most of the digital technologies and its deployment is lagging behind international competitors. For 2028, the EU's global position has been assessed by technology experts as 'medium' for most technology areas, 'low' for AI, Blockchain, Microelectronics and NGI & XR and considered 'strong' for none of the technologies, as concluded by experts participating in the Delphi exercise of this study, in particular in relation to the EU's expected position at the start of the next MFF (2028), and expected position in 2036 (+2 years after the end of the next MFF) in a scenario where the current level of EU support was to continue unchanged. However, while the EU is underperforming internationally on various metrics of digital technologies, it has opportunities to create value across many application areas.

A trusted regulatory framework and strong data protection standards make the EU globally recognised for promoting interoperability and safety. Initiatives such as the Digital Single Market and the EU's commitment to ethical standards in Artificial Intelligence and Cybersecurity further strengthen its role in shaping global digital norms. Open source is seen as a strength and a potential strategy to close gaps where Europe lags behind global competitors, particularly the US and China.

The reliance on non-EU countries for digital products, services, infrastructure, and strategic investments poses high risks. This is why a stronger focus on EU digital technology, supply chains favourable to productive technology deployment, and protection of intellectual property would be essential to reduce vulnerabilities and capture greater economic value.

Heavy reliance on non-EU providers for cloud, AI infrastructure, GPUs and semiconductors is a strategic vulnerability. Stakeholders suggest boosting EU-based capabilities where feasible and leveraging strengths in integration to negotiate partnerships. Europe's niche expertise and quality standards are seen as assets in global positioning and could be further leveraged.

Technology trends and cross-fertilisation potential

The EU has a range of opportunities across technology areas and it should build on strengths in order to take leadership in the future. These include among others AI, data and robotics: Trustworthy and Explainable AI, Open-source Development, Human-Robot Interaction; in Microelectronics: "More-than-Moore" (power/WBG, RF, MEMS, SiPh), RISC-V, Chiplet and modular architectures, 3D stacking and wafer-level packaging, advanced packaging and 3D integration, green electronics; in Cybersecurity: the European Digital Identity Wallet, critical infrastructure protection; in Cloud-Edge-IoT: Intelligent IoT Devices at the Edge, Connected Mobility; in Quantum: reduction of error rates, quantum computing capability, in Blockchain: smart contracts, supply chain traceability, in NGI, XR: decentralisation and diversification of XR engines, use in aerospace, media.

Strong interdependencies exist, notably AI and Data as central enablers across domains (robotics, cybersecurity, photonics, microelectronics, NGI, XR). Cloud-Edge-IoT continuum links sources to intelligence, requiring interoperability and sovereignty measures (e.g. RISC-V, open-source orchestration). Cybersecurity underpins safe deployment, intersecting with blockchain for identity and trust models. HPC, Quantum, Photonics and Microelectronics increasingly converge, and integration can be further leveraged. Such synergies suggest that targeted investments in one area can catalyse gains across others, but require modular and agile design and shared governance.

Sectoral applications

Digital technologies underpin virtually all industries, with early adopters in digital/ICT, defence, aerospace, transport, health, manufacturing, research organisations and also the public sector. Opportunities for the EU were identified particularly related to manufacturing, as well as to automotive and pharmaceutical industries and also related to services for example in the field of telecommunications and gaming as part of the creative industries. However, readiness and deployment maturity vary markedly. Limited co-design with end-users, particularly among SMEs, hinders alignment with real needs. Slow internal decision-making and lack of digital leadership in organisations impede adoption. Application-driven public programmes leading to clear showcasing and awareness raising of sector-specific use-cases with detailed return on investment could unlock deployment bottleneck. Simplifying often complex technological solutions is also key. Governments can act as first movers, but rigid, legacy IT systems and risk-averse cultures slow innovation. Greater use of innovative procurement, interoperable platforms and pilot programmes can de-risk adoption, while public administrations should increase collaboration with industry in co-development, applying clear regulatory guidance to foster GovTech solutions.

Infrastructure, Skills and Ecosystems

Advanced research and innovation networks in the EU are seen as a general strength with a well-developed ecosystem of universities, research institutions, and growing entrepreneurial hubs around them across the EU that foster collaboration and commercialisation.

However, reliance on non-EU infrastructures is a concern across technology fields. Stakeholders call for targeted investment in EU-based capabilities and federated experiences. The maintenance and upgrade of existing infrastructures are under-supported, undermining reliability and deterring broader use. Support for cross-border access to digital infrastructures is also reported as lacking in Europe's public funding programmes.

Europe relies on non-EU advanced and mature-node foundries, advanced packaging facilities and unified quantum fabrication hubs; design toolchains and pilot lines remain fragmented, with complex access and R&I-industry application gaps.

Significant pre-exascale/exascale assets exist but face non-EU hardware dependence, SME/industrial access remains limited, HPC–cloud interfaces are still underdeveloped, AI workload adaptation and hybrid quantum-classical links can be strengthened, edge-node deployment remains uneven and with few long-term maintenance plans.

Rollout of standalone 5G/6G and fibre is uneven and cross-border coordination scarce, while open orchestration frameworks and sovereign, low-latency networks are needed to support real-time, decentralised applications and digital-twin environments. Data remains siloed across sectors and regions with inconsistent governance; secure, scalable data lakes, national data libraries and interoperable data spaces (including spatial data) require sustained funding, unified APIs and simplified access for SMEs and public bodies.

Reliance on non-EU hyperscalers persists amid fragmented markets; federated cloud–edge initiatives are nascent, HPC-cloud integration is underdeveloped, digital-twin and sectoral testbeds are uneven, key software toolchains remain fragmented, public-sector systems are often outdated, and energy-efficient, sovereign platforms need prioritisation.

A widespread digital skills shortage affects adoption and operation of new technologies, and posing a challenge particularly for SMEs, which often lack the resources to attract or develop digital talent. While in the EU there is a dynamic growth in the number of professionals with digital tech skills relevant for the 12 areas in focus (in particular in the field of quantum technologies but also AI), there is still a lower share of skilled professionals within ICT functions in the EU than in the US in general.

There is a mismatch between the share of skilled professionals in ICT and engineering roles, who develop and lead technologies and those in other job functions, where digital skills are needed to effectively apply and deploy these technologies. Stakeholders suggest actions with targeted training and more integrated labour markets to improve access to expertise, as well as the need for foundational digital education for young professionals and attract/retain talents.

The European digital ecosystem is challenged by the fragmentation of the European market, which limits the ability of companies to scale and compete internationally.

Deployment is often hindered by differing national standards and regulations, making cross-border scaling difficult.

Interoperability

The EU has a strong foundation of interoperability solutions supported by robust digital infrastructure, coordinated policy efforts and a growing interoperability ecosystem. This ecosystem is supported by a network of solution providers and specialised SMEs and start-ups offering modular, standards-based technologies. However, interoperability is undergoing a fundamental transformation, increasingly viewed through the lens of technological sovereignty as organisations seek to avoid vendor lock-in and maintain strategic autonomy over their digital infrastructure. While the Interoperable Europe Act has been an important shift to meet these goals, these ambitions face significant challenges from fragmented technology infrastructure across EU member states. This is viewed as particularly problematic as interoperability demands are evolving beyond static data sharing towards real-time synchronisation across borders and sectors. This evolution requires not just technical compatibility but coordinated governance frameworks that can support dynamic, cross-jurisdictional digital services while preserving EU technological sovereignty.

Investment options

In light of the future European Competitiveness Fund and an EU programme supporting deployment, several investment options may exist that can potentially address the stronger deployment of digital technologies across sectors while paying attention to technological dependencies that might jeopardize the competitiveness and security of the EU economy. They can have different ability to address one or both of the principal challenges identified in this study, notably the high level of dependence on digital solutions that have been developed or are controlled by global (non-EU) players in almost every technology domain, which can increase prices impacting the competitiveness of Europe's goods and services vis a vis its international counterparts and create supply-chain vulnerabilities, and secondly the slow and uneven rates of adoption of digital technologies across the wider European economy, in both the public and private sectors, which constrains productivity growth and underlines service innovation and quality.

Four investment options were conceived as distinct funding mixes that imply different and contrasting scenarios. Three of the four options emphasise one funding logic above all else (e.g., a sharp focus on productivity or on strategic autonomy) while the fourth is more open and reflects the many and various priorities of all stakeholders. These stylised treatments are designed to draw out the strengths and weaknesses of particular funding strategies, with a view to a preferred option (likely a hybrid) that strikes the right balance across the specific objectives and benefit types. The four investment options are outlined below:

- **Investment Option 1 - Competitiveness/Productivity**: Technology areas: More focus on areas where exploitation potential and productivity gains are high across the wider economy, and less on expanding EU capabilities in the most advanced digital technologies/ Investment types: High on Deployment support services, Low on new Infrastructure, Medium on Ecosystem and Skills.
- **Investment Option 2: - Competitiveness/ Resilience**: Technology areas: More focus on expanding EU capabilities in areas where EU global dependencies are high (AI, Cyber, semiconductors, etc.) and where there is potential to achieve substantial improvements in emerging / fast moving markets. Investment type mix: Medium/low on Deployment, High on building capabilities including new and expanded Infrastructures, Medium/Low on Ecosystem and Skills.
- **Investment Option 3 - AI Continent**: Technology areas: Central focus on AI technologies in general and the intersection between AI and other technology

areas where the synergies are expected to be very high (e.g., HPC, Cloud, Microelectronics, Data etc.). Investment type mix: High on Deployment, High on new and expanded Infrastructure, Medium on Ecosystem and skills

- **Investment Option 4 - Stakeholder priorities**: Technology areas: More open support for all technology areas where stakeholders are prioritising investment (AI, Cyber, Data, Interoperability, etc.) Investment type mix: High on Deployment support services, Medium on Infrastructure development, Low on Ecosystem and Skills.

Implementation mechanisms

Based on the findings of this study, a future digital programme needs to be simpler, faster and more flexible than the current programme to improve its effectiveness and its optimal ability to strengthen Europe's future prosperity and security. In terms of support for early adoption, stakeholders argue that the most innovative deployments should be prioritised, while acknowledging the administrative challenge of clearly defining and recognising substantive innovation potential. A minority went on to suggest that the focus should be sharper still (not just major innovations) but major innovations with dual-use applications, those with both civilian and security benefits, should be favoured, especially given current geopolitical considerations.

On the subject of making any future programme more strategic, stakeholders suggested setting measurable targets, such as increasing the yearly adoption rate of strategic technologies. Furthermore, the majority of stakeholders argued that additional incentives could be introduced to strategically encourage the use of European providers and solutions, for instance by offering a higher funding percentage when European technologies are chosen.

Résumé

Cette étude, commandée par la Direction générale des réseaux de communication, du contenu et des technologies (DG CNECT) de la Commission européenne, vise à mieux comprendre le déploiement des technologies numériques stratégiques au sein de l'Union européenne. Elle identifie les domaines numériques dans lesquels un financement destiné à soutenir le renforcement des capacités numériques, le déploiement et le développement des compétences et des infrastructures est essentiel en vue du prochain cadre financier pluriannuel (CFP) (2028-2034). Les principales conclusions de cette étude sont présentées dans les sections suivantes.

État des lieux du marché des technologies numériques critiques

L'Europe dispose d'un écosystème dynamique de start-ups qui soutient le déploiement des technologies et qui a connu des progrès considérables au cours de la dernière décennie qui fût marquée par une montée en puissance de l'esprit d'entreprise et une mobilisation accrue du capital-risque. En 2025, l'UE comptait 20 720 start-ups spécialisées dans les technologies numériques de pointe, dont 728 ont connu une expansion (3,5%) et sont toujours en activité, et 40 ont atteint le statut de licorne (0,2%).

Le défi de l'Europe consiste non seulement à accélérer la montée en puissance des start-ups technologiques, mais aussi à favoriser leur phase de croissance en mettant davantage l'accent sur la demande pour permettre l'émergence de licornes, tout en maintenant un solide vivier de nouvelles start-ups malgré le ralentissement du financement des phases de démarrage.

Le déploiement des technologies en Europe se heurte à des défis majeurs car la recherche et l'innovation sont souvent en décalage avec les applications concrètes et les efforts de commercialisation peinent encore à répondre à la demande du marché ou à se traduire par des bénéfices et des gains de productivité. Comme souligné, la question centrale n'est pas seulement de savoir comment faire figure de leader dans le développement de l'IA mais comment mieux la mettre en œuvre et l'intégrer dans l'ensemble de l'économie.

Les technologies numériques les plus couramment adoptées comprennent l'intelligence artificielle, l'analyse de données, la cybersécurité et le cloud ainsi que, dans une moindre mesure l'Internet de nouvelle génération (ING) et la réalité étendue (XR), la technologie quantique ou la photonique. L'adoption inégale des technologies numériques de pointe est un problème important à résoudre parce qu’elle peut nuire à la productivité et à la compétitivité de certaines industries et certaines régions par rapport aux principaux innovateurs mondiaux.

Le rythme de déploiement des technologies numériques varie considérablement d'un pays et d'un secteur à l'autre au sein de l'UE et varie plus particulièrement d'une région à l'autre et d'un sous-secteur à l'autre, ce qui affecte à la fois les développeurs de technologies numériques européens et ceux qui utilisent ces technologies.

L'Europe souffre d'un sous-investissement critique dans les technologies numériques de pointe au sein du secteur privé. En moyenne, les entreprises européennes investissent moins de 50 000 € par an dans les technologies numériques critiques. En particulier, les dépenses des entreprises restent modestes dans des domaines tels que l'intelligence artificielle, l'analyse de données, la connectivité avancée, la cybersécurité et le cloud-edge-IoT.

Les plus gros investisseurs sont les entreprises de taille moyenne, qui font preuve d'un engagement proportionnel à leur taille dans les technologies numériques critiques. Elles font preuve d'une plus grande agilité que les petites entreprises ou les grandes sociétés dans l'adoption de solutions numériques

Les futurs investissements privés devraient croître toutes technologies confondues, avec une progression plus rapide dans le domaine de l'intelligence artificielle. Le déploiement de la photonique et de l'informatique quantique devrait également constituer une future perspective d'investissement pour les entreprises, mais dans une moindre mesure que le calcul haute performance (HPC), l’ING et la XR.

Un autre défi majeur concerne la réalisation de bénéfices, car, par exemple, les coûts de l'IA sont extrêmement élevés alors que leur capacité à générer suffisamment de revenus est actuellement limitée. La formation et l'exploitation de grands modèles nécessitent des dépenses massives en infrastructure informatique, en centres de données et en énergie, qui dépassent souvent ce que les entreprises peuvent gagner grâce aux abonnements ou aux frais d'utilisation.

Programmes politiques visant à soutenir le déploiement des technologies

Dans le cadre du CFP actuel (2021-2027), des investissements importants ont été réalisés par le biais de plusieurs programmes de financement de l’UE. Le montant total de la contribution de l'UE allouée aux programmes DIGITAL et CEF Digital s'élève à 9,8 milliards d'euros, dont 7,93 milliards pour DIGITAL et 1,89 milliard pour CEF Digital. Le CEF Digital soutient principalement les infrastructures numériques et, dans une moindre mesure, les installations d'essai dans les domaines de la connectivité avancée, de l'IA, de l'informatique quantique et du HPC, tandis que le programme pour une Europe numérique (DIGITAL) investit massivement dans le déploiement, les activités liées à l'écosystème, les installations d'essai et les compétences dans les domaines de l'IA, du HPC, de la microélectronique, de l’ING, des données, de l'interopérabilité et des questions transversales. Dans l'ensemble, des domaines tels que la photonique, la blockchain, la XR et la robotique bénéficient d'un soutien relativement moindre.

La Facilité pour la reprise et la résilience (FRR) de l'UE a été l'une des sources d'inspiration pour les feuilles de route nationales, en tant qu'instrument financier central de NextGenerationEU. L'une des exigences fondamentales de la FRR est que chaque plan national doive consacrer au moins 20% de ses ressources à la transformation numérique, en finançant des projets qui améliorent la connectivité (par exemple, la 5G et le haut débit), numérisent l'administration publique, soutiennent la numérisation des PME, développent les compétences et l'éducation numériques, et promeuvent les technologies de pointe telles que l'IA, la cybersécurité et l'informatique quantique. Selon les estimations, 149 milliards d'euros ont été alloués par la FRR aux objectifs de la décennie numérique.

Au-delà de Digital Europe et du CEF Digital, 30 autres programmes de l'UE apportent leur soutien au déploiement des technologies, tels qu’Horizon Europe ou le Fonds européen de défense (FED).

Au niveau des États membres de l'UE, le montant total des financements prévus jusqu'en 2030 est estimé à 110 milliards d'euros, ce qui représente un investissement global considérable, plusieurs fois supérieur au programme Europe numérique actuel, et souligne la nécessité pour les futurs programmes de l'UE de s'appuyer sur les efforts des États membres, de les coordonner et de rechercher des synergies avec eux. Les programmes nationaux ciblent principalement le déploiement des technologies d'intelligence artificielle et de cybersécurité, et des financements publics importants sont également consacrés à la microélectronique et à la connectivité avancée, conformément à leurs priorités stratégiques.

L'investissement total dans les technologies numériques de demain varie considérablement d'un État membre de l'UE à l'autre, au-delà de ce que les seuls facteurs structurels peuvent expliquer. Ces disparités risquent d'aggraver les écarts de performance entre les régions, soulignant la nécessité de soutenir des projets paneuropéens et multinationaux.

Principaux défis liés au déploiement des technologies

Le manque d'investissements est considéré comme le principal obstacle à la transformation numérique, tant pour les grandes entreprises que pour les PME, principalement en raison des coûts initiaux élevés liés aux infrastructures, aux logiciels et aux compétences, auxquels s'ajoutent des retours sur investissement tardifs ou difficiles à mesurer, ainsi qu'un accès limité au financement, en particulier pour les start-ups et les PME. Cette situation est aggravée par un accès limité au financement auprès des banques ou d'autres sources financières. Sur le plan technique, de nombreuses entreprises sont confrontées à des systèmes informatiques obsolètes, à la difficulté d’intégrer de nouvelles technologies numériques avancées sur plusieurs plateformes, à des applications d’IA encore immatures et à des menaces en matière de cybersécurité.

Si les PME comme les grandes entreprises considèrent les contraintes d’investissement comme une priorité, les PME sont particulièrement affectées par la complexité des marchés publics et les charges administratives, tandis que les grandes entreprises sont davantage préoccupées par la fragmentation du marché.

La fragmentation du marché constitue un défi majeur, puisque les divergences entre les marchés nationaux et les systèmes réglementaires associés, mais aussi les différences en matière de préférences des consommateurs et de conditions économiques, entravent le déploiement des technologies. Pour les entreprises du secteur du numérique, ces variations constituent des obstacles importants à leur expansion et à leur fonctionnement sans heurts dans plusieurs États membres de l’UE.

Les entreprises soulignent également la nécessité de mieux démontrer la valeur des produits et services numériques auprès des clients, ainsi que de s'adapter à l'évolution rapide de leurs attentes. Le manque de compréhension des possibilités offertes par la technologie peut entraver les efforts de numérisation et ralentit l'adoption des nouvelles technologies malgré leur maturité technique.

Dans le secteur public, les organisations considèrent que la disponibilité limitée des financements publics, l'incertitude juridique et la complexité réglementaire, combinées à un soutien limité à la mise en œuvre (en particulier dans le cas de l'IA) et à la pénurie de compétences numériques avancées au sein de la main-d'œuvre, constituent les principaux obstacles limitant l'adoption des technologies de pointe. Les organismes publics se heurtent à des obstacles liés à leur dépendance technique vis-à-vis de systèmes anciens dont la modification est coûteuse et qui résistent souvent au changement. Ce problème est amplifié par un manque de financement et des investissements privés limités, ce qui rend difficile le remplacement d’infrastructures obsolètes par des plateformes modernes et interopérables.

Position mondiale de l'UE, ses dépendances et ses contre-dépendances

La position mondiale de l'UE est loin d'être optimale dans la plupart des technologies numériques et son déploiement accuse un retard par rapport à ses concurrents internationaux. D'ici à 2028, la position mondiale de l'UE a été évaluée par des experts en technologie comme « moyenne » pour la plupart des domaines technologiques, « faible » pour l'IA, la blockchain, la microélectronique, l'ING et la XR, et n'a été jugée « forte » pour aucune de ces technologies, comme l'ont conclu les experts participant à l'exercice Delphi de cette étude. En particulier, cela concerne la position attendue de l'UE au début du prochain CFP (2028) et à la position attendue en 2036 (+2 ans après la fin du prochain CFP) dans un scénario où le niveau actuel de soutien de l'UE resterait inchangé. Cependant, bien que l'UE affiche des performances inférieures à la moyenne internationale selon divers indicateurs relatifs aux technologies numériques, elle dispose d'opportunités pour créer de la valeur dans de nombreux domaines d'application.

Grâce à un cadre réglementaire fiable et des normes strictes en matière de protection des données, l'UE est devenue une référence mondiale pour la sécurité et l'interopérabilité. Des initiatives telles que le marché unique numérique et l'engagement de l'UE en faveur de normes éthiques dans le domaine de l'intelligence artificielle et de la cybersécurité renforcent encore son rôle dans l'élaboration de normes numériques mondiales. L'open source est considéré comme une force et une stratégie potentielle pour combler les écarts où l'Europe est à la traîne par rapport à ses concurrents mondiaux, en particulier les États-Unis et la Chine.

La dépendance vis-à-vis des pays tiers pour les produits, services, infrastructures et investissements stratégiques numériques comporte des risques élevés. C'est pourquoi il serait essentiel de mettre davantage l'accent sur les technologies numériques de l'UE, sur des chaînes d'approvisionnement favorables au déploiement productif des technologies et sur la protection de la propriété intellectuelle afin de réduire les vulnérabilités et de générer une plus grande valeur économique.

La forte dépendance vis-à-vis de fournisseurs non européens pour le cloud, les infrastructures d'IA, les processeurs graphiques et les semi-conducteurs constitue une vulnérabilité stratégique. Les parties prenantes consultées suggèrent de renforcer les capacités européennes lorsque cela est possible et de tirer parti des atouts en matière d'intégration pour négocier des partenariats. L'expertise de niche et les normes de qualité de l'Europe sont considérées comme des atouts pour son positionnement mondial et pourraient être davantage mises à profit.

Tendances technologiques et potentiel de fertilisation croisée

L'UE dispose d'un large éventail d'opportunités dans divers domaines technologiques et devrait s'appuyer sur ses atouts pour, à l'avenir, jouer un rôle de premier plan. Cela concerne notamment l'IA, les données et la robotique: IA fiable et explicable, développement open source, interaction humain-robot; en microélectronique: «More-than-Moore» (puissance/WBG, RF, MEMS, SiPh), RISC-V, architectures Chiplet et modulaires, empilement 3D et encapsulation au niveau de la plaquette, encapsulation avancée et intégration 3D, électronique verte; en cybersécurité: le portefeuille européen d'identité numérique, la protection des infrastructures critiques; dans le domaine du cloud-edge-IoT : appareils IoT intelligents en périphérie, mobilité connectée; en informatique quantique: réduction des taux d'erreur, capacité de calcul quantique; en blockchain: contrats intelligents, traçabilité de la chaîne d'approvisionnement; en ING et XR : décentralisation et diversification des moteurs XR, utilisation dans l'aérospatiale et les médias.

Il existe de fortes interdépendances, notamment entre l'IA et les données, qui constituent des catalyseurs essentiels dans tous les domaines (robotique, cybersécurité, photonique, microélectronique, ING, XR). Le continuum cloud-edge-IoT relie les sources aux capacités d'intelligence, ce qui nécessite des mesures d'interopérabilité et de souveraineté (par exemple, RISC-V, orchestration open source). La cybersécurité est le fondement d'un déploiement sûr et recoupe la blockchain pour les modèles d'identité et de confiance. Le

HPC, l'informatique quantique, la photonique et la microélectronique convergent de plus en plus, et cette intégration peut être davantage mise à profit. Ces synergies suggèrent que des investissements ciblés dans un domaine peuvent catalyser des gains dans d'autres, mais nécessitent une conception modulaire et agile ainsi qu'une gouvernance partagée.

Applications sectorielles

Les technologies numériques sont à la base de pratiquement tous les secteurs, les premiers à les adopter étant notamment ceux du numérique/des technologies de l’information et de la communication (TIC), de la défense, de l'aérospatiale, des transports, de la santé, de l'industrie manufacturière, des organismes de recherche ainsi que le secteur public. Des opportunités pour l’UE ont été recensées, en particulier au niveau de l’industrie manufacturière ainsi que les industries automobile et pharmaceutique, et également en ce qui concerne les services, par exemple dans le domaine des télécommunications et des jeux, dans le cadre des industries créatives. Cependant, le niveau de préparation et la maturité du déploiement varient considérablement. Le manque de co-conception avec les utilisateurs finaux, en particulier parmi les PME, empêche une adaptation aux besoins réels. La lenteur des processus décisionnels internes et l'absence de leadership numérique au sein des organisations freinent l'adoption de ces technologies. Des programmes publics axés sur les applications, permettant de mettre clairement en avant et de faire connaître des cas d'utilisation spécifiques à chaque secteur avec un retour sur investissement détaillé, pourraient lever les obstacles au déploiement. La simplification de solutions technologiques souvent complexes est également essentielle. Les gouvernements peuvent jouer un rôle de pionniers, mais la rigidité des systèmes informatiques hérités et les cultures peu enclines à prendre des risques ralentissent l'innovation. Un recours accru aux marchés publics innovants, aux plateformes interopérables et aux programmes pilotes peut réduire les risques liés à l'adoption, tandis que les administrations publiques devraient renforcer leur collaboration avec le secteur privé dans le cadre du co-développement, en appliquant des orientations réglementaires claires pour favoriser les solutions GovTech.

Infrastructures, compétences et écosystèmes

Les réseaux de recherche et d’innovation avancés dans l’UE sont considérés comme une force générale dotée d’un écosystème bien développé d’universités, d’établissements de recherche et de pôles d’entrepreneuriat en pleine croissance autour d’eux dans l’ensemble de l’UE, qui favorisent la collaboration et la commercialisation.

Cependant, la dépendance vis-à-vis d'infrastructures non européennes est une source de préoccupation dans tous les domaines technologiques. Les parties prenantes réclament des investissements ciblés dans les capacités basées dans l'UE et des approches fédérées. La maintenance et la mise à niveau des infrastructures existantes ne bénéficient pas d’un soutien suffisant, ce qui nuit à leur fiabilité et décourage une utilisation plus large. Le soutien à l’accès transfrontalier aux infrastructures numériques serait également insuffisant dans les programmes de financement public européens.

L'Europe dépend de fonderies de puces de pointe et de génération avancée situées hors de l'UE, d'installations de conditionnement de pointe et de pôles de fabrication quantique unifiés; les chaînes d'outils de conception et les lignes pilotes restent fragmentées, avec des modalités d'accès complexes et des lacunes dans les applications entre la R&I et l’industriel.

Il existe d’importantes capacités pré-exascale/exascale, mais ceux-ci sont confrontés à une dépendance vis-à-vis du matériel non européen; tant l'accès des PME et de l'industrie reste limité, les interfaces HPC-cloud sont encore sous-développées, l'adaptation des charges de travail d'IA et les liaisons hybrides quantiques-classiques peuvent être renforcées, et le déploiement de l’edge computing reste inégal et s'accompagne de peu de plans de maintenance à long terme.

Le déploiement des réseaux 5G/6G autonomes et de la fibre optique est inégal et la coordination transfrontalière fait défaut, alors que des cadres d'orchestration ouverts et des réseaux souverains à faible latence sont nécessaires pour prendre en charge les applications décentralisées en temps réel et les environnements de jumeaux numériques. Les données restent cloisonnées entre les secteurs et les régions, avec une gouvernance incohérente; des lacs de données sécurisés et évolutifs, des bibliothèques de données nationales et des espaces de données interopérables (y compris les données spatiales) nécessitent un financement soutenu, des API unifiées et un accès simplifié pour les PME et les organismes publics.

La dépendance vis-à-vis des hyperscalers non européens persiste dans un contexte de marchés fragmentés; les initiatives fédérées de cloud-edge en sont à leurs balbutiements, l'intégration HPC-cloud est sous-développée, les jumeaux numériques et les bancs d'essai sectoriels sont inégaux, les chaînes d'outils logiciels clés restent fragmentées, les systèmes du secteur public sont souvent obsolètes, et les plateformes souveraines et écoénergétiques doivent être prioritaires.

Une pénurie généralisée de compétences numériques affecte l'adoption et l'exploitation des nouvelles technologies, ce qui pose un défi particulier aux PME, qui manquent souvent de ressources pour attirer ou former des talents numériques. Si l'on observe dans l'UE une croissance dynamique du nombre de professionnels possédant des compétences en technologies numériques pertinentes pour les 12 domaines ciblés (en particulier dans le domaine des technologies quantiques, mais aussi de l'IA), la part de professionnels qualifiés occupant des fonctions dans le secteur des TIC reste globalement inférieure dans l'UE par rapport aux États-Unis.

Il existe un décalage entre la proportion de professionnels qualifiés occupant des postes dans les TIC et l'ingénierie, qui développent et pilotent les technologies, et celle des personnes occupant d'autres fonctions, où des compétences numériques sont nécessaires pour appliquer et déployer efficacement ces technologies. Les parties prenantes consultées proposent des mesures comprenant des formations ciblées et une meilleure intégration des marchés du travail afin d'améliorer l'accès à l'expertise, tout en soulignant la nécessité d'une éducation numérique de base pour les jeunes professionnels et d'attirer/fidéliser les talents.

L'écosystème numérique européen est confronté au défi de la fragmentation du marché européen, qui limite la capacité des entreprises à se développer et à être compétitives à l'échelle internationale. Le déploiement est souvent entravé par des normes et des réglementations nationales divergentes, ce qui rend difficile l'expansion transfrontalière.

Interopérabilité

L'UE dispose d'une base solide en matière de solutions d'interopérabilité, soutenue par une infrastructure numérique robuste, des efforts politiques coordonnés et un écosystème d'interopérabilité en pleine expansion. Cet écosystème s'appuie sur un réseau de fournisseurs de solutions, de PME spécialisées et de start-ups proposant des technologies modulaires et fondées sur des normes. Cependant, l'interopérabilité connaît actuellement une transformation fondamentale, de plus en plus envisagée sous l'angle de la souveraineté technologique, les organisations cherchant à éviter la dépendance vis-à-vis d'un fournisseur unique et à préserver leur autonomie stratégique sur leur infrastructure numérique. Si le règlement pour une l'Europe interopérable a marqué un tournant important pour atteindre ces objectifs, ces ambitions se heurtent à des défis de taille liés à la fragmentation des infrastructures technologiques entre les États membres de l'UE. Cette situation est considérée comme particulièrement problématique, car les exigences en matière d'interopérabilité évoluent, passant du simple partage de données statiques à une synchronisation en temps réel au-delà des frontières et des secteurs. Cette évolution nécessite non seulement une compatibilité technique, mais également des cadres de gouvernance coordonnés capables de soutenir des services numériques dynamiques et transfrontaliers tout en préservant la souveraineté technologique de l'UE.

Options d'investissement

Compte tenu du futur Fonds européen pour la compétitivité et d'un programme de l'UE visant à soutenir le déploiement, plusieurs options d'investissement pourraient permettre de renforcer le déploiement des technologies numériques dans tous les secteurs, tout en tenant compte des dépendances technologiques susceptibles de compromettre la compétitivité et la sécurité de l’économie de l’UE. Elles peuvent présenter des capacités variables pour relever l’un ou les deux principaux défis identifiés dans cette étude. Premièrement, il s’agit du niveau élevé de dépendance vis-à-vis de solutions numériques développées ou contrôlées par des acteurs mondiaux (non européens) dans presque tous les domaines technologiques, pouvant entraîner une hausse des prix affectant la compétitivité des biens et services européens par rapport à leurs homologues internationaux et créer des vulnérabilités dans la chaîne d’approvisionnement. Deuxièmement, les rythmes lents et inégaux d'adoption des technologies numériques dans l'ensemble de l'économie européenne, tant dans le secteur public que privé, ce qui freine la croissance de la productivité et pèse sur l'innovation et la qualité des services.

Quatre options d'investissement ont été conçues comme des combinaisons de financement distinctes, qui impliquent des scénarios différents et contrastés. Trois de ces quatre options privilégient une logique de financement par rapport à toutes les autres (par exemple, une attention particulière portée à la productivité ou à l'autonomie stratégique), tandis que la quatrième est plus ouverte et reflète les priorités nombreuses et variées de l'ensemble des parties prenantes. Ces approches schématisées visent à mettre en évidence les forces et les faiblesses de stratégies de financement particulières, dans l'optique de définir une option privilégiée (probablement hybride) qui établisse un juste équilibre entre les objectifs spécifiques et les types d'avantages. Les quatre options d'investissement sont présentées ci-dessous:

- **Option d'investissement 1** – Compétitivité/Productivité: Domaines technologiques: mettre davantage l'accent sur les domaines présentant un fort potentiel d'exploitation et des gains de productivité importants pour l'ensemble de l'économie, et moins sur le renforcement des capacités de l'UE dans les technologies numériques les plus avancées. Types d'investissement: niveau élevé pour les services d'aide au déploiement, faible pour les nouvelles infrastructures, moyen pour l'écosystème et les compétences.
- **Option d'investissement 2** - Compétitivité/Résilience: Domaines technologique : accent mis davantage sur le renforcement des capacités de l'UE dans les domaines où les dépendances mondiales de l'UE sont élevées (IA, cybersécurité, semi-conducteurs, etc.) et où il existe un potentiel d'améliorations substantielles sur les marchés émergents ou en évolution rapide. Répartition des types d'investissement: moyenne/faible pour le déploiement, élevé pour le renforcement des capacités, y compris les infrastructures nouvelles et étendues, moyenne/faible pour l'écosystème et les compétences.
- Option d'investissement 3 - « AI Continent »: Domaines technologiques: accent mis principalement sur les technologies d'IA en général et sur l'intersection entre l'IA et d'autres domaines technologiques où les synergies devraient être très importantes (par exemple, le HPC, le cloud, la microélectronique, les données, etc.). Répartition des types d'investissement: élevé pour le déploiement et pour les infrastructures nouvelles et étendues, moyenne pour l'écosystème et les compétences
- **Option d'investissement 4** - Priorités des parties prenantes: Domaines technologiques: soutien plus ouvert à tous les domaines technologiques dans lesquels les parties prenantes accordent la priorité aux investissements (IA, cybersécurité, données, interopérabilité, etc.) Répartition des types d'investissement: élevé pour les services de soutien au déploiement, moyenne pour le développement des infrastructures, faible pour l'écosystème et les compétences.

Mécanismes de mise en œuvre

D'après les conclusions de cette étude, un futur programme numérique doit être plus simple, plus rapide et plus souple que le programme actuel afin d'améliorer son efficacité et sa capacité à contribuer de manière optimale à la prospérité et à la sécurité futures de l'Europe. En ce qui concerne le soutien à l'adoption précoce, les parties prenantes consultées estiment que la priorité devrait être donnée aux déploiements les plus innovants, tout en reconnaissant la difficulté administrative que représente la définition et la reconnaissance claires d'un potentiel d'innovation substantiel. Une minorité des parties prenantes a suggéré que l'orientation devrait être encore plus précise (ne pas se limiter aux innovations majeures), mais que les innovations majeures à double usage, celles présentant à la fois des avantages civils et sécuritaires, devraient être privilégiées, en particulier compte tenu des considérations géopolitiques actuelles.

En ce qui concerne le renforcement du caractère stratégique de tout futur programme, les parties prenantes ont suggéré de fixer des objectifs mesurables, tels que l'augmentation du taux d'adoption annuel des technologies stratégiques. En outre, la majorité des parties prenantes ont fait valoir que des incitations supplémentaires pourraient être mises en place pour encourager stratégiquement le recours à des fournisseurs européens et à des solutions européennes, par exemple en offrant un pourcentage de financement plus élevé lorsque des technologies européennes sont choisies.

Introduction

Considering the rapid evolution of digital technologies and markets, the geopolitical context, the intensifying global technological race and the importance of the digital and sustainable transformation of industry and society, the **European Union faces several significant challenges for the deployment of digital technologies that hinder its potential for growth and global competitiveness**. The gap between R&I results and the uptake of digital technologies by the public and private sector remains high in Europe, while limitations in the deployment of digital infrastructures, shortages of digital skills, and gaps in the European value-chains also directly impact Europe's competitiveness and strategic autonomy in the digital domain. Overall, the adoption of digital technologies remains slow, and the path toward creating a cohesive Digital Single Market is also hampered by legal and technical barriers, including limited interoperability and common standards. In addition, the EU must navigate societal, environmental, ethical, and other challenges that digital transformation inherently presents. Addressing these multifaceted issues is essential for the EU to enhance its digital capabilities, foster innovation, and secure its position in the global digital economy.

Study objectives

In this context, the European Commission's Directorate-General for Communications Networks, Content and Technology (DG CNECT) has commissioned a study to enhance the understanding on the deployment of strategic digital technologies for Europe, entitled "Study on the EU's critical digital capacities deployment beyond 2027".

The **general objective** of the study is to support the European Commission with identifying digital areas in which funding to support digital capacity building, deployment, and infrastructure development is critical under the next Multiannual Financial Framework (MFF) (2028-2034).

This translates into the following **specific objectives:**

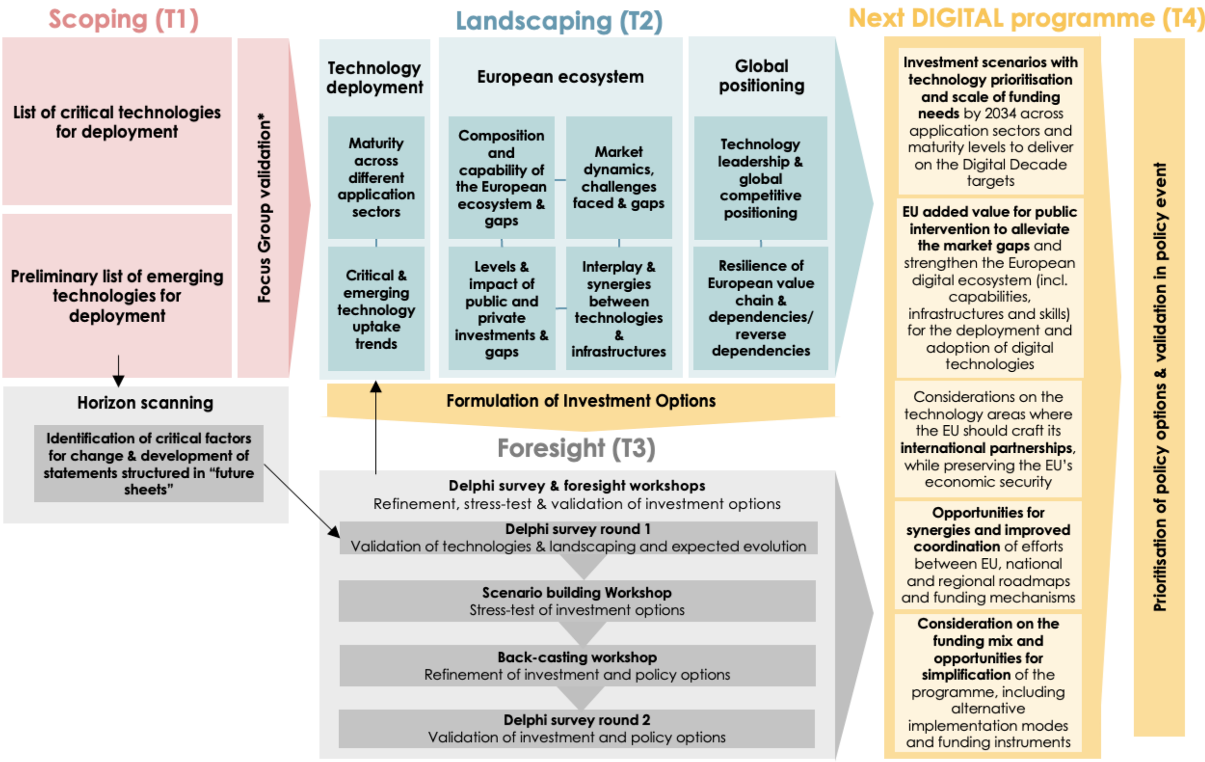
- the provision of the current state of play of the digital landscape covering the *deployment of digital strategic technologies, and infrastructures, as well as the necessary skills* to deploy these technologies and infrastructures, including related public and private investments
- the identification of relevant *emerging digital technologies, infrastructures and capabilities* for deployment and roll out in the period 2028-2034 to strengthen digital ecosystems and build digital capacity across the EU; address global challenges, ensure EU industrial competitiveness as well as economic security and sovereignty
- the *mapping of the European ecosystem around digital technology deployment* in different application sectors, including levels of public and private investments and challenges, gaps and obstacles encountered for their scaling-up
- the *analysis of the global digital ecosystem surrounding digital technologies for deployment*, assessing the level of global competitiveness of the EU in the different areas of technology investment, to identify the EU's strengths and unique competitive advantages, and assess dependencies
- the exploration of *future trends, funding gaps, foreseeable challenges (including market failures), and investment needs* for which a European approach would be beneficial in the digital sector in the period 2028-2034, to feed into the development of strategic (investment) options that can support priority setting for an optimal design of the next digital technology deployment programme under the next MFF, with the idea that the insights provided can be relevant in the longer run and tested and revised in the course of the next programme

As an outcome, the study will provide a list of key considerations to support the Commission's preparation of the 2028-2034 programming period.

Analytical framework

To develop the approach tailored to the needs of this strategic study, we have developed an analytical framework to feed into the development of the EU strategy for the deployment and adoption of critical and emerging digital technologies under the next MFF (see overview below).

Figure 1 Analytical framework



Source: Technopolis Group (2025)

The study has been divided into two main phases, as illustrated in the below figure and further detailed in annex of this report:

- **Phase 1 – Scoping and landscaping**: the first phase consisted in identifying critical and emerging digital technologies for deployment relevant to the next MFF through scoping and horizon scanning, further refined via expert discussions, the Delphi process and stakeholder consultations. The landscaping analysis provided additional insights into technology trends, ecosystem dynamics, investment levels, and EU competitiveness, forming the basis for preliminary investment options.
- **Phase 2 – Foresight and strategic considerations**: The second phase validated the findings and developed future scenarios and strategic roadmaps for investments with a 2028 and to a lesser extent 2036/40 time horizon, with the aim of addressing identified gaps and inform prioritisation exercises. These were tested against contextual factors in the second round of foresight workshops, leading to recommendations for the next EU digital programme, validated through stakeholder workshops in July 2025.

The study has adopted a mixed research approach for data collection & analysis, ensuring compliance with the Better Regulation Guidelines on integration and triangulation of the findings.

- **Robust indicator framework** drawing from various data sources to analyse the adoption of advanced digital technologies by industry, and structured around capability assessment, market structure, composition and investments.
- **Far-reaching and large-scale stakeholder consultation strategy** to seize key changes in the technology deployment and the consolidation of digital ecosystems across application sectors, allowing to define, test and assess options for investments.

- **Forward-looking approach**, to test and develop a vision, beyond 2028 and up to 2034, accounting for uncertainty and criticality of action.
- Assessment of the options through **muti-criteria analysis** to appraise the likely impact of the options, together with a **Cost-Benefits Analysis** (CBA).

As a note, the study has also been able to leverage some of the evidence collected through the parallel study on **"Study on the EU's strategic digital technologies for EU R&I Investments",** which expanded the data sources and validation opportunities for this study, while ensuring alignment of stakeholder consultation tools to avoid overlaps and stakeholder fatigue.

Scope of critical digital technologies

The 2030 Digital Decade Policy Programme[1] provided a starting point for this study as it sets EU-wide targets to boost adoption of key digital technologies such as AI, cloud, big data, semiconductors, quantum, edge computing, and 5G. It also aims to strengthen digital skills, secure and sustainable infrastructure, and the digital transformation of businesses and public services to ensure competitiveness, resilience, and sovereignty.

The analytical framework of this study is embedded in the literature of digital transformation, digital maturity models and in existing assessment structures of digital policies that have been developed at EU, international and other levels. The framework follows the Digital Compass targets and other relevant studies including the OECD national digital strategy assessment framework[2], the Joint Research Centre's work on digitalisation of SMEs and further national studies.

Consideration on critical technologies and capabilities for deployment in the EU

In its pursuit of technological sovereignty and global leadership, the European Commission prioritises investments in critical and emerging digital technologies holding transformative potential for creating new markets and advancing strategic autonomy. With regards to the identification of these technologies for deployment, several EU strategic documents and reports present lists of critical technologies which play a pivotal role in ensuring resilience, economic security, sovereignty, and long-term competitiveness. These include most importantly:

- the **EU strategic foresight report**[3] in 2022 provided a future-oriented analysis of the major role played by digital technologies and looked at the role of critical technologies in achieving transition (key technologies for the twinning),
- the **2025 Strategic Foresight Report** [4] analysed how to advance to a higher level of resilience, including through the adoption and strengthening of digital technologies,
- the **EU Roadmap on critical technologies** for security and defence[5] which outlined a path to boost RD&I and reduce strategic dependencies in critical technologies and value chains for security and defence,
- the **EU Observatory of Critical Technologies** which identifies, monitors and assesses critical technologies for space, defence and related civil sectors[6],

[1] https://digital-strategy.ec.europa.eu/en/library/digital-decade-policy-programme-2030
[2] OECD Digital Economy Papers, *Assessing national digital strategies and their governance*, 2022, https://www.oecd.org/en/publications/assessing-national-digital-strategies-and-their-governance_baffceca-en.html
[3] COM(2022)289 final, 2022 Strategic Foresight Report, Twinning the green and digital transitions in the new geopolitical context, June 2022
[4] https://commission.europa.eu/strategy-and-policy/strategic-foresight/2025-strategic-foresight-report_en
[5] COM(2022) 61 final, Roadmap on critical technologies for security & defence, February 2022
[6] EU Monitor, Commission contribution to EU defence in the context of the strategic compass https://www.eumonitor.eu/9353000/1/j9vvik7m1c3gyxp/vlqhmpt8ptzd?ctx=vg9pjpw5wsz1

- the Strategic Technologies for Europe Platform (STEP)[7] with a specific emphasis put on **digital technologies and deep tech innovation**[8] as target investment areas,
- the **European Commission Recommendation on critical technology areas** for the EU's economic security for further risk assessment with Member States (2023) which lists technology areas for the EU's economic security for further assessment with Member States[9]. The list includes ten areas related to advanced semiconductors technologies, Artificial Intelligence, quantum technologies, biotechnologies, advanced connectivity, navigation and digital, advanced sensing, space & propulsion technologies, energy technologies, robotics & autonomous systems and advanced materials, manufacturing & recycling technologies.

The technologies as identified in the above sources are characterised by their potential and relevance for driving significant increase of performance and efficiency as well as potential radical changes for sectors & capabilities. Their criticality is also assessed in regard to their relevance for both the civil and military sectors and its potential to advance both domains, as well as risk of uses of certain technologies to undermine peace and security. To this end, the ReArm Europe Plan/Readiness 2030[10] outlines legal and financial means to support the defence investments of Member States. Finally, another aspect related to their criticality relates to their potential misuse in violation of human rights, including restricting fundamental freedom[11].

In addition to these critical technologies, strategic technology frameworks such as interoperability hold a significant transformative potential for digitalisation, while contributing to the Union's resilience, digital sovereignty and competitiveness and promoting positive cross-border spillover effects within the EU's single market.

The review of the above reports and technology lists formed the basis for the scoping of technology areas and sub-areas in this study. The scoping and current trends of each technology & sub-technology areas are presented in the Technology Annexes to this report, following the definitions of the STEP framework.

To qualify as "**critical**" under the STEP framework, a technology must meet one of the two conditions stated below (not cumulative in the assessment of criticality)[12].

[7] C(2024)3148 final, Guidance Note concerning certain provision of Regulation (EU) 2024/795 establishing the Strategic Technologies for Europe Platform (STEP), May 2024
[8] Understood as innovation with the potential to deliver transformative solutions, rooted in cutting-edge science, technology, and engineering, including innovation that combines advances in the physical, biological, and digital spheres. Deep tech sectors, sub-sectors, applications, and definitions may change as technologies and markets evolve over time.
[9] C(2023)6689, Commission Recommendation on critical technology areas for the EU's economic security for further risk assessment with Member States, October 2023 - the list includes 10 areas related to advanced semiconductors technologies, Artificial Intelligence, quantum technologies, biotechnologies, advanced connectivity, navigation and digital, advanced sensing, space & propulsion technologies, energy technologies, robotics & autonomous systems and advanced materials, manufacturing & recycling technologies.
[10] Please see: https://ec.europa.eu/commission/presscorner/detail/en/qanda_25_790
[11] C(2023) 6689 final, Commission Recommendation on critical technology areas for the EU's economic security for further risk assessment with Member States, October 2023
[12] "Authorities in charge of the programmes falling within the scope of the STEP Regulation should set specific criteria to meet the above conditions in their funding processes (e.g., calls for proposals) and accordingly must assess compliance with these conditions in the evaluation of the submitted projects."

Box 1 Criteria to assess a technology's "criticality" under the STEP framework

Innovativeness: bring to the internal market an innovative, emerging, and cutting-edge element with significant economic potential.

- The technology should exhibit at least two of the following three characteristics: innovative, emerging, or cutting-edge.
- *Additionally*, the technology must demonstrate significant economic potential by having a substantial impact on development or manufacturing, addressing various Union markets, and generating positive spillover effects across Member States.

Strategic dependencies: contribute to reducing or preventing the strategic dependencies of the Union.

- The technology should meet several of the following factors: enhancing Union industrial and technological leadership, supporting critical infrastructures, increasing manufacturing capacity (only where a strategic dependency has been identified), strengthening security of supply, and promoting positive cross-border effects within the internal market.

Drawing from these key sources, as well as corpus of literature composed of strategic roadmap, Strategic Research & Innovation Agendas, foresight and industry report as well as portfolio of funded projects from funding programmes such as Horizon Europe (ERC & EIC portfolios, partnerships) and Digital Europe, the study team drew a first list of technology trends.

Together with the portfolio analysis of key research and technology organisations (RTOs) in Europe, experts were consulted in a series of 14 focus groups to identify, characterise and select the most important technology trends. Each focus group gathered between 15 to 25 technology experts and were carried out between the February 24th 2025 and March 3rd. This bottom-up approach based on expert assessment allowed to define the scope of each technology areas, in regard to the 13 others. The table below provides the overview of the scoping of each technology area.

Table 1 Scoping of each technology area

Technology areas	Sub technology areas	Scope
Advanced microelectronics and photonics	Microelectronics, High frequency chips and Semiconductors	Micro- and Nanoelectronics deal with semiconductor components and highly miniaturised electronic subsystems and their integration in larger products and systems. They include the fabrication, the design, the packaging and testing from nano-scale transistors to micro-scale systems integrating multiple functions on a chip. The scope of the area spans from **emerging materials** & substrate, front-end process innovation that goes **beyond conventional CMOS** technologies, **novel architectures and devices structures** & **heterogenous integration and packaging** to alternative **computing paradigms**, quantum electronics & post-quantum security, AI-driven hardware and **software/hardware co-design** as well as **advanced sensing & bio-integrated** electronics.
	Photonics (including high energy laser) technologies	Photonics is a multidisciplinary domain dealing with light, encompassing its generation, detection and management. Among other things it provides the technological basis for a variety of electronic components and equipment such as photodiodes, LEDs and lasers. The scope of the area spans from **emerging materials** & photonics materials research to advanced **packaging and co-integration of photonics** with microelectronics & other technologies (e.g. Quantum), **integrated photonics & photonic integrated circuits** (PIC). It also encompasses development for next-generation **interconnect & communication**, next

Technology areas	Sub technology areas	Scope
		generation of **optical sensing and imaging** as well as **design, simulation & layout** tools and metrology.
Advanced computing and quantum technologies	High Performance Computing (HPC)	From a technology perspective, the scope of the area spans from the **hybridisation of new computing paradigm** (AI, Quantum) with HPC, to hardware and system level integration with **advanced integration & packaging**, **specialised accelerators & processors architectures**, as well as hardware-software codesign and the development of **an application software ecosystem**. It also includes key HPC technical challenges such as **secure and adaptive HPC** architectures or **sustainable computing**.
	Quantum (computing, sensing, cryptography, communication)	The quantum technology area spans from **quantum computing** including for instance scalable quantum information processing & storage, fault tolerant QC & hybridation of classical-quantum computing to Quantum as a service. It also includes **quantum sensing technologies** such as optical atomic clocks, quantum gravitometers and magnetometers and **quantum communication technologies** such as quantum networks and repeaters. Moreover, it focuses on **key component technologies** such as quantum control & readout.
AI, data and robotics	AI (Computer vision, language processing, object recognition)	The scope of the area encompasses **machine-based AI systems** across advanced computing paradigms, including Edge AI, high-performance computing and quantum-enhanced AI, as well as emerging non-silicon architectures. It spans the development of **adaptive machine learning algorithms**, such as self-supervised, federated, causal and transfer learning, and the integration of **evolving AI paradigms** including multimodal generative AI, causal and neurosymbolic approaches. It also covers the **design of neural network** architectures such as recurrent and convolutional networks, alongside critical aspects of **AI ethics, including explainability, trustworthiness** and environmental sustainability. Applications range from deep reasoning and autonomous AI agents to embedded and networked intelligence in domains such as AIoT, robotics and advanced control systems.
	Data analytics and data sharing technologies	Data analytics & data sharing technologies for big data encompasses hardware and software that integrate, organise, manage, analyse and present data. It is characterised by "four Vs": volume, velocity, variety and value. Big Data technologies are new generation of technologies and architectures, designed to economically extract value from very large volumes of a wide variety of data, by enabling high-velocity capture, discovery and/or analysis. The scope of the area covers the development of **novel data architectures** capable of handling diverse data types, including synthetic data, alongside **advances in data storage** such as DNA-based solutions and next-generation compression algorithms. It also includes **real-time and prescriptive analytics** designed to extract actionable insights from complex data environments. Particular emphasis is placed on **secure and interoperable data sharing frameworks**, including the implementation of trustworthy and EU-compliant data spaces, the emergence of data intermediaries, and the development of sustainable business models such as Data-as-a-Service (DaaS), which collectively underpin a more decentralised and sovereign data economy.
	Robotics, exoskeletons, drones and vehicles	It addresses the advancement of robotics **systems capable of operating in dynamic and unstructured environments**, integrating novel mechanical architectures, adaptive materials, and next-generation sensors and actuators. It includes human-centric robotics such as exoskeletons, humanoids, care and soft robots, with a focus on intuitive human-robot interaction and

Technology areas	Sub technology areas	Scope
		socially-aware navigation. Developments in **cognitive robotics** aim at seamless AI integration through enhanced perception, knowledge representation and autonomous decision-making, including hybrid and joint action planning. **Emerging energy solutions** are also in focus, such as self-powered systems and structural integration of energy storage, while **new robotic modalities**, including nanobots, open pathways for applications in highly specialised and constrained contexts.
Cloud-edge-IoT and advanced digital security	Cybersecurity technologies incl. cyber-surveillance, security, intrusion systems, digital forensics, digital identity technologies	It covers **advanced cryptographic techniques** such as post-quantum (quantum-safe) cryptography, lightweight cryptography for IoT, and crypto-agility for futureproofing digital infrastructures. It includes **data security and privacy solutions** like synthetic data generation, decentralised identity and digital wallets, alongside cloud and edge security approaches including confidential computing and fog/edge computing security. The domain also encompasses **IoT and hardware security** through secure IoT chips and embedded system security. **AI-driven security and automation** play a growing role, with developments in zero-trust orchestration platforms, automated contain-and-remediate orchestration, AI-augmented digital forensics, and the use of AI/ML for anomaly detection and behavioural analytics. It further addresses challenges linked to offensive AI, AI system security, explainable (XAI) security, digital twin security and continuous authentication. **Network and infrastructure protection** is reinforced through 5G/6G security advancements and measures against ransomware and extortion threats. Digital sovereignty, verifiable credentials, secure payments are also covered.
	Cloud -Edge - IoT	It addresses the **integration of devices, systems and components** across the computing continuum, including intelligent IoT devices at the edge and the adoption of RISC-V hardware in cloud-edge infrastructures. It encompasses **orchestration** approaches such as operating systems for edge IoT systems, enabling traceability, safety and security, as well as stateful serverless computing across the cloud-edge. Ensuring **trust and performance** is central, with a focus on a seamless secure computing continuum and the use of confidential computing to address evolving security and privacy requirements. The **convergence of Cloud-Edge-IoT with AI** is also key, through developments in AI-native or cognitive cloud architectures that provide scalability and flexibility, and edge computing solutions that enable real-time insights and intelligent decision-making. Finally, **green computing** objectives are supported by energy-efficient edge computing systems and advancements in **telco cloud-edge and connectivity**.
	Blockchain, distributed ledger	From a technology perspective, the scope of the area includes **foundational developments** in blockchain and distributed ledger technologies, such as scalability, consensus mechanisms, blockchain interoperability and their application in various industries and in the public sector. The area further explores **innovative infrastructures** including decentralised marketplaces, decentralised physical infrastructure networks, and the integration of AI and ML with blockchain. It also covers emerging use cases and enablers such as green blockchain, open and next generation hardware for the future internet, AI-generated content (AIGC) including generative AR, and frameworks supporting data ownership and sovereignty.
Advanced connectivity and next generation internet	Advanced digital communications and connectivity (incl. 6G) (hereinafter	The scope of the area covers advanced digital communication and connectivity systems, including **AI-driven network management**, networks for AI, low-power wide area networks, and time-sensitive networking with deterministic routing. It encompasses **next-generation network infrastructures** such as multi-access edge

Technology areas	Sub technology areas	Scope
	referred to as Advanced connectivity)	computing, reconfigurable and adaptive wireless technologies, new radio technology, and ultra-dense networks. The area also includes developments in **network softwarisation and virtualisation**, including cloud-native networking, network function virtualisation and 6G digital twin modelling. Integrated/joint communications and radar/radio sensing (**ISAC/JCAS**) is emerging as a solution for integrating communications and sensing into one system, in particular for 6G. **Optical and radio technologies**, next generation WiFi, and open radio access networks contribute to a more programmable and flexible connectivity landscape. In addition, it includes **quantum technology for communication** as well as **satellite technologies**, particularly advanced non-terrestrial communication systems, expand coverage and resilience, while **surveillance and protection technologies** ensure secure and robust network operation.
	Next generation internet and extended & virtual reality	The scope of the area covers **technologies for the next level of immersion**, including multisensorial XR systems, human digital twins, digital humans, and digital twins of objects active in **virtual worlds**, supported by next generation communication technologies and AI-driven smart glasses to enable responsive and embodied virtual experiences. It also includes **decentralised and secure Web3**, encompassing secure decentralised finance (DeFi) 3.0, next generation peer-to-peer systems, and advanced encryption and privacy tools that foster trust and autonomy in decentralised digital environments. Finally, it addresses **sovereign Web 4.0 infrastructure** through enabling technologies such as the spatial web, scalable IoT ecosystems, and the decentralisation and diversification of XR development platforms, supporting an open, resilient and sovereign digital infrastructure for future applications.
Enabling technologies and cross-cutting dimensions	Technologies for interoperability and next generation of digital government	The scope of the area covers interoperability and the next generation of digital government through the deployment of reusable interoperability solutions, specifications and frameworks, including in the area of **semantic data interoperability** and machine readability, and through GovTech cooperation, while supporting the creation of digital twins for public administration and services while ensuring platform neutrality in digital transformation efforts. It includes the use of **Artificial Intelligence for public services**, both as a means to enhance interoperability and to optimise service delivery and decision-making across the public sector. Furthermore, it encompasses **trusted digital infrastructure for cross-border public services**, including the deployment of digital identity wallets, the development of cross-border and cross-domain data spaces, and the design of digital public infrastructure that ensures secure, accessible and sovereign service provision across Member States.

Source: Technopolis Group (2025)

Report structure

The report is structured as follows:

- **Policy, regulations and public investments**: this first chapter gives an introduction into the policy framework and analyses the level and types of public investments into digital technology deployment.
- **Market context and state of play**: provides an overview of the EU digital landscape, including policy and regulatory frameworks and public and private investment efforts at EU and national levels, moreover it analyses the EU's international positioning

- **Trends & challenges**: identifies the main trends and barriers to digital technology deployment in the EU, covering technological capabilities, sectoral use-cases, infrastructures, skills, ecosystem development.
- **Future investment scenarios and assessment:** provides an analysis on the investment needs to support the deployment of advanced digital technologies and capabilities in the EU, it presents a list of investment options, contextual factors, and introduces strategic considerations for programme design
- **Conclusions**: summarises key findings and outlines emerging considerations to support future EU action in digital technology deployment

The report is accompanied by various annexes:

Annex 1 presents the technology assessment scorecard and provides a summary of key quantitative indicators, alongside a comparative analysis across technology areas.

Annex 2 sets out the methodological approach adopted for data collection in greater detail.

Annexes 3–15 comprise 13 in-depth technology area reports outlining major deployment trends and opportunities across each domain.

Annex 16 contains a consolidated summary of stakeholder and expert consultation findings.

1. Policy, regulations and public investments

In the current geopolitical context, where the EU seeks to reinforce its competitiveness and is mindful of the need to enhance its economic security and the resilience of its value-chains, **a reconsideration of the EU's strategic investment into the deployment and adoption of critical and emerging digital technologies under the next multiannual financial framework (MFF) is essential.** In addition to multi-level public and private investments, it is also key for the EU to reflect upon the prioritisation of these investments, to allocate resources effectively and efficiently and build critical mass in Europe. In the current context, focus, speed and scale are of the essence.

1.1 Policy context for digital technology deployment

The **Digital Decade Policy Programme (DDPP)**[13] is the EU's main strategic instrument for setting the policy framework for the deployment of digital technologies with concrete targets for a human-centric, sustainable, and more prosperous digital future by 2030. The DDPP also establishes a framework for multi-country projects (MCPs), implemented through a range of mechanisms, including the newly introduced **European Digital Infrastructure Consortia (EDICs)**, in areas of critical importance for the EU such as common data infrastructure and services, skills and training in cybersecurity, and connected and innovative public administrations. In parallel, each EU Member State has adopted a national strategic roadmap outlining the actions taken and planned to achieve the 2030 Digital Decade objectives and targets. On this basis, the European Commission has defined EU-level trajectories to guide progress towards key targets, reflecting the expected evolution of the Union based on current trends. In addition, the Digital Decade serves as one of the key policy reference frameworks for the National and Regional Partnership Plans introduced for the next multiannual financial framework[14].

EU policies as presented in this section below are highly relevant for the deployment of digital technologies as they provide strategic direction, funding, and regulatory frameworks that enable faster adoption and scaling. By prioritising investments in critical infrastructure like high-speed broadband, technologies such as AI, and semiconductors, supporting innovation and start-up ecosystems, addressing skills gaps through education initiatives, and reducing dependencies on external suppliers, EU digital, start-up and skills policies can create a supportive environment that drives digital transformation, strengthens economic security, and boosts Europe's global competitiveness.

Such context has pushed some policy priorities on top of the EU's agenda, such as security and defence (incl. dual-use technologies), but also the need to strengthen the EU's strategic autonomy in critical technologies and value chains. The **European Sovereignty Fund** suggested by President von der Leyen during her State of the Union Speech of 2022[15], aim to "*make sure that the future of industry is made in Europe*". In 2023, the European Commission published the new Communication on the **EU's Economic Security Strategy**[16]**,** mainly focused on "minimising the risks in the context of increased geopolitical tensions and accelerated technological shifts, while preserving maximum levels of economic openness and dynamism". Such strategy pursues three priorities: promoting EU's competitiveness, protecting the EU from economic security risks and partnering with the broadest possible range of countries who share concerns or interests on economic security. In practice, this translates into reducing dangerous foreign dependencies in key sectors, stress-testing supply chains, and ensuring the EU can withstand geopolitical shocks. The strategy reaffirmed the need to strengthen European resilience in areas like energy, health, food security and defence capabilities[17], directly linking economic security & strategic

[13] Decision (EU) 2022/2481 establishing the Digital Decade Policy Programme 2030
[14] See: https://commission.europa.eu/topics/budget/eu-budget-2028-2034-explained/investing-people-member-states-and-regions_en
[15] European Commission (2022), Ursula von der Leyen, *State of the Union Speech 2022*, Online
[16] JOIN(2023) 20 final, Joint Communication on European Economic Security Strategy, June 2023, Online
[17] *Ibid.*

autonomy. The strategy emphasises de-risking critical economic supply chains, maintaining open global markets and beneficial trade while tightening safeguards around strategic technologies and inputs.

The **Draghi report on the 'Future of European Competitiveness'**[18] states that "*EU's future competitiveness will increasingly depend on the digitalisation of all sectors and the advancement of cutting-edge technologies, which will drive investment, create jobs, and foster economic growth*". The report further outlines that, as part of Europe's competitiveness strategy for the next decade, policies and initiatives focused on digitalisation and advanced technologies, must prioritise three key areas:

- **High-speed/capacity broadband networks and related equipment and software** to "enable connectivity and distribute sustainable digital services essential to EU citizens and businesses",
- **Computing and AI** (e.g. infrastructure, platforms and advanced technologies) to "*develop and scale up digital services, enabling companies to innovate, boost their productivity and upscale, notably concerning cloud, high-performance computing and quantum, as well as AI and its industrial applications*", and
- **Semiconductors** as "*key driver and enabler for the electronics value chain, and a strategic element of Europe's security and industrial strength*"[19].

In her new political guidelines[20] (2024), President von der Leyen announced a **new plan for Europe's sustainable prosperity and competitiveness** and quoted the Draghi report mentioning the motto "*Boost productivity with digital tech diffusion*". President von der Leyen also called to invest record amounts in new technologies for Europe to **drive the green and digital transition**, with the aim to build "*a continent reconciled with nature and leading the way on new technologies*"[21]. Public investments in advanced digital technologies have an important role to play in meeting those challenges, leveraging private investments and driving the sustainable and smart transformation of industry and society. In her political guidelines[22], von der Leyen pledges to "*step up our investment in the next wave of frontier technologies, in particular supercomputing, semiconductors, the Internet of Things, genomics, quantum computing, space tech and beyond*"**.** The Political Guidelines also call for a **Union of Skills**, under which the current Pact for Skills Initiative will be further developed. Moreover, the recent Communication of the Commission on the Union of Skills (2025)[23] highlighted that Europe's competitiveness relies heavily on its human capital, yet faces major challenges including skills shortages, declining educational performance, and fragmented governance. Specifically relevant for this study, the **STEM Education Strategic Plan**[24] is a key initiative of the Union of Skills. The Union of Skills initiative aims to address these by promoting lifelong learning, improving access to quality education and training, supporting businesses in talent development, and ensuring cross-border recognition of skills, ultimately fostering a more innovative, inclusive, and resilient EU economy.

In the 2025 State of the Union and its Letter of Intent, President von der Leyen re-stressed that Europe must strengthen its autonomy and competitiveness. While Europe leads in research, a persistent challenge lies in scaling up innovation, making the deployment of frontier digital technologies (such as AI and quantum) essential to securing Europe's digital and economic future.[25]

The 2025 Strategic Foresight Report builds on this perspective by stressing that Europe's competitiveness will increasingly depend on achieving greater strategic autonomy in frontier technologies and the infrastructures that support them. It highlights areas such as AI,

[18] Draghi M., The future of European competitiveness, a competitiveness strategy for Europe, September 2024 Online
[19] Draghi M., The future of European competitiveness, a competitiveness strategy for Europe, September 2024 Online
[20] EC (2024), Europe's Choice, Political Guidelines for the next European Commission 2024-2029, July 2024, Online
[21] EC (2023) Ursula von der Leyen, *State of the Union Speech 2023*, Online
[22] EC (2024), Europe's Choice, Political Guidelines for the next European Commission 2024-2029, July 2024, Online
[23] https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX%3A52025DC0090
[24] https://education.ec.europa.eu/focus-topics/stem
[25] EC (2025), State of the Union 2025 – Letter of Intent, Online

computing capacity, data resources and foundational models. Strengthening Europe's position in these areas is presented as essential to scaling up innovation, reducing external dependencies and enabling the broad deployment of digital technologies in line with Europe's economic and security interests.[26]

These orientations are reflected in the **European Strategic Agenda for 2024-2029** adopted by the European Council meeting on the 27th of June 2024[27] and the **Budapest Declaration** on the New European Competitiveness Deal[28] which sets as objectives:

- **Bolstering EU competitiveness**: by reinforcing EU sovereignty in strategic sectors, make Europe a technological and industrial powerhouse, and strengthen economic security, reduce harmful dependencies and diversify and secure strategic supply chains, including capacity in strategic sectors[29]
- **Making a success of the green & digital transitions**: by exploiting untapped potential of data, promote data interoperability and encourage investment in game-changing digital technologies, advancing their application while ensuring privacy & security
- **Promoting an innovation- and business-friendly environment**: by boosting research and innovation capacity in emerging & enabling technologies, including for dual use, to achieve industrial strength in key sectors

The European Commission introduced the Competitiveness Compass[30] in early 2025 with the objective to restoring Europe's competitiveness and unleashing its growth, placing critical emerging technologies, particularly digital technologies, at its heart. The Compass explicitly prioritises emerging digital technologies, including AI, advanced computing, and data infrastructure, building on earlier strategies such as the Digital Decade policy. The Compass establishes competitiveness as one of the EU's overarching principle for action and intends to address three main imperatives for the EU:

- **Closing the Innovation gap:** focusing on reviving the innovation cycle and directly addressing obstacles preventing companies from emerging and scaling up while ensuring the conditions for advanced technologies to thrive in tomorrow's economy. This entails nurturing world class industrial developments in specific technology sectors of importance such as AI, semiconductor and quantum technologies, robotics, space technologies or connected and autonomous mobility. At the same time, it aims to ensure the diffusion of innovation and advanced technologies across the whole economy, investing in state-of-the-art digital infrastructure, integrating advanced digital technologies such as AI into strategic sectors where Europe has been traditionally strong, as well as in the public sector, and ensuring the digitalisation of public services.
- **Setting up a joint roadmap for decarbonisation & competitiveness**, with a specific focus on raising the profile of the EU as an attractive location for manufacturing, including for energy intensive industries while promoting cleantech.
- **Reducing excessive dependencies and increasing security** is the third imperative focusing on bolstering resilience and control in the context of a fraught geopolitical and global competitive landscape. This third objective builds upon the diversification and reduction of dependencies through international partnerships (e.g. digital trade agreements); levelling the playing field addressing the challenges of unfair competition (e.g. through European preference in public procurement); and investing in preparedness, security and defence industry.

These objectives are the product of a re-calibration of Europe's strategic orientations, putting a stronger emphasis on resilience, adaptability and strategic autonomy, all the while

[26] EC (2025), 2025 Strategic Foresight Report, Online
[27] European Council (2024), Strategic Agenda 2024-2029, June 2024, Online
[28] European Council, Budapest Declaration on the New European Competitiveness Deal, November 2024, Online
[29] Described as defence, space, Artificial Intelligence, quantum technologies, semiconductors, 5G/6G, health, biotechnologies, net-zero technologies, mobility, pharmaceuticals, chemicals and advanced materials
[30] COM(2025)30 final, A competitiveness Compass for the EU, January 2025, Online

fostering sustainable competitiveness. This longer-term evolution is embedded into the development of different EU strategic frameworks.

1.2 Regulatory and legal context

The EU has established a strong regulatory environment to ensure stability and security for the deployment of digital technologies, implementing landmark legislations such as the AI Act and the Chips Act. It also addresses skills shortages through initiatives such as the Union of Skills and the STEM Education Strategic Plan, which focus on improving human capital and talent development, particularly in sectors that are strategic for the Union's competitiveness and strategic autonomy. Looking ahead, the EU is preparing additional measures such as the Cloud and AI Development Act[31] and the Digital Fairness Act[32] to further strengthen Europe's technological capabilities and reinforce the resilience of its digital ecosystem.

Europe has developed a strong regulatory framework providing a stable and secure environment to develop and operate digital technologies[33] with key measures such as the AI[34] and Chips[35] Acts, the Net Zero Industry Act[36] and Critical Raw Materials Act[37] and global standards. The aforementioned Competitiveness Compass introduces a shift in focus towards nurturing world-class industrial developments, reducing reliance on non-EU suppliers and building domestic capacity in critical sectors with new initiatives such as the **Cloud and AI Development Act** or the **Quantum Act**[38]. It also intends to support digitalisation and diffusion of advanced digital technologies across the whole economy, for instance investing in state-of-the-art digital infrastructures and improve digital connectivity (e.g. **Digital Networks Act**[39]) or digitalisation of public services.

In this context, the **Chips Act** is undergoing an evaluation and review to ensure it remains fit for purpose as markets, technologies and geopolitics evolve, with possible targeted adaptations to further reinforce Europe's semiconductor ecosystem and reduce strategic dependencies.[40]

Other forthcoming measures include the **Digital Fairness Act**, aimed at reinforcing consumer trust and fair dealing in the platform economy, and a new **Media Resilience Programme** to support pluralism, security, and resilience in Europe's information ecosystem.[41]

EU regulatory framework

- Cutting edge digital capacities: **AI Act** (2024), **Chips Act** (2023), **EuroHPC Regulation** (and revisions introducing AI Factories, 2024), **Quantum Act** (Q4 2026)
- Data: **GDPR** (2016) **Open Data Directive** (2019), **Data Governance Act** (2022), **Data Act** (2024), **EU cloud and AI Development Act** (Q4 2025-Q1 2026)
- Connectivity: **European Electronic Communications Code** (2018), **Gigabit Infrastructure Act** (2024), **Digital Network Act** (Q4 2025)
- Interoperability**: Interoperable Europe Act** (2024)
- Platforms and infrastructures: Directive on **Platform workers** (2023), **Digital Markets Act** (2022), **Digital Services Act** (2022), **Interoperable Europe Act** (2022),

[31] https://www.eu-cloud-ai-act.com/
[32] https://digital-strategy.ec.europa.eu/en/consultations/commission-launches-open-consultation-forthcoming-digital-fairness-act
[33] COM(2025)30 final, A Competitiveness Compass for the EU, January 2025, Online
[34] Regulation (EU) 2024/1689 (AI Act). https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=OJ:L_202401689
[35] Regulation (EU) 2023/1781 (Chips Act). https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32023R1781
[36] Regulation (EU) 2024/1735 (Net Zero Industry Act). https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=OJ:L_202401735
[37] Regulation (EU) 2024/1252 (Critical Raw Materials Act). https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=OJ:L_202401252
[38] As mentioned in the Competitiveness Compass, Online
[39] https://www.digital-networks-act.com/
[40] EC (2025), Commission launches public consultation and call for evidence on the evaluation and review of the Chips Act, Online
[41] EC (2025), State of the Union 2025, Online

EU regulatory framework
• Cybersecurity: European Cybersecurity Competence Centre (2021), **Digital Operational Resilience Act (**2022), **Cybersecurity Act (2019 – currently under review) Cyber Resilience Act** (2024), revised Directive on the Security of Network and Information Systems - **NIS2 Directive** (2022A), **Cyber Solidarity Act** (2024), delegated act on the **cybersecurity of cross-border electricity flows** (2024), • Others: **European Media Freedom Act** (2024), **Amendment of the General block exemption regulation** (GBER – State Aid) to support the twin transition (2023), Revision of **eIDAS Regulation** (2023), Legislative proposals on **crypto assets and digital operational and cyber resilience** (2020), **European Business Wallet** (2025), **Directive on the resilience of Critical Entities** (2024) • Twin transition: **Net Zero Industry Act** (2023), **Right to Repair** (2023), Revision of the **Energy Efficiency Directive** (2023), Delegated **Act of the Taxonomy Regulation** (2023), **Ecodesign Regulation on servers and data storage products** (2021), Packaging waste regulation (2024), Restriction of hazardous substance directive (2011) • **Corporate Sustainability** Due Diligence Directive (2024), the **Batteries Regulation** (2023), the **Conflict-Minerals Regulation** (2017), and the **Deforestation Regulation** (2023).

Source: Technopolis Group (2025), Own compilation

The European Commission developed a comprehensive set of instruments and initiatives to **ensure the conditions for advanced technologies to thrive** and put Europe at the forefront of innovation in advanced digital sectors while investing in **new growth engines**[42]. These strategic frameworks and initiatives linked to the Digital Decade provide an approach that shifts from sectoral fragmentation towards comprehensive investment in technology-driven competitiveness, strategic autonomy and resilience.

In the field of Artificial Intelligence, the **Apply AI Strategy**[43] is an overarching European AI strategy, aimed at making Europe an 'AI Continent' by boosting AI adoption, innovation, and technological sovereignty. It prioritises an AI-first approach for strategic decision-making, supports SMEs, and promotes European, open-source AI solutions, particularly in the public sector. The Strategy has three main pillars: sectoral flagships targeting AI adoption across 10 key industries (from healthcare and mobility to energy and creative sectors); support measures to enhance technological sovereignty, including AI Factories, testing facilities, and workforce development; and a new governance system.

EU strategic policy initiatives
In addition to the above regulatory environment, EU main digital policy initiatives, linked to the EU Digital Decade: • **Connectivity**: White Paper on How to master Europe's digital infrastructure needs? (2024), Recommendation on Secure and resilient submarine cable infrastructures (2024); Accelerating investments in Europe's Gigabit connectivity, 5G Action Plan (2016), 5G Toolbox, Smart Networks and Services Joint Undertaking SRIA, EU Electronic Communications Code (2018) • **NGI:** Next Generation Internet initiative (2018); Virtual and Augmented Reality Industrial Coalition (2022); Strategy on Web 4.0 and virtual worlds (2023) • **Cybersecurity**: ProtectEU: European Internal Security Strategy (2025), including coordinated risk assessments; EU cyber blueprint ; Union of Skills, Cyber Skills Academy, Cyber Diplomacy Toolbox, 5G Cybersecurity Toolbox, international initiatives, such as cyber dialogues and International Counter Ransomware Initiative • **AI**: White Paper on AI (2020), AI Package, incl. proposed AI Act, Communication on fostering an EU approach to AI, revised coordinated Action Plan on AI (2021), Proposal for an AI liability directivity (proposal, 2022); AI on demand platform; EU AI Office (2024); InvestAI initiative (2025), AI Continent Action Plan (2025) Apply AI Strategy, AI Factory Initiatives & AI in Science (Q1 2025); Coordinated Plan on Artificial Intelligence (2018);

[42] COM(2025)30 final, A competitiveness Compass for the EU, January 2025, Online
[43] https://digital-strategy.ec.europa.eu/en/policies/apply-ai

EU strategic policy initiatives
• **Data**: European Strategy for Data (2020) to make Europe a global leader in the data-agile economy, legislative framework for data governance, Revised Broadband Guidelines, Evaluation of the Technology Transfer block exemption regulation, Consumer IoT sector inquiry, Data Union Strategy (Q4 2025); European Alliance for Industrial Data, Edge and Cloud • **Super and quantum computing:** EuroHPC Joint Undertaking (adopted in the Horizon 2020 framework); Launch of National Competence Centres (NCCs) in 2020 with the EuroCC; Two EuroHPC supercomputers were inaugurated in 2022; hosting agreements for another six quantum computers in June 2023; EU Quantum Technologies Flagship Initiative (2018); deployment of the national EUROQCI networks (secure quantum communication infrastructure); European declaration on quantum technologies, Quantum Strategy (Q2 2025) • **Semiconductor:** Chips for Europe Initiative, including the Chips Fund and the Design Platform; Chips Joint Undertaking • **Blockchain:** European Blockchain Service Infrastructure (EBSI); European Blockchain Strategy; European Blockchain Sandbox ; European Blockchain Partnership; European Blockchain Observatory and Forum (EP) • **Skills**: Digital Education Action Plan (2021-2027), Cybersecurity Skills Academy (2023), New Skills Agenda (2020), Council Recommendation to reinforce Youth Guarantee, Council Recommendation on improving the provision of digital skills in education and training (2023), Union of Skills (2025), Action Plan on Basic Skills (2025), STEM Education Strategic Plan (2025) • **Online platforms**: Initiative to improve labour conditions of platform workers, Communication on better working conditions for a stronger social Europe: harnessing the full benefits of digitalisation; for the future of work, new and revised rules to deepen the Internal Market for Digital Services, etc. • **Public sector**: a reinforced EU interoperability policy (Interoperable Europe Act) to ensure coordination and common standards for secure and borderless public sector data flows and services, European Data Space for Smart Communities ([44]), EU Local Digital Twin (LDT) Toolbox ([45]), and CitiVerse European Digital Infrastructure Consortium (EDIC) ([46]). • **Contribution to the Green transition**: Circular electronics initiative, policy framework for sustainable products of the circular economy action plan (2020) including measures for durability, reparability, energy efficiency of mobile phones, tablets and laptops; Common charger, Right to Repair (to extend the lifecycle of electronic devices and to avoid premature obsolescence); JRC Code of Conduct for energy efficiency in Datacentres (updated yearly); Action Plan on Digitalising the Energy System, Initiatives to achieve climate-neutral, highly energy-efficient and sustainable datacentres by no later than 2030 and transparency measures for telecoms operators on their environmental footprint; EU Green Public Procurement criteria for datacentres, server and cloud services; Advanced Materials Act (2026) • **Other sectoral initiatives**: Digital Finance (framework to enable convenient, competitive and secure Digital Finance, Strategy towards an integrated EU payments market), Digital identity (draft Architecture and Reference Framework for the European Digital Identity wallet), Education (European Student Card Initiative), Media and audiovisual (Action plan), European Data Space for Cultural Heritage, European Collaborative Cloud for Cultural Heritage, AI dedicated strategy for the Cultural and Creative Sectors (as announced in the AI Continent Action Plan), Health (Promotion of electronic health records based on a common European exchange format, eHealth Network guidelines, European health data space), consumers (New consumer agenda, Code of conduct for energy smart appliances) Democratic system (European Democracy Action Plan); Actions to combat counterfeiting and better protect intellectual property rights (2024); Defence: Action plan on synergies between civil, defence & space industries (2021), European Defence Industrial Strategy (2024) EU preparedness strategy (2025), Space: Space Act (Q2 2025)

Source: Technopolis Group (2025), Own compilation

The Competitiveness Compass reaffirms the need to reduce excessive dependencies and increasing security to ensure the EU's long term competitiveness. In this regard, the EU developed a series of instruments to prevent the leakage of sensitive technologies and know-how, while also focusing on ensuring a level playing field in a context of global competition. The EU has rolled out an **Anti-Coercion Instrument** (enabling trade retaliation against economic blackmail) and updated its **Foreign Direct Investment (FDI) Screening Regulation** to better vet inbound investments for security risks. The Foreign Subsidies

44 https://www.ds4sscc.eu/
45 https://interoperable-europe.ec.europa.eu/collection/ldttoolbox
46 https://ldtcitiverse-edic.eu/

Regulation (2023) is a set of rules implemented by the EU to address distortions caused by foreign subsidies. In January 2025, the European Commission issued a recommendation urging Member States to **review outbound investments** in critical technologies – such as AI, semiconductors and quantum – to evaluate if they pose risks to EU security[47]. The aim is to plug a gap: while inbound foreign investments are now scrutinised in the EU, there is currently no EU-wide system to monitor European firms' offshoring of critical technology.

Fostering international digital partnership is at the core of the **International Digital Strategy for the EU**, which aims to boost EU's technological competitiveness through economic cooperation, promote high level of security for the EU and its partners and shape global digital governance and standards[48]. The objectives of the strategy reflect the orientations of the compass in building global connections around the world to support both economic growth and security, diversifying and reducing dependencies, while ensuring a level playing to counter unfair competition. In this regard, the Compass aims to introduce both a revision of the **directive on public procurement** to integrate a European preference for strategic sectors and technologies, and other instruments such as the **review of the horizontal merger and control guidelines** or a **joint purchasing platform for critical raw materials**.

EU strategies and programmes addressing the international dimension of digitalisation, reducing dependencies and increasing security
International dimension: Global Digital Cooperation Strategy (2021), Global Gateway (digital transformation as key pillar), Global Digital Cooperation Strategy (2021), Digital for Development Hub (multi-stakeholder platform to foster digital cooperation between Europe and international partners), Strategy for standardisation and its five pillars (2022), Mapping of opportunities and action plan to promote the European approach in bilateral relations such as the Digital Partnerships, Trade and Technology Councils (incl. EU-US), Digital dialogues, Global Digital Compact, OECD ministerial meetings, G7 and G20 meetings; International Digital Strategy for the European Union (June 2025)
Reducing dependencies & increasing security: EU dual use control list (2021), FDI investment screening regulations (2021), anti-coercion instrument (2023), Foreign Subsidies Regulation (2023), Recommendations on outbound investment control (2025), Review of horizontal Merger & control guidelines, new state aid framework (Q2 2025), revision of directive on public procurement (2026), joint purchasing platform for critical raw materials (Q2-3 2025)

Source: Technopolis Group (2025), Own compilation

1.3 Public investments to support the deployment of digital technologies

1.3.1 Funding scope and volume in EU-level programmes and initiatives for the deployment of digital technologies

The EU has made the digital transition a core strategic priority, supported by programmes such as the **Digital Europe Programme (DIGITAL) and the Connecting Europe Facility (CEF) Digital Pillar (CEF Digital).** DIGITAL funds key areas including HPC, AI, cybersecurity, skills, and semiconductors, while CEF Digital focuses on advanced connectivity, quantum technologies, and HPC infrastructure. The Digital Europe Programme has a **substantial leverage factor of 79% on EU contributions**, with significant variation between the technology areas as shown by the analysis of programme and funding data. Digital priorities are also embedded in broader instruments such as **Horizon Europe, InvestEU, the European Defence Fund, Erasmus+ or the EU Space Programme** among others, which together drive innovation and strategic autonomy. Horizon Europe in particular has played a pivotal role in funding early-stage and breakthrough research and enabling technologies that later scale through other deployment-oriented programmes. This progression has been visible across several technology areas, including semiconductors, AI, supercomputers, cloud, and data.

Funding the deployment of digital technologies has been a growing priority for the EU. In **2014, CEF Digital started supporting the roll-out of digital infrastructure (in particular**

[47] EU 2025/63, Commission Recommendation on reviewing outbound investments in technology areas critical for the economic security of the Union, January 2025, Online
[48] JOIN(2025)140 Final, An International Digital Strategy for the European Union, June 2025, Online

5G), with the Digital Europe Programme launching a broader range of support for digital technologies since the end of 2021, focusing on five Specific Objectives (SOs):HPC, AI, Cybersecurity, Skills and Best use of digital capacities, with a sixth SO on semiconductors added with the publication of the Chips Act in September 2023.

Under the current MFF (2021-2027), the total amount of targeted contribution from the EU for **DIGITAL and CEF Digital together totals €9.83 bn**, with €7.93 bn for DIGITAL and €1.89 bn for CEF Digital. CEF Digital is mostly supporting digital infrastructures and to a lesser extent testing facilities (AI Factories) in the areas of Advanced Connectivity, AI, Quantum and HPC, whereas DIGITAL is heavily investing in deployment, ecosystem activities, testing facilities and skills in the areas of AI, HPC, Microelectronics, NGI, Data, Interoperability and Crosscutting issues. Overall, areas such as Photonics, Blockchain and Robotics receive comparably less support.

Table 2 EU public funding (DIGITAL and CEF Digital) targeting deployment of digital technologies

	Technology deployment (demonstration, piloting, small to full scale production & broad roll-out)	Testing facilities, pilot lines and technology infrastructures, large scale demonstration, etc.	Digital infrastructures (connectivity, cloud, etc.)	Advanced digital skills development (workforce upskilling/re-skilling)	Ecosystem building (networking, collaboration, standardisation, etc.)	Total
AI	272	594	322	40	93	1 321
Blockchain	10	0	0	3	47	60
Cybersecurity	151	29	66	52	852	1 150
HPC	56	759	582	31	5	1 433
Microelectronics	501	197	521	313	2	1 533
NGI	483	42	54	19	16	614
Advanced Connectivity	1	0	1383	0	7	1391
Cloud-Edge-IOT	18	0	101	5	31	155
Data	45	20	233	14	115	427
Photonics	3	3	0	5	0	12
Quantum	64	41	190	14	12	321
Robotics	8	25	0	5	2	40
Technologies for Interoperability	30	2	103	15	304	455
Crosscutting	301	30	39	190	60	920
Total	1 945	1 741	3 594	708	1 850	9 837

Source: Technopolis Group based on the Digital Europe Dashboard, Work Programmes of Digital Europe and CEF Digital (in m €).

Note: It has to be noted that since the implementation of the programmes is still ongoing, the final allocation of funding can differ. The dedicated interoperability budget line under DIGITAL amounts to around €190 million in 2021-2027.

Overall, the EU has made significant investments across all investment types in this MFF, with a relatively strong focus on Digital Infrastructure (37%), with all other categories representing close to 20% each, except skills which had a lower allocation of 8%. There are noticeable differences when looking at specific technology areas. In the area of AI, the EU has invested heavily in Testing Facilities, whereas investments in Blockchain, Cybersecurity, Advanced Digital Content/Connectivity and Quantum focus heavily on Technology Deployment. Data and Quantum show high investments in Digital

Infrastructures. Skills and Ecosystem activities are relatively evenly distributed among the technology areas.

The table below provides a list of key European Partnerships and public-private networks and initiatives supporting the R&I and to some extent the deployment of digital technologies in Europe. Their role for the latter could be further strengthened. Many of these Partnerships develop Strategic R&I Agendas that were an important source of information for this analysis.

Table 3 European Partnerships and networks

Type of partnerships	Partnerships & Networks	Recent SRIAs
Advanced microelectronics and photonics	cPP European Partnership on Photonics	Photonics21 Multiannual Strategic Roadmap 2021-2027
	Chips Joint Undertaking	Multiannual Work Programme 2023-2027 of the Chips JU
	European Semiconductor Industry Association (ESIA) Industrial Alliance on Processors and Semiconductor Technologies	
Advanced computing and quantum technologies	EuroHPC Joint Undertaking	EuroHPC Joint Undertaking Multi-Annual Strategic Programme (2021 – 2027) - 2024 revision by INFRAG and RIAG
	Quantum Flagship + Possible new partnership on quantum	Quantum Flagship – SRIA 2030: Roadmap and Quantum Ambitions Over the Decade
AI, data and robotics	cPP AI, Data and Robotics Partnership, EDICs	Strategic Orientation Toward an AI, Data, Robotics Roadmap 2025-2027 Commission Implementing Decision setting up the European Digital Infrastructure Consortia (ALT-EDIC, LDT CitiVERSE EDIC, EUROPEUM-EDIC, DC-EDIC, IMPACTS-EDIC)
	EIT Digital	Strategic Innovation Agenda for 2022-2024 and 2026-2030
	EOSC Partnership	Strategic Research and Innovation Agenda of the European Science Cloud (EOSC) 2025 – 2027
	European AI Alliance, AI4Europe Platform, Big Data Value Association (BDVA)	
Cloud-edge-IoT and advanced digital security	European Cyber Security Organisation European Cybersecurity Competence Centre (ECCC)	ECCC strategic agenda
	The European Cloud, Edge and IoT Continuum initiative The IoT-European Platforms Initiative The European Alliance for Industrial Data, Edge and Cloud Alliance for IoT and Edge Innovation Computing	AIOTI SRIA – Advancing Next Generation IoT and Edge Computing Research and Innovation 2023 - 2030

Type of partnerships	Partnerships & Networks	Recent SRIAs
Advanced connectivity and next generation internet	Smart Networks and Services (SNS) JU Next Generation Initiative European Telecommunications Standards Institute (ETSI) Networld Europe Future partnership on "Virtual Worlds"	Strategic Research and Innovation Agenda 2021 – 2027 European Technology Platform NetWorld2020 SNS JU SRIA 2021-2027
Technologies for interoperability	Interoperable Europe Act foresees cooperation with the Committee of the Regions, the EU Cybersecurity Agency (ENISA) and the European Cybersecurity Competence Centre Interoperable Europe Board, the central governance body established under the Interoperable Europe Act to coordinate matters related to cross-border interoperability of public services across the EU	Interoperability is embedded within larger domain-specific SRIA documents

Source: Technopolis Group (2025)

Including DIGITAL and CEF Digital, around 30 Commission programmes contribute some of their budget to digital topics creating a broad but also complex funding landscape[49].

Horizon Europe[50] has played a pivotal role in funding early-stage and breakthrough research and enabling technologies that later scale through other deployment-oriented programmes, primarily leveraging the European Research Council (ERC) for frontier research and the European Innovation Council (EIC) for deep-tech. The EIC Impact Report 2025[51] highlighted that the EIC is a crucial instrument for scaling breakthrough technologies, mobilising investment and strengthening Europe's leadership in strategic sectors. Since its launch in 2021, the Horizon Europe EIC portfolio has expanded to 706 start-ups and SMEs supported under the EIC Accelerator, alongside 402 Pathfinder projects and 183 Transition projects. Including the extended EIC portfolio, which incorporates projects and companies supported under the EIC Pilot phase (2018-2020) and the SME Instrument Phase II, the total accounts for approximately 800 start-ups and SMEs and 400 technology projects initiated between 2014 and 2020. More broadly, the Horizon Europe is expected to dedicate 35% of its €93.5 bn[52] research and innovation budget to the digital transition during the 2021-2027 period, with the legal obligation to earmark at least €13 bn for core digital general-purpose technologies. Digital aspects are integrated in the Horizon Europe programme across several clusters, notably Cluster 4: Digital, Industry & Space.

The **European Innovation Council**,[53] a leading deep-tech investor that leverages private co-investments to scale-up innovation with the relevant **partnerships and joint undertakings**[54] and it addresses challenges and strategic priorities that require critical mass and a long-term perspective. **Creative Europe**[55] supports digital transformation by funding projects that enhance the use of new technologies in cultural and creative sectors, from digital distribution of audiovisual works to innovative online cultural experiences. Creative Europe has committed 25% of its budget to the digital transition between 2021 and

---

[49] See also Digital tracking here https://commission.europa.eu/strategy-and-policy/eu-budget/performance-and-reporting/horizontal-priorities/digital-tracking_en
[50] Horizon Europe | European Commission (europa.eu).
[51] EIC (2025). Scaling deep tech in Europe, https://eic.ec.europa.eu/document/download/7b947b36-66cb-4471-a2d0-158d5ae6770f_en?filename=EIC-Impact-Report-2025.pdf
[52] According to the latest mid-term review, following the technical adjustments as stated in Communication - 52024DC0110 - EN - EUR-Lex (europa.eu).
[53] EIC Transition | European Innovation Council (europa.eu).
[54] I.e., Chips Joint Undertaking, European High Performance Computing Joint Undertaking, Smart Networks and Services Joint Undertaking.
[55] Creative Europe - Culture and Creativity | European Commission (europa.eu).

2023, supporting the competitiveness of the media and cultural and creative sectors, as well as cultural diversity. **InvestEU**[56] supports investments in strategic policy priority areas through a policy-driven and market-based approach enabling implementing partners to invest in high EU policy priority areas, such as the digitalisation of the economy and strengthening of certain strategic value chains.[57] The InvestEU Fund aims to mobilise a total of €372 bn of additional public and private investments, through an EU budget guarantee of €26.2 bn.[58] **External financial instruments** such as the Neighbourhood, Development, and International Cooperation Instrument (NDICI)[59] and the Instrument for Pre-accession Assistance (IPA)[60] allocate budget to support digitalisation efforts in third countries and accession countries, thus supporting partner regions in aligning to EU's broader objectives in digitalisation, foreign policy, and global competitiveness. The **European Defence Fund** (EDF) plays a vital role in strengthening the European Union's strategic autonomy and security by fostering cooperation and innovation in the EU defence sector. The EDF contributes significantly to the development of cutting-edge digital technologies, which are essential for modern defence capabilities and for ensuring the security of the Union's digital infrastructure. The **Erasmus+ programme** has played an active role in supporting the deployment of digital technologies. Since 2014, Erasmus+ funded around 29 000 projects on themes related to digitalisation.[61] In 2023 only, Erasmus+ invested €834.2 m of its budget in cooperation projects supporting digital transition.[62] In line with of the Digital Education Action Plan (2021-2027), the Erasmus+ programme actively supports the enhancement of digital skills for citizens of all ages and capacity-building for digital education, including the use of AI in education and training. The interim evaluation of the 2021-2027 Erasmus+ programme, adopted in July 2025, shows that 29% of Erasmus+ participants from 2021 to 2023 felt that their attitude towards the deployment of digital technologies had changed after their mobility experience, and that they were more inclined to use them in their studies or work.[63] The **EU Space Programme**, total contribution of €14.9 bn, of which €1.9 bn linked to the digital transition[64], in particular through supporting space observation (crucial for instance in digital twins of the Earth in Destination Earth) and navigation (Galileo satellites). It also contributes to supporting quantum research. Conversely, digital capabilities (e.g. in the context of Destination Earth) may prove crucial for the digitalisation of space services (e.g. Copernicus).

1.3.2 Leverage factor on private investments from public programmes

The Digital Europe Programme has a substantial leverage factor of 79% on EU contributions, with significant variation between the technology areas as shown by the analysis of programme funding data. The table below presents the direct leverage of the Digital Europe Programme, based on currently granted projects (excluding procurements, financial instruments, contribution agreements), presenting the level of other public and private investments that the EU public co-funding managed to generate. Direct leverage is measured as the amount of funding committed by beneficiaries as part of the project financial application and reporting procedures. The calculations are based on the information about total project budget and the EU co-funding.

The total leverage by all beneficiaries is proportionally high in the areas of Robotics, Microelectronics and Technologies for Interoperability. In technology deployment, the

[56] InvestEU Programme | European Union (europa.eu).
[57] Such as in semiconductors, data technologies, 5G and gigabit networks and quantum technologies.
[58] Digital-related areas fall mainly under the Research Innovation and Digitalisation window as well as under the SMEs window and Sustainable Infrastructure window.
[59] Neighbourhood, Development and International Cooperation Instrument – Global Europe (NDICI – Global Europe) | European Commission (europa.eu).
[60] Overview - Instrument for Pre-accession Assistance - European Commission (europa.eu).
[61] Commission Staff Working Document on the Interim evaluation of the 2021-2027 Erasmus+ programme and final evaluation of the 2014-2020 Erasmus+ programme, p. 116. eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52025SC0186
[62] *Erasmus+ annual report 2023*, Publications Office of the European Union, https://data.europa.eu/doi/10.2766/833629
[63] Erasmus+ 2021-2027 interim evaluation and the Erasmus+ 2014-2020 final evaluation, eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52025DC0395
[64] https://commission.europa.eu/strategy-and-policy/eu-budget/performance-and-reporting/programme-performance-statements/eu-space-programme-performance_en

leverage of DIGITAL has been the highest in the technology areas of Blockchain, Robotics, Photonics, NGI and Microelectronics. It is important to note that this does not include leverage of investments at end-user level, as DIGITAL is set up mostly as an indirect delivery programme, with beneficiaries supporting private companies (in particular SMEs) and public authorities. End users also invest (in kind or in cash) in digital transformation as a response to the original EU investment.

Table 4 Direct leverage factors of the Digital Europe Programme (in million € and %)

	Technology deployment (demonstration, piloting, small to full scale production & broad roll-out)		Testing facilities, pilot lines and technology infrastructures, large scale demonstration, etc.		Digital infrastructures (connectivity, cloud, etc.)		Advanced digital skills development (workforce upskilling/re-skilling)		Ecosystem building (networking, collaboration, standardisation, etc.)		Total	Share
AI	31,1	91%	174,2	96%	0,5	2%	15,8	40%	12,0	45%	233,7	77%
Blockchain	9,8	101%	0,0		0,0		1,9	72%	3,3	62%	15,0	85%
Cybersecurity	95,8	69%	27,7	97%	28,8	119%	39,5	81%	210,1	82%	401,9	81%
HPC	26,1	47%	1,8	100%	1,3	100%	18,6	61%	2,1	42%	49,8	53%
Microelectronics	28,9	100%	33,6	100%	0,0		52,2	100%	0,0	0%	114,7	99%
NGI & XR	3,7	100%	6,0	24%	7,2	98%	6,5	38%	2,4	32%	25,7	43%
Advanced Digital Connectivity	0,4	36%	0,0		0,0		0,0		2,6	100%	3,0	80%
Cloud-Edge-IOT	15,1	83%	0,0		13,6	100%	1,4	28%	5,9	100%	36,0	84%
Data	17,7	68%	17,0	86%	89,4	90%	5,0	36%	34,7	51%	163,7	72%
Technologies for Interoperability	6,1	97%	2,2	100%	7,5	100%	3,5	90%	10,8	80%	30,1	90%
Photonics	3,4	100%	3,4	100%	0,0		0,2	4%	0,0		7,0	59%
Quantum	58,9	93%	4,4	84%	55,4	93%	13,7	97%	6,3	53%	138,7	90%
Robotics	10,6	128%	24,5	100%	0,0		4,9	100%	2,8	139%	42,8	108%
Crosscutting	159,0	85%	29,6	100%	0,5	66%	56,2	68%	121,5	81%	366,7	82%
Total	467,6	80%	324,4	92%	204,1	87%	219,5	68%	414,6	75%	1630,2	79%

Source: Technopolis Group based on Digital Europe Dashboard data (cutoff date 11 September 2025)

1.3.3 Funding scope and volume of key national programmes for the deployment of digital technologies

Total investment in critical digital technologies varies significantly across EU Member States, beyond what structural factors alone explain. This unevenness may widen regional performance gaps, highlighting the need for support of pan-EU and multi-country projects. The overall level of national funding allocated for the period 2023-2030 to support digital technology deployment amounts to an estimated €110 bn, which is a significant total investment greater than current EU level investments. However, the public sector survey results show a very uneven picture across EU Member States with some respondents also indicating moderate increase or no change in the future public spending on deployment, and only a few planning new programmes. **National programmes target most the deployment of Artificial Intelligence, cybersecurity technologies and invest most in microelectronics and advanced connectivity** in line with strategic priorities.

As part of the Digital Decade Policy Programme (DDPP), all Member States have submitted national roadmaps, and 21 Member States has later updated them [65] with the objective to guiding EU Member States in their efforts to accelerate the digital transformation of their public and private sectors. The roadmaps provide a structured overview of national

[65] https://digital-strategy.ec.europa.eu/en/policies/national-strategic-roadmaps

programmes, both ongoing and planned, across mainly 13 broad areas[66] ranging from gigabit connectivity to SMEs and digital skills, including a description of relevant measures along with expected funding levels. The implementation of the roadmaps are funded by a mix of national public budgets, EU-level funding mechanisms, and sometimes private or co-financed resources (as detailed in most of the roadmap documents or related reporting)[67].

The EU's Recovery and Resilience Facility (RRF)[68] has been one of the sources for the national roadmaps as the central financial instrument of NextGenerationEU. A core requirement of the RFF has been that each national plan allocates at least 20% to digital transformation, funding projects that enhance connectivity (e.g., 5G, broadband), digitise public administration, support SME digitalisation, develop digital skills and education, and promote advanced technologies like AI, cybersecurity, and quantum computing. A recent analysis[69] further stressed the central role of the Recovery and Resilience Facility (RRF) in supporting digital transformation, given the fact that it accounted for 76.4% of total Digital Decade investments financed through EU funding instruments. According to the estimates of the JRC, **€149 bn has been dedicated from the RRF to digital decade targets**. As concluded by a recent evaluation[70], across the EU, funding allocated to investments and reforms in the area of R&I amounted to €55.6 bn. From this amount, approx. €10 bn has been directed across the EU towards digital transformation. These efforts aim to boost Europe's digital resilience, competitiveness, and long-term strategic autonomy while addressing regional disparities and skill gaps. While the RRF is not regional, many national plans include regionally focused projects (e.g., broadband in rural areas, local digital hubs, training centres in lagging regions), aiming to reduce territorial disparities.

At the level of EU Member States, the critical importance of the digital transformation has been widely recognised, and **all EU countries are investing to varying degrees in national efforts to develop and deploy advanced digital technologies.** The overall level of projected funding in the period up to 2030 is expected to be **around €110 bn**, which is a significant total investment that is many times greater than the current Digital Europe Programme and underlines the need for future EU programmes to build on, coordinate and pursue synergies with Member State efforts. The decision about where best to focus EU investments needs to reflect national commitments, to ensure there is strong European added value and optimal impacts from a finite investment.

From 2021 onwards, EU Member States have substantially expanded budgets for the digitalisation of SMEs, public administrations, and digital skills, driven largely by the Recovery Plans and the policy momentum generated in the aftermath of the pandemic, as noted in several national digital roadmaps[71].

EU Member State have multiple initiatives to promote the digital transformation, however, they differ in terms of overall budget and focus:

- Larger Member States have a broader portfolio of initiatives with substantial investment in the development and demonstration of advanced applications such as semiconductors, cloud and quantum computing
- Smaller Member States often focus on a specific type of deployment initiatives (gigabit connectivity, SME support, digital skills, support to e-government, etc.)

[66] Basic Digital Skills, ICT Specialists, Connectivity Gigabit, 5G, Semiconductors, Quantum computing, Cloud AI Data analytics, SMEs digital intensity, Unicorns, Key Public Service, e-Health, Edge nodes, Digital Identity

[67] The countries that provided information about the breakdown of national and EU level funding include: Austria, Croatia, Cyprus, Czechia, Denmark, France, Germany, Greece, Hungary, Ireland, Latvia, Lithuania, Luxembourg, Malta, Poland, Portugal, Slovakia, Slovenia, Spain, Sweden

[68] https://commission.europa.eu/business-economy-euro/economic-recovery/recovery-and-resilience-facility_en

[69] Torrecillas, J. and Nepelski, D. (2025). Update of Mapping of EU funds to Digital Decade targets 2021-2027, Publications Office of the European Union, Luxembourg, 2025, https://data.europa.eu/doi/10.2760/4123945, JRC141966.

[70] European Commission: Directorate-General for Research and Innovation, Paulović, T., Mariani, C., Mirambell Huguet, M., Ruiz, T. et al., Study on the R&I measures in the Recovery and Resilience Facility – Final report, Publications Office of the European Union, 2025, https://data.europa.eu/doi/10.2777/1207951

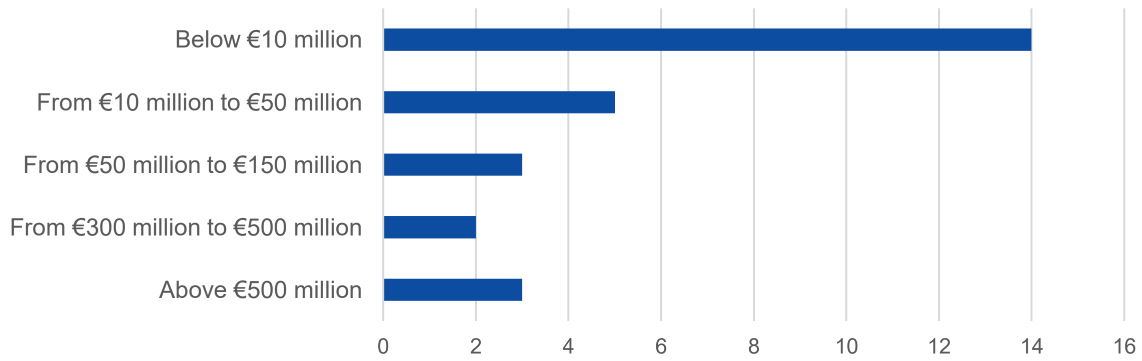
[71] See in Spain Digital 2026, https://espanadigital.gob.es/sites/espanadigital/files/2022-08/Digital%20Spain%202026-Executive%20Summary.pdf; or. https://www.gov.pl/web/cyfryzacja/strategia-cyfryzacji-polski-do-2035-roku

The level of total investment in digital technologies differs markedly by Member State, and to an extent that is not explained solely by structural factors like size. As found by the analysis of the national roadmaps submitted to the DDPP, the level of unevenness is likely to drive further divergence in performance across the region and underlines the importance of support for pan-EU and multi-country projects. Including national and RRF funding, Germany (€46 bn), France (€10 bn), Italy (€65 bn), and Spain (€26 bn) have the largest public budgets, followed by a long tail of Member States notably 17 countries planning to invest less than €3 bn in digital infrastructure, skills and technology. It should be noted that while absolute figures help gauge total investment in digital technology adoption, relative figures adjusted for country size provide additional and important insight. According to public budgets dedicated to digital technology as a share of GDP, the countries with the highest rate include Latvia (4.99), Italy (2.84), Greece (2.57), Cyprus (2.21) and Bulgaria (2.11).

More specifically as known from national level studies, Germany invested €0.7 bn in the digitalisation of the economy, €5 bn in digital infrastructure and €3.3 bn in digital R&I in 2024 as calculated by ZEW[72]. The Netherlands has earmarked approximately €430 m in core digital and technology investments, including €230 m for semiconductor and deep-tech projects and €200 m to support the scaling of tech startups[73]. These investments were announced as part of country's annual 'Budget Day' (Prinsjesdag 2025). Another example from a small Member State is Lithuania that indicated a national budget of €6 m on digitalisation of businesses, and €5 m on secure, performant and sustainable digital infrastructure up to 2030[74].

The annual budgets of individual national-level programmes supporting the adoption/uptake of digital technologies are below €10 m in several Member States as found by the public sector investment survey (see Figure below).

Figure 2 Annual funding dedicated to national level digital programmes [What is the estimated yearly funding scale of national-level programmes supporting the adoption/uptake of digital technologies?]



Source: Technopolis Group (2025) based on public sector survey on public investments (input from 21 different EU MS, Austria, Belgium, Bulgaria, Croatia, Denmark, Finland, France, Germany, Greece, Hungary, Italy, Ireland, Latvia, Lithuania, Luxembourg, Netherlands, Portugal, Romania, Slovakia, Slovenia, Sweden) and review of DD roadmaps, covering the EU27

The distribution of projected aggregate funding as outlined in the national digital decade roadmaps (including various sources of funding) is concentrated on four of the 17 areas: **investment in gigabit connectivity (infrastructure) dominates expenditure** (€76.7 bn or 30% of the estimated total); there are major commitments to invest in semiconductors, with an estimated expenditure until 2030 of around €48.6 bn (20% of the total); investment

[72] Bertschek, I., Heinemann, F., Breithaupt, P., Niebel, T., Schildknecht, J., Heumann, S., & Mahendran, T. (n.d.). Berechnung des Digitalhaushalts. ZEW – Leibniz-Zentrum für Europäische Wirtschaftsforschung, Agora Digitale Transformation https://www.zew.de/en/press/latest-press-releases/size-of-federal-digital-budget-disclosed-for-the-first-time?utm_source=chatgpt.com

[73] https://digital-holland.com/news/digital-transformation-and-innovation-whats-new-in-the-budget-memorandum-and-national-budget

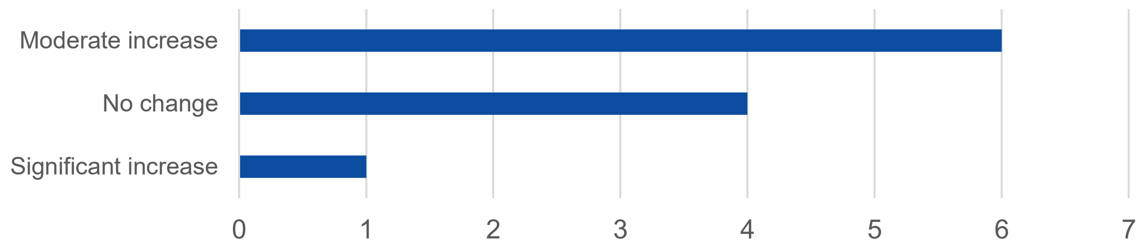
[74] https://eimin.lrv.lt/media/viesa/saugykla/2024/5/wzspkh-PiZI.pdf

in digital skills amounts to around €33 bn in total (13%), while support for 'unicorns' is also high, at around €26.4 bn (11%). There are various areas (like edge nodes or e-ID) with few discernible initiatives and typically smaller investments where they are listed and disclosed. These differences between areas may represent the breadth of the area in question, so digital skills are almost universal whereas edge nodes are a much narrower and specific type of computer.

It has to be noted that in many countries it is difficult to make a full budget breakdown for the deployment of digital technologies or even to digital technologies, because they are supported by programmes with a wider scope such as under SME investment support programmes.

Regarding future expected investments, the public sector survey results show an uneven picture with respondents indicating moderate increase or no change, and only a few planning new investments. Many point out that they are rather planning to accelerate existing programmes. For example, Poland builds on programmes such as the Digital Poland Programme[75], now complemented by measures such as the proposed digital services tax[76] and expanded AI and GovTech tools. In Spain, actions stem from the Digital Spain 2026 (España Digital 2026[77]) strategy and it continues support for SME digitalisation, skills development, and public administration digitisation. In Italy, implementation continues under the Italia Digitale 2026 framework[78], largely financed through EU recovery funds and focused on deploying cloud, connectivity, and digital public services.

Figure 3 How is the scale of those funding programmes supporting advanced digital technologies at national level expected to evolve by 2028?

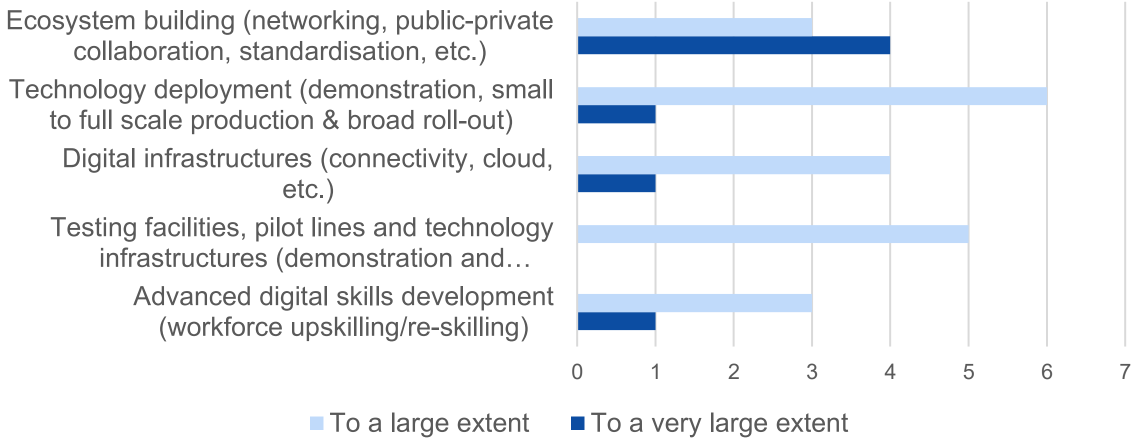


Source: Technopolis Group (2025) based on public sector survey on public investments, n=11, one response per MS: Austria, Bulgaria, Denmark, Germany, Greece, Hungary, Finland, Latvia, Luxembourg, Netherlands, Slovenia

As found by the public sector survey (although including a low response rate), **most national programmes address ecosystem building such as fostering networks, collaboration, public-private partnerships followed by technology deployment (demonstration, roll-out, support services promoting uptake).** Skills development is addressed to the least extent, indicating a gap between the recognised importance of this policy area and the funding currently available. However, it is important to note that initiatives related to advanced digital skills are often managed by ministries other than those for economy or research, which were the primary respondents to this survey. A related study on the 'Digitalisation of Business in the EU Member States'[79] found that most Member States have broad digitalisation strategies, but many still lack practical, business-oriented support, particularly for SMEs. Policy efforts increasingly promote **open data access, interoperability, and cloud adoption through pilot projects, national cloud initiatives, and cloud provider certification**. European Digital Innovation Hubs further support experimentation, skills development, and vendor matchmaking.

[75] https://www.polskacyfrowa.gov.pl/en/
[76] https://www.gov.pl/web/cyfryzacja/uslugi-cyfrowe-w-polsce-maja-byc-opodatkowane-na-rownych-zasadach
[77] https://espanadigital.gob.es/
[78] https://innovazione.gov.it/italia-digitale-2026/
[79] https://digital-strategy.ec.europa.eu/en/library/digital-decade-2025-digitalisation-business-eu-member-states

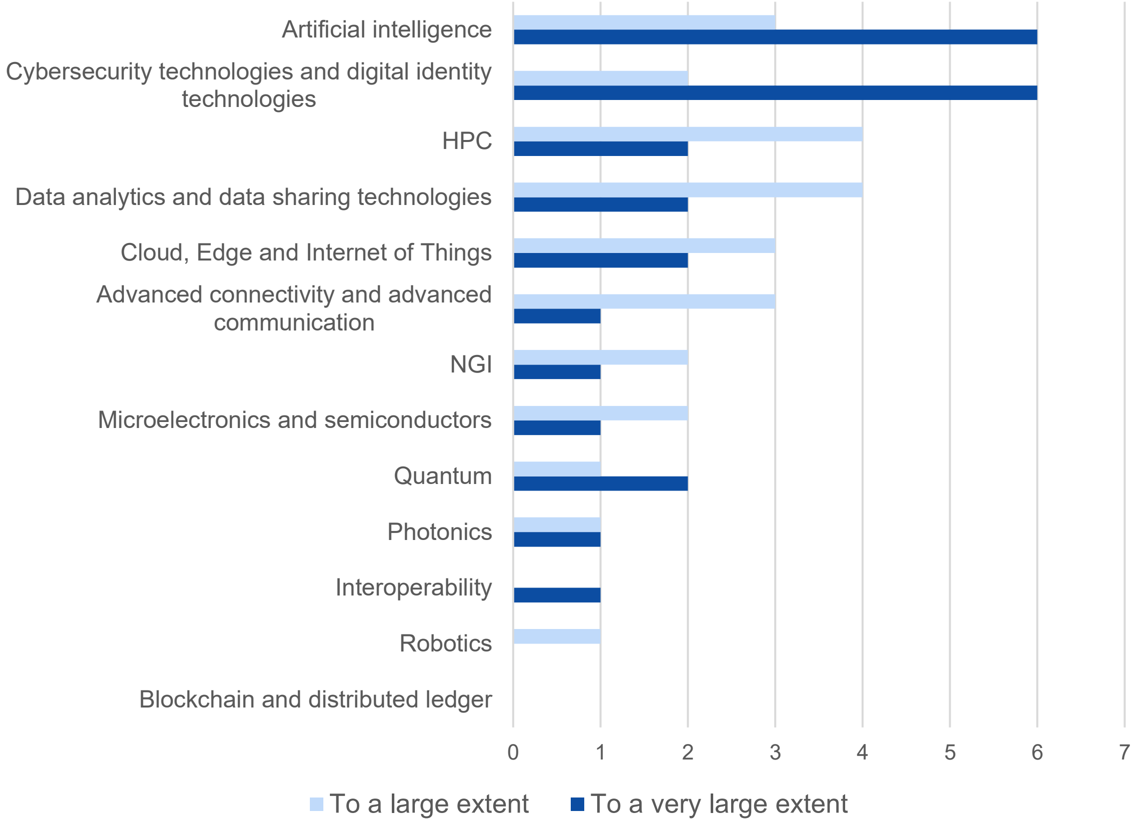
Figure 4 To what extent are these national programmes expected to provide the following types of support for the adoption/uptake of advanced digital technologies by 2028?



Source: Technopolis Group (2025) based on public sector survey on public investments, n=21 (input from 21 different EU MS, Austria, Belgium, Bulgaria, Croatia, Denmark, Finland, France, Germany, Greece, Hungary, Italy, Ireland, Latvia, Lithuania, Luxembourg, Netherlands, Portugal, Romania, Slovakia, Slovenia, Sweden)

National programmes target most the deployment of Artificial Intelligence and Cybersecurity technologies to a very large or large extent in line with strategic priorities, although the low response rate to the survey has to be noted when interpreting these results. As found by the study on digitalisation of business, most Member States have introduced national AI strategies or integrated AI into wider digitalisation plans, offering grants for AI R&D, public-private testing partnerships, regulatory sandboxes, and skills programmes. However, their impact is hindered by persistent structural challenges, including talent shortages, fragmented data ecosystems, and limited access to high-performance computing. Blockchain technologies have not been identified as particularly in scope. Interoperability is a technology area that despite its importance has been selected only by one respondent as targeted to a very large extent. Some national programmes are open and the thematic foci are defined by the project beneficiaries (such as for example the annual calls of K-PASS and FORTE in Austria).

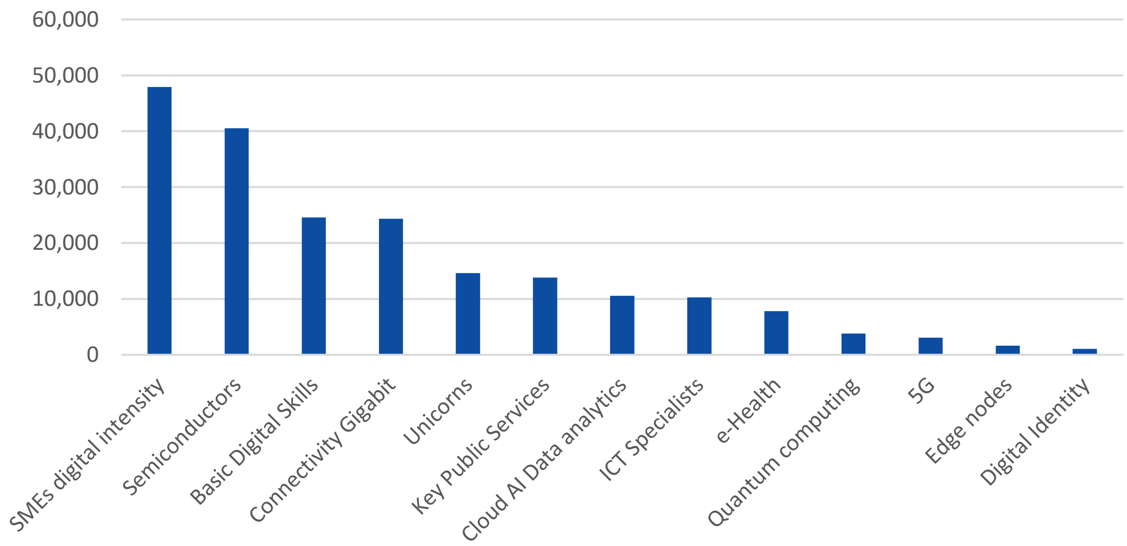
Figure 5 To what extent are these national programmes expected to support the adoption/uptake of these advanced digital technologies by 2028?



Source: Technopolis Group (2025) based on public sector survey on public investments, (input from 15 different EU MS, Austria, Bulgaria, Croatia, Denmark, Finland, Germany, Greece, Hungary, Italy, Luxembourg, Latvia, Netherlands, Romania, Slovenia, Sweden)

The review of the national digital decade roadmaps and national digitalisation strategies also show that **semiconductors and advanced connectivity** are among the technology areas with the highest level of funding.

Figure 6 Public budget dedicated to measures in the national digital roadmaps (in € million)



Source: National Digital Decade strategic roadmaps - https://digital-strategy.ec.europa.eu/en/policies/national-strategic-roadmaps

Regarding the concrete actions, the digital decade national roadmaps include tens of initiatives or even more (in the case of Spain 67 or Germany 50 measures) **, which underlines Member States' focus on support for the further deployment of more basic digital technologies** whereby the great majority of public bodies, businesses or citizens are benefiting from the transition. There are fewer initiatives concerned with the early deployment of advanced digital technologies, which suggests this remains an important area where EU and multi-country projects have an important role to play.

The text box presents a selection of examples of the types of initiatives being implemented by Member States.

Box 2 Examples of national-level funding to support the adoption of selected critical digital technologies

Austria. The Quantum Austria initiative, launched in 2021, with €107 m in funding by the RRF, aims to boost research in quantum sciences, quantum computing and high-performance computing.[80]

Belgium. As part of its Digital Decade strategic roadmap (2023–2030), Belgium has allocated a budget of ~€913.7 m to a suite of 166 measures spanning digital infrastructure, skills, cybersecurity, business digitalisation, and e-government services.[81]

Bulgaria. Under its Recovery and Resilience Plan, Bulgaria is investing €297 m from 2021 to 2026 to modernise public administration, expand digital services, and strengthen national cybersecurity capacity, thereby supporting the digitalisation of both government and business.[82]

Croatia. Under its Recovery and Resilience Plan, Croatia is investing €130 m between 2021 and 2026 to expand gigabit broadband and roll out 5G networks as part of its digital transition.

Cyprus. Cyprus has launched a €10 m programme (2021–2026) to upgrade connectivity so that internet access becomes "gigabit-ready," with the first €3.5 m call already boosting ultrafast broadband uptake.

Czechia. ROBOPROX, a Czech programme of ~€18.3 m running from 2023 to 2028, aims to develop and strengthen R&I capacities in robotics and advanced industrial production.[83]

Denmark. The National Strategy for Quantum Technology, adopted in 2023, allocates DKK 1.2 bn (~€160 m) through 2027 to reinforce Denmark's global position in quantum computing, quantum communication, and quantum security, combining large-scale research funding with targeted commercialisation support.[84]

Estonia. The Digital Transformation Grant (Digipöörde toetus) has a total budget of €56.5 m (until funding is exhausted) and runs until the end of 2025, financing projects that help enterprises adopt automation, digital and robotics technologies to improve efficiency and competitiveness.[85]

Finland. The Competitive Edge project (2022-2024), funded by Business Finland through the Recovery and Resilience Facility, provided a budget of over €230 m to support R&D in edge computing.[86]

France. The 'Plan Quantique', a €1 bn programme for the period 2021-2025, aims to exploit the second quantum revolution and targets all quantum technologies, including sensors, communication and cryptography[87].

[80] EC, Quantum Austria – Promotion of quantum sciences, Online
[81] EC (2025), State of the Digital Decade 2025 report – Belgium short country report, Online
[82] EC, Bulgaria's recovery and resilience plan, Online
[83] ROBOPROX, Online
[84] The Danish Government (2023), National strategy for quantum technology, Online
[85] Invest in Estonia, Incentives, Online
[86] Business Finland (2025), Nokia's Veturi project strengthened the position of Finnish companies as pioneers in edge computing, Online
[87] France 2030, La Stratégie Nationale Quantique, Online

Germany. The Quantum Technologies Programme, launched in 2023 with €2 bn in funding, aims to establish Germany as a world leader in quantum technologies.[88] The 5G Innovation Programme provides €66 m to fund the introduction of 5G.[89]

Greece. The Interoperability and Web Services Development measure (4A04M), funded with €27.9 m from the RRF for 2022–2025, focuses on upgrading public-sector systems with interoperability frameworks, APIs, and secure data-exchange platforms to enable seamless communication between registries and services.[90]

Hungary. The GINOP Plusz-3.2.1 Modern Business Programme, with a budget of €180 m for 2021–2026, finances SME digitalisation projects and promotes the uptake of AI, cloud services, big data, cybersecurity, and Industry 4.0 solutions to raise productivity and competitiveness.[91]

Ireland. The Open Data Strategy 2023-2027 aims to establish easy access to high-quality government data in order to promote trust and stimulate innovation via the public service's open data platform, while strengthening data publishing, platform services, and user engagement across sectors,[92]

Italy. The AI fund with a budget of €1 bn, and as part of the Italian Strategy for AI 2024-2026, aims to support the development of AI, through for instance providing funding for technology transfer from research to market and scale up for mature companies.[93] As in many other Member States, the RRF Plan of Italy supports the digitisation of Italian cultural heritage and provision of access to cultural resources and digital services. The Italian Strategy for Quantum Technologies[94] launched in 2025 aims to enhance research, promote industrial innovation and strengthen technological skills. Italy also has several other initiatives on HPC, for example the Italian Research Centre on HPC, Big Data and Quantum Computing is dedicated to this strategic area.

Latvia. The Cybersecurity Strategy of Latvia 2023-2026 allocates €20.5 m to enhance cybersecurity systems of businesses, SMEs and public sector organisations.[95]

Lithuania. The State Digitisation Development Programme 2021–2030 has a budget of €449.7 m and runs until 2030, financing projects that expand digital infrastructure, strengthen digital public services, support business digitalisation, and develop digital skills across sectors.[96]

Luxembourg. The Accelerating Digital Sovereignty 2030 initiative provides €100 m for flagship projects in AI, data, and quantum technologies, with the aim of strengthening Luxembourg's digital sovereignty through new infrastructure, advanced R&D, and cross-sector collaboration.[97]

Malta. The Digital Technologies Programme[98] is led by the Maltese agency Xjenza Malta, and supports capacity-building efforts related to AI, digital trust, knowledge and data, representation and analysis, technology for sustainability, quantum computing and other emerging technologies. The capacity-building efforts are aimed at researchers, but also entrepreneurs and organisations involved in these emerging technologies.

Netherlands. The National Technology Strategy, adopted in 2024 with goals extending to 2035, supports funding and policy-measures for ten priority key enabling technologies (such as AI, optical systems, semiconductor technologies, and cybersecurity) with the aim of boosting economic growth, international competitiveness, resilience, and reducing strategic dependencies.[99]

Poland. The Artificial Intelligence Fund, announced in 2025 and with an approximate budget of €230 m, aims to foster the development of technologies such as the Polish Large Language Model (PLLuM) and the application of AI in sectors such as healthcare and defence.[100]

[88] Bundesministerium für Bildung und Forschung, Handlungskonzept Quantentechnologien, Online
[89] Federal Ministry of Transport (2021), 5G Innovation Programme, Online
[90] Ministry of Digital Governance (2024), The Greek national digital dedcade strategic roadmap, Online
[91] Cabinet Office of the Prime Minister (2024), National Digitalisation Strategy 2022-2030, Online
[92] The Open Data Unit, Open Data Strategy 2023-2027, Online
[93] Reuters (2024), Italy to set up AI fund of 1 billion euros, PM says, Online
[94] See here: https://www.mur.gov.it/sites/default/files/2025-09/Strategia_italiana_tecnologie_quantistiche_ENG.pdf
[95] Online
[96] Digital Skills & Jobs Platform (2022), Lithuania – State Digitisation Development Programme 2021-2030, Online
[97] The Luxembourg Government, The strategic initiative "Accelerating digital sovereignty 2030", Online
[98] Xjenza Malta available at https://xjenzamalta.mt/2025/04/07/digital-technologies-programme-2025/
[99] Ministry of Economic Affairs and Climate Policy (2024), National Technology Strategy, Online
[100] Dudkowiak & Putyra (2025), Poland invests in innovation – the establishment of the Artificial Intelligence Fund, Online

Portugal. The Microelectronics Agenda, running from 2022 to 2025 with a budget of €67.5 m, invests in R&D, skills, and industrialisation to strengthen Portugal's capacity in semiconductors, chip design, and advanced microelectronics.[101]

Romania. Through its Recovery and Resilience Plan, Romania is allocating €1.4 bn between 2021 and 2026 to digitise public administration, focusing on cloud platforms, interoperability, secure eID/e-signature, and enhanced cybersecurity.[102]

Slovakia. Through its Recovery and Resilience Plan (2023–2026), Slovakia is investing €45 m in national high-performance computing infrastructure to strengthen research and industrial deployment of AI, data analytics, and HPC applications.[103]

Slovenia. Under its Recovery and Resilience Plan (2021–2026), Slovenia has allocated €50 m to support the digital transformation of businesses, funding the adoption of advanced digital technologies to improve competitiveness.[104]

Spain. The AI strategy, launched in 2024 with an approximate budget of €2.1 bn, includes plans to support SMEs integrate AI solutions and products, as well as improve the performance of Spanish supercomputer 'Marenostrum' and facilitate its access to industry.[105]

Sweden. Vinnova, the Swedish innovation agency, provided funding in 2024 for the development of advanced solutions in AI with a budget of ~€4.6 m[106].

Source: Technopolis Group (2025) based on desk research

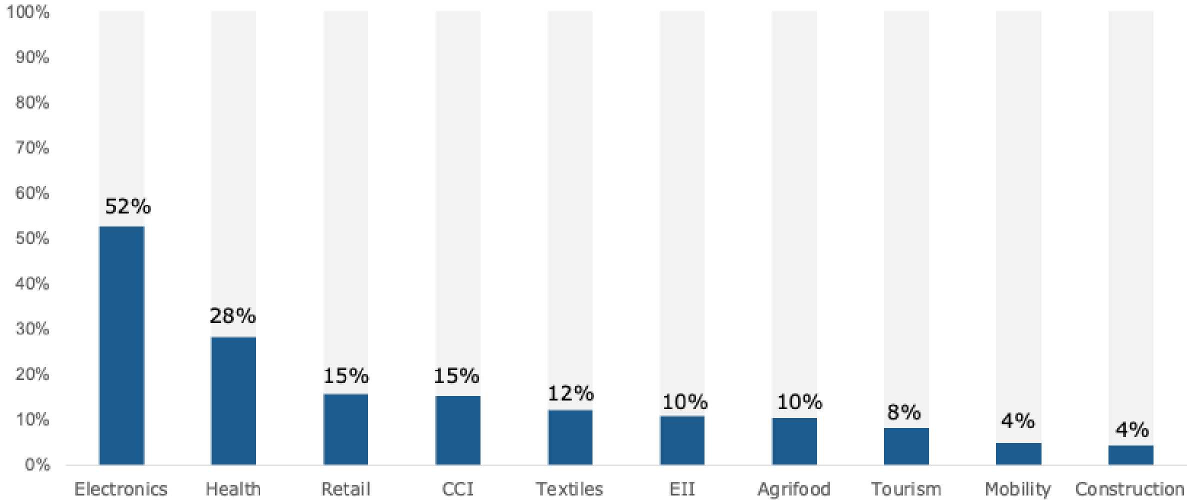
1.3.4 Regional programmes for the deployment of digital technologies

The European Regional Development Fund (ERDF) is perceived as highly relevant for supporting the digitalisation of the economy and has been given high importance in the public sector survey with respondents indicating it 'to a very large or large extent' relevant for deployment[107]. Indeed, the **ERDF plays a key role in supporting the deployment of digital technologies across EU regions, particularly by addressing regional disparities and strengthening economic and social cohesion**. According to the analysis of the Joint Research Centre, 10% of the Cohesion Policy (2021-2027) funding which includes the ERDF but also the ESF+, and JTF, contributed to Digital Decade targets in this period.

Funding distribution of ERDF across industrial ecosystems has been analysed as part of the EU report of the European Monitor of Industrial Ecosystems in 2024[108]. The analysis of ERDF data reveals varying levels of commitment to the digital transition across EU industries, with distinct trends in each sector. Electronics stands out with 52.6% of the ERDF co-funding dedicated to digital transition, the highest among all industries, which is also due to the nature of this industry closely related to digitalisation. This figure underscores the strategic importance of electronics as a foundational element in the digital economy, with €2.7 bn invested into projects with a digital component. Health, retail and the cultural and creative industries follow with an allocation of 28%, 15% and 15% dedicated to the digital transition. ERDF supported the least the digital transformation in construction, mobility and tourism in terms of the share in all types of projects. The Figure below provides a full overview.

[101] Micro-electronics, Online
[102] EC, Romania's recovery and resilience plan, Online
[103] Ministry of Investments, Regional Development and Informatization (2023), National digital decade strategic roadmap of the Slovak Republic, Online
[104] EC, Slovenia's recovery and resilience plan, Online
[105] Ministry for the Digital Transformation and the Civil Service, 2024 Artificial Intelligence Strategy, Online
[106] Vinnova, AI for advanced digitalization 2024, Online
[107] It has to be noted though that the public sector survey on investments had a low response rate and cannot be considered as fully representative, in particular for this question.
[108] https://monitor-industrial-ecosystems.ec.europa.eu/ and https://ec.europa.eu/commission/presscorner/detail/en/ip_25_335

Figure 7 ERDF funding dedicated to the digital transition of industrial ecosystems



Source: Technopolis Group based on Kohesio data, European Monitor of Industrial Ecosystems

Across Europe, regional initiatives play a key role in driving digital transformation, complementing national and EU-level strategies with targeted investments tailored to local strengths and needs. Many regions focus on supporting SMEs, innovation ecosystems, and emerging technologies through grants, infrastructure development, and strategic programmes. Examples include cybersecurity support schemes, AI innovation hubs, digitalisation vouchers, and large-scale ecosystem investments. The following cases illustrate diverse regional approaches to digital investment.

Box 3 Examples of regional-level funding to support the digital transition

Austria (Styria). In Styria the Cyber!Sicher programme offers grants (ongoing since 2019) for SMEs to boost cybersecurity through consulting, investment, and training, typically offering up to €15,000 per project.[109]

Belgium (Flanders). The Flanders Policy Plan Cybersecurity, launched in 2019 and extended in 2024, operates an annual budget of €15m and promotes cybersecurity research and the use of cybersecurity solutions by businesses.[110]

Czechia (Ústí Region). Under the Just Transition Programme 2021–2027, the Ústí Region provides Digital Vouchers for SMEs, covering up to 80% of eligible costs with grants ranging from CZK 50,000 to CZK 500,000 to support digitalisation projects.[111][112]

Germany (Baden-Württemberg). The AI Innovation Park in Heilbronn received €50 m (from 2023) to build regional strengths in AI research, start-ups, and applied use cases.[113][114]

Netherlands (North Brabant). Through Project Beethoven (2024–2030), national and regional authorities are investing €2.51 bn to reinforce the Brainport ecosystem, backing education, talent, housing and infrastructure for the semiconductor/chip-equipment industry.[115]

Spain (Community of Madrid). GovtechLab Madrid operates with an annual €155 000 budget to run open-innovation challenges and technical assistance that connect public needs with digital/GovTech and AI solutions from start-ups and SMEs.[116]

[109] Cyber-solutions, Funding for digitalization in Austria, Online
[110] EC (2025), Study on Digitalisation of Business in the EU Member States: Initiatives, Impacts and Contribution to the Digital Decade – Belgium, 2024 Report, Online
[111] Ústí Region, Business, Online
[112] Support to the implementation of the Just Transition in the Czech Republic, Online
[113] Wirtschaft digital, IPAI – Innovation Park AI Baden-Württemberg, Online
[114] IPAI, A vision takes form: IPAI presnts next development stage of the IPAI campus, Online
[115] Brainport Eindhoven (2024), State and region put 2.5 billion euros into public facilities in Brainport Eindhoven and national talent plan for growth of national chip industry, Online
[116] EIPA, Madrid Govtech, Online

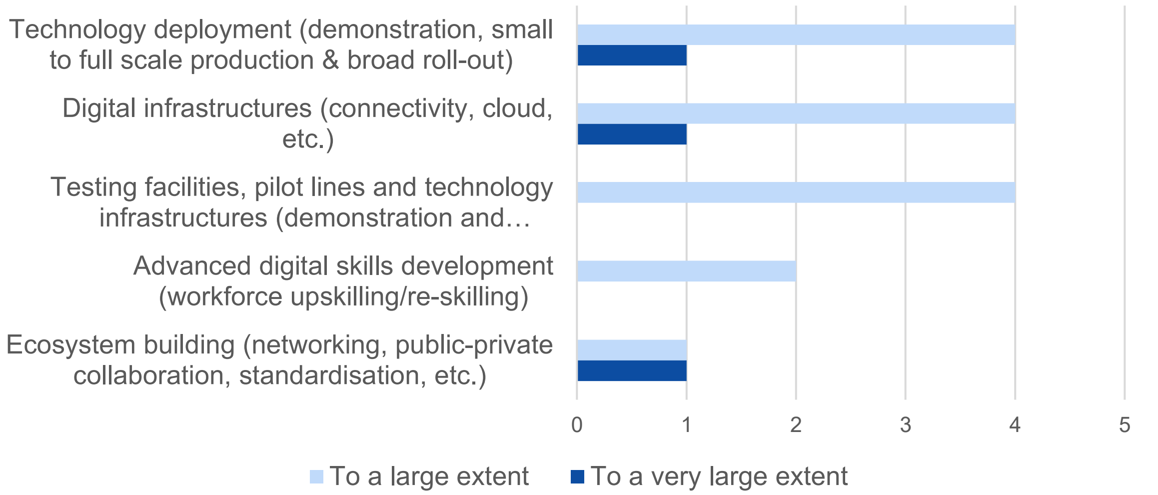
Sweden (Västra Götaland). AI Sweden, headquartered in Gothenburg and co-funded by Västra Götalandsregionen and ERDF partners, benefited from ~€9 m (2020–2024) from Vinnova to scale applied AI across sectors.[117][118]

Romania (North-East Region). The eDIH – Digital Innovation Zone (eDIH-DIZ), launched in 2022, has a budget of €4 m, for the period 2022-2025 (approx.), and helps SMEs and public health institutions adopt AI and other key enabling technologies in the manufacturing and smart health sectors.[119]

Source: Technopolis Group (2025) based on desk research

Within EU programmes implemented at national level, support for technology deployment and digital infrastructure is generally the strongest area of focus. This is reflected in the results of the public sector investment survey and confirmed by desk research on digitalisation programmes. By contrast, EU programmes implemented at national level place less emphasis on ecosystem building.

Figure 8 To what extent are these EU programmes implemented at national level expected to provide the following types of support for the adoption/uptake of advanced digital technologies by 2028?



Source: Technopolis Group (2025) based on public sector survey on public investments, n=21, (input from 21 different EU MS, Austria, Belgium, Bulgaria, Croatia, Denmark, Finland, France, Germany, Greece, Hungary, Italy, Ireland, Latvia, Lithuania, Luxembourg, Netherlands, Portugal, Romania, Slovakia, Slovenia, Sweden)

1.3.5 Synergies between EU and national level programmes

Blended EU-, national-, regional-, and private-funding is seen essential to scale pilots, sustain operations, and achieve real-world impact, particularly in strategic areas such as AI, Quantum, or HPC. At the same time, the lack of harmonised support structures across Member States risks creating uneven opportunities and deepening gaps in digital transformation.

The stakeholder consultation found that in order to maximise impact, 74% of respondents think that a future EU programme supporting the deployment/adoption of digital technologies should further strengthen synergies with national funding schemes. Public sector representatives noted that the EU could place greater emphasis on providing funding that complements national programmes more effectively. This could be done by putting in place more mechanisms for exchange and coordination and alignment of timelines.

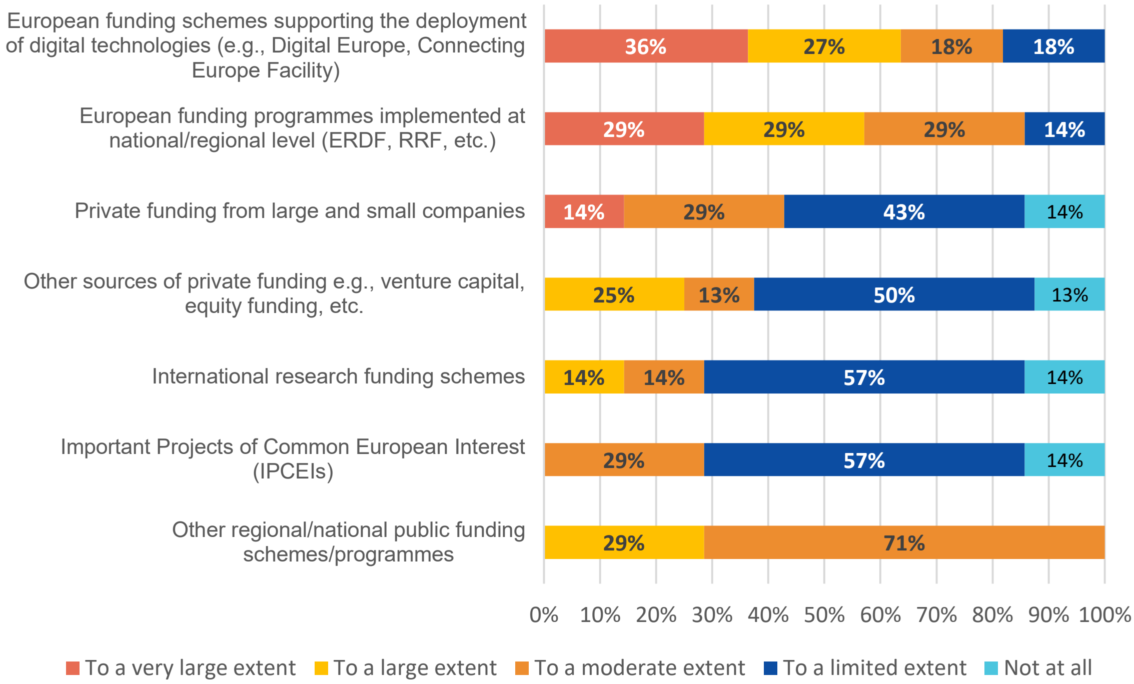
The perception is that synergies are already well in place between national programmes and European funding schemes in support of the deployment of digital

[117] AI Sweden, About, Online
[118] Vinnova, Artificial Intelligence, Online
[119] Digital-Innovation Zone, EDIH-DIZ: The digitalization initiative for SMEs in the manufacturing and healthcare sectors, Online

technologies (such as DIGITAL and CEF Digital). Synergies with EU funding programmes implemented at national or regional level (such as the ERDF and the RRF) are also present but to a lesser extent.

On the other hand, some stakeholders also pointed out that the decision of the European Commission to discontinue the use of the Recovery and Resilience Facility (RRF) funds in combination with Digital Europe projects limits the availability of complementary financing sources, which has had an impact on some deployment areas.

Figure 9 In your experience, to what extent are there synergies between these national programmes supporting advanced digital technologies with the following additional funding sources, for the adoption/uptake of digital technologies?



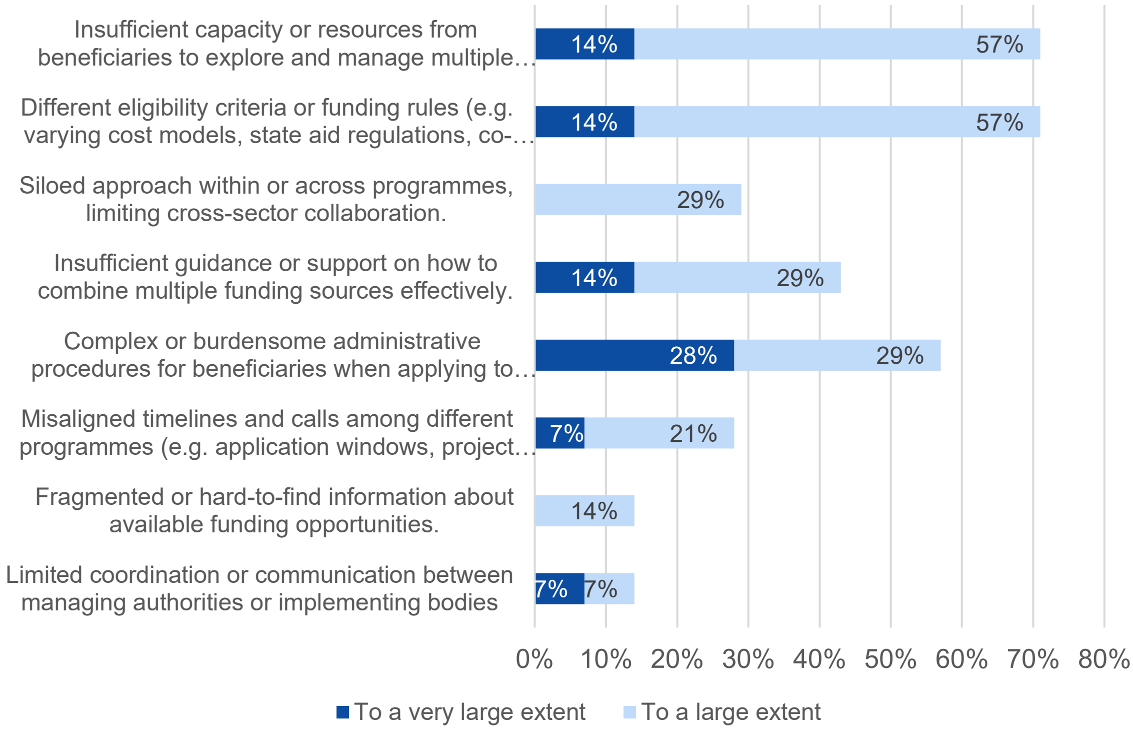
Source: Technopolis Group (2025) based on public sector survey on public investments, n=21, (input from 21 different EU MS, Austria, Belgium, Bulgaria, Croatia, Denmark, Finland, France, Germany, Greece, Hungary, Italy, Ireland, Latvia, Lithuania, Luxembourg, Netherlands, Portugal, Romania, Slovakia, Slovenia, Sweden)

Several examples demonstrate the importance of synergies. For example, co-funding models, such as the Dutch national top-ups for DIGITAL projects or the blending of funding between EU programmes and Spanish regional schemes (Basque Country) have successfully attracted companies that might not otherwise participate, especially SMEs, and fostered the adoption of critical digital technologies. In these schemes, the DIGITAL programme covers part of the project costs, while the national programme fills the gap, ensuring that projects receive sufficient funding for effective implementation. In contrast, some stakeholders also highlighted that sometimes Member States struggle to provide complementary national support.

Several stakeholders noted that projects relying solely on public funding often find it difficult to maintain long-term sustainability once the funding ends. Introducing venture capital or private investment earlier in the project lifecycle is seen as a potential way to address this, ensuring that only commercially viable innovations move forward.

Insufficient capacity or resources from beneficiaries to explore and manage multiple funding sources and different eligibility criteria or funding rules (e.g. varying cost models, state aid regulations, co-funding rates) **are considered as the two most important limiting factors** that hinder the combination of funding between national programmes and other funding sources. To a less degree the coordination or communication between managing authorities or implementing bodies are sometimes limited or information is fragmented and hard to find.

Figure 10 From your p-erspective, to what extent do the following factors limit the possibilities to simultaneously combine funding between national programmes and other funding sources (co-funding mechanism)?



Source: Technopolis Group (2025) based on public sector survey on public investments, n=21, (input from 21 different EU MS, Austria, Belgium, Bulgaria, Croatia, Denmark, Finland, France, Germany, Greece, Hungary, Italy, Ireland, Latvia, Lithuania, Luxembourg, Netherlands, Portugal, Romania, Slovakia, Slovenia, Sweden)

2. Market context and state of play

The European digital technology landscape is undergoing profound change, driven by rapid advances in areas such as Artificial Intelligence, cloud, and data infrastructure. These developments are fostering a **wave of new digital applications and experimentation with the aim to increasing innovation, competitiveness and societal value across** sectors, industries, Member States and regions. At the same time, Europe faces growing pressures, as global rivals such as the US and China but also other competitors invest heavily to secure technological leadership.

2.1 European digital tech start-ups driving adoption

The European start-up landscape that is underpinning technology deployment has shown remarkable progress over the past decade, marked by a strong rise in entrepreneurship and increased mobilisation of venture capital. The EU digital start-up landscape is performing well, and digital tech start-up creation has accelerated significantly in the EU as shown by various metrics. The cumulative number of start-ups, notably the total number of start-ups founded up to 2025 has been 3 times higher than in 2015. The pool of talented entrepreneurs has expanded, and their aspirations have grown. Europe's next challenges revolve first of all around accelerating the scaling of tech start-ups and fostering their **growth-stage, coupled with a stronger market and demand focus**. Secondly, **early-stage funding should simultaneously be maintained** to secure a strong pipeline of future start-ups amid the global recalibration in financing.

In 2025, the EU boasted 20,720 advanced digital tech start-ups[120], out of which 728 scaled up[121] (3.5%) and are still operational and 40 reached the unicorn status (0.2%) as demonstrated by the calculations carried out for this study. The definitions of technology areas, scaleups and unicorns also follow the scoping of the technologies as presented in the technology annexes.

Table 5 Number of digital tech start-ups, scaleups and unicorns in 2025

Technology	Startups	Scaleups	Unicorns	Total
Data analytics	6,272	260	7	6,539
Cloud-Edge-IoT	5,205	220	9	5,434
Artificial Intelligence	5,037	**305**	**15**	5,357
Blockchain	2,738	121	3	2,862
Cybersecurity	2,176	95	1	2,272
NGI	1,360	51	0	1,411
Robotics	944	58	2	1,004
Advanced connectivity	582	27	7	616
HPC	422	38	6	466
Photonics	186	29	1	216
Microelectronics	130	40	3	173
Quantum technologies	94	24	2	120
Total (removing duplications)	19,952	728	40	20,720

Source: Technopolis Group (2025) based on Crunchbase

[120] For this analysis, start-ups are defined as established after 2015, the analysis takes into account the 12 advanced digital technologies in the focus of this study excluding interoperability since related technologies are included under other fields such as data and cannot be captured via specialised start-ups in the field

[121] Scaleups are defined as young fast-growing companies 10 years old or younger that have received at least €10 million in investment within the past 10 years.

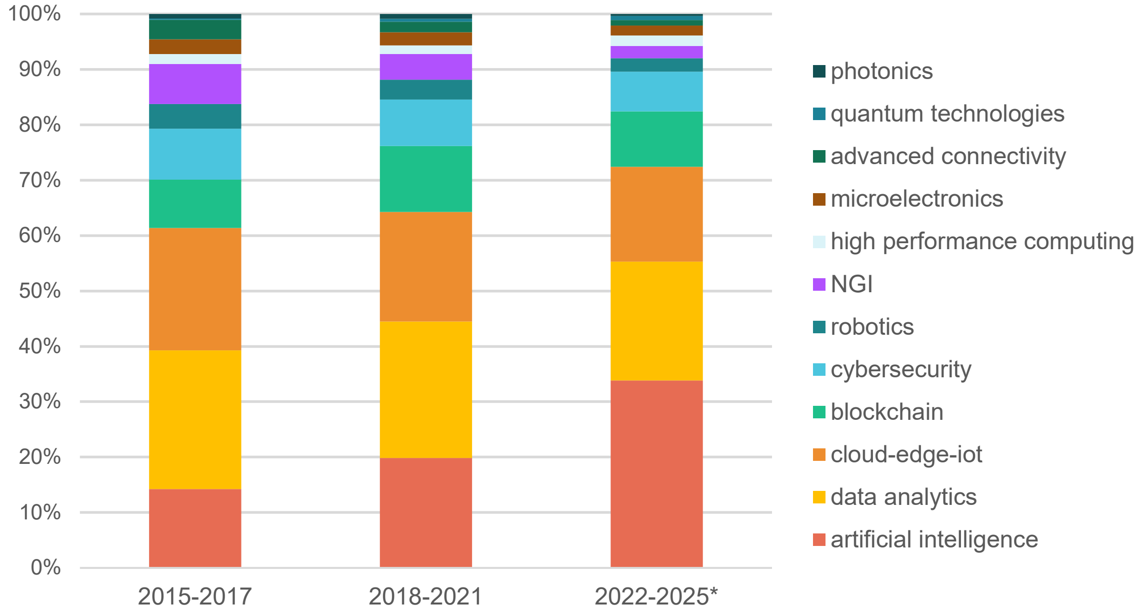
Other reports mention 35,000 early-stage companies active in Europe[122] and talk about even 58,000[123] tech start-ups, however, these estimations include the UK and other European but non-EU countries, moreover, other technologies, for example biotech, which are not covered in this study.

All these figures show a vibrant digital start-up ecosystem in Europe, in particular remarkable growth in the number of start-ups since 2010. The population of early-stage companies in Europe has expanded significantly, rising more than fourfold over the period of 2010-2024. This growth reflects also the emergence of a large and diverse talent pool with an estimated 50 000 entrepreneurs that Europe nurtures and more and more retains. The European startup ecosystem is demonstrating growing ambition, with a rising number of entrepreneurs pursuing global markets, and high-impact innovation[124]. As it was also highlighted in the EU start-up and scaleup strategy[125], Europe outpaced the United States in the creation of new technology start-ups between 2018 and 2023, with an annual average of approximately 15,200 firms compared to 13,700 in the US. The growth is driven by the European talent pool of 3.5 million technology specialists and professionals, recording a 24% annual growth rate on par with that of the United States[126].

The distribution of digital tech start-ups per 3 year period resulted in some shifts. In particular, AI tech start-ups increased their relevance (see Figure below). Over the period of 2015-2025, most of the digital tech start-ups were active in the field of data analytics (6,539). The next largest clusters of start-ups were in Cloud-to-Edge-to-IoT (5,434) and AI (5,357). However, the 3-year comparison shows that AI has gained the most prominence, while Cloud-Edge-IoT decreased and Data Analytics maintained its relative position. More narrowly specialised fields and novel technologies such as Quantum (120), HPC (466) and Photonics (216) remain smaller in absolute terms, reflecting the relatively larger distance to market in these technology areas. The number of Microelectronics start-ups is also lower compared to other technology areas, given its capital intensity, long development cycles, dependence on incumbents, and investor reluctance.

[122] Atomico (2024), State of the European Tech 2024
[123] https://www.start-upblink.com/blog/united-states-vs-europe-start-up-ecosystems-in-2025/
[124] See also the analysis of Crunchbase: https://news.crunchbase.com/venture/europe-most-ambitious-global-startups-mignot-index/ and here: https://www.indexventures.com/perspectives/europes-most-ambitious-startups-arent-becoming-global-theyre-starting-that-way/ and https://www.eurostartentreprises.com/en/business-advice/why-the-european-startup-ecosystem-is-flourishing
[125] European Commission. (2025). The EU Start-up and Scaleup Strategy: Choose Europe to start and scale — Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions (COM(2025) 270 final).
[126] Ibid

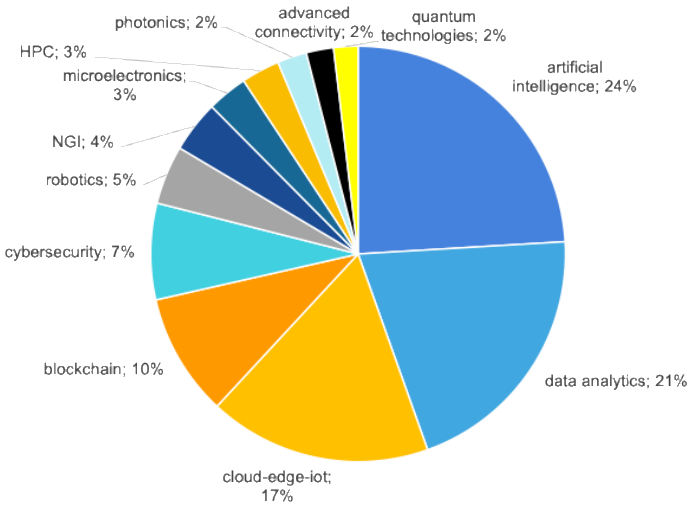
Figure 11 Distribution of digital tech start-ups per 3-year period in the EU



*Source: Technopolis Group (2025) based on Crunchbase Note: * 2025 was not yet a full year when data calculations were made for this report*

Scaling up, however, has proved to be more constrained even if it has also shown progress in the EU over the past years in particular in the field of AI and data. The figure below shows the distribution of digital tech scaleups across the different technology areas in the EU-27 active in 2025. The largest share of tech companies with a weight in the economy as demonstrated by their power to grow is concentrated in the area of Artificial Intelligence and Data analytics, while Quantum and Advanced Connectivity are on the lower end. In the case of NGI and XR, European start-ups often kick off in one or a handful of countries before expanding and this fragmentation makes it even harder for XR and NGI platforms (which typically need huge user bases) to scale fast.

Figure 12 Distribution of digital tech scaleups per technology area in the EU-27 in 2025



Source: Technopolis Group (2025) based on Crunchbase

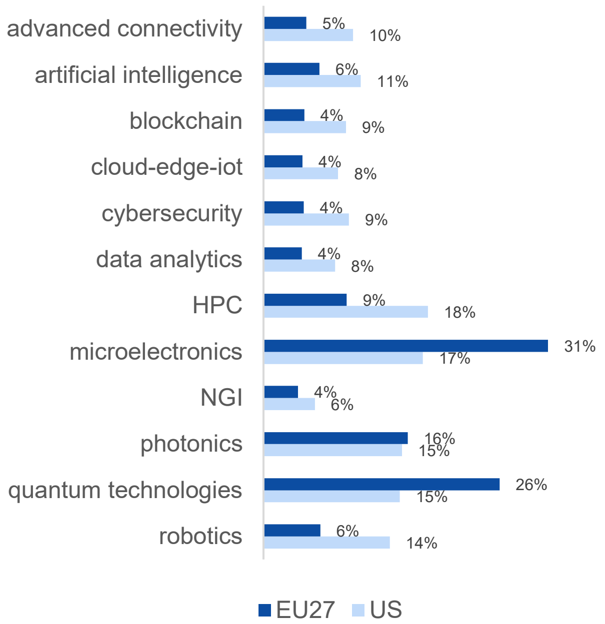
Despite the EU's progress, its digital tech start-up ecosystem still lags behind the US, due to lack of public funding and in part because of structural weaknesses in the European venture capital market and the limited role of pension funds in financing high-risk innovation[127]. According to Start-upBlink's 2025 Global Start-up Ecosystem Index[128], the US remains the top

[127] Arnold, Nathaniel and Claveres, Guillaume and Frie, Jan-Martin, Stepping Up Venture Capital to Finance Innovation in Europe. IMF Working Paper No. 2024/146, Available at SSRN: https://ssrn.com/abstract=4904562
[128] https://lp.start-upblink.com/report/

performer by a wide margin, dominating both in number and quality of ecosystems, number of start-ups, scaleups, unicorns and corporates involved in start-ups.

EU scaleups show a higher rate though than the US in the field of photonics, quantum and microelectronics when taking into account the ratio of scaleups and start-ups in each ecosystem.

Figure 13 Share of scaleups in the total number of start-ups per digital technology in 2025 in the EU and US



Source: Technopolis Group (2025) based on Crunchbase

As shown by the various success stories of American scaleups, the difference among European and US digital tech start-up ecosystems is not in start-up creation and not even simple scaling (given that many start-ups and scaleups fail even in the US), but the coupling of **venture capital with system-oriented strategies and clearer pathways for market adoption and technological leadership**. For example, Wayve[129], a US-based autonomous driving technology company, is backed by substantial venture capital, including over €1 bn raised in its 2024 Series C round, with strategic investments from Microsoft and NVIDIA. Its business model is highly system-oriented, focusing on developing autonomous driving software that can be integrated across diverse vehicle platforms and geographies, supported by robust infrastructure, regulatory compliance, and strategic partnerships. To accelerate market adoption, Wayve has pursued a clear deployment pathway through extensive trials, collaborations with established automotive and logistics firms, and significant scaling of its technology teams to address real-world operational challenges.

According to the estimates based on Crunchbase data, approximately 7% of EU AI startups (founded after 2015) have moved to the US[130] in order to better leverage relevant market scale**.** A related study concluded that around 5.1% of startups in a European sample move across borders with 85% of these relocations directed to the US[131]. Even if not moving to the US, European digital tech startups often create an office in the US. For example, key EU tech companies such as Mistral AI, Parloa, Quantum Systems employ approx. a quarter of their employees in the US. Analysing the top 50 AI tech start-ups and where they employ their workforce, it was found that while the **top 50 EU AI tech start-ups employ on average 14% of their workforce in the US,** it is only 5% in the case of the top US tech start-ups in the EU.

129 https://wayve.ai/press/series-c/
130 Technopolis Group based on Crunchbase data
131 Weik, Stefan & Achleitner, Ann-Kristin & Braun, Reiner, 2024. "Venture capital and the international relocation of startups," Research Policy, Elsevier, vol. 53(7).

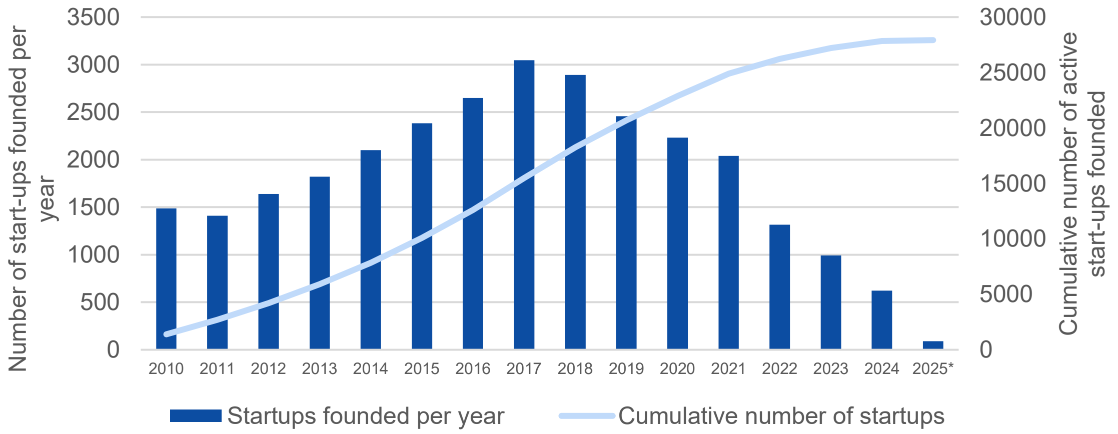
EU company founders cite easier access to funding, closeness to large, integrated markets, simpler regulatory frameworks, and the availability of seasoned commercial and sales talent as key drivers for relocation to the US, as highlighted in a recent study of the European Investment Bank[132].

The United States is widely seen as providing a more favourable environment for start-up growth. By contrast, the European Union is commonly perceived as fragmented, overly bureaucratic, and risk-averse, especially in its support for companies as they move beyond the early growth phase. Core issues are perceived as different national regulations, tax systems, stock option rules, and exit frameworks that make cross-border business and fundraising in the EU complex and inefficient[133].

On the other hand, some leading US tech start-ups also build a strong presence in Europe mainly for market reasons. Expansion is driven by access to large enterprise customers, regulatory and compliance needs (since they cannot supply the market given regulatory needs efficiently if not having an office in Europe), and the requirement for local operations in regulated and data-sensitive sectors such as finance, healthcare, industry, public services, and cloud infrastructure. Europe functions as a core commercial and operational market, not just an expansion outpost. Databricks[134] is one example as it has major operations in Europe as it is one of its largest enterprise markets, requiring local sales, engineering, compliance, and customer delivery teams to serve regulated industries and large industrial clients at scale.

The EU digital start-up landscape is performing well and digital tech start-up creation has accelerated significantly in the EU as shown by various metrics. The cumulative number of start-ups, notably the total number of start-ups founded up to 2025 has been 3 times higher than in 2015. The number of active start-ups in 2025 is roughly twice as high as in 2018, based on a comparison between the Crunchbase analysis conducted for this study and an earlier assessment. However, the number of new digital tech start-ups created each year has been slowing down after the boom over the period of 2010-2018. Strong ecosystems in cities such as Berlin, Paris, Amsterdam, and Stockholm nurture a concentration of digital tech companies, in particular in AI, data but also cybersecurity and blockchain.

Figure 14 Digital tech start-ups created over time in the EU-27



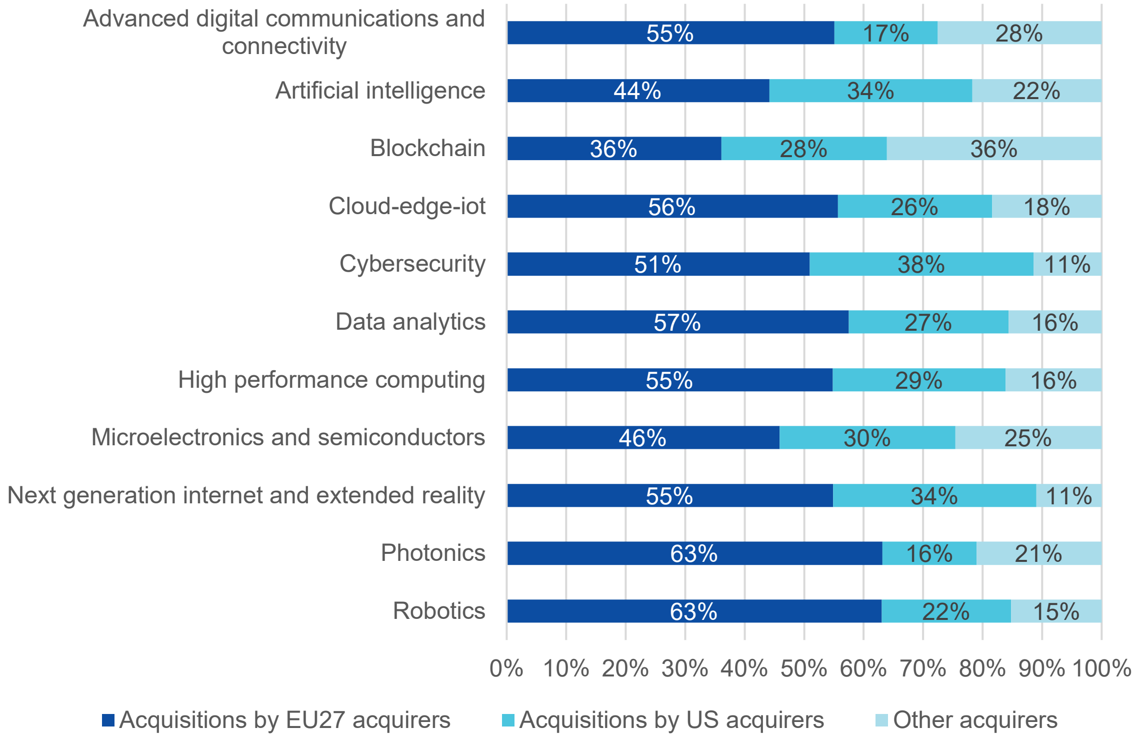
Source: Technopolis Group (2025) based on Crunchbase

Acquisitions are a common exit among startups that survive past early stages, but only a minority of all startups actually get acquired[135]. For startups, acquisition often represents a primary exit pathway, offering scale, capital, and global reach that would be difficult to achieve independently. The analysis in this study found that an average of 5% of tech start-ups founded after 2015 across the 12 technology areas monitored have been acquired. Interestingly, **the**

[132] European Investment Bank. (2026). Drivers of relocation by innovative EU startups and scaleups (ISBN 978-92-861-6061-5; DOI: 10.2867/0703470).
[133] See also the analysis here: https://cepa.org/article/across-the-pond-for-profits-european-startups-head-to-the-us/
[134] https://www.iamsterdam.com/en/business/key-sectors-for-business/tech-and-ai/stories/databricks
[135] Berger, M., Calligaris, S., Greppi, A., & Kirpichev, D. (2025). *Acquisitions and their effect on start-up innovation: Stifling or scaling?* (OECD Science, Technology and Industry Working Papers No. 2025/10). OECD Publishing. https://doi.org/10.1787/b4efd3ab-en

largest share of acquisitions (on average 53%) occurs within the EU, where both the acquirer and target are from the EU27. The second-largest share is attributed to the US, accounting for an average of 27% of acquisitions conducted by US-based acquirers.

Figure 15 Distribution of acquisitions of EU digital tech start-ups in terms of the origin of the acquirer



Source: Technopolis Group based on Crunchbase (2025) Note: there has been no acquisitions of start-ups identified in the case of quantum technologies

Besides monitoring the uptake of digital technologies, the profit margins generated by digital technology companies in the EU constitute another relevant indicator. They reflect whether these firms are able to commercialise such technologies profitably, thereby signalling a positive economic impact captured in the market.

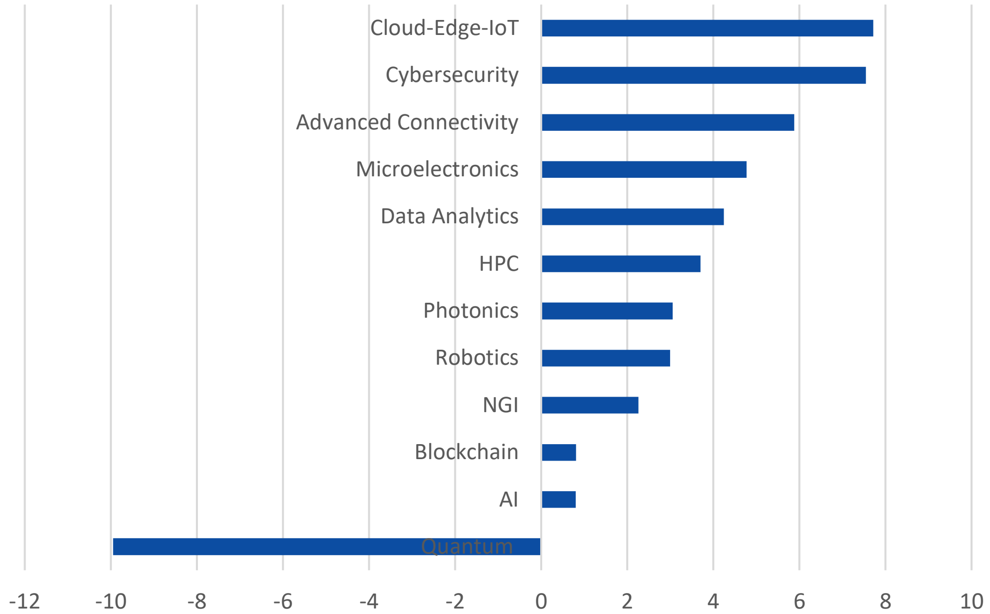
The indicator of profit margin shows how efficiently a company generates profit from its core business activities before interest and taxes. A positive value indicates operating profitability, while a negative percentage indicates an operating loss. **The analysis of profit margins of technology companies active across the technology areas in scope shows that while firms in cloud-edge-IoT have higher profit margins, companies in quantum report overall negative values. AI is also still at the end of the ranking.** As also highlighted in a recent Harvard Business Review[136], Artificial Intelligence companies today struggle to generate sustainable profits despite rapid technological progress and massive investment inflows.

The business models underpinning generative AI and related services are often unproven or economically fragile, with high infrastructure and operating costs (especially for compute and data centres) outpacing current revenue streams[137]. Despite massive global investment, AI is not yet a sustainable or profitable because its costs, especially for training and running models are extremely high while pricing power remains limited due to competition and user expectations for low-cost services[138].This situation raises important questions about long-term viability and whether continued capital subsidies and investor optimism can justify ongoing losses. While some observers suggest that focusing on user adoption and market growth rather than immediate profitability may be acceptable at this early stage of AI's evolution, the

[136] Kost, D. (2025). AI companies don't have a profitable business model. Does that matter? Harvard Business Review. https://hbr.org/2025/11/ai-companies-dont-have-a-profitable-business-model-does-that-matter
[137] Ibid
[138] https://www.theatlantic.com/economy/2025/12/nvidia-ai-financing-deals/685197/

core concern remains **whether there is a durable economic foundation that can support future profit generation**. Without clearer paths to sustainable revenue and value capture, the lack of profitability could undermine investment, slow innovation, and eventually trigger a shakeout of weaker firms, similar to historical technology cycles.

Figure 16 Average profit margin of EU tech start-ups/ tech companies in specific digital technologies in 2024 (%)



Source: Technopolis Group based on Orbis, Crunchbase and Glass.ai analysis (2025)

2.2 Uptake of critical digital technologies

The pace of digital technology deployment varies significantly not only across countries and sectors, but at more granular levels, particularly across EU regions and in sub-sectors affecting both Europe's digital-technology developers and those that apply these technologies. The uneven adoption of advanced digital technologies is undermining the productivity and competitiveness of certain industries and regions relative to the world's leading innovators. Various market and systemic failures are impeding diffusion, and giving rise to adverse social impacts, that justify targeted public intervention.

Building on the momentum generated by Europe's digital tech start-ups as discussed above, it is essential how these innovations are being adopted and applied across sectors of the economy. While start-ups often act as catalysts of change and introduce disruptive solutions, their impact ultimately depends on the extent to which different industries and the public sector integrate these technologies into their operations. In this process, Europe still has a long way to go.

SME's digital maturity continues to trail larger firms as Eurostat data demonstrate. As the market survey conducted in this study also indicates, **the main hurdles in digitalisation are particularly faced by micro and small companies, while medium-sized companies and midcaps in some cases outperform large and legacy players in advanced digital technology adoption**. In 2024, 73% of EU SMEs reached a basic level of digital intensity, which is around 20 percentage points below the EU 2030 target[139]. Moreover, the European digital ecosystem faces smaller and less dynamic domestic markets than many of their global counterparts, as also highlighted by the Digital Economy and Society Index (DESI)[140] of the European Commission.

[139] Eurostat (2025). Digitalisation in Europe – 2025 edition, https://ec.europa.eu/eurostat/web/interactive-%20publications/digitalisation-2025
[140] https://digital-strategy.ec.europa.eu/en/policies/desi

Based on the European Monitor of Industrial Ecosystems' market survey (Table 6), 2024 has witnessed a leap forward in the rate of adoption of several advanced digital technologies, notably in aerospace and defence and electronics. Cloud technologies are the most widely adopted technologies across all ecosystems, followed by AI and the Internet of Things. Data on the use of digital technologies are also collected by Eurostat (see Table 6).

Artificial Intelligence has been adopted most in aerospace and defence, in cultural and creative industries (respectively in publishing and motion picture) **and in health/ pharmaceuticals** (see Tables below). The electronics industry is also among the adopters of AI, driven by automation, use in chip design and for quality control, predictive maintenance, and supply chain optimisation.

The adoption of **Robotics** is relevant in **manufacturing and proved to be high in aerospace, energy intensive industries, agri-food, in pharma** as captured by the European Monitor of Industrial Ecosystems. Robotics enhances precision manufacturing, maintenance, and inspection. Energy-intensive industries deploy robots to improve operational efficiency, reduce downtime, and support hazardous tasks. In agri-food, robotics is used in automated harvesting, processing, and quality control. Further details by the sectoral adoption trends of critical digital technologies are presented in Chapter 3.

Table 6 Adoption of advanced digital technologies in the EU economy – share of firms using this technology in 2024

	Artificial Intelligence	Robotics	Cloud	Big Data	Internet of Things	Augmented and virtual reality	Blockchain	Edge
Aerospace and Defence	44%	22%	44%	33%	33%	21%	0%	11%
Agri-Food	22%	20%	37%	13%	24%	3%	5%	7%
Cultural and Creative Industries	38%	5%	45%	17%	21%	15%	3%	7%
Construction	16%	9%	37%	15%	23%	14%	4%	5%
Electronics	37%	16%	47%	23%	41%	9%	6%	15%
Energy Intensive Industries	26%	19%	37%	16%	28%	4%	8%	7%
Health (pharmaceuticals and medical devices)	34%	19%	53%	19%	31%	2%	8%	10%
Mobility, Transport and Automotive	19%	15%	38%	19%	31%	5%	4%	6%
Retail	17%	6%	31%	11%	17%	1%	3%	4%
Social Economy	15%	4%	40%	6%	7%	0%	2%	2%
Textiles	26%	9%	33%	13%	21%	5%	5%	6%
Tourism	23%	3%	38%	11%	20%	8%	6%	4%

Source: Technopolis Group (2024) based on market CATI survey and the European Monitor of Industrial Ecosystems

Eurostat data shows more moderate use of AI technologies across sectors, however, with a similar prominence. Sophisticated **Cloud computing services** have the highest adoption rate in the pharmaceuticals industry, followed by the chemicals and electronics industry. **Data analytics** is the highest in pharma, chemicals and in publishing and motion picture.

Table 7 Use of digital technologies by enterprises in specific industries and sectors (latest available year)

Indicator	Food, beverage (C10-12)	Textiles (C13-15)	Chemicals (C20)	Pharma (C21)	Electrical equipment (C27-28)	Automotive (C29-30)	Construction (F)	Retail (G47)	Tourism (accommodation and food I)	Publishing, motion picture(J58-60)
Artificial Intelligence (enterprises use at least one of the AI technologies, 2025)	12%	12%	28%	41%	26%	24%	11%	15%	12%	56%
Artificial Intelligence (Enterprise AI technologies were developed by own employees, 2024)	1%	1%	3%	NA	3%	4%	1%	2%	1%	12%
Cloud services (enterprises buying sophisticated cloud computing services, 2025)	30%	36%	54%	71%	51%	48%	35%	32%	27%	64%
Data analytics (enterprise conducts data analytics using its own employees, 2025)	32%	29%	59%	70%	47%	47%	20%	30%	21%	54%
Robotics (Use of industrial or service robots, 2022)	10%	7%	17%	17%	22%	36%	3%	4%	2%	3%
Internet of Things (use of connected devices or systems that can be monitored or remotely controlled via the internet, 2021)	29%	20%	37%	42%	36%	32%	26%	29%	28%	31%
Cybersecurity (use of at least 7 ICT security measures, 2024)	27%	27%	57%	74%	52%	54%	26%	32%	19%	61%

Source: Eurostat, ICT Usage in Enterprises statistics, available here: https://ec.europa.eu/eurostat/web/digital-economy-and-society/database

Adoption rates of most digital technologies are broadly similar between EU and US firms, as found in a recent European Investment Bank survey[141], although there are sectoral differences. EU manufacturing firms lead in the use of big data/AI and robotics, while US firms show higher adoption of the Internet of Things in both services and infrastructure. Within the EU, manufacturing firms are most advanced in robotics and IoT, construction firms mainly adopt IoT and drones, and service and infrastructure firms primarily rely on digital platforms and IoT.

As suggested by the public survey results**, the most often adopted digital technology in the public sector was Artificial Intelligence** with a similar adoption pattern to private companies (23% of respondents participating in the public sector adoption survey indicated the use of this technology).

Examples include:

[141] European Investment Bank. (2025). EIB Investment Survey 2025: European Union overview (ISBN 978-92-861-6006-6). European Investment Bank.

- AI tools are used or being evaluated for automatic text classification, entity linking (both with encoder models) and as querying interfaces (decoder models).
- Public sector organisations support schools in deploying AI-based tools that tailor learning paths to individual student needs, helping bridge achievement gaps.
- Digital platforms, including AI assistants, simplify complex tasks like budget planning, personnel management, and policy tracking, increasing operational efficiency.
- With AI-powered data analytics, authorities can monitor educational outcomes, predict trends (e.g., school dropout risk), and make evidence-based policy decisions.
- Advanced tools such as emotion recognition and sentiment analysis software help identify at-risk students, enabling early interventions in coordination with local schools.

However, adoption is progressing more cautiously than in the private sector both in the EU and globally. In a public sector survey[142] conducted by SAS with 1 600 organisations (ministries, national and regional agencies, schools, administrations, etc.), it was observed that 44% already use GenAI, but governments show lower policy readiness, managerial understanding, and staff awareness than the private sector. Key barriers include data security and privacy concerns, governance challenges, cultural resistance to change, legacy IT integration issues, and shortages in specialised expertise.

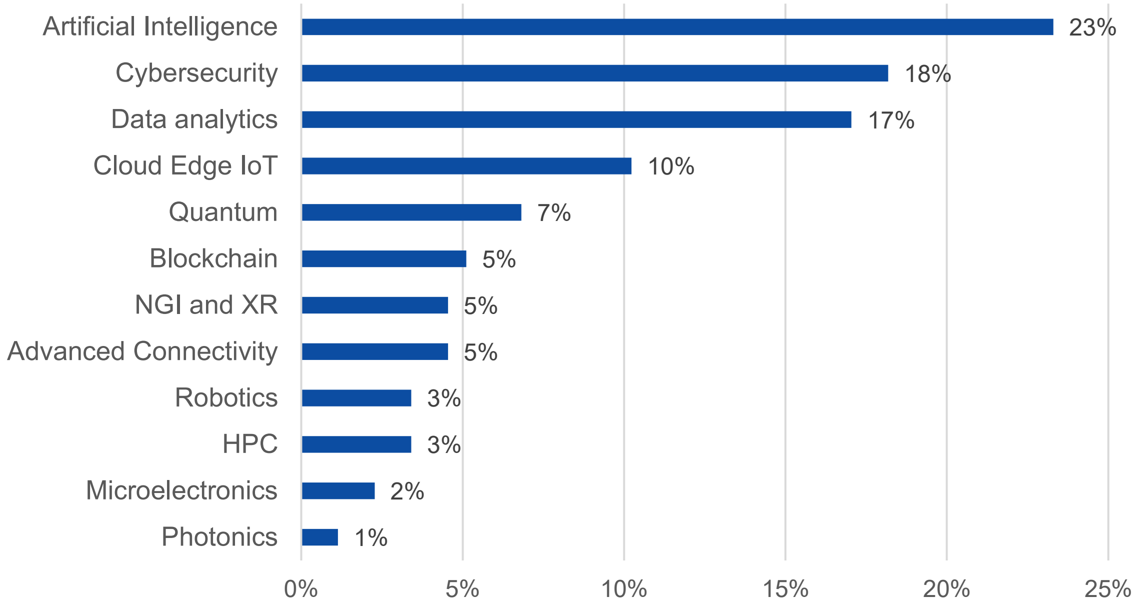
This was corroborated by the findings of the in the public sector survey conducted in the framework of this project (see Figure 17). **AI adoption was followed by Cybersecurity (18%)**, as ensuring a high level of digital security is essential to fully realise the benefits of public-service and public administration digitalisation. Strengthening cybersecurity capabilities is therefore critical to enable and safeguard this transformation. It is also a challenge that budget allocation for safety and oversight remains limited, creating potential risk gaps.

Public sector organisations expressed that they often use data management technologies, such as master data management, data products, advanced data processing when organising public events. More specifically, Data Analytics has been adopted by 17% of the respondents. Indeed, government organisations hold vast volumes of sensitive data, making also the potential impact of AI highly significant for public-sector productivity, service delivery, and security.

Although XR is adopted a much lower number of organisations, some pioneers stressed that virtual mentoring platforms and digital training modules can help attract new talent, upskill existing staff, and improve teacher well-being.

[142] SAS (2025). Your journey to a GenAI future: A strategic path to success for government, available at https://www.sas.com/en/whitepapers/your-journey-to-a-gen-ai-future-a-strategic-path-to-success-for-government-114056.html?utm_source=google&utm_medium=cpc&utm_campaign=-gbc-gps-emea&gad_source=1&gad_campaignid=22990937023&gbraid=0AAAAAD_WZgCo5KKm2eh6TxWnS57yqV5En&gclid=Cj0KCQjw35bIBhDqARIsAGjd-cbfocd_TI1JO0ekCwod04lyVzpNUbZNTahpkIGpjHJ0aNHZyiczpzEaAqbpEALw_wcB

Figure 17 Share of public sector organisations adopting specific digital technologies in 2025 – based on survey results



Source: Technopolis Group (2025) based on the public sector adoption survey, n=109

Despite these challenges, early adopters in government are seeing notable gains: improved employee satisfaction, stronger risk management, and cost and time efficiencies. Overall, the public sector remains cautious but optimistic, expecting GenAI to significantly boost efficiency, innovation, and predictive capabilities as frameworks mature and trust increases.

The use of AI has important implications in particular in the education sector. According to the OECD's 2024 TALIS survey[143], teachers' use of AI in education varies widely across Europe, with lower secondary teacher adoption ranging from about 14 % in France to 40% in Malta. On average, 32 % of teachers in EU countries and 36 % across the OECD reported using AI tools in the classroom or to support teaching in the previous year. AI was used for tasks such as making predictions, suggesting decisions, or generating text, and the variation largely reflects differences in national education policies, technological infrastructure, and cultural approaches to adopting new technologies. In the field of education, based on data collected in 2024 during the early adoption phase of GenAI in education, a recent JRC[144] study shows that teachers and students began experimenting with the technology rapidly. Many viewed it as a tool that could enhance learning and teaching, for example by simplifying complex concepts or personalising feedback, but concerns emerged around academic integrity, bias, privacy, and over-reliance on AI. There is a strong and recurring need to support the education sector in addressing the human-centred and ethical use of AI in education. As an action, the European Commission has developed and published ethical guidelines[145] on the use of Artificial Intelligence and data in teaching and learning to help teachers and educational staff understand both the opportunities and ethical risks associated with AI in education and to support them in using these technologies responsibly and effectively in their practice.

National ministries noted that they are already working with many of these technologies and are now focusing on gaining access to HPC services to train new models on increasingly large datasets. They emphasised the importance of interoperability, particularly in enabling multiple specialised AI agents to work together with minimal latency. In this context, systems composed of restricted AIs can dynamically adjust their level of autonomy based on task complexity, user trust, and performance feedback.

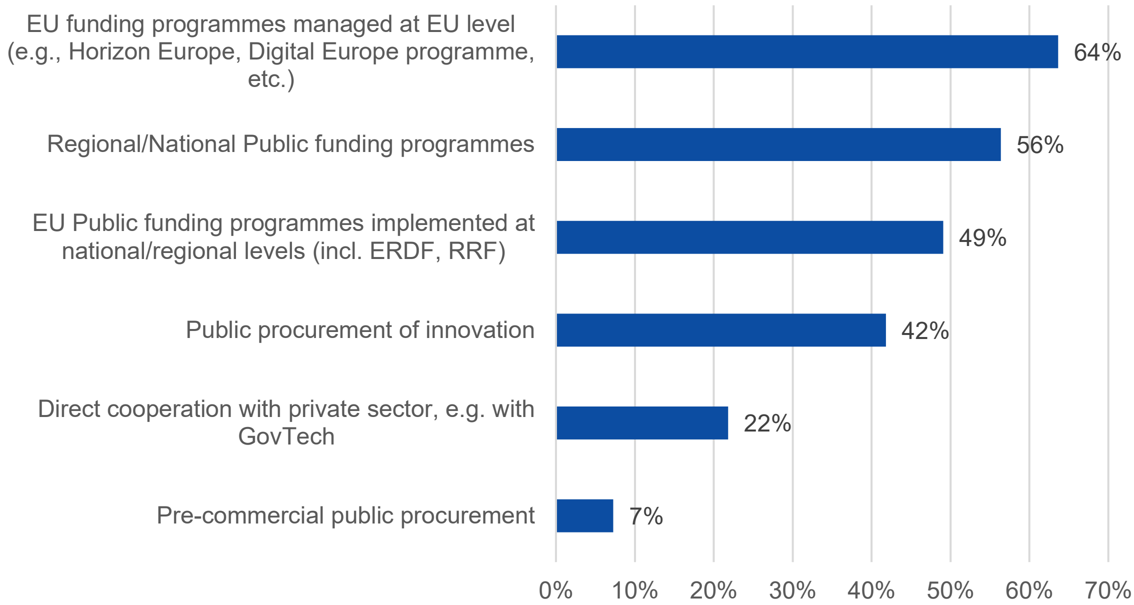
[143] OECD. (2025). Results from TALIS 2024: The state of teaching (TALIS). OECD Publishing. https://doi.org/10.1787/90df6235-en
[144] Villar Onrubia, D., Cachia, R., Rietz, C., Feltrero, R., Niemi, H., et al. (2025). Generative Artificial Intelligence in secondary education: Uses and perceptions from the perspective of early adopters across five EU Member States. Luxembourg: Publications Office of the European Union. https://data.europa.eu/doi/10.2760/8636621 (JRC144345).
[145] See here: https://education.ec.europa.eu/focus-topics/digital-education/action-plan/ethical-guidelines-for-educators-on-using-ai

Many administrations are also investing in secure and quantum-secure digital identities for citizens and businesses. Digital identity is seen as a foundational element for the adoption of emerging technologies, providing a secure and trusted ecosystem and offering an additional layer of functionality across applications.

Some are exploring spatial-web technologies, interoperability frameworks, and human digital twins to support XR-based learning environments and institutional digital transformation.

The primary channels of digital technology adoption in the public sector were identified by respondents as EU funding programmes, complemented by national and regional public funding. Pre-commercial public procurement, however, was mentioned far less frequently.

Figure 18 Channels of investment for public organisation's adoption of advanced digital technologies



Source: Technopolis Group (2025) based on the public sector adoption survey, n=109

The digital transformation of the public sector is fundamental to Europe's strategic autonomy, educational innovation, and long-term societal resilience. Stakeholders stressed the need for systemic, long-term investment frameworks that move beyond pilot projects and enable widespread deployment of Artificial Intelligence, virtual reality technologies and data-driven infrastructures across education and public services.

It was also highlighted that ensuring interoperability and open standards across strategic digital technologies such as XR, cloud, AI, and IoT will be essential to building sovereign, secure, and citizen-centric digital public infrastructures. This technological evolution must be matched with dedicated support for public education and workforce upskilling in the next MFF, aligned with the EU Green Deal and Digital Decade commitments.

Sustained support for cross-sector data spaces and federated learning ecosystems is key to advancing shared innovation capabilities. This includes enabling public-sector experimentation and deployment of human digital twins, virtual campuses, and interoperable immersive learning environments that can strengthen European talent, research capability, and digital sovereignty.

Most importantly, stakeholders responding to the survey also stressed that the objective of public sector organisations is to be able to effectively address public sector and citizens' needs and technology comes only second. Technology adoption should not be monitored on its own as the focus should be on the problem that it is solving.

2.3 Private investments underpinning the development and adoption of digital technologies

2.3.1 Firm investments into digital technologies

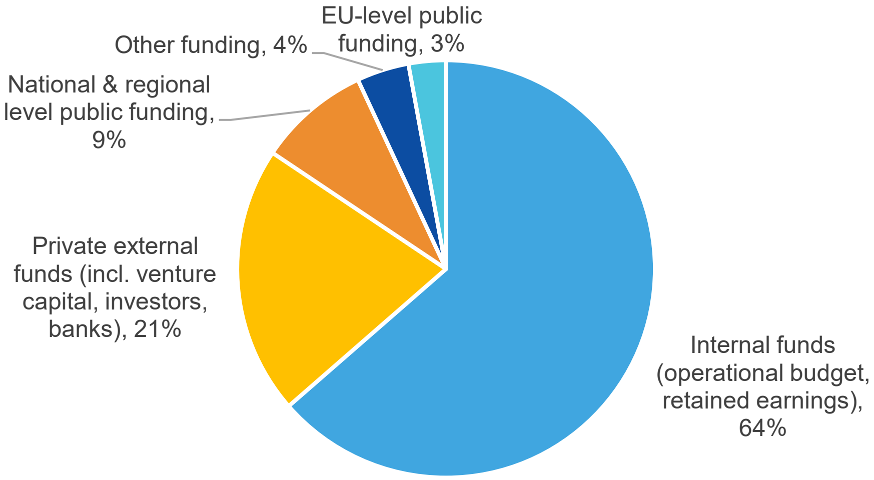
Medium-sized enterprises show a strong engagement in advanced digital technologies relative to their size. However, the **underinvestment in deployment is evidenced by the fact that on average the largest share of European companies invest less than €50,000 annually** in critical digital technologies. In particular, in areas such as AI, Data analytics, Advanced Connectivity, Cybersecurity, and Cloud–Edge–IoT, company investments are generally modest. Future investments are projected to grow across most technologies but the most rapidly in the area of Artificial Intelligence. The deployment of Photonics, Quantum are also expected to be a future investment target by companies, but less so for HPC and NGI.

The extent and nature of companies' investments in digital technologies exhibit significant heterogeneity across firm sizes, sectors and geographies. Within the EU, the divergences are compounded by national-level variations in policy frameworks, regulatory environments, and the availability of funding instruments supporting the digital transition[146].

Source and volume of investments

Companies in EU industries use mostly (63% of companies investing in digital technologies) their internal funds to finance the use of advanced digital technologies, such as AI or Data analytics as found by the telephone-based market survey conducted in the framework of the study on R&I investment needs[147]. One-fifth of the companies surveyed (21%) indicated that they use private external funds and it is only a very small share (9%) that rely on national or regional public funding. 9% of the firms indicate that they use national or regional level public funding and 3% to use EU level funding. Several also mentioned that they combine internal funds with national, regional or EU-level programmes, and private capital. Other funding sources include a mix of internal resources and public funding, commercial revenues, or customer-funded projects. A smaller number mentioned market-based funding mechanisms such as equity investment or contracts from organisations such as the European Space Agency.

Figure 19 Source of investment into the adoption of digital technologies by firms



Source: Technopolis Group (2025) market CATI survey, n=177, excluding ICT and research companies that develop the digital technologies

Many companies expect their future funding sources to shift and diversify, with a mix of internal financing, public investment, and EU or national grants as found by the market survey. Some foresee relying more on self-generated revenue as they grow, aiming for greater financial independence, while others hope to access additional external support through

[146] https://digital-strategy.ec.europa.eu/en/library/digital-decade-2025-digitalisation-business-eu-member-states
[147] Technopolis Group (forthcoming) Study on EU's strategic digital technologies for R&I Investments

European funding programmes, government initiatives, or private investors. A number of respondents also anticipate forming new partnerships, winning competitive grants, or leveraging technological advancements to secure new funding opportunities. Overall, there is a clear expectation of increased financial resources in the coming years, though the balance between public, private, and internal funding will vary across organisations.

On average, the largest share of European companies responding to the survey invest less than €50,000 annually in critical digital technologies, highlighting a clear underinvestment in deployment. Investment volumes for adopting digital technologies are in general lower than those for research. In the case of Microelectronics, Quantum and HPC, the investment is mostly targeted at research.

- Companies tend to allocate relatively higher investment amounts, ranging from €500,000 to €2 m in fields such as Microelectronics, Photonics, and Quantum technologies.
- In areas such as AI, Data analytics, Advanced Connectivity, Cybersecurity, and Cloud–Edge–IoT, company investments are generally modest, with most spending below €50,000, as reported by 31% to 50% of firms.
- The capital-intensive nature of Robotics and Photonics is evident by the higher share of companies spending between €250,000 and €500,000 and notably between €500,000 and €2 m on these technologies.
- In the case of Blockchain, 16% of companies invest between €2-10 m, which is mainly due to the high upfront cost in implementing blockchain-based financial solutions. These companies typically invest in blockchain infrastructure, asset tokenisation, and DeFi (decentralised finance) projects.
- Next generation of Internet and XR are technologies where deployment related investments are the lowest (50% of companies investing less than €50,000).
- Notably, a significant proportion of companies indicate no specific annual investment at all in certain technologies, despite having adopted them, for example, 18% for Cloud–Edge–IoT, 10% for AI, and 10% for Photonics.

Table 8 Volume of investments that companies are spending on average in the R&D and adoption of digital technologies annually (shares should be understood in the total of respondents per technology)

	Advanced connectivity	Artificial Intelligence	Blockchain	Data analytics	Cloud, Edge, IoT	Cybersecurity	HPC	Microelectronics	NGI and XR	Photonics	Quantum	Robotics	Technologies for Interoperability
Less than €50,000	31%	33%	18%	40%	35%	42%	23%		50%	20%		13%	27%
From €50,000 to €100,000	12%	16%		12%	13%	15%	31%					27%	18%
From €100,000 to €250,000	15%		33%	20%	12%	4%		40%	21%	20%	33%	8%	27%
From €250,000 to €500,000	12%	6%		11%	9%	8%			14%		16%	14%	17%
From €500,000 to €2 million	4%	6%	15%	3%	6%	7%	23%	40%		30%	15%	8%	
From €2 million to €10 million		1%	16%			2%	8%			10%		3%	

	Advanced connectivity	Artificial Intelligence	Blockchain	Data analytics	Cloud, Edge, IoT	Cybersecurity	HPC	Microelectronics	NGI and XR	Photonics	Quantum	Robotics	Technologies for Interoperability
From €10 million to €50 million					3%					10%			
None	8%	10%			18%	9%			7%	10%			9%

Source: Technopolis Group (2025) market CATI survey, n=380, Note: the remaining percentages reflect 'I do not know' responses, the distribution of the sample size among technologies is presented in the methodological annex at the end of this report

More specifically, average annual investment levels in deployment specifically range from €49 528 to €550 833 per technology area. The highest average investment levels are observed in Photonics, Blockchain, and HPC, reflecting the capital-intensive nature of these technologies and their demanding infrastructure requirements. Interestingly, the smallest average amounts are invested into the deployment of Data Analytics, NGI&XR and AI, where a large share of companies and especially SMEs invest smaller volumes when adopting these technologies.

Companies with smaller AI budgets primarily invest to optimise internal processes and build in-house capabilities. **Key areas of spending include hiring and training employees, acquiring AI software and tools, and integrating AI into existing systems**. Investments also target productivity gains accelerating development cycles, reducing programming time, and streamlining workflows, as well as upgrading infrastructure, including high-performance computing and IT systems.

Many smaller businesses also report that their investments in digital technologies mainly concern the personal time of the owner or of the staff and not direct financial investments (such as investing in new digital infrastructure).

In the case of Blockchain, companies, for example, invest in DeFiChain to support decentralised financial services, which has in general higher average cost. Companies report diverse investment priorities for cloud technologies, largely focused on scaling infrastructure, ensuring service availability, and building custom data solutions. Key areas include strengthening server capacity, supporting cloud migration, developing cloud-based tools, improving data storage and sharing systems, and enabling edge computing. Some organisations also emphasise cloud investments to enhance client support, audience measurement, and internal operations, while a few indicate no current cloud-related spending.

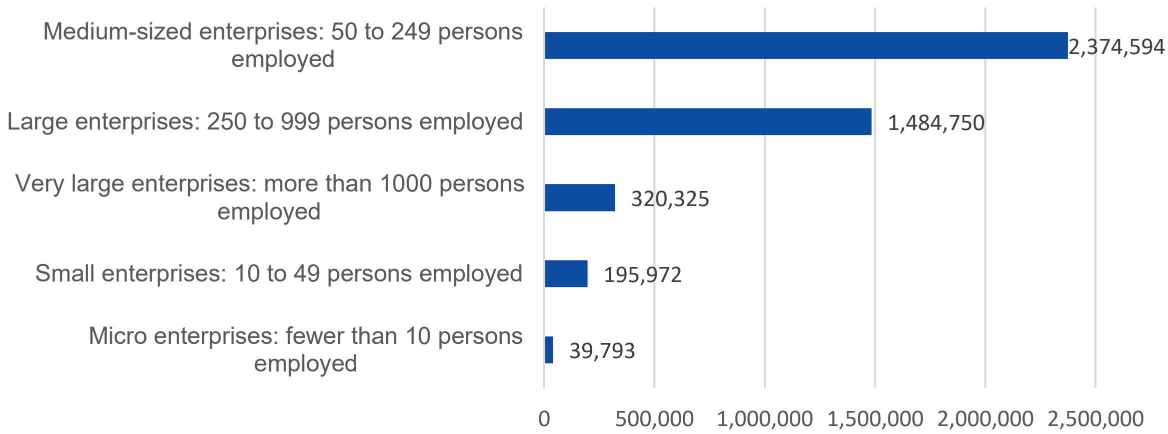
Table 9 Average annual investments into the deployment of digital technologies by European companies responding to the market survey

Technology areas	Average annual investment of companies
Photonics	€550.833
Blockchain and distributed ledgers	€470.500
High-Performance Computing (HPC)	€351.909
Cloud, Edge, Internet-of-Things	€270.190
Microelectronics	€146.250
Cybersecurity technologies and digital identity	€144.956
Robotics	€106.389
Advanced digital communications and connectivity	€80.458
Technologies for interoperability	€78.150
Quantum	€75.207
Artificial Intelligence	€55.277
Next-generation internet and extended reality	€53.625
Data analytics and data sharing technologies	€49.528

Source: Technopolis Group (2025) market CATI survey, n=380

On average, medium-sized enterprises invest more annually in digital technologies than large or small companies. Midsize companies are key drivers of national economies and essential players in the global business landscape. However, while they are actively adopting digital technologies, they often operate outside the spotlight of major investors.

Table 10 Average yearly investment into advanced digital technologies per company size

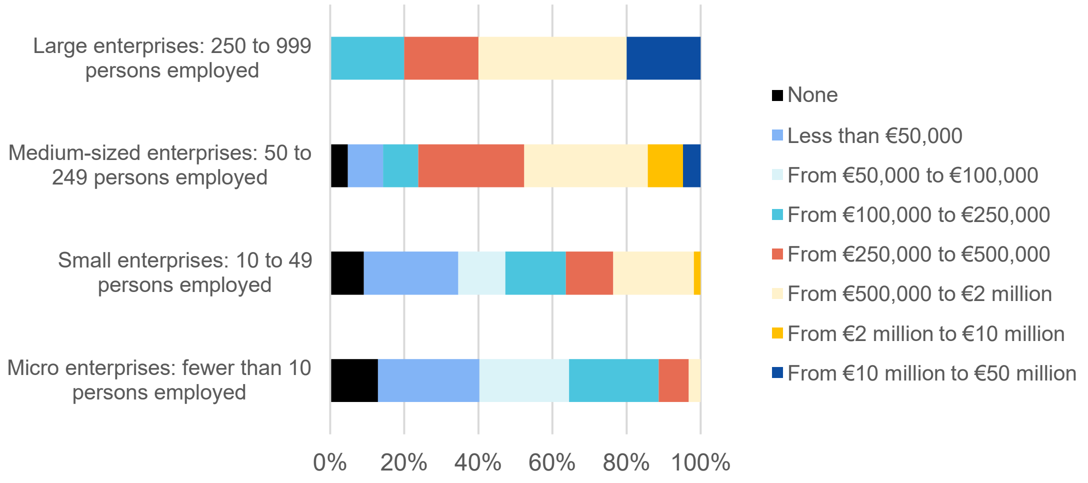


Source: Technopolis Group (2025) market CATI survey, n=380

Relative to their size, medium-sized enterprises show the strongest engagement in advanced digital technologies, with approximately 33% investing between €500,000 and €2 m per year. Large companies demonstrate a much wider investment range, varying from €100,000 to €50 m annually, reflecting both their scale and diverse technological strategies. By contrast, micro-enterprises allocate the least resources to digitalisation, with around 13% reporting no investment at all, underscoring persistent gaps in adoption across firm sizes.

Related research found that **micro-enterprises and older firms consistently exhibit the lowest levels of digital activity**[148]. For older firms in particular, this may reflect the composition of their existing capital stock, which is often less digitised or more traditional in nature, making advanced digital solutions more complex and costly.

Figure 20 Level of investment in digital technologies by firms (other than ICT) on a yearly average



Source: Technopolis Group (2025) based on market CATI survey, n=380

Large companies that innovate tend to invest more in digital technologies. Europe has seen significant investment by large firms into **Advanced Connectivity** (communication and digital infrastructure), strengthening its position in next-generation networks. Nokia committed €360 m[149] in Germany towards microelectronics and communications technologies, while Ericsson announced a €200 m expansion in Ireland[150], secured European Investment Bank funding, and advanced 5G deployments through partnerships in Sweden and Romania. Deutsche Telekom[151] invested €16 bn in 2024 (including €5.8 bn in Germany) to expand high-performance fibre networks, reaching over 10 million connections by year-end. Complementing these infrastructure efforts, telecom operators such as Orange[152] and Swisscom are supporting innovation via dedicated corporate venture capital arms, channelling resources into start-ups and sustainable digital solutions. **Cybersecurity** accounts for 9% of European IT investments as found by the latest report of the European Union Agency for Cybersecurity (ENISA)[153]. In 2023, median IT spending rose to €15 m, while security spending doubled from €0.7 m to €1.4 m, highlighting cybersecurity's growing priority for organisations. **Blockchain**-related investments in finance are gaining momentum with the example of a €140 m funding round for the German Solaris.[154] Europe's blockchain investment landscape has been more heavily focused on crypto applications.[155] While there is recognition of the broader potential of blockchain technologies across various sectors, crypto remains the primary area of investment to date.

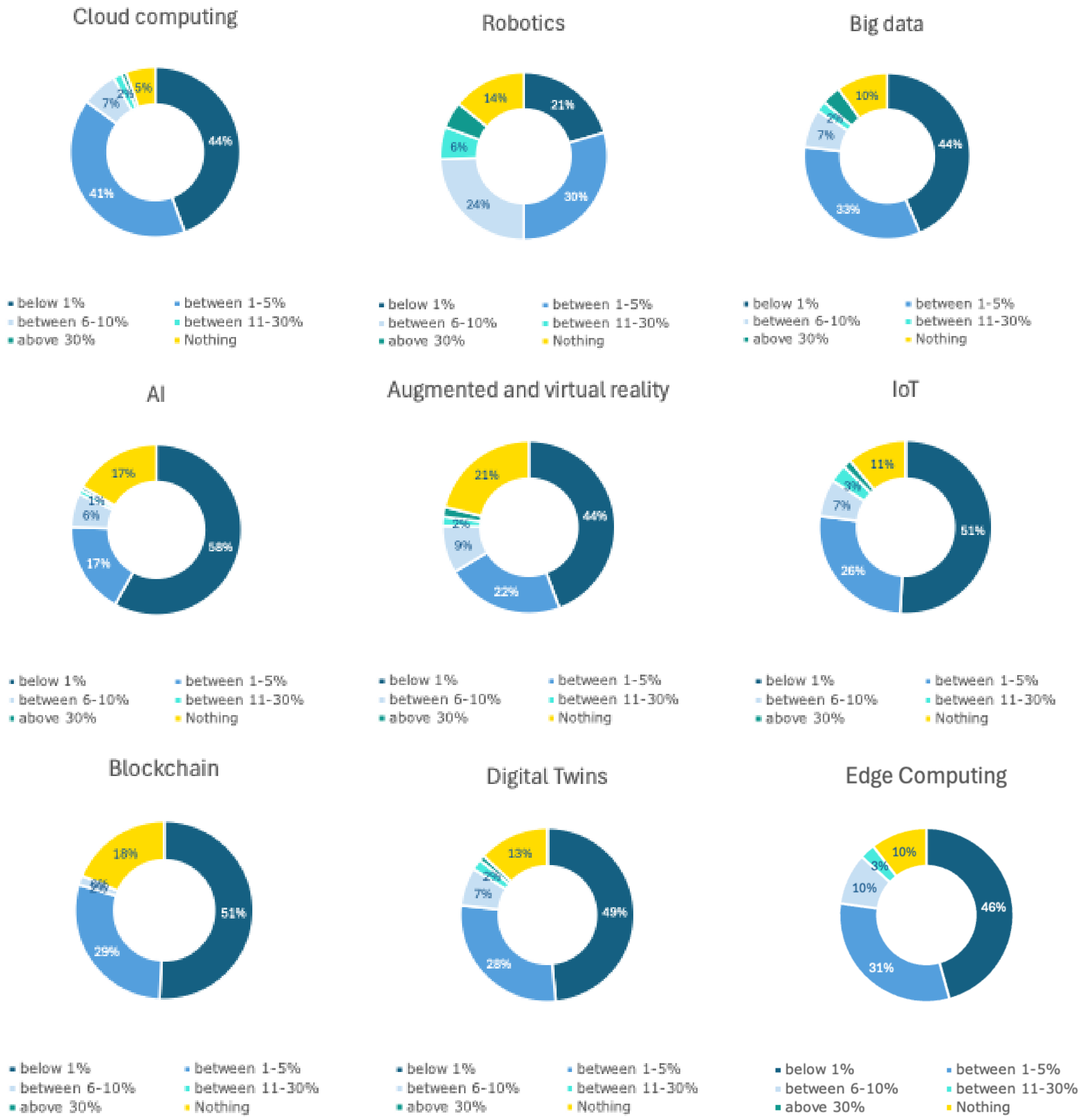
The low investment into digital technologies in particular by small companies has been also highlighted by the European Monitor of Industrial Ecosystems, tracking private-sector investment in advanced digital technologies across the EU-27 in 2024 based on enterprise

[148] Kren, J., & O'Toole, C. (2024, April). What drives SME investment in digitalisation? Micro-data evidence for Ireland (ESRI Working Paper No. 777). The Economic and Social Research Institute (ESRI).
[149] https://www.nokia.com/about-us/news/releases/2024/01/17/nokia-plans-eu360-million-investment-in-microelectronics-and-communications-technology-in-germany/ ;
[150] https://www.ericsson.com/en/press-releases/2025/4/ericsson-invests-eur-200-million-at-athlone-facility-to-boost-high-performing-programmable-networks-leadership ;
[151] https://bericht.telekom.com/geschaeftsbericht-2024/lagebericht/konzernstrategie/investitionen.html#:~:text=Im%20Jahr%202024%20investierten%20wir,einzelne%20unserer%20Wettbewerber%20in%20Deutschland.
[152] https://www.orange.com/en/orange-digital-investment-oranges-corporate-venture-capital-holding-company-dedicated-innovation
[153] https://www.enisa.europa.eu/news/navigating-cybersecurity-investments-in-the-time-of-nis-2
[154] https://pitchbook.com/news/articles/european-fintech-emerges-stronger-after-vc-downturn
[155] https://www3.weforum.org/docs/WEF_Pathways_to_the_Regulation_of_Crypto_Assets_2023.pdf

survey data. It found that private investment in particular of SMEs remained relatively low in line with the findings above. **Overall, 47% of businesses invested less than 1% of their turnover in digital technologies, and 30% invest between 1-5%.** Investment tends to focus on more mature technologies like cloud computing (€137 bn), big data (€90 bn), and IoT (€ 85 bn), though robotics and cloud computing have seen the sharpest increases.

SMEs show stronger engagement in **Robotics**, with 10 out of 12 industrial ecosystems investing over 5% of their turnover in this area. **Cloud** computing is the single largest recipient of investments by SMEs, with annual business spending estimated at €136 bn. Certain industrial ecosystems such as electronics, significantly surpass the 5% investment threshold. This sector reports especially high investments in Cloud computing (23.19%), Edge computing (22.73%), Robotics (19.05%), IoT (12.28%), and Big Data (5.88%), highlighting sector-specific priorities and varying levels of technological maturity.

Figure 21 SME investment in advanced digital technology by type of technology (share of turnover invested)



Source: Technopolis Group (2025) based on the European Monitor of Industrial Ecosystems

Future investments are projected to grow across most technologies but the most rapidly in the area of Artificial Intelligence, reflecting its already well-documented growth in applications. The deployment of **Photonics** and **Quantum** technologies are also expected to be a future investment target by companies. Higher investments are expected in Data analytics and Robotics. On the other hand, investments in NGI, Blockchain and Cloud-Edge-IoT are expected to grow less.

Table 11 Volume of future investments that companies plan to spend on average in the R&D and adoption of digital technologies annually

	Advanced connectivity	Artificial Intelligence	Blockchain	Data analytics	Cloud, Edge, IoT	Cybersecurity	HPC	Microelectronics	NGI and XR	Photonics	Quantum	Robotics	Technologies for Interoperability
Less than €50,000	**31%**	19%	16%	**34%**	**35%**	**42%**	**16%**		**50%**	**20%**	**17%**	8%	**27%**
From €50,000 to €100,000	12%	18%		14%	13%	15%	8%					**22%**	18%
From €100,000 to €250,000	15%	**20%**	**33%**	17%	12%	4%	8%	**40%**	21%	**20%**	**17%**	16%	**27%**
From €250,000 to €500,000	12%	5%		9%	9%	8%	**16%**		14%	10%	16%	14%	18%
From €500,000 to €2 million	4%	11%	16%	9%	6%	7%	8%	**40%**		**20%**	16%	16%	
From €2 million to €10 million		4%	16%			2%	8%			10%	16%	5%	
From €10 million to €50 million		1%			3%					10%			

Source: Technopolis Group (2025) market CATI survey, n=380

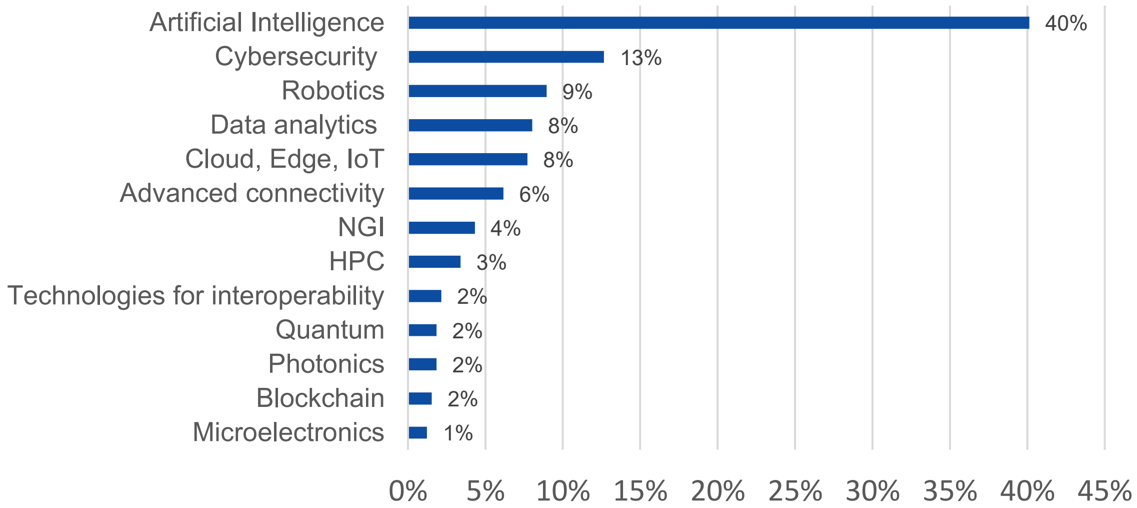
Many companies reported that they plan to use digital technologies primarily to stay ahead of market demands, improve manufacturing and services and to make further efforts to boost efficiency. The objective to reduce environmental impact has also been highlighted by many. Digital technologies are planned to be used to create new products and integrate them into business processes. Among the future goals are the improvement of connectivity, interoperability, and enhancing cybersecurity capabilities.

Type of investments per technology

Companies are prioritising investments in a wide range of advanced digital technologies, with strong emphasis on AI, robotics, cybersecurity, cloud computing, and data management as indicated by the results of the market survey. Many focus on improving and automating production processes, developing next-generation solutions, offering technology-based services and enhancing efficiency and security.

Artificial Intelligence is a primary focus, involving the development of AI solutions and models, the application of AI for internal support and defence, increasing the accuracy of AI in learning use cases, and developing physical technologies such as generative AI features; this emphasis often combines AI with advanced production methods such as additive manufacturing, robotics, and computer vision. Simultaneously, companies are heavily **investing in cybersecurity and data management**, which includes extending digital security, implementing cybersecurity solutions, researching privacy enhancing technologies, building up cloud space platforms and services, and establishing the necessary infrastructure for data collection, future data analysis, and interconnectivity. Furthermore, investments in **robotics and automation** are driving efficiency improvement and reduced labour costs, leading to the introduction of robots in factories, development of better robotic control systems, and automation of industrial processes. Finally, there is investment in new technologies for new products, building new control software capabilities, working on VR and AR solutions, and advancing specialised fields like photonics and telecommunication technology alongside foundational hardware like chip design, microelectronics, and FPGA, and crucial digitalisation efforts such as implementing systems such as Microsoft 365 and improving UX and SEO.

Figure 22 Focus of technology investments - Share of companies investing into different types of technology areas as main target



Source: Technopolis Group (2025) market CATI survey, n=380

Investments are generally distributed across various types of activities depending on the specific digital technology, with a notable emphasis on scaling pilot projects into real-world applications. Companies adopting Microelectronics, Photonics, HPC, Robotics, and Blockchain tend to focus their spending more on scaling pilot projects into real-life demonstrations. In addition, building or leveraging technological infrastructure is a key investment activity particularly for companies involved in HPC and Blockchain. Skills development has been the most relevant in the case of Photonics, Advanced Connectivity and NGI, while collaboration with key players in the value chain are rated as the most important investment target for Photonics, Quantum, Robotics and Blockchain.

Table 12 Share of firms that invested in the specific digital technology and in the related type of activities (What types of investments has your organisation made to support the Adoption & Uptake of the specific digital technology?)

	Advanced connectivity	Artificial Intelligence	Blockchain	Data analytics	Cloud, Edge, IOT	Cybersecurity	HPC	Microelectronics	NGI	Photonics	Quantum	Robotics	Technologies for Interoperability
Scaling pilot projects into real-life demonstration and full production	58%	62%	100 %	69%	63%	58%	70%	80%	64%	80%	66%	73%	55%
Purchasing and integrating advanced digital technologies	54%	58%	83%	63%	44%	63%	53%	20%	64%	70%	66%	57%	64%
Building or using research & technology infrastructures (testing facilities, pilot lines)	38%	46%	100 %	34%	47%	60%	70%	60%	36%	50%	50%	32%	37%

	Advanced connectivity	Artificial Intelligence	Blockchain	Data analytics	Cloud, Edge, IOT	Cybersecurity	HPC	Microelectronics	NGI	Photonics	Quantum	Robotics	Technologies for Interoperability
Building or using digital infrastructures (industrial digital twin, connectivity, data spaces)	58%	58%	83%	43%	53%	40%	77%	40%	50%	30%	76%	46%	55%
Skills development of R&D staff (hiring and/or training)	70%	66%	83%	69%	69%	62%	54%	40%	71%	80%	66%	65%	55%
Collaborations with key players in the value-chain	65%	58%	100 %	60%	63%	58%	69%	60%	65%	90%	83%	76%	64%

Source: Technopolis Group (2025) based on market CATI survey, n=380

The type of technology investments show a diverse pattern across specific digital technologies as found by the expert consultations and further desk research.

Within **Advanced Connectivity,** investments focus on **integrating technologies and systems to improve communication, connectivity, and product functionality**. Key efforts include enhancing Wi-Fi and network performance, enabling faster and more reliable connectivity, and ensuring interoperability between devices and customer systems, particularly for security and communication purposes. Some companies pursue strategic acquisitions to strengthen their development capabilities and software development to support integration.

In the case of **Artificial Intelligence**, **most companies are still in the early stages of adopting AI, investing primarily on building internal skills, developing proofs of concept, and exploring process automation opportunities rather than pursuing large-scale deployments**. Many are investing in training employees, experimenting with new tools and algorithms, and adapting existing products to incorporate AI capabilities. Common application areas include healthcare, marketing and sales, manufacturing, telecommunications, and robotics, while infrastructure development often involves acquiring software tools, hardware, and integrating AI into existing systems. However, a notable share of companies report low or no current investment, reflecting a mix of early experimentation, resource constraints, and uncertainty about implementation strategies. In the future, companies expect to invest in enhancing process efficiency, automate tasks, improve product quality, and reduce costs through computer vision, language models, process monitoring, data analytics, and customer-facing AI solutions. Some plan to invest in adapting products to work with multiple AI systems, while others emphasise infrastructure development, scaling AI training services, and building intelligent platforms for clients. Some companies invest in sales, marketing, and workforce training to support AI adoption.

Blockchain investments are concentrated on emerging areas such as **programmable money and decentralised finance** (DeFi), with some also exploring digital finance infrastructure and virtual finance innovations.

Within **Cloud-Edge-IoT**, businesses invest in developing server and cloud infrastructure, migrating existing software to the cloud, and building global infrastructures capable of handling high service loads. Companies are also investing in **IoT sensor integration and data processing, productization of smart city and agricultural solutions**, and custom solutions for data storage, sharing, and finance applications. Additional efforts include training staff in coding and platform management, packaging solutions as services, and deploying identity and access management solutions to cloud providers. Strategic goals generally centre on expanding market-ready products, enhancing delivery processes, and supporting clients efficiently, though some respondents report no current investment or focus in this area.

Company investments in **Cybersecurity** span a broad range of areas. Key priorities include **securing networks, protecting data and digital identities, meeting compliance requirements** (for example NIS2), and integrating security solutions across cloud environments and software systems. Many organisations focus on network protection, identity validation, firewall upgrades, backup and segmentation, and advanced threat detection, including AI-driven methods to prevent fingerprinting and deepfake attacks. Several companies emphasise DevSecOps practices, employee training, and developing in-house cybersecurity solutions, while others invest in certifications and external expertise to strengthen their security posture. Strategic goals often centre on protecting clients' data and privacy, keeping up with evolving threats, and ensuring interoperability between tools.

In the case of **Data analytics**, most companies report a diverse range of activities with varying investment levels. Some focus on **software development, sales and pricing strategies, and forecasting, while others prioritise generating statistics and insights to inform decision-making.** A number of companies are concentrating on improving data interoperability among local stakeholders, enabling data-driven planning or even supporting circular business models.

In **HPC**, a strong emphasis is planned on **scaling up HPC service offerings, expanding data centre capacity, integrating AI training capabilities**, and creating automated client onboarding and resource management systems. Some are also exploring GPU programming, new CPU architectures, quantum computing, and data transfer technologies, often in collaboration with semiconductor suppliers.

In **NGI and XR**, the focus is on **future readiness, product development, and enhancing customer experiences through new features and applications**. Key priorities include developing XR products and platforms, exploring location-based AR and mixed reality solutions, and improving ease of use to support real-world applicability. Some organisations are investing in education and skills development for employees, while others are building the infrastructure needed to support XR ecosystems, such as head-mounted displays. However, XR is still much less a priority of company investments than AI.

In **Photonics**, investments concern particularly **sensors, optoelectronics components, and laser technologies**. In the future, companies plan to invest in developing new systems for measurements, advancing sensor and fibre laser technologies, and purchasing specialised equipment such as cameras to support these developments. Some companies are also investing in hiring and training personnel to build the necessary expertise.

In **Quantum**, current deployment related investments are limited and focus on purchasing software licenses and scaling first solutions, moreover on improving calculation speed and project efficiency to streamline development processes. Future investments are targeted to **moving from prototyping to full product manufacturing and market entry**. The mentioned activities include scaling prototypes into market-ready products, implementing technological solutions, and investing in employee training and development to support production and commercialisation. Some investment is also directed toward strengthening sales departments to enable effective go-to-market strategies. Additionally, there is targeted interest in post-quantum cryptography, reflecting a growing focus on integrating advanced security technologies into products.

Most companies' investments in **Robotics** focus on **improving production efficiency, reducing labour costs, and accelerating manufacturing processes** through the integration of new machines and robotic systems. Key investments include automation of production lines, testing and prototyping, building robotic control systems, and introducing robots into specific sectors such as food processing and metalworking. Some companies are investing in software and hardware for robots or developing custom machines tailored to client needs, while others focus on enhancing their ability to integrate robotics applications within their plants. Strategic motivations often include remaining competitive, keeping pace with technological advances, and increasing productivity and capacity.

2.3.2 Venture capital investments into digital technologies

Venture capital investment in the EU has grown alongside the rising number of start-ups, indicating clear progress and helping to address long-standing funding gaps. Over the past decade, the number of seed financing rounds has increased steadily, reflecting greater availability of early-stage capital. However, most recently VC started to withdraw from early-stage financing which can create a gap for future start-up creation in Europe. Due in part to structural factors, overall EU venture capital investment in digital technology start-ups remains significantly lower than in the United States across all technology domains. It is still an issue that many successful EU start-ups leave and look for investment in the US and the dominance of US investors in EU start-ups is high.

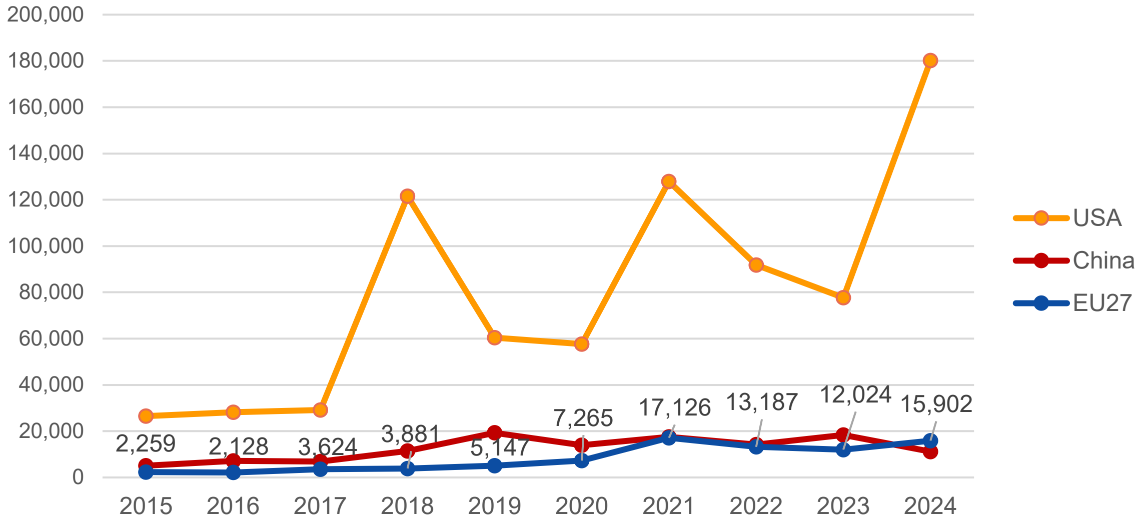
Venture capital plays a vital role in strengthening the EU's innovation ecosystem by providing the funding and strategic support that digital start-ups and scale-ups need for growing. However, **many of Europe's most promising tech companies struggle to access late-stage financing, limiting their ability to expand internationally and compete globally.** Beyond capital, VC also brings mentorship, market access, and business expertise, helping companies mature and navigate complex global markets. In the context of the Draghi report's call for bold action to secure Europe's competitiveness in critical technologies, VC plays an important role.

The EU landscape of 12 key digital technology areas[156] attracted a total €82 bn in venture capital since 2015 and €16 bn in 2024 only as the analysis of Crunchbase data particularly extracted for tech companies active in these technologies shows. Since 2015, investment in European start-ups has grown substantially, with early-stage funding more than doubling and growth-stage funding tripling. In line with global trends, investment into European digital technologies has expanded substantially over the past decade.

Between 2015 and 2024, capital invested in the EU grew at a compound annual growth rate (CAGR) of around 20% overall, with seed funding rising by 21.6% per year, early VC by 21.8% per year, and growth VC by 19.1% per year. A particularly sharp acceleration occurred in 2021 and 2022. From 2020 to 2021, investment volumes surged by 179%, while the number of funding rounds increased by 38%, peaking at €101 bn. Growth was visible across all stages, although it is the increase in Growth VC that is most revealing, where funding volumes rose by 266% and the number of rounds by 79%. Following these two exceptional years, the VC-backed ecosystem seems now to be entering a period of stabilisation. Investment levels have corrected downward from their 2021–22 highs, but remain well above pre-pandemic levels and broadly consistent with the long-term growth trajectory of European venture capital.

[156] The venture capital analysis could only capture the 12 technology areas and not interoperability and GovTech as they cannot be well-scoped in start-up databases.

Figure 23 Venture capital investment (seed, early and growth without exits, debt financing, IPO, grants) into 12 digital technology areas in the EU over time (in € million)

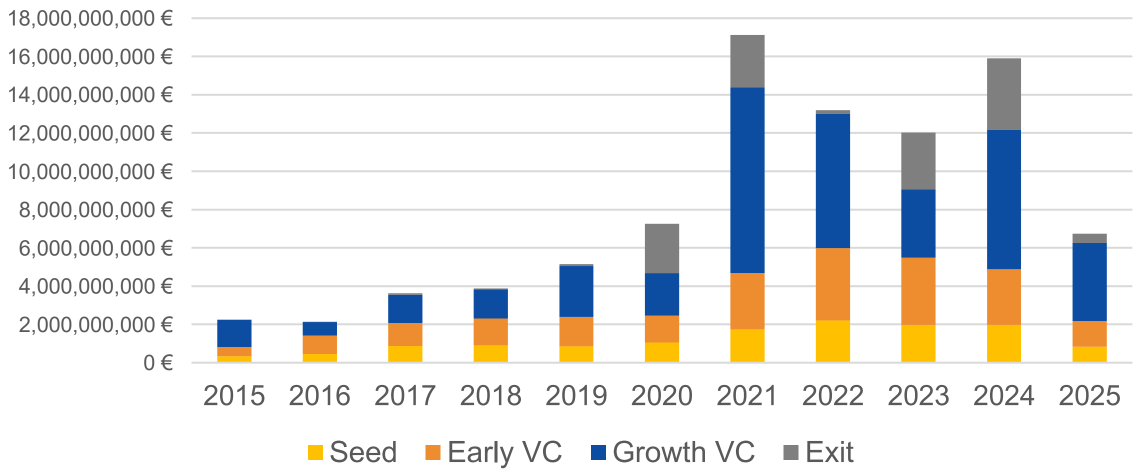


Source: Technopolis Group (2025) based on Crunchbase

Over the last decade, the number of seed financing rounds has climbed steadily, reflecting a growing availability of seed capital. In 2015, there were 607 seed-stage deals; by 2022, that count had more than doubled to 1,307 before easing slightly to 1,018 in 2023. Meanwhile, growth-stage venture-capital activity accelerated sharply around 2020–2021: early-VC deals increased from 98 in 2020 to 161 in 2021, a 64% year-over-year jump. Despite this surge in growth VC count, the 2021 spike in total funding was heavily skewed by top ten mega-rounds of at least €200 m, which together accounted for 54% of all 2021 funding volume. Notably, a single €2.3 bn round raised by Northvolt, which has since filed for bankruptcy, represented 19% of the entire VC funding pool that year. In other words, although more companies secured growth capital in 2021, over half of the funding was concentrated in just ten massive rounds, and nearly a fifth of that total flowed to Northvolt alone.

Trends also reflect that venture capital is withdrawing from early-stage investments due to the uncertain economic times, which creates a significant challenge for start-ups. Despite increasing integration, public stock markets remain largely national, highlighting an opportunity to establish a pan-European platform dedicated to technology companies.

Figure 24 VC investment into critical digital technologies in the EU over time and per funding stage



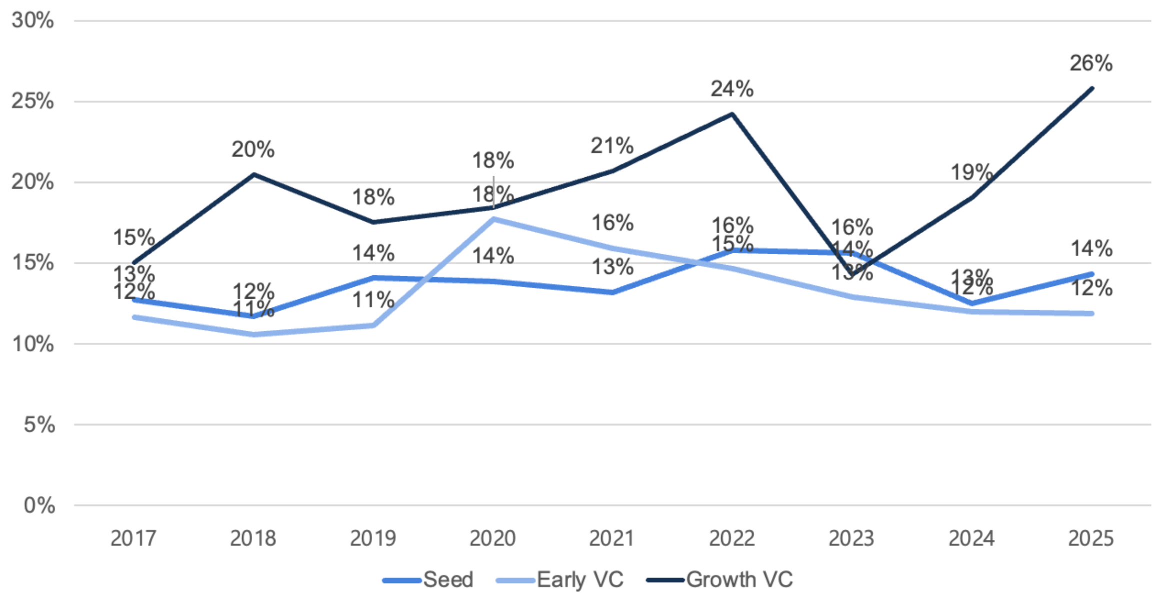
Source: Technopolis Group (2025) based on Crunchbase

European investors have improved in supporting local growth-stage companies, but many still depend on foreign capital, in particular on US investors for later-stage funding. This evolution has contributed to a growing number of successful scale-ups, however, when companies reach the later stages of development, where funding rounds are typically larger and risks perceived to be lower, they often face a funding gap that domestic capital cannot fully cover. As a result, many high-potential European firms continue to rely on foreign investors, particularly from the US, to secure the resources needed to scale globally. This dependency not only limits Europe's financial returns from innovation but can also lead to strategic assets and decision-making shifting abroad, reducing Europe's long-term competitiveness in the 12 digital technology areas analysed.

In 2024, **most VC investment in the EU went into tech companies in the field of Artificial Intelligence** among the 12 digital technology areas in the focus of this report. In 2024, AI has seen a sharp rise in investor interest, capturing 23% of funding rounds and the highest share of all the VC amount. A key bottleneck for the EU VC landscape is that while European start-ups progressed at similar rates to their US peers, far fewer secure large funding rounds, with only 4.1% raising more than €15 m compared to 8.3% in the US, highlighting a significant growth-stage funding gap that has halved Europe's potential capital raised since 2015[157]. In 2024/2025, venture capital funding into Blockchain, notably cryptocurrency start-ups experienced a significant decline.

European investors have improved in supporting local growth-stage companies, but many still depend on foreign capital in particular US investors for later-stage funding. As shown in the Figure below, the share of US investors has been growing and represented 26% in growth VC in 2025. This evolution has contributed to a growing number of successful scale-ups, however, when companies reach the later stages of development, where funding rounds are typically larger and risks perceived to be lower, they often face a funding gap that domestic capital cannot fully cover. As a result, many high-potential European firms continue to rely on foreign investors, particularly from the United States, to secure the resources needed to scale globally. This dependency not only limits Europe's financial returns from innovation but can also lead to strategic assets and decision-making shifting abroad, reducing Europe's long-term competitiveness in the 12 digital technology areas.

Figure 25 Share of US investors backing up as main investors EU digital tech companies (in the 12 digital technologies monitored)



Source: Technopolis Group (2025) based on Crunchbase

2.3.3 R&D investments in ICT

Europe's ability to generate and retain leading positions in the global digital economy remains constrained, while its supply chains for critical technologies remain highly vulnerable. The Draghi report[158] underscores this vulnerability: in 2021, the ICT sector

[157] Atomico (2024). State of European Tech
[158] https://commission.europa.eu/topics/eu-competitiveness/draghi-report_en

accounted for 5.5% of EU GDP (€718 bn) and 4.5% of business-economy jobs (€6.7 m), with services outweighing manufacturing. Yet, despite this economic weight, the EU remains heavily dependent on external actors, sourcing more than 80% of its digital products, services, infrastructure, and intellectual property from outside Europe. At the same time, Europe's share of global ICT revenue has declined from 22% in 2013 to 18% in 2023, while the US increased its share from 30% to 38% and China from 10% to 11%.

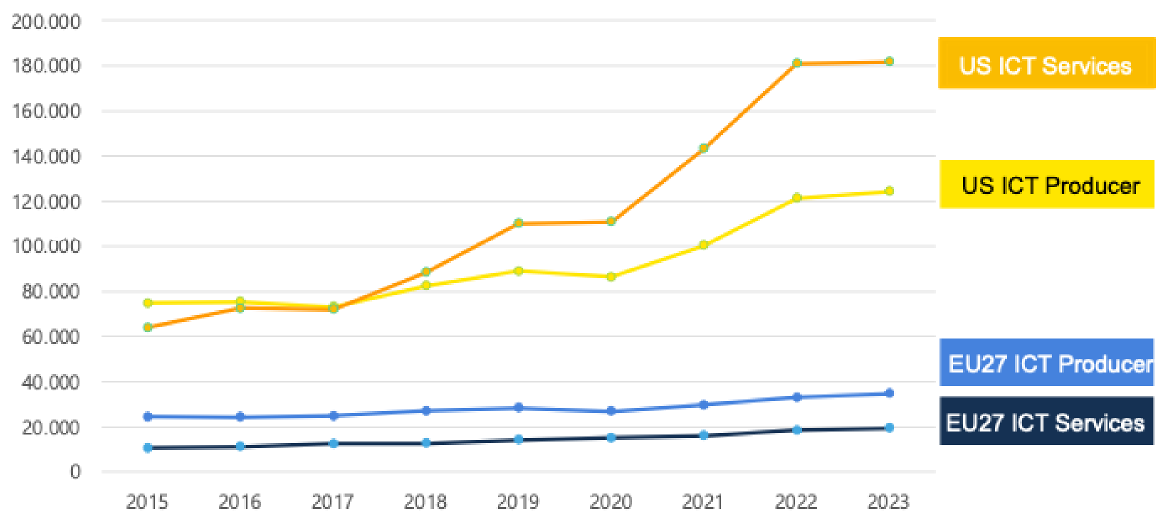
A strong **domestic ICT industry serves as a cornerstone for effective and sustainable digital deployment** by ensuring that the foundational technologies, services, and expertise needed for digital transformation are available in the broader economy. This reduces reliance on external providers, enhances digital sovereignty, and enables faster, more secure, and tailored implementation of digital solutions across sectors such as health, education, manufacturing, and public services.

Business expenditure on R&D (BERD) in the ICT sector is a key indicator of the private sector's commitment to advancing and supplying digital innovations and plays a critical role in supporting the deployment of digital technologies across the EU. The **EU R&D Investment Scoreboard**[159] captures IT investments by tracking the annual research and development expenditures of the top corporate R&D investors globally, including companies within the ICT sector. This includes firms in areas such as software, hardware, semiconductors, telecommunications, and IT services. Growth in BERD of the ICT sector has accelerated faster than RDI investments of other research-intensive industries globally.

The EU's performance in terms of R&D investment in Information and Communication Technology (ICT) sectors, encompassing both hardware and software, presents a mixed picture, with notable areas of strength but also significant gaps. The EU has been expanding its investments substantially. In 2023, the EU core group of companies invested €33 bn in ICT hardware R&D, however, the sector's R&D share among the EU 800 decreased from 16.5% in 2013 to 14% in 2023. The expenditure growth has not kept pace with the US or China (see further comparison in Section 2.5).

Over the past decade, ICT software has been one of the main drivers of global R&D growth, with ICT software alone accounting for nearly half of total R&D increases between 2013 and 2022 as found by the European R&D Investment Scoreboard. Although its contribution dropped to 14.7% in 2023, it remains a key sector, albeit with a slowing growth rate, its lowest since 2016. The ICT hardware sector also experienced moderate growth in 2023, but still above its long-term average.

Figure 26 Private R&D investments by the ICT producer and ICT services sectors in the EU and US over the period from 2015-2023 (in € million)



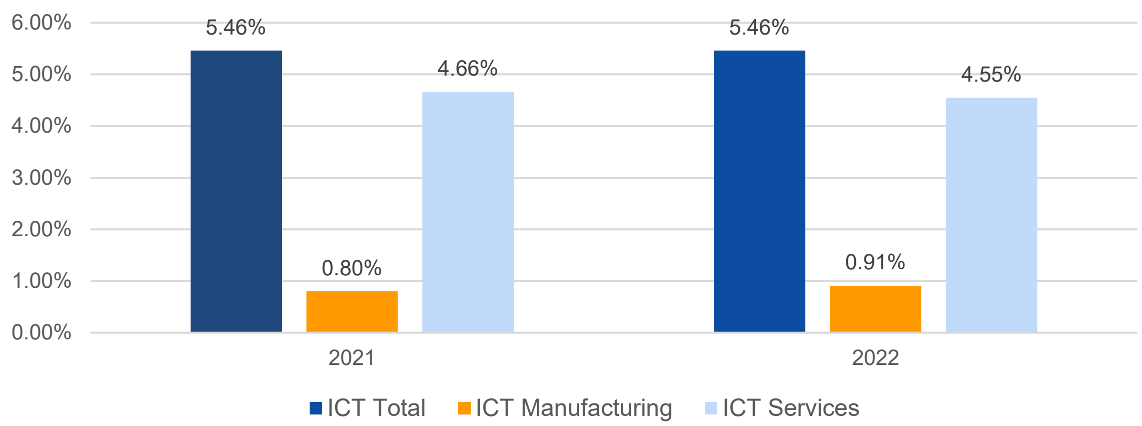
Source: Technopolis Group (2025) based on the European R&D Investment Scoreboard 2024

[159] https://iri.jrc.ec.europa.eu/scoreboard/2024-eu-industrial-rd-investment-scoreboard

ICT investments in the EU show structural weaknesses. ICT hardware and software sectors made up only 14% and 7.8% of total R&D investment by the EU's top 800 companies well below global averages in 2024. The EU's total ICT software R&D spending in 2023 amounted to just €19.2 bn, far behind the US's €143.6 bn and even below what a single firm like Alphabet spends. However, the EU shows signs of strength in certain areas such as semiconductors, with companies such as ASML and Infineon posting high R&D growth. Nonetheless, it struggles with R&D productivity and lags in translating investments into commercial success. This is evident in lower returns on R&D, less efficient R&D-to-labour productivity, and fewer high-performing M&A activities compared to US 'superstar' ICT firms.

While Europe's economy has shifted decisively towards services over manufacturing over the past decade, the rapid expansion of the services sector has shown signs of a recent deceleration (from 2021 to 2022). ICT investments monitored as a share of ICT in gross value added (GVA) further complement the picture in investment gaps. EU data show a modest growth over time from 4.8% in 2019 to 5.4% in 2022[160]. This indicator sheds light on how widely digital technologies are diffused across the economy. Between 2012 and 2022, the ICT services share of GVA in the EU grew steadily by 24.8%, before experiencing a slight dip in 2022. By contrast, the share of ICT manufacturing remained largely stable, rising by only 0.6% over the period. This also reflects to some extent that the EU industry is becoming increasingly dependent on services like software, cloud, data platforms, and digital solutions. Below, the share of ICT manufacturing and ICT services are compared in 2021 and 2022.

Figure 27 Percentage of the ICT sector in Gross value added in EU-27



Source: Eurostat,
https://ec.europa.eu/eurostat/databrowser/view/tin00074/default/table?lang=en&category=t_isoc.t_isoc_se

2.4 Geographic specialisation in digital transformation within the EU

Digital technology development and commercialisation both in terms of start-ups, patent applications and innovation is concentrated around some countries and regions such as **Germany, France, Finland, the Netherlands or Sweden**, with divergence related to specific technologies.

The uneven adoption of digital technologies across EU countries and regions hinders the productivity and competitiveness of EU industries and regions, necessitating targeted public interventions to address market and systemic failures.

A persistent digital divide across the EU is evident from various statistics measuring innovation and digital transformation each showing similar patterns. DESI 2025 data[161] shows a marked imbalance in digital uptake across the EU, with Northern and Western Member States leading in digital integration, connectivity, and public digital services. By contrast, many Southern and Eastern countries continue to lag behind the EU average, particularly in the adoption of digital

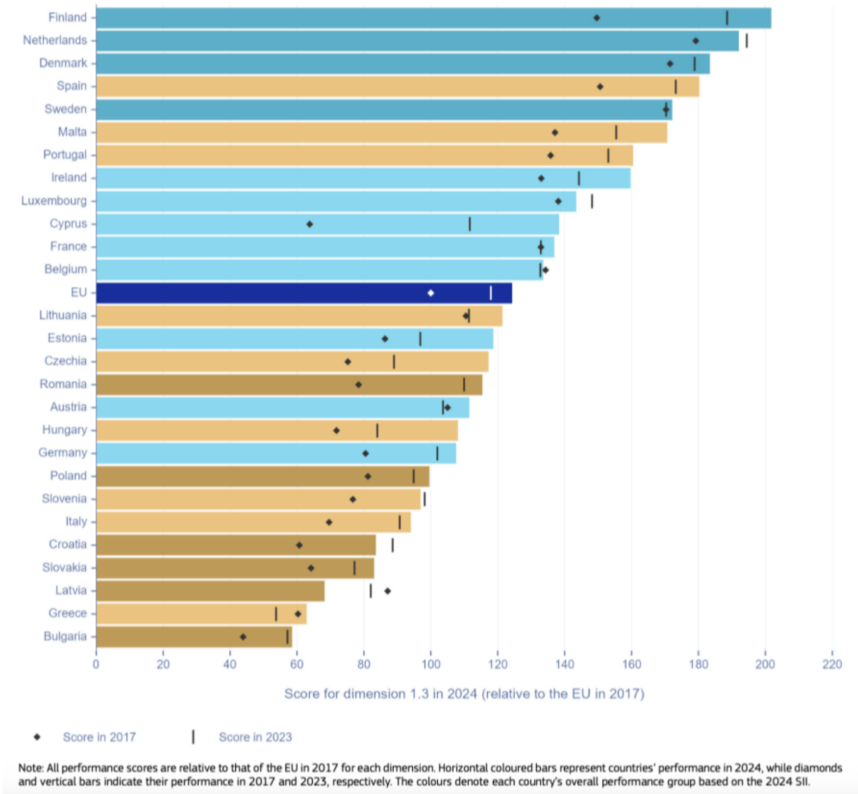
[160] See https://ec.europa.eu/eurostat/databrowser/view/tin00074/default/table?lang=en&category=t_isoc.t_isoc_se
[161] https://digital-decade-desi.digital-strategy.ec.europa.eu/datasets/desi/charts/desi-indicators?period=desi_2025&indicator=desi_dsk_ab&breakdown=ind_total&unit=pc_ind&country=AT,BE,BG,HR,CY,CZ,DK,EE,EU,FI,FR,DE,EL,HU,IE,IT,LV,LT,LU,MT,NL,PL,PT,RO,SK,SI,ES,SE

technologies by businesses. For instance, the share of companies using AI, Cloud, or Data Analytics was highest in Finland, Denmark, and the Netherlands, and lowest in Greece, Romania, and Bulgaria in 2024. However, there are notable exceptions to these broad trends, such as Estonia performing strongly in cloud adoption, and Malta and Slovenia showing relatively high levels of AI uptake.

In terms of geographical coverage, the 'digitalisation dimension' of the recent innovation European Innovation Scoreboard 2024[162] measures the penetration of digital technologies and includes two indicators: broadband penetration, as a share of enterprises with a maximum contracted download speed of at least 100 Mb/s for their fastest fixed internet connection, and Individuals with above basic overall digital skills.

The best-performing Member States are Finland, the Netherlands, Denmark and Sweden, and Spain, with scores 70% above the EU average. At the other end of the scale, Latvia, Greece and Bulgaria record the lowest performances with scores below 70.

Figure 28 Innovation performance of the EU Member States in the digitalisation dimension



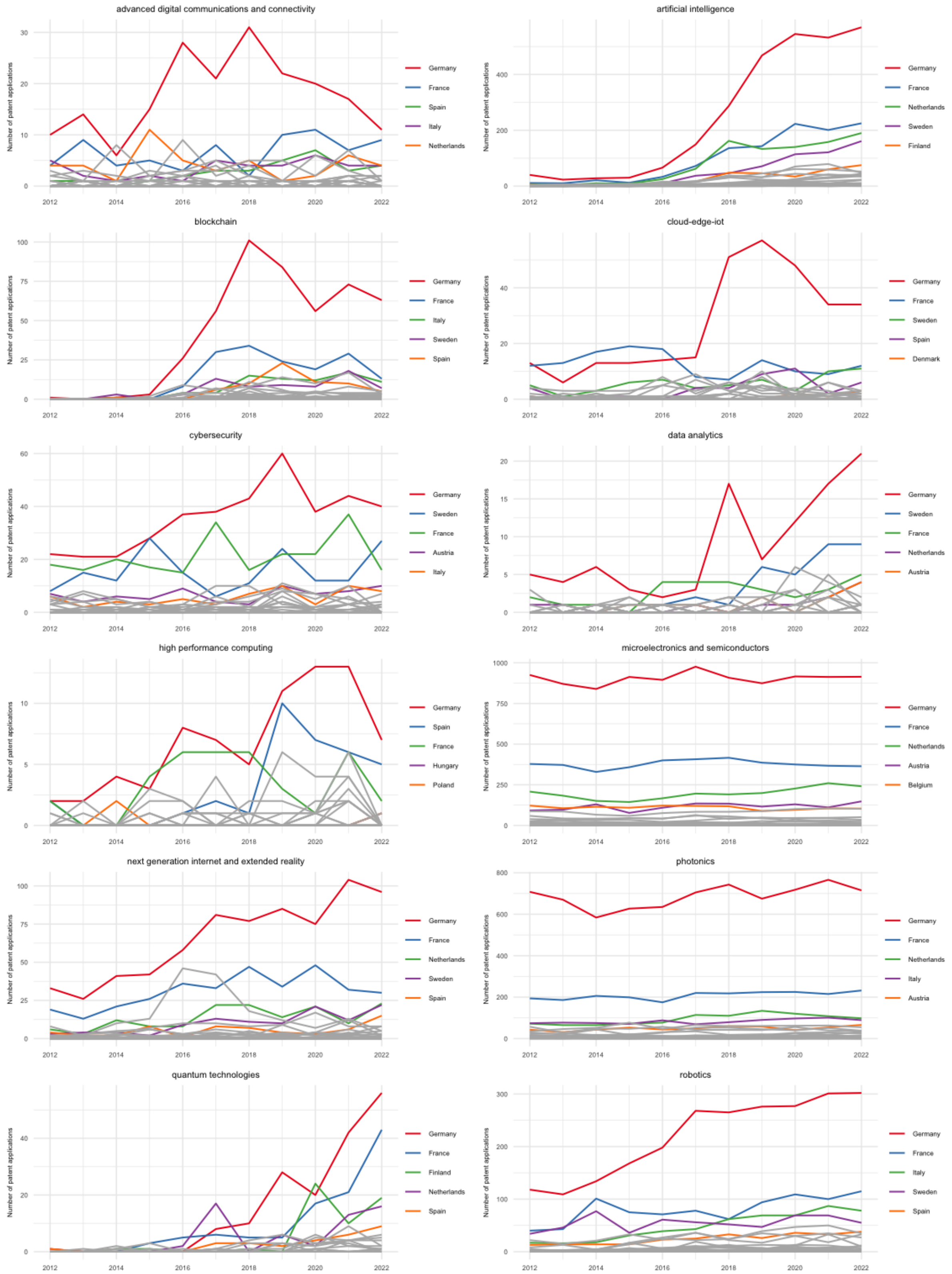
Source: European Innovation Scoreboard (2024)

Between 2017 and 2024, the EU average improved by 24 percentage points, driven by an improved performance in the Digitalisation dimension in 25 Member States, with the largest performance increases for Cyprus (75 percentage points), Finland (52 percentage points) and Czechia (42 percentage points). Performance has decreased for only 2 Member States in that period, Latvia and Belgium, with the strongest decline for Latvia (-19 percentage points).

Geographical concentration patterns of patent applications in digital technologies are aligned with the size and innovation performance of the different EU countries, with Germany and France as leaders in many digital technology fields in terms of patenting.

[162] European Commission, Innovation Scoreboard (2024), https://www.research.org.cy/wp-content/uploads/european-innovation-scoreboard-2024-KI0924445ENN.pdf

Figure 29 Total number of patent applications per technology area in EU-27 countries, 2014–2022

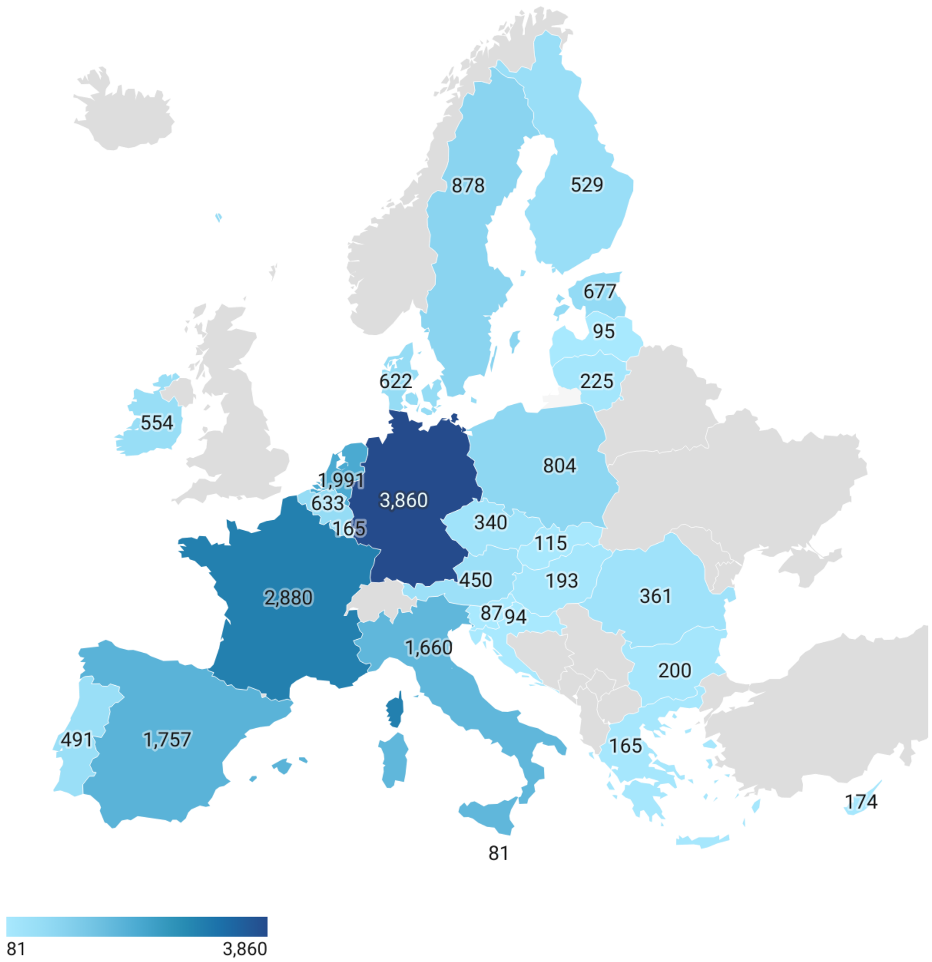


Source: Fraunhofer ISI (2025) based on PATSTAT
Note: The time series is plotted using a 3-year moving average to highlight long-term trends

The Figures above illustrate the evolution of the total patent applications per technology area in the EU-27 between 2014 and 2022. Germany and France ranks the highest in almost all digital technologies (except for Data analytics where Sweden is the second and HPC where Spain occupies the second position). The countries in third to fifth positions, however, differ in the various technology fields. Finland and the Netherlands have, for instance, a strong positioning in the quantum field, while Sweden ranks high in Cybersecurity and Data analytics technologies, and Spain in HPC. The patent distribution also reflects the European digital and innovation divide and should be complemented with reflections on the spread of the digital technology adoption to assess the extent to which cross-border deployment is effective when specific countries hold prominent specialisations in certain fields (technology supply side). This is less the case in very niche areas where the EU market is very concentrated (e.g. Microelectronics, Photonics).

Regarding digital technology start-ups, the geographical hotspots are found similarly in Germany, France, Netherlands. The map below illustrates the geographic distribution of digital-technology start-ups and scale-ups founded after 2015, as identified from Crunchbase. The five leading countries together account for 57% of all start-ups: Germany tops the list with 3,860 firms (18%), followed by France with 2,880 (14%), Netherlands with 1,991 (9%), Spain with 1,757 (8%), and Italy with 1,660 (8%). Some of the smaller Member States also perform well relative to their size such as for example Estonia.

Figure 30 Geographic distribution of digital tech start-ups and scaleups founded after 2015 in the EU



Source: Technopolis Group (2025) based on Crunchbase

2.5 EU global positioning and international benchmarking

The EU's global position in digital technology deployment should be assessed not simply by comparing the rate of technology adoption, but by its capacity to generate economic value and build competitive advantages from innovations based on digital technologies. While the EU is underperforming internationally on various metrics of digital technologies, it has opportunities to create value across many application areas. In terms of technology capabilities, **the EU's is relatively better positioned globally in Photonics and Quantum, while it is lagging behind in AI, Blockchain, Microelectronics and NGI**. The reliance on non-EU countries for digital products, services, infrastructure, and strategic investments poses high risks. This is why a stronger focus on EU digital technology, supply chains favourable to productive technology deployment, and protection of intellectual property would be essential to reduce vulnerabilities and capture greater economic value.

The global position of the EU in digital technology deployment has been central to many recent policy debates, recently culminating in the publication of the Draghi Report[163]. The analysis of the EU's global positioning provides both insight into the opportunities and potential offered by digital deployment (learning from others) and is a proxy for overall international competitiveness which is an important source of income for the EU (e.g. through exports), as well as increasingly a measure for strategic autonomy (by analysing specific dependencies).

The EU has captured comparatively less productivity growth from the ICT sector and large-scale digital services than the United States, reflecting slower diffusion of advanced digital technologies across European industries, as stated in the Draghi report[164]. This lag has contributed to a widening productivity gap, particularly in fast-moving, high-productivity sectors including software and cloud services and AI-driven firm activities, where rapid digital adoption fuels competitiveness.

Moreover, the EU's rate of adoption of AI, particularly generative AI, has been significantly slower than in the US, creating a measurable gap in spending, employee usage, and organisational readiness[165]. According to the 2023 McKinsey Global Survey on the state of AI[166], surveyed companies in North America reported a 40% adoption rate of genAI in at least one business function, whereas the figure for surveyed European companies was about 30%. Following most recent estimates, while global generative-AI adoption reached 71%, Europe remained behind North America also in 2025.

For 2028, the EU's global position has been assessed as 'medium' for most technology areas, 'low' for AI, Blockchain, Microelectronics and NGI & XR and considered strong for none of the technologies, as concluded by experts participating in the Delphi exercise of this study. This is the result in particular in relation to the EU's expected position at the start of the next MFF (2028), and expected position in 2036 (two years after the end of the next MFF) in a scenario where the current level of EU support was to continue unchanged.

For 2036, experts expect the position:

- to remain the same in Advanced Connectivity, Cloud, Cybersecurity, Data Analytics, HPC, Microelectronics,
- to deteriorate in Photonics, Quantum, Robotics,
- to improve in Blockchain, Interoperability, NGI & XR.
- to be highly competitive in 2036 in Technologies for Interoperability.

In terms of underlying factors and strengths, experts rate the EU skills & competences as relatively high, while digital infrastructures and ecosystems score well only in two areas (Blockchain and Interoperability), and medium for all other areas.

---

[163] Draghi, M. (2024). The future of European competitiveness: A competitiveness strategy for Europe [Report to the European Commission]. European Commission.
[164] Draghi, M. (2024). The future of European competitiveness: A competitiveness strategy for Europe [Report to the European Commission]. European Commission.
[165] https://www.mckinsey.com/capabilities/quantumblack/our-insights/the-state-of-ai
[166] https://www.mckinsey.com/capabilities/quantumblack/our-insights/the-state-of-ai-in-2023-generative-ais-breakout-year

Table 13 Global positioning of the EU vis-a-vis other countries

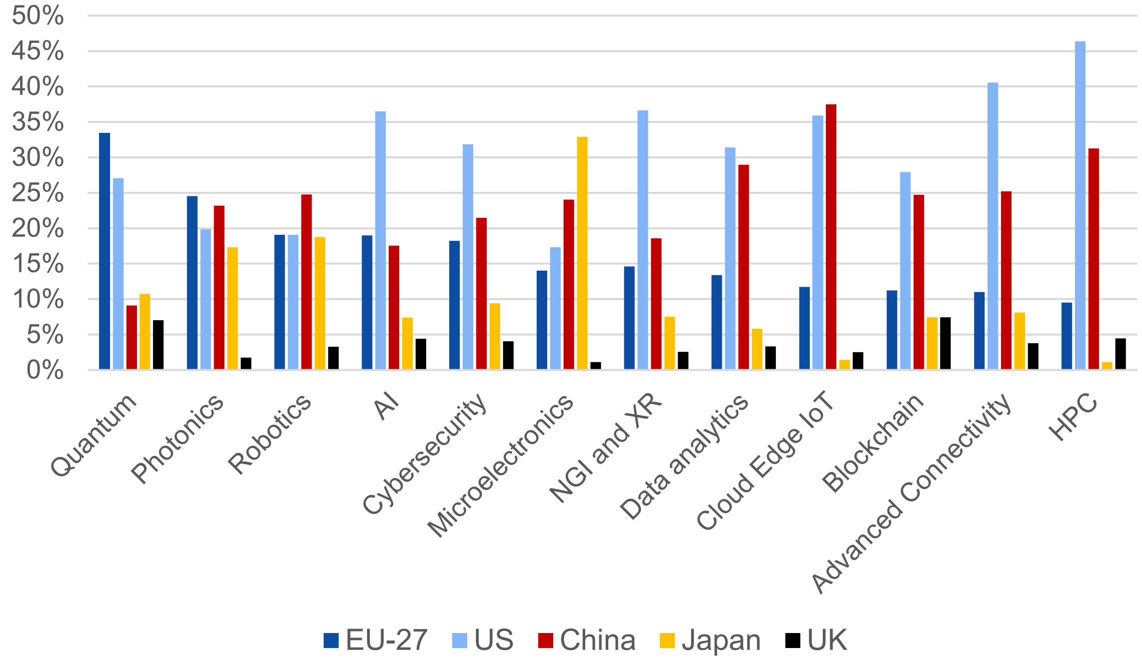
Technology area	Positioning 2028	Positioning 2036	Digital infrastructures	Skills & competences	EU digital ecosystem
Advanced connectivity	Medium	Medium	Medium	High	Medium
AI	Low	Low	Medium	Medium	Medium
Blockchain	Low	Medium	High	Medium	Medium
Cloud	Medium	Medium	Medium	High	Medium
Cybersecurity	Medium	Medium	Medium	Medium	Medium
Data Analytics	Medium	Medium	Medium	High	Medium
HPC	Medium	Medium	Medium	High	Medium
Microelectronics	Low	Low	Medium	High	Medium
NGI and XR	Low	Medium	Medium	Medium	Medium
Photonics	Medium	Low	Medium	High	Medium
Quantum	Medium	Low	Medium	High	Medium
Robotics	Medium	Low	Medium	High	Medium
Technologies for Interoperability	Medium	High	High	High	High

Source: Technopolis Group (2025), Delphi Analysis. High means high level of competitiveness vis-à-vis other countries for global positioning. For digital infrastructures, skills & competences, EU digital ecosystem, 'high' indicates whether these aspects are appropriately in place as enabler in order to address the challenges for deployment.

Regarding technology development and innovation, patent data provides further evidence regarding the EU's position in various technologies. The EU's world share of patent applications varies across technology areas and overall it shows the following:

- **In Quantum and Photonics, the EU leads globally in patent applications and remains a strong competitor in Robotics.**
- **In AI, Cybersecurity, and NGI the EU is relatively far behind** the #1, but is (close to) second place.
- **In Data Analytics, HPC, Cloud, Microelectronics, Blockchain, and Advanced Digital Communications the EU is third following the US and China respectively.**

Figure 31 World share of patent applications of the EU and its major competitors in 2022 (latest available year with robust data) (%)



Source: Fraunhofer ISI (2025) based on PATSTAT

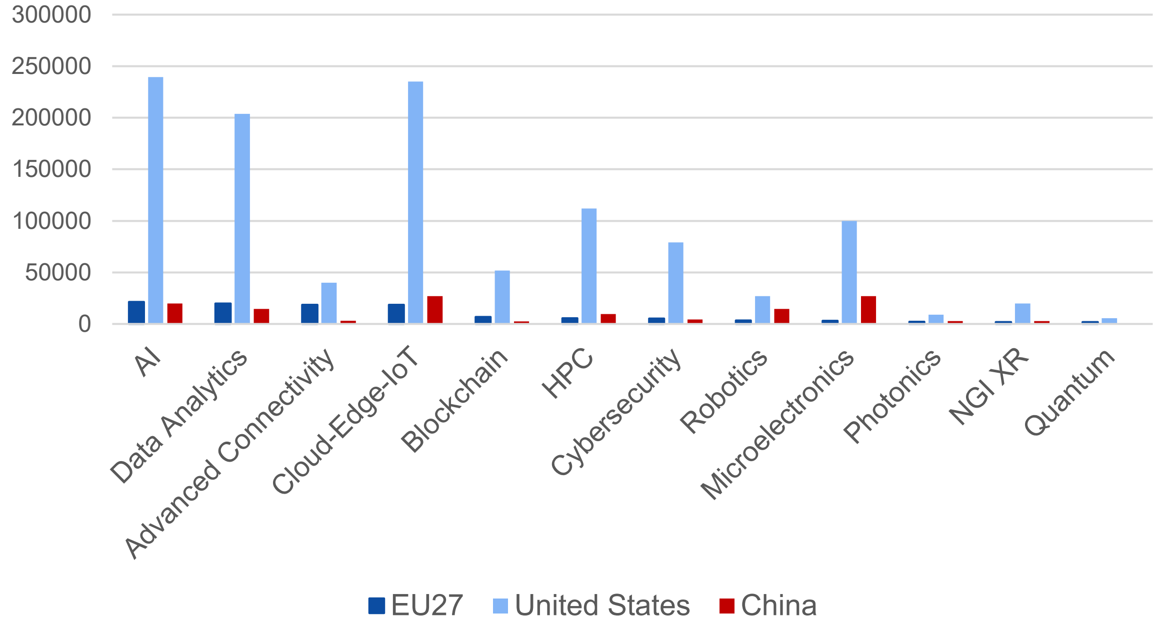
In terms of trends, the share of the EU in global patent applications is gradually decreasing in most areas in the period 2012-2022, except for Quantum, the only area in which the EU has the highest share. As such, the overall position of the EU can be characterised as being in 'third place' after the US and China, with the exception of Quantum and Photonics (see technology annexes with the yearly figures per technology area).

Despite the EU's progress, its digital tech start-up ecosystem lags behind the US, in part because of structural weaknesses in the European venture capital market and the limited role of pension funds in financing high-risk innovation[167]. According to Start-upBlink's 2025 Global Start-up Ecosystem Index[168], the US remains the top performer by a wide margin, dominating both in number and quality of ecosystems, number of start-ups, scaleups, unicorns and corporates involved in start-ups.

EU digital tech companies (related to the 12 technology areas analysed[169]) attracted €109 bn in venture capital investment over the period from 2015 to 2025, but are significantly behind the US. At the same time, the EU exhibits relatively smaller gap in Advanced Connectivity, Robotics, Photonics, and Quantum.

[167] Arnold, Nathaniel and Claveres, Guillaume and Frie, Jan-Martin, Stepping Up Venture Capital to Finance Innovation in Europe. IMF Working Paper No. 2024/146, Available at SSRN: https://ssrn.com/abstract=4904562
[168] https://lp.start-upblink.com/report/
[169] VC data into interoperability could not be collected given the overlapping character of this technology area with other domains.

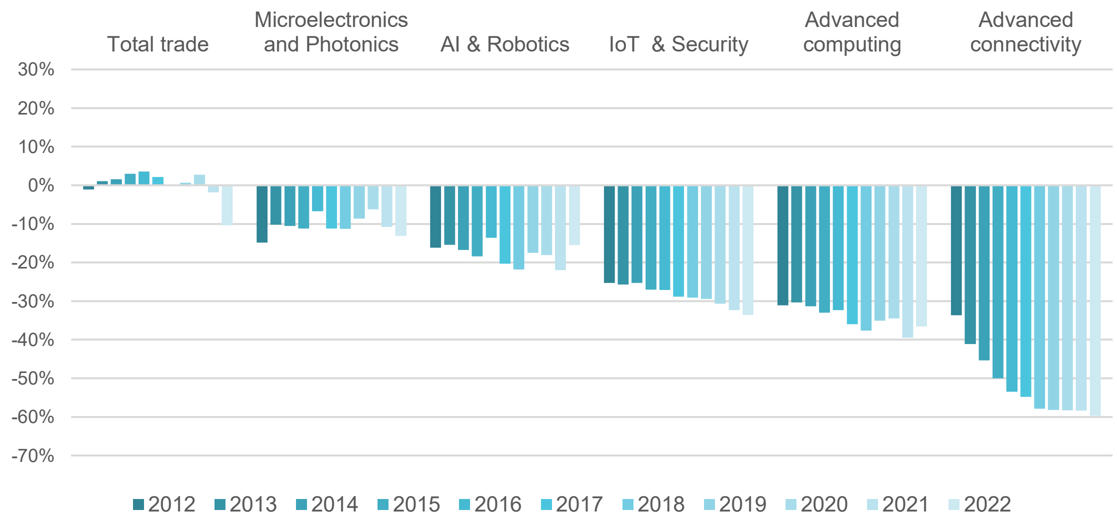
Figure 32 Level of VC investment into tech companies in the EU in 2015-2025 per technology (in € million)



Source: Technopolis Group (2025) based on Crunchbase

The trends of a gradual decline in Europe's global position are mirrored in export data and market shares that measure competitiveness in high-value digital and technology industries and indirectly reflect commercialisation opportunities and dependencies**.** The Figure below presents the trade balance for digital technologies in the period 2012-2022. **Although the overall EU trade balance is positive (meaning it exports more than it imports), in digital technologies there are strong negative trade balances in all areas ranging from -10% to -60%, with a worsening trend over the last decade in every case.** It is particularly significant in the areas of Advanced Connectivity and Advanced Computing.

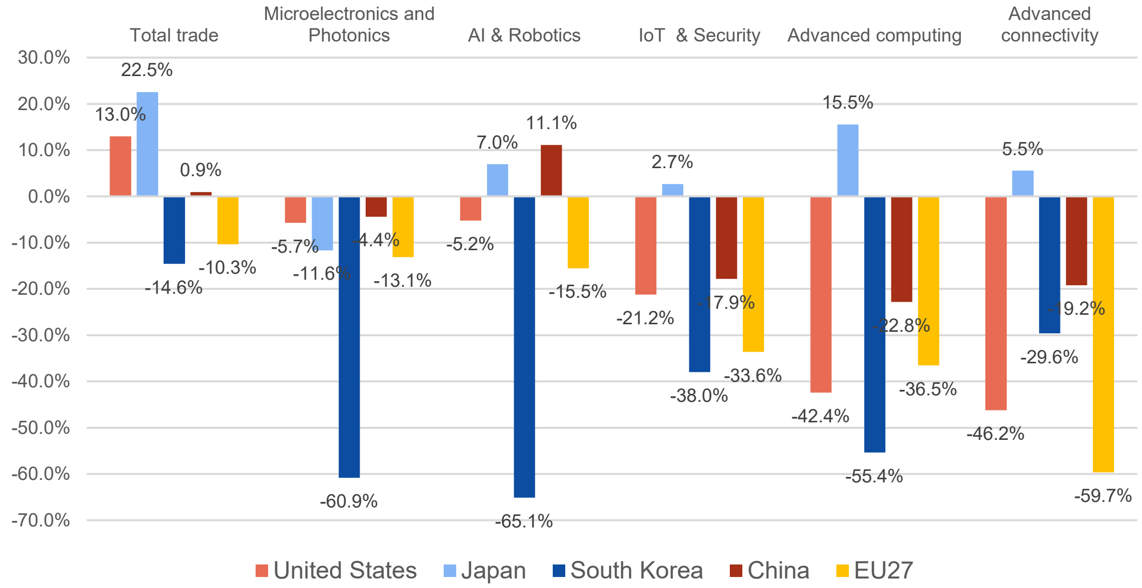
Figure 33 EU-27 Trade balance in relation to overall trade volume in 2022 for digital technologies



Source: Fraunhofer ISI (2025) based on UNCOMTRADE

The EU and US run negative trade balances in most technology areas, while China and Japan perform better in terms of positive trade balance. The figure below presents in more detail the trade patterns of the EU-27 and other comparator countries on key digital technologies. It is to be noted that this only concerns goods, as digital services are not recorded in the same way.

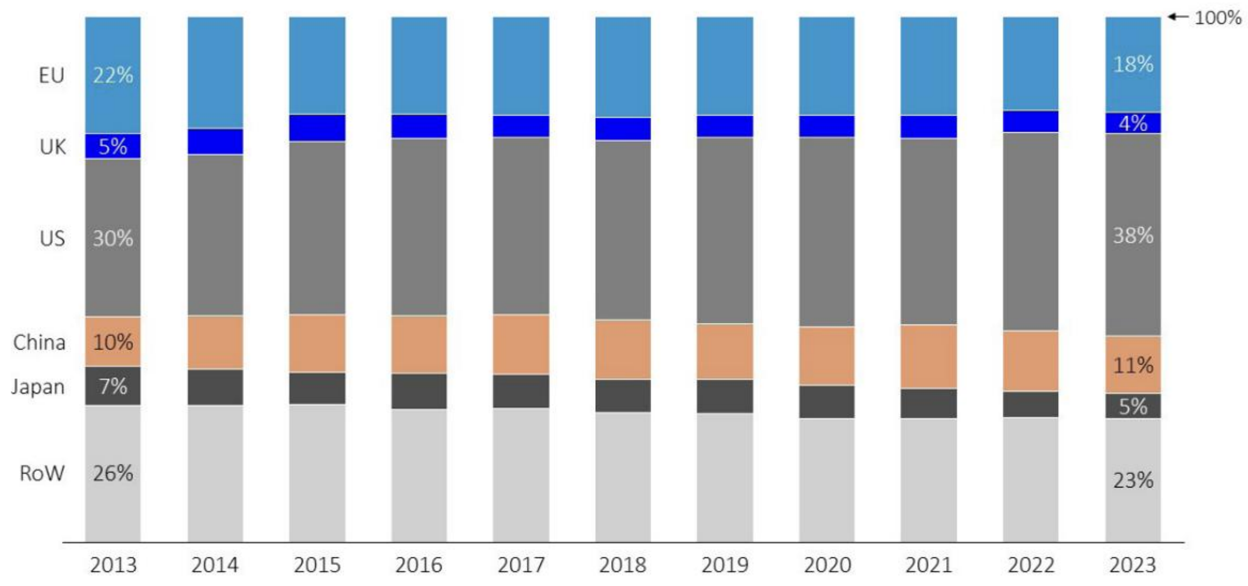
Figure 34 Trade balance in relation to overall trade volume in 2022 for digital technologies: comparison between EU-27, China, US, Japan and South Korea



Source: Fraunhofer ISI, based on UMCOMTRADE for the European Monitor of Industrial Ecosystems (2024)

Similar statistics also show that over the past decade, Europe remained a net importer of ICT products and services. Despite expansion in the EU's digital technology sectors during this second digital revolution, its share of global ICT output has declined from 22% in 2013 to 18% in 2023, while the US share rose from 30% to 38% over the same period.

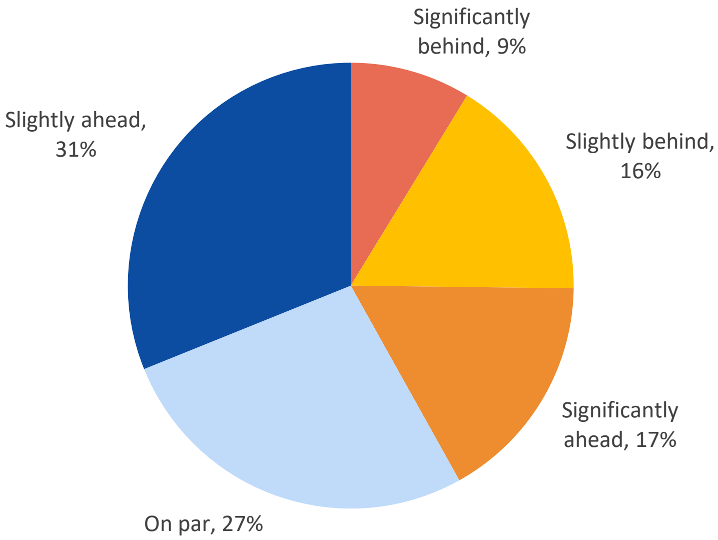
Figure 35 ICT global market share by geographic area (2013-2023)



Source: IDC, 2024

On the other hand, the market survey results indicate that the majority of companies perceive themselves as globally competitive in digital technologies. This self-assessment provides a positive counterpoint to structural challenges identified above. It suggests that, despite the bleaker picture presented by patent and trade data and despite uneven adoption trends, European companies feel confident in their technological capabilities and innovation potential, signalling strong ambition and a readiness to compete internationally.

Figure 36 How would you rate your organisation's ability to innovate in critical digital technologies compared to your global competitors (including from other EU-27 countries)



Source: Technopolis Group (2025), based on market CATI survey, n=380

3. Trends, challenges and use cases

This section of the report provides insights on the main trends and challenges related to the deployment of digital technologies in Europe. It covers technology trends, application and use cases, skills, ecosystem and international dimensions. It summarises the main findings, which are further detailed in the analysis by technology area in the technology annexes attached to this report (Annexes 1–13).

3.1 Digital technology deployment trends and opportunities

Digital technologies are evolving at an unprecedented pace, with rapid advances occurring across multiple fields. They also transform and amplify one another, creating complex interdependencies and new dynamics.

The most transformative technological trends cutting across the entire digital ecosystem are centred on advances in Artificial Intelligence. In particular, the emergence of AI agents, multi-agent systems, and explainable and trustworthy AI is reshaping how digital systems operate, moving from passive tools toward autonomous, adaptive, and accountable decision-making infrastructures. These developments are not standalone: they depend fundamentally on progress across the underlying computing, data, and connectivity layers, and enable other technological trends for example related to robotics and virtual words.

At the foundation of the stack, advancements in computing and data infrastructures are enabling the large-scale training, deployment, and orchestration. The growing role of high-performance computing is especially critical, both for training increasingly complex models and for supporting computationally intensive applications such as digital twins and real-time simulation. In parallel, the emergence of sovereign computing infrastructures reflects strategic priorities around resilience, security, and technological autonomy. Bridging the gap between hardware capabilities and effective use is another key trend. High-productivity programming environments and new language models are lowering barriers to development and enabling a broader range of users to leverage advanced computing resources. Quantum communication technologies are also advancing through a set of core building blocks, including quantum key distribution, quantum random number generation, and, in the longer term, quantum networks.

At the infrastructure and connectivity level, the Cloud–Edge–IoT continuum is enabling workloads to be dynamically distributed across endpoint devices, edge nodes, and cloud data centres. This coordinated use of network and computing resources supports latency-sensitive and data-intensive applications, including industrial automation, smart systems, and AI-enabled services. Closely linked to this is the increasing emphasis on high-quality data access, data sharing, and interoperability, which underpins industrial competitiveness and allows AI and digital services to scale across organisational and sectoral boundaries.

On the hardware side, **microelectronics and photonics innovations** remain fundamental enablers of the entire stack. In particular, chiplet and modular architectures represent a significant shift in semiconductor design since the early era of Moore's Law. By separating functions, such as processing, memory into specialised components that are later integrated within a single package, these approaches improve performance, flexibility, yield, and supply-chain resilience, while supporting heterogeneous computing architectures required by AI and high-performance workloads.

These technological trends influence the emergence of future virtual worlds and advanced digital ecosystems. Decentralised and secure Web 3.0 architectures provide the foundations for trusted data exchange, transparency, and new platform and business models, while sovereign and interoperable Web 4.0 infrastructures respond to strategic priorities around resilience, digital autonomy, and secure cross-border interoperability. Building on these layers, immersive technologies, including augmented, virtual, and extended reality, expand the boundaries of human–machine interaction and experience.

The Table below highlights the critical technological trends relevant for deployment across European industries and society, within each technology area in scope. Detailed descriptions of these trends are further explained in the technological annexes (Annexes 1–13).

The prioritisation of trends stems from experts' considerations, captured through the Delphi survey, scoping and foresight workshops, and semi-structured interviews. The level of priority for the deployment of these technologies by 2028 takes into account their maturity level and readiness for deployment, the existence of relevant use-cases in key sectors with potential market uptake in Europe, as well as their potential economic and societal impact. High priority for deployment was defined as actions that must be implemented first because they are critical to achieving core objectives, while medium-priority actions are important but less urgent steps that support long-term progress rather than immediate needs.

Table 14 Key technology trends impacting the future use of technologies by 2028

Technology Area	High priority for deployment	Medium priority for deployment
Advanced digital communication & connectivity	Mobile networks (5G, 6G, next generation connectivity) Multi-access edge computing Cloud-native networking Optical communication technology Advanced Non-Terrestrial Communication Systems *Cross-technology:* AI-driven network management	Time sensitive networking and deterministic routing Reconfigurable and Adaptive Wireless Technologies Joint Communication and Sensing (JCAS) and Integrated Sensing and Communication (ISAC) Network Function Virtualisation
Artificial Intelligence	Foundation models AI Agents / Multi-agent systems Explainable AI, Trustworthy AI Supervised (self-supervised), unsupervised, reinforced, transfer learning, federated learning and causal machine learning and other adaptive learning algorithms Natural language processing (NLP) and Natural language understanding and other language models Novel AI-human interaction such as prompt engineering, natural user interfaces, speech recognition, intelligent personal assistants *Cross-technology priority:* HPC for AI Edge AI AIoT (Artificial Intelligence of Things)	Decentralised multi-agent systems Causal AI Frugal AI / Green AI Neurosymbolic AI (former Hybrid AI) Classic Symbolic AI Recurrent neural networks Convolutional Neural Network Fairness and privacy and copyright-aware machine learning techniques Multimodal (gen) AI Narrow AI/Specific AI Embodied AI Open-source AI Cross-technology priority Neuromorphic computing
Blockchain	Scalability Blockchain interoperability Zero-knowledge technology Self-Sovereign Identity / Verifiable Credentials Regulatory Compliant Private Payments Smart Contracts AI & ML integration with blockchain Green blockchain	Consensus Mechanisms Decentralised marketplace Decentralised physical infrastructure networks (DePINS) Central Bank Digital Currency
Cloud-edge-IoT	Energy-efficient computing systems Interoperability with HPC/AI factories Integrating RISC-V hardware in the Cloud-Edge for cutting-edge and sustainable processors in Europe Increasing data processing at the Edge contributing to a more resilient,	AI native cloud / cognitive cloud offering scalability and flexibility On-prem 5G/6G Edge-Cloud for Industry 4.0 and beyond to ensure resilience and reliability Seamless data connectivity across different networks & space Edge (satellites)

Technology Area	High priority for deployment	Medium priority for deployment
	green and secure computing ecosystem Edge computing and AI convergence for real-time insights and intelligence decision-making Integration of IoT with digital twins Intelligent IoT devices at the Edge	Operating systems and orchestration concepts for edge IoT systems to enable processes, traceability, safety and security Seamless secure computing continuum & confidential computing to enhance security and privacy needs
Cybersecurity & digital identity technologies	Ransomware & Extortion Protection Secure IoT Chips Zero-Trust Orchestration Platforms Use of AI/ML for Anomaly Detection & Behavioural Analytics Offensive AI & AI System Security Embedded System Security Lightweight Cryptography for IoT Decentralised Identity Digital Wallets Post-Quantum (Quantum-Safe) Cryptography Self-Sovereign Identity / Verifiable Credentials Zero-Knowledge Technology	Automated "Contain-and-Remediate" Orchestration Continuous Authentication Crypto-Agility / Futureproofing Fog/Edge Computing Security AI-Augmented Digital Forensics 5G/6G Security Advancements Explainable (XAI) Security / Digital Twin Security Confidential Computing Synthetic data to train and test security systems Regulatory Compliant Private Payments
Data analytics	Data interoperability Data security technologies Data spaces & other data intermediaries (data sharing platforms and business models) Data management and governance technologies and standards, including trust protocol & data usage control technologies High value datasets & data quality & technologies for addressing bias in datasets Advanced data analytics (prescriptive), real-time analytics and implementing AI in data analytics Privacy preserving techniques for data sharing	Data storage technologies, including DNA data storage & novel data compression algorithms New data architectures (mesh, fabric, lake, biomimetic) Data visualisation and human-data interaction technologies Multimodal data sharing for AI integration (Text, Video, Speech, etc.) Novel data connectors Federated data space architecture and data ecosystems Synthetic data
HPC	High Productivity Programming & Language Models Hardware / Software Co-Design Specialised AI accelerators Open-Source Software development	Confidential Computing Quantum Computing Hybrid Quantum-Classical HPC High Performance I/O systems and tools Sustainable computing / Energy-efficient logic devices Photonic Communications and Computing Mixed Precision Computing Open-Source & Custom ISAs (RISC-V) Heterogeneous Target-Independent HPC & Performance portability Object Storage and adapted lawyered software storage Neuromorphic Computing 3D Stacking (2.5/3D Integration)
Microelectronics	3D stacking and wafer-level packaging for high-density integration Chiplet and modular architecture for flexible system design	High-resolution multi-Sensor fusion and real-time processing Advanced metrology and yield optimisation solutions Reconfigurable and Adaptive AI Hardware

Technology Area	High priority for deployment	Medium priority for deployment
	In-Memory Computing and Emerging Memories Technology AI-Optimised semiconductor toolchains and software co-design Novel transistor architectures beyond traditional CMOS Open Instruction Set Architectures (e.g. RISC-V) for Custom Processor Design Wide Bandgap (WBG) and Ultra-Wide Bandgap (UWBG) Material for high efficiency electronics	AI in Electronic Design Automation High-NA EUV and alternative lithography techniques for Sub-2nm Nodes Domain-specific architectures for optimised processing Bio-integrated electronics Advanced photonic materials & light-matter engineering (Perovskites, Metamaterials) Brain-inspired and neuromorphic chips Quantum and superconducting electronics for computing and sensing 2D and Dirac Materials for scalable and ultra-low power devices Minimal Fab and low-volume production
NGI & XR	*NGI:* Decentralised applications (dApps) Decentralised finance (DeFi) platforms Develop privacy, security, interoperability (advanced encryption and privacy tools) Next-generation peer-to-peer systems *XR:* Multisensorial technologies Digital twins of objects active in virtual words Wearable immersive devices User devices to satellite connectivity and frugal offline resources on devices	*NGI:* Fog and cloud computing infrastructure *XR:* Humanistic agents Automating virtual worlds production with AI generated contents Public service immersive multi-user platforms
Photonics	Photonic accelerators & neural networks for advanced computing Biomedical imaging and sensing Test Equipment and Metrology Optical computing architectures Laser communication PIC design, simulation, and layout tools Heterogeneous Integration Advanced packaging & co-Integration Photonic Integrated Circuits (PICs)	Chip to chip, and board to board optical interconnects Photonics-based stealth and countermeasures (incl. High energy laser) Advanced Photonic Sensing (4D sensing) Nanophotonic Integration Fibers including HCF Quantum Photonic devices Metamaterials and meta surfaces Two-dimensional (2D) materials Novel laser architectures QDs in photonic integrated devices Free-space optics & novel optical systems Nonlinear optical materials
Quantum	Development of quantum sensor technologies and applications Reduce error rates in quantum computers to the point of industrial viability Quantum algorithms and software development Quantum stability and scalability Quantum metrology Green quantum computing Development of key enabling technologies for the large-scale integration of qubits (control and readout electronics in view of large-scale integration)	Access to quantum computing capability Quantum random number generators (QRNG) for the development of secure keys to protect against quantum decryption Quantum Key Distribution Quantum networks
Robotics	Robot safety & dependability	Novel robot production processes

Technology Area	High priority for deployment	Medium priority for deployment
	Human robots teaming and collaboration Communication system for robots Robot-AI integration Software for robotics Platform for robots and autonomous systems Smart/advanced materials and energy efficient and energy conserving structures for robots	Self-powered robotic & energy and battery to improve autonomy and expand potential application Novel actuation technology for higher power to weight ratios and energy efficiency Chips for robotics Novel robotic control technologies & force and motion control (for real dexterity) Swarm robotics Bio-compatible/bio-inspired and soft robotics
Technologies for interoperability & GovTech	Semantic Data interoperability and digital transformation: • Machine readability • Platform Neutrality Infrastructure: • Digital Public Infrastructure • Cross border data spaces Artificial Intelligence for Interoperability	Digital Twins for Public Administration and Services Artificial Intelligence in the Public Sector

Source: Technopolis Group (2025) based on desk research, Delphi survey, foresight workshops and validation workshop

3.2 Key challenges

Trends in technology deployment are driven by multiple challenges that affect not only how technologies evolve, but also the pace and scale at which they are adopted. The most frequently cited challenges to digital technology adoption in Europe are **market fragmentation and interoperability issues, insufficient investment in commercial deployment and shortage of digitally skilled workforce** for technology adoption. Investment constrains are rated as the most important barrier for both large companies and SMEs. Also often mentioned by stakeholders, the **lack of agility in public support** to technology deployment and administrative burden create additional challenges given the speed of technology development in those digital fields.

3.2.1 Challenges of deployment in the private sector

Insufficient investment was identified as the most significant barrier to deployment for both large companies and SMEs, as confirmed by market data in the previous Chapter (see Figure below). Firms' investments are constrained because digital transformation requires substantial upfront spending on infrastructure, software, and skills, while returns may take time to materialise or are difficult to quantify. This is compounded by limited access to finance via banks or other financial sources. Start-ups and SMEs often lack the funding and investor confidence needed to sustain projects, leading to a reliance on short-term initiatives. Despite these barriers, many see AI, cloud computing, automation, and digital twins as critical tools for improving efficiency, sustainability, and competitiveness, provided the ecosystem can overcome regulatory, financial, and human capital obstacles.

Market fragmentation is another key challenge in the EU to overcome, which stems from divergent national markets and related regulatory systems, but also differences in consumer preferences and economic conditions. For digital businesses, these variations present substantial obstacles to expanding and operating seamlessly across multiple EU Member States. This well-known challenge[170] continues to feature on the top for company executives both for large companies and SMEs. At the same time, fragmentation is amplified by market pressures such as strong global competition (particularly from Asia), unpredictable demand, and stagnating growth in some parts of Europe.

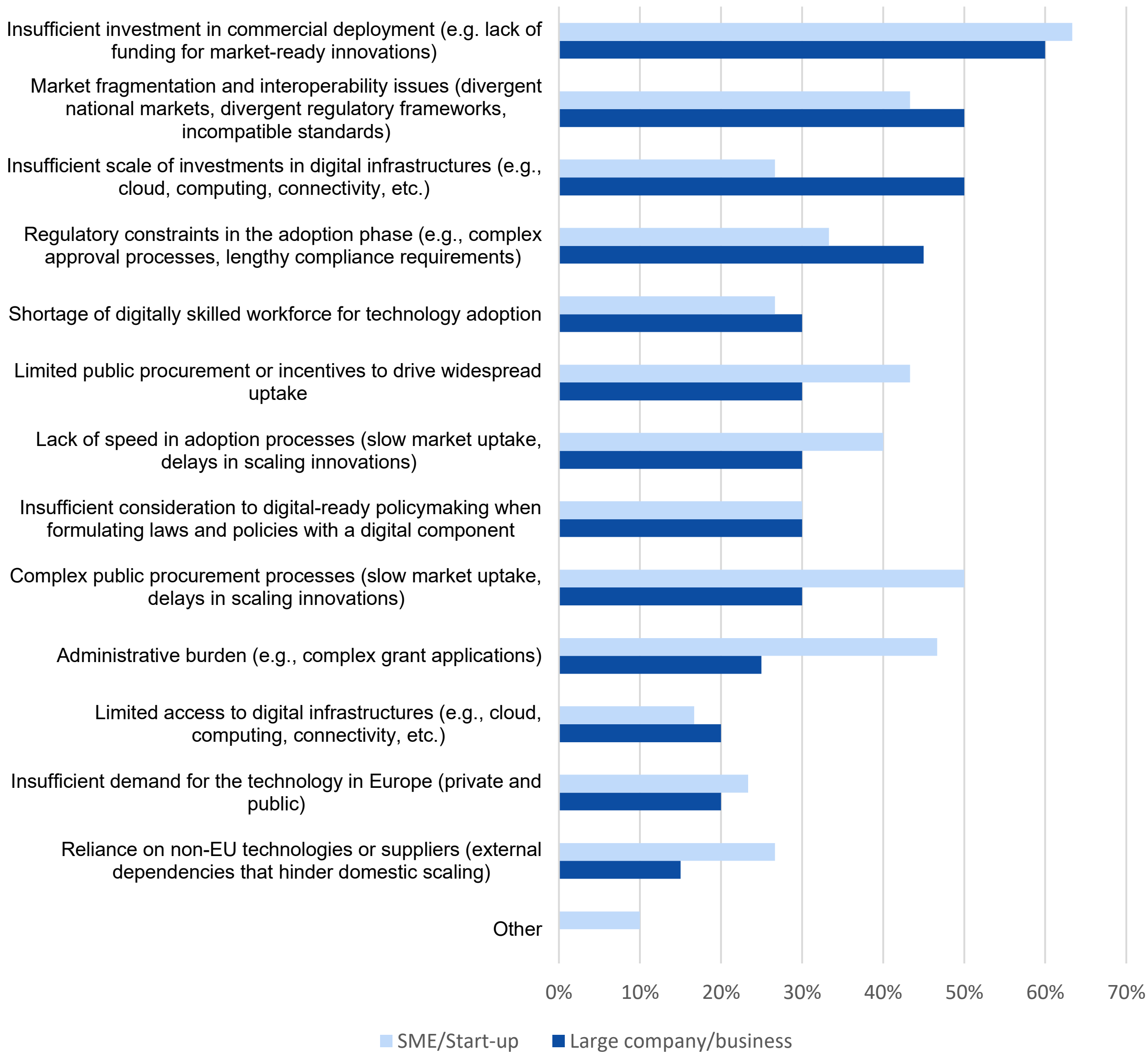
[170] See also in 'The future of European competitiveness': Report by Mario Draghi

Insufficient investment in digital infrastructure is identified as the third most significant barrier by companies, highlighting persistent gaps in high-speed connectivity, data infrastructure, and advanced computing capabilities.

Regulatory complexity is an issue especially in highly regulated sectors like healthcare and finance, where fragmented rules across countries make compliance even more costly and time-consuming. More specifically, consulted companies mentioned that the EU AI Act introduces too many and strict rules on transparency, risk classification, and compliance obligations, particularly for high-risk AI systems. In contrast, Japan's regulatory approach is more flexible and industry-driven, focusing on voluntary guidelines and innovation support rather than prescriptive legal requirements. It was stressed that regulation should be co-developed alongside the technologies themselves. Traditionally, regulation follows innovation, but developing both in parallel could give Europe a unique advantage and reduce future conflicts between policy and technological growth.

Shortages of skilled staff, the need for continuous reskilling, and difficulties in recruiting talent to support digital transformation is another main challenge stated by companies in general. Many employees are not accustomed to working with advanced technologies, and highly educated specialists are often hard to find.

Figure 37 Challenges and barriers to digital technology deployment in Europe as identified by large companies and SMEs/start-ups in 2025



Source: Technopolis Group (2025), stakeholders' survey, n=231

There is a clear difference between the challenges faced by large companies and SMEs. While insufficient investment is the primary obstacle for both, SMEs and start-ups identify complex public procurement processes (slowing market uptake) and administrative burden as their next most significant issues. For large companies, market fragmentation emerges as a more prominent concern.

For SMEs and start-ups, **administrative bureaucracy and difficult public tendering systems slow innovation** and create barriers to market access. With regards to regulatory constraints, this is often nuanced as a barrier to technology uptake. On the one hand it creates hurdles and sometimes lengthy and cumbersome compliance issues, while on the other it provides a clear and stable framework for technology companies to operate in.

Interviews also highlight that on the technical side, both large companies and SMEs struggle with legacy IT, the difficulty of integrating new advanced digital technologies across multiple platforms, immature AI applications, and cybersecurity threats. From other sources[171], it is also understood that there is pressure pushing companies to implement AI quickly without a clear strategy, often prioritising speed over planning. Many organisations lack the digital foundations needed to support AI, making it difficult to transition from legacy processes. The rapid pace of technological change risks obsolescence, while dependence on a single vendor creates potential lock-in in a volatile ecosystem.

Interviews suggest would-be adopters get stuck mid-cycle: having become aware of a potential innovative application and positively evaluated its relevance to their situation, organisations struggle to find the time (and service providers willing to help) to run real-world trials within their own organisations, which would allow a final decision as to whether to adopt or reject an innovation. The disruption and opportunity cost of a poor decision can be considerably higher than the financial cost, which can cause many would-be adopters to wait. This is echoed in the feedback about uncertainty regarding the relevance of innovative technologies or their cost effectiveness. Both challenges are more problematic when suppliers and the ultimate developers are based in other countries or regions outside Europe. For many organisations, adopting digital technology solutions involves risks and vulnerabilities in terms of cybersecurity. These can be mitigated if technology suppliers provide strong account management and remain committed to continuous support and tailoring their systems.

On the demand side, companies also point to the need to better demonstrate the value of digital products and services to clients, as well as to manage rapid changes in client expectations. Many find that there is a lack of awareness and understanding among citizens and SMEs about the benefits and accessibility of certain technologies, such as high-performance computing or XR. This lack of understanding can hinder digitisation efforts and is causing a slow adoption of new technologies despite their technical maturity. The need for the development of digital solutions that are industry and demand-driven was also emphasised. If products and innovations do not meet real industrial demand, public investments risk being wasted. However, while industry should lead, societal aspects must also be taken into account to ensure inclusive and sustainable innovation.

The high cost of energy is also identified as a significant barrier in particular for some technology investments such as in microelectronics, quantum or HPC. For companies deciding where to establish high-tech facilities such as wafer fabrication plants, energy prices can be a major deciding factor. In some European countries, the cost of electricity is prohibitively high, making investment less attractive compared to countries in Asia.

Lastly, what stands out is the quest for impact: organisations are increasing their use of AI tools, but this rising usage does not translate into meaningful business impact because adoption is treated as a technology rollout rather than a transformation of work and ways of working, as also highlighted in a recent report[172]. Firms often focus on pilots and tool deployment without embedding AI into core workflows, reimagining job roles, or addressing psychological and organisational barriers that hold employees back from fully integrating AI into their daily tasks. As a result, AI remains under-leveraged, with many

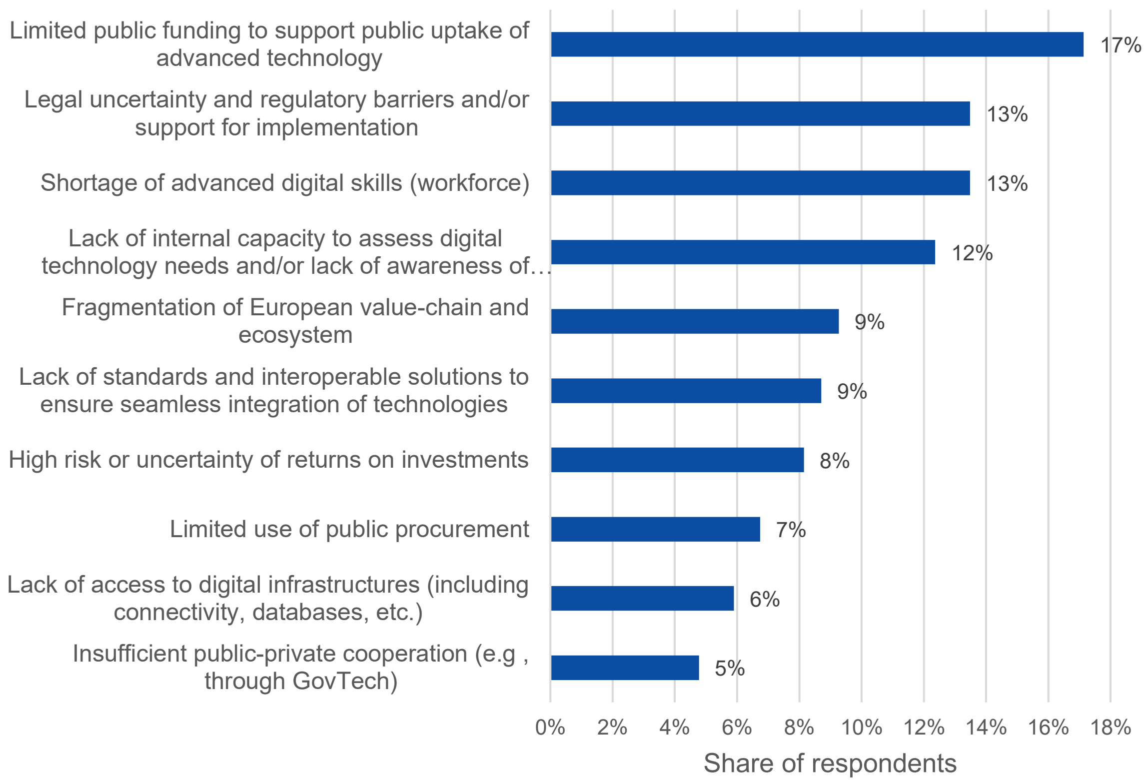
[171] McLarty, M. (2025). Enterprise AI adoption in 2025: What actually works
[172] Boston Consulting Group. (2025). The AI adoption puzzle: Why usage is up but impact is not. https://www.bcg.com/publications/2025/ai-adoption-puzzle-why-usage-up-impact-not

employees using it only at a basic level and companies struggling to realise measurable value despite growing usage[173].

3.2.2 Challenges in the public sector

Public sector organisations such as ministries, national and regional agencies, technology centres and universities see the **limited availability of public funding, the legal uncertainty and regulatory complexity combined with limited support for implementation (in particular in the case of AI) and the shortage of advanced digital skills in the workforce** as the most important barriers limiting the uptake of advanced technologies. Many organisations face a **lack of internal capacity** to assess technology needs and low awareness of existing solutions, which prevents them from identifying the most suitable tools and strategies.

Figure 38 Factors that limited most public sector organisations' ability to adopt digital technologies



Source: Technopolis Group (2025), Public sector survey on digital technology adoption, n=107

Public organisations **face barriers in terms of technical reliance on legacy systems that are costly to change and often resistant to change.** This problem is amplified by a lack of funding and limited investments, which makes it difficult to replace outdated infrastructure with modern, interoperable platforms. Many digitalisation efforts remain at the pilot stage, with little capacity or incentives to scale solutions across entire organisations or regions. The absence of advanced technologies such as AI, automation, and data analytics leads to long processing times and weak decision-making capacity, while fragmented IT systems and data silos hinder collaboration. Moreover, the public sector struggles with a shortage of digital skills, both in terms of specialised IT staff and the wider workforce, making it harder to implement and maintain new tools. Innovative public procurement was cited as considerably under-used in Europe as a tool for the public sector to drive technology adoption as first mover.

The results suggest that on average the public sector tends to be less open to adopting innovative digital solutions than is the case with the private sector. This reflects wider research on the issue (see the work of the Observatory of Public Sector Innovation[174], OECD), beyond

[173] Ibid
[174] https://oecd-opsi.org/

digital, which found that the public sector has fewer strong incentives to innovate as compared with the private sector and confronts an array of other cultural and structural barriers such as the need to minimise risk and maximise economy.

3.2.3 Technology specific challenges that hinder deployment

Drawing from desk research, interviews, Delphi results and foresight workshops, the section below highlights some of the key challenges that hinder the deployment of digital technologies in Europe.

In the case of Advanced Connectivity, security and resilience are seen as central concerns in the current geopolitical context. With networks becoming more complex and data-rich, threats grow in scale and sophistication. Europe's digital connectivity ecosystem faces multiple structural barriers, including misalignment between infrastructure development and the specific needs of sectors such as healthcare, automotive, and defence, which often underestimate connectivity's strategic importance. Slow rollout of critical infrastructure, such as fibre networks, 5G standalone, edge nodes, and advanced satellite systems combined with limited funding and investment incentives, further hampers progress, especially as non-European competitors gain momentum. Market fragmentation across EU Member States, regulatory inconsistencies, weak commercialisation of research, and limited venture capital restrict scalability and global competitiveness. Dependence on non-European suppliers and US-based cloud hyperscalers raises concerns over digital sovereignty, while gaps in standardisation influence, AI-driven network management, and specialised digital skills add to the challenge.

In **Artificial Intelligence**, deployment faces several interrelated technical, economic, and security challenges. **Models can generate inaccurate or biased outputs, particularly in high-stakes domains.** Leading US systems still outperform most EU models on key benchmarks, though higher accuracy often comes at the cost of significantly slower runtimes. Organisations also struggle to scale AI from experimentation to reliable, cost-effective production, while limited transparency in "black box" systems complicates accountability and regulatory compliance. Additional barriers include data privacy and security risks, rising energy consumption, latency issues in real-time applications, and the need for substantial computational power, specialised hardware, and cooling infrastructure. Heavy reliance on a small number of hardware vendors further raises resilience and digital sovereignty concerns.

Blockchain and distributed ledger technologies: Public blockchains continue to struggle with throughput, finality, and confirmation time limitations, while private networks experience fewer scalability constraints due to smaller node sets. At the same time, blockchain ecosystems remain fragmented, with many networks operating in isolation, creating security risks, limiting user bases, and making cross-chain interoperability, through shared standards and communication protocols, essential but still underdeveloped. Public sector adoption introduces additional constraints, including requirements for decentralised yet compliant data storage, data localisation for sensitive information, human-in-the-loop governance, and adherence to EU data protection rules, with initiatives like the European Blockchain Services Infrastructure offering a trusted but not fully interoperable solution. Emerging modular architectures that separate consensus, execution, and data availability, along with hybrid consensus models, show promise but are still maturing and must meet the demands of low-latency applications such as real-time finance and gaming. Privacy and security challenges persist in deploying self-sovereign identity and digital wallet solutions, which require continuous maintenance, stakeholder coordination, and integration across systems, while smart contracts increasingly need formal verification to reduce exploit risks. Further complexity arises from efforts to integrate blockchain with AI/ML, where auditability benefits are offset by concerns over data integrity and reliability, and from the shift toward greener consensus mechanisms that improve energy efficiency but raise validator costs and accessibility barriers.

In **Cloud-Edge-IoT**, the convergence of cloud infrastructure, edge computing, and connected devices is seen as a cornerstone of Europe's digital transformation, reshaping how data is processed, stored, and used. This computing continuum enables new capabilities but also introduces challenges around scalability, security, and technological sovereignty. A key issue is the need for real-time, low-latency performance, which centralised cloud infrastructure often cannot deliver. **Security, privacy, and data sovereignty** are growing concerns in distributed environments. Local processing limits exposure to hyperscalers, while technologies like Confidential Computing and Meta-Operating Systems (Meta-OSs) enhance privacy, traceability, and trust, particularly in sensitive sectors like health and public services. Deployment complexity is another major hurdle. Systems span diverse hardware and platforms, and skills shortages add strain. Solutions include modular architectures, AI-assisted management, low-code tools, and stateful serverless computing, which simplify operations and reduce technical barriers.

Ensuring interoperability is critical for cross-border and cross-sector use, however the lack of unified standards hinders integration. Meta-OSs, open-source platforms, and a unified API layer are vital to orchestrate services and connect federated cloud and data providers. Resilience and reliability are essential, especially for critical systems. Edge computing ensures local functionality during network disruptions, key for robotics, autonomous systems, and industrial control. Sustainability is an increasing priority. Energy-efficient edge systems, Green IoT, and low-power semiconductor designs, including RISC-V integration, help lower the digital infrastructure's carbon footprint.

In **Cybersecurity and digital identity technologies**, deployment across the EU is progressing but remains uneven across sectors and Member States. Key priorities include **cloud and edge security**, with growing interest in vendor-neutral, sovereignty-focused solutions. Key challenges to overcome include:

- **AI in cybersecurity**, balancing its benefits for defence with its misuse by attackers; developing adversarially robust AI.
- **Endpoint and IoT security**, requiring hardware roots of trust, secure lifecycle management, and harmonised certification across Member States.
- **Zero Trust adoption**, slowed by legacy IT systems, fragmented procurement, and vendor lock-in, especially in the public sector.
- **Encryption and post-quantum readiness**, ensuring smooth, coordinated migration to post-quantum cryptography with shared toolkits.
- Threat intelligence sharing, limited by inconsistent taxonomies and insufficient privacy-preserving mechanisms across borders.
- **Cloud security sovereignty**, with strategic dependence on non-EU hyperscalers exposing critical infrastructures.

In the field of **Data analytics and related technologies**, high technical complexity of deploying data space infrastructure, combined with fragmented solutions and insufficient guidance, impedes technology deployment. Key challenges range across technical architecture, interoperability, data governance, security/privacy, and implementation/scalability. The key challenges to overcome include:

- **Technical architecture**: Coordinating a massively distributed architecture is difficult; the system must handle heterogeneous infrastructure and network conditions. It is challenging to guarantee scalability when data operations span many sites not defined a priori. Also, embedding sharing capabilities by design (as opposed to bolting them on later) is a challenge, requiring common protocols and possibly new integration technology.
- **Interoperability challenges**: Each sector or company may use its own data formats (e.g. a hospital vs. an energy grid operator). Converting and normalising these into standard or open formats is difficult but essential. Adopting common data exchange APIs and standardised data representations can mitigate this heterogeneity as also further described below as part of the Interoperability and GovTech area.
- **Data governance**: Establishing robust data governance in a multi-organisation environment is another major challenge. Data spaces require clear rules and mechanisms for data ownership, usage rights, compliance with laws, and ethical data use.

In **High Performance Computing** **sovereignty has become a transversal concern**. Europe's HPC ecosystem faces structural weaknesses, including heavy dependence on NVIDIA hardware and software, creating risks of technological lock-in and limited competition. Despite ambitions to strengthen semiconductor sovereignty, Europe remains technologically behind leading global producers and continues to rely on imported critical components. Funding is fragmented and largely focused on low-TRL research, leaving many projects stuck at prototype stage without clear pathways to industrial scaling. Software portability lags behind increasingly diverse hardware architectures, while industrial users remain reliant on legacy systems that are difficult to adapt to new accelerators. Although Europe shows strength in energy-efficient system design and domain-specific HPC applications, it struggles to integrate AI effectively and scale innovations. Limited funding for ambitious projects, a fragmented innovation approach that avoids "picking winners," and strategic dependence on a small number of global memory chip suppliers further constrain competitiveness and resilience.

In **Microelectronics**, Europe's semiconductor ecosystem faces structural weaknesses across the value chain. Advanced chip manufacturing has largely shifted to Asia, leaving Europe focused on mature technologies and dependent on external suppliers for cutting-edge logic, AI processors, GPUs, and memory components that underpin digital transformation in areas such as Artificial Intelligence, connectivity, and smart industry. The EU also has a comparatively small and fragmented fabless sector, limited access to non-European EDA software and design IP, and insufficient backend manufacturing and advanced packaging capacity. Heavy reliance on foreign providers for critical raw materials further heightens geopolitical risks.

In Next Generation Internet (NGI) and extended reality technologies, one of the key challenges of deployment is the fragmentation of the European digital ecosystem, as NGI and XR initiatives often lack coordination, shared infrastructure, governance and alignment. The market fragmentation translates into a lack of interoperability and common standards across different platforms, devices and systems. Many NGI and XR projects operate in isolation, led by small teams without strategic coordination or scale-up support. Current XR experiences often fall short in presence, realism and personalisation. Many systems fail to create a convincing sense with issues such as motion latency, narrow fields of view, and imperfect spatial tracking disrupting immersion. XR technologies have the capability to collect vast and highly sensitive datasets, including personal, biometric, and behavioural information that raises questions about trust in the technology. The XR ecosystem is characterised by a dependence on non-EU hardware and platform providers which dominate consumer-facing and high-value layers of the XR value chain. This raise concerns on the trade risks and the pricing power of those dominant non-EU organisations, putting at stake not only the availability of key technologies but also their profitability and sustainability. Adoption is also constrained by high costs and bulky form factors (hardware (like VR/AR headsets, smart glasses, or wearables) that is still large, heavy, or uncomfortable compared to what users expect for everyday use), and limited battery life.

Photonics is a fast-growing field and a key digital technology for Europe, however, the photonics ecosystem is fragmented, limiting its ability to scale innovations. The sector is dominated by SMEs and startups that struggle to access growth capital, leading to an inability to transition from R&D to commercialisation. The photonics value chain is scattered across numerous regions and lacks consolidated manufacturing capacity. European photonics firms report severe delays on the provision and high reliance on Chinese suppliers for key components. Europe lacks hyperscaler tech firms that would drive large-scale adoption of photonic technologies (as seen in the US and China). In addition, there is limited alignment between photonics R&D and major European industrial players, weakening demand signals. Many promising technologies stagnate at TRL 5–6 due to insufficient mechanisms for industrial transition and late-stage funding. End users in critical mass-market segments (e.g., consumer imaging, data centres) are often non-European, weakening local demand and market feedback loops. A further key challenge of photonics industry is the severe skills shortage.

In **Quantum technologies**, **the key challenges to overcome include:**

- Error correction and scalability, with fault-tolerant quantum computing requiring large-scale integration, stable architectures and a large number of logical qubits,
- Increasing the number of entangled qubits and developing low-power control and readout electronics
- Development of key enabling technologies, including advanced cooling technologies
- Hybrid HPC–quantum integration, where tools, middleware, and software stacks for seamless workflows are still in development
- Algorithm and software readiness, as most applications rely on NISQ-era interim solutions with limited real-world advantage
- Quantum communication scaling, needing quantum repeaters, entanglement distribution, and robust layering of classical and quantum protocols
- Deployment of quantum sensing, requiring miniaturisation, energy efficiency, integration with classical sensors, and ruggedisation for real-world environments.
- Metrology and certification, to establish standards and reliability benchmarks for quantum components and systems

In the field of **Robotics**, high-precision sensors, actuators, and robust materials make robots expensive to build and maintain. High implementation costs remain a barrier, especially for SMEs. In addition, most robots today are energy-inefficient, leading to short operating times and high operational costs**. Challenges persist related to AI-robot integration**: Robots perceive the world through cameras, LiDAR, touch sensors, etc., but making sense of those inputs is difficult. Vision algorithms (often based on deep learning) can misidentify objects if lighting or angles change, and robots lack the common-sense understanding of scenes that humans use. A major challenge is moving from mere geometric perception to semantic perception – understanding what objects are, how they relate, and what context they imply. Achieving economies of scale in robotics is challenging as robot designs often vary widely by application, and demand for each type can be limited. Additionally, high-precision components or sensors might face supply constraints. **Security challenges**: Weak authentication or encryption in robot controllers, for instance, can allow hackers to intercept or alter commands. Operational disruption is a major concern – a malware attack could halt a manufacturing plant's robots, leading to costly downtime.

In the case of the deployment of **interoperability and GovTech cooperation**, Europe faces a complex web of regulatory, technical, cultural, and infrastructure challenges that collectively impede the realisation of the EU's digital transformation ambitions. While GovTech innovations encounter barriers at the organisational level, interoperability faces additional complexities arising from cross-border coordination, semantic harmonisation, and multi-jurisdictional governance requirements. A major barrier to broader GovTech cooperation, particularly for AI applications, is the **lack of clear and harmonised regulation as well as preferential procurement practices**. National GovTech regulations often differ even when EU-wide rules exist, making compliance more complex and costly. Variations in data protection laws, such as GDPR, create further uncertainty. Despite strong interest from public bodies and many promising use cases, including automating administrative processes and enhancing decision-making, efforts have stalled due to uncertainty around compliance, ethics, and data usage. Secondly, many public administrations across Europe continue to **rely on outdated legacy IT systems that are siloed, inflexible, and poorly integrated.** These systems fundamentally limit both internal organisational efficiency and external interoperability capabilities. For GovTech solutions, legacy infrastructure makes it difficult to adopt newer innovations, particularly those requiring real-time data exchange or cloud-based infrastructure. For interoperability initiatives, the problem is magnified by semantic fragmentation, where different EU member states use incompatible data formats, classification systems, and metadata standards that prevent seamless information exchange (as also addressed as part of the data analytics section). Interoperability solutions face unique deployment challenges related to **multi-stakeholder coordination and governance**. Cross-border interoperability requires sustained collaboration between different national governments, regional authorities, and diverse organisational cultures. This creates coordination complexity where technical standards must be negotiated, governance frameworks must be established, and conflicting national interests must be reconciled. At the infrastructure level, both GovTech and interoperability deployments are hampered by the **fragmentation and competitiveness of European cloud services**. For interoperability, this fragmentation is particularly problematic as cross-border services require consistent, reliable infrastructure that can operate across different national technology ecosystems. For GovTech, funding is another challenge, as many GovTech companies depend heavily on public financing, leaving them exposed to shifts in government budgets and policy priorities. Insufficient access to essential support structures, such as legal guidance, financial resources, and professional networks, constrains the growth and cross-border expansion of GovTech technologies.

3.3 Cross-fertilisation among technologies

Technologies are not developing in isolation but have important cross-technology implications. Artificial Intelligence is the most cross-cutting technology that is amplifying technology trends across many other areas such as edge, quantum, robotics or HPC as already included in the Table below. AI acts as a catalyst for innovation, accelerating development within sectors and opening up entirely new frontiers at their crossroads.

The Table below highlights the cross-fertilisation potential across digital technologies as well as with non-digital technology fields, based on experts' considerations captured through the Delphi survey. The data presented in the different columns capture the views of the experts in the given fields, while the rows show the selected technologies' cross-fertilisation selected from other fields.

Table 15 Cross-fertilisation potential between technology areas based on experts' input

Technology	Microelectronics	Photonics	HPC	Quantum	AI	Data	Robotics	Cybersecurity	Cloud-Edge-IoT	Blockchain & DL	Advanced connectivity	NGI & extended reality	Tech for interoperability
Digital tech areas:													
Microelectronics		H	H	H*	H*	M	H*	H	H*	M	H*	H	M
Photonics	H		H	H	M	M*	M*	M	M	M*	H*	H	M
HPC	H	H*		H	H	H	H	H*	H	H*	M	H*	H
Quantum	M	M*	M*		M*	M*	M	H	H	H*	H	M*	M*
Artificial Intelligence	H	H	H	H		H	H	H*	H	H	H*	H	H
Data	H	M*	H*	H*	H		H*	H	H	H	H*	H	H
Robotics	H*	M*	M*	M*	H	M		H	M	M*	H*	M*	H*
Cybersecurity	H	H	H	H	H	H	H*		H	H	M*	H	H*
Cloud-Edge-IoT	H	H	H	H*	H	H*	H	H		H*	H	H	H
Blockchain and DL	H	H	H	H*	H	H	H	H	M		M	M*	H*
Advanced connectivity	H	H	H*	M	H	M*	M*	H	H	M		M	H
NGI & extended reality	M	M*	H	M*	H	M*	H	H	M	H	H*		H
Tech for interoperability	M	M	H	M	M*	H	H	M*	H	H	M*	H	

Technology	Microelectronics	Photonics	HPC	Quantum	AI	Data	Robotics	Cybersecurity	Cloud-Edge-IoT	Blockchain & DL	Advanced connectivity	NGI & extended reality	Tech for interoperability
Non digital tech areas:													
Advanced manufacturing	H	M*	M*	M	H*	H*	H	M*	H	M*	H	M*	M
Advanced materials	H	M*	H*	H	M	M*	H	M*	M	M*	M*	M*	M
Agri-food technologies	M	M	L*	M*	M	M*	M*	M*	M	M*	M*	M	M*
Biotechnologies	M	M*	M*	M*	H*	M*	M	M	M	M*	M	M*	H*
Circular raw materials	M*	M*	M	M*	M	M*	L	L	M	M*	M	M	M*
Clean & renewable energy	M*	M	H	M	M*	M	L	M	M	M*	M*	M*	H*
Environmental tech	M*	M	M*	M*	M	M	L	M*	M	M*	M*	M*	H*
Medical and healthcare	H*	H*	M*	H*	H	M*	H	H	H	M	M*	H*	H*

Source: Technopolis Group (2025) based on Delphi survey and foresight workshops
Note: the * symbolises considerable divergence of opinion amongst experts.

Digital technology areas have high potential for cross-fertilisation. Technology areas such as Artificial Intelligence, High-Performance Computing, Cloud, Microelectronics, and Cybersecurity particularly stand out as central pillars in Europe's digital and industrial strategies. These strong interdependencies suggest that investments in one domain can catalyse innovation and efficiency gains across others.

Building on these, a broader picture emerges of how these interlinked domains can be further integrated to form a strategic backbone for technological deployment and innovation across Europe. The synergies between these areas are not only technical but also systemic, shaping the infrastructure, security, performance, and sovereignty of Europe's digital future. Some examples are provided below.

Artificial Intelligence is the most interconnected digital technology, with strong potential to integrate across nearly all other domains. It acts both as an enabler (AI for X) and as a beneficiary (X for AI), accelerating innovation system-wide. In **robotics**, AI enables autonomy, predictive maintenance, and human-robot collaboration through advanced sensing and decision-making algorithms. In **cybersecurity**, AI is central to real-time threat detection, anomaly analysis, and security orchestration (SOAR). AI is also key in **photonics** and **microelectronics**, powering chip design optimisation and enabling energy-efficient, domain-specific architectures such as **neuromorphic computing** and **AI accelerators**. In **Next Generation Internet** and **XR/ virtual worlds** technologies, AI supports immersive environments through **generative content**, **humanistic agents**, and **real-time natural language interfaces**, while simultaneously ensuring trust through **explainability** and **ethical AI frameworks**. In **blockchain**, AI enhances smart contract automation and fraud detection, while **privacy-preserving AI** aligns with cryptographic methods like **zero-knowledge proofs** and **secure multi-party computation**.

The **Cloud-Edge-IoT continuum** serves as the architectural bridge linking data sources to intelligence and action. It cross-fertilises with nearly every domain. The integration of AI and

Cloud enables cloud architectures that are designed from the ground up to natively integrate AI capabilities, providing enhanced scalability, flexibility, and adaptability for AI-driven workloads. **AI at the edge** enhances latency-sensitive use cases like autonomous driving and industrial automation; **confidential computing** strengthens **cybersecurity** by securing data-in-use; and **Meta-Operating Systems (Meta-OSs)** provide interoperability across devices and systems, enabling federated, sovereign data spaces. In the context of **digital sovereignty**, European control over **RISC-V-based microelectronics**, **open-source cloud orchestration**, and **distributed ledger technologies** becomes critical. These enable interoperable, low-power, and resilient infrastructure that reduces dependence on foreign hyperscalers and hardware providers.

Cybersecurity is not only an enabler but a necessary layer for safe deployment across sectors. As digital systems become more distributed and complex, from **robotics** to **NGI**, the importance of **post-quantum cryptography**, **zero-trust architectures**, and **privacy-enhancing technologies (PETs)** continues to grow. These link directly with **blockchain** innovations in secure identity management (e.g., **SSI**) and **verifiable credentials** for sectors such as healthcare, finance, and public services. Blockchain also enables new models for trust and automation, like **smart contracts**, **tokenised assets**, and **decentralised physical infrastructure networks (DePINs)**, which coordinate real-world compute, connectivity, and energy resources. These are increasingly relevant for enabling secure and sovereign **AI training**, **federated data sharing**, and **IoT deployments**.

Data analytics and related technologies are deeply interconnected digital enablers that form the foundation of the digital transition across both public and private sectors. In particular, data—along with the availability, accessibility, and quality of datasets—**underpins the development and performance of AI models**. Privacy-enhancing technologies are closely aligned with **cybersecurity**, ensuring secure data sharing and compliance with data protection regulations. Additionally, emerging data storage technologies are pushing the boundaries of innovation, with advances in **biotechnology** (such as DNA-based data storage) and the **use of advanced materials**. **Photonics** also play a vital role in data-related technologies, especially in high-speed data transmission through photonic-based communication systems. Moreover, data technologies serve as critical enablers for emerging applications such as **digital twins and extended reality**, including virtual worlds technologies, by supporting real-time data processing, modelling, and immersive user experiences.

High-Performance Computing and **Quantum** technologies are increasingly converging. Hybrid HPC–quantum workflows, where quantum systems act as specialised co-processors, are emerging in domains like **drug discovery**, **climate modelling**, and **materials science**. This integration requires high software compatibility and open ecosystems, highlighting the need for investment in **interoperable software stacks**, **domain-specific languages**, and **middleware**.

Photonics and **Microelectronics** are essential to scaling both HPC and quantum systems. For example, **silicon photonics** enables high-speed, low-power data transfer critical to next-generation data centres. Similarly, the development of **spin qubits** and compact **cryogenic systems** intersects with microelectronics advances in **3D stacking**, **chiplets**, and **ferroelectric FETs**, underlining the need for packaging technologies and integrated design across hardware layers.

The increasingly strong interconnection between Microelectronics and Photonics is also evident and hinges on unified system-level integration and advanced packaging (chiplets, 3D stacking) to combine logic, memory, analogue and optical components, guided by "electronic–photonic co-design." Reducing power per bit in PICs and using wide-bandgap semiconductors (SiC, GaN, etc.) complements low-power photonic elements for high-performance and harsh environments. Closing toolchain gaps, aligning mature microelectronic EDA/PDKs with lagging photonics design tools, appears as key for European digital ecosystems.

NGI and XR technologies represent human-facing domains where multiple technology threads converge. XR systems, such as **multisensorial smart glasses** and **digital human twins**, blend **AI**, **IoT**, **cloud-edge** and **blockchain** to deliver personalised, immersive, and secure user experiences. Importantly, these technologies intersect with Europe's strategic goals for **reskilling**, **accessible services**, and **industrial productivity**. For instance, integrating **XR into manufacturing** enhances assembly, maintenance, and design processes, highlighting a promising cross-fertilisation with **advanced manufacturing**, **AI**, and **connectivity infrastructure**. Similarly, **human-centric robotics** supports the care sector, addressing labour shortages and expanding inclusive services.

Robotics technology is interconnected with advancements in Artificial Intelligence, driving the development of adaptive robotics capable of operating in unstructured environments. For example, developments in vision-language-action models, spatial reasoning, and systems-level integration are unlocking potential for more capable and autonomous AI systems, particularly in humanoid robotics. Equally critical is the cross-fertilisation with data technologies, which form the digital backbone of robotics. To safeguard these intelligent systems, synergies with **cybersecurity technologies** are essential, protecting against unauthorised access, data breaches, and operational sabotage. Furthermore, robotics is a highly interdisciplinary field that benefits significantly from cross-fertilization with other emerging technologies. Biotechnologies, for instance, are contributing to the development of bio-inspired and soft robotics, enabling machines that mimic biological systems in movement and function. Meanwhile, breakthroughs in materials science, particularly in advanced and nanoscale materials are paving the way for nano-robotics, with potential applications in medicine, environmental monitoring, and manufacturing.

By definition, interoperability is a cross-cutting capability that spans all critical digital technologies. It allows systems, platforms, and applications from different vendors or domains to communicate, exchange information, and operate seamlessly together.

In addition**,** beyond digital technology fields, cross-cutting advances in **advanced materials** and **clean energy** are essential to scaling all digital technologies sustainably. Innovations in **wide bandgap semiconductors** (e.g., GaN, SiC) underpin more efficient **power electronics**, essential for edge computing, robotics, and HPC systems. Meanwhile, materials for **quantum sensors**, **photonic chips**, and **neuromorphic processors** are enabling specialised, miniaturised devices that integrate across the stack.

Energy efficiency is a shared challenge, whether for data centres, edge devices, or blockchain validation. Techniques like **carbon-aware scheduling**, **AI-based workload optimisation**, and **in-memory computing** represent areas of cross-fertilisation between **HPC**, **AI**, **microelectronics**, and **cloud architectures** that serve both performance and sustainability goals.

Cross-fertilisation potential in Europe stems not just from co-existence but from deep technical integration across domains. At the deployment level, this **requires modular system design, open standards, and shared governance frameworks**. By nurturing synergies across core and emerging technologies, Europe can strengthen technological sovereignty, enable scalable innovation, and deliver inclusive societal benefits. Strategic coordination across these domains will be critical to unlock their full transformative potential.

3.4 Technology applications, use cases and sectoral considerations for deployment of digital technologies

Digital technologies are reshaping economies in Europe and worldwide, underpinning virtually every facet of modern life with digital systems and infrastructure. This digitalisation not only alters the range of products and services people produce and consume, but also enhances their price-performance, both for the applications themselves and for the goods and services into which they are integrated. Further to this, this evolution generates virtuous cycles: improvements in digital technology stimulates investment in advanced systems, which in turn accelerate the performance of the downstream products and services that depend upon them.

This section presents the main application areas and key use cases relevant to the deployment of the different digital technology areas in Europe.

3.4.1 Applications and sectorial readiness for the deployment of digital technologies

The relevance for deployment is understood in terms of the potential use cases that can drive development in the industry, In general, the information collected in the scope of this study showcase the importance of the digital and ICT sector, but also of the defence, security and aerospace sectors. Other sectors such as R&I but also public administration can also drive early adoption of specific advanced digital technologies as well, playing an important role in lowering the risks for market adoption in other sectors.

The opportunity of the EU for the deployment of critical digital technologies have been also highlighted related to **manufacturing sectors and in the context of industrial platforms such as automotive and pharmaceuticals** and also related to services for example in the field of **telecommunications and gaming** as part of the creative industries. In these fields there are very important concrete use cases and a need for the EU to invest in and nurture European digital tech firms.

The table below presents the results of the Delphi survey, further discussed during the foresight workshops, and highlights the critical sectors for the deployment of those technologies.

Table 16 Relevance (potential) of application sectors for digital technologies in Europe by 2028

	Microelectronics	Photonics	HPC	Quantum	AI	Data analytics	Robotics	Cybersecurity	Cloud	Blockchain	Advanced connectivity	NGI	Interoperability
Digital and ICT	H	H	H	H	H	H	H	H	H	H	H	H	H
Security & defence	H	H	H	H	H	H	H	H	H	H	H	H	H
Aerospace	H	H	H	H	H	H	H	H	H	L	H	H	H
Mobility, Transport and Automotive	H	H	M	H	H	H	H	H	H	M	H	H	H
Health and pharma	M	M	H	H	H	H	H	H	H	H	H	H	H
Electronics	H	H	M	H	H	M	H	H	H	L	M	M	H
Public administration	L	L	M	M	H	H	M	M	M	M	M	H	H
Logistics	M	L	M	H	H	M	H	M	H	H	M	M	H
Energy-Renewables	H	M	M	H	H	H	L	M	M	M	M	M	H
Education and training	M	M	H	M	H	M	M	M	M	H	M	H	H
Finance	M	L	M	H	H	H	L	M	M	H	L	L	H
Agriculture and food	M	M	M	M	H	M	H	M	M	M	H	L	H
Energy intensive industries	L	M	M	M	M	H	L	M	M	M	H	L	H
Cultural and creative industries	L	L	L	L	H	H	L	L	L	H	M	H	H
Construction	L	L	L	L	M	M	H	L	L	L	L	M	H
Proximity and social economy	L	L	L	L	L	M	L	L	L	L	L	M	H
Tourism	L	L	L	L	L	M	M	L	L	L	L	M	H
Retail	L	L	L	L	M	M	L	L	L	M	L	M	H
Textiles	L	L	L	L	M	H	L	L	L	L	L	L	H

Source: Technopolis Group (2025) based on a mix of Delphi survey, stakeholder consultation and desk research
Note: L – Low, M – Medium, H – High

The below section showcases some of the key application sectors for digital technologies in the EU based on expert consultations conducted in the framework of this study. They are further presented in the technology annexes.

Advanced communications and connectivity technologies are evolving towards highly intelligent, energy-efficient, and ultra-reliable systems. Developments focus on autonomous and AI-native networks, seamless integration of terrestrial and non-terrestrial networks, and deployment of advanced optical communication (including fibre optics and free-space optics). These innovations enable low-latency, high-throughput applications across a wide range of sectors such as in **aerospace, mobility and transport, defence, healthcare, and electronics.** Key enablers include AI-driven automation, energy-efficient sensors, photonic chips, and dynamic spectrum management.

Artificial Intelligence has transformative potential across all sectors. However, its uptake remains uneven, with certain sectors significantly better positioned to adopt and benefit from AI. Industries that lead AI adoption include aerospace and defence, cultural and creative industries and healthcare[175]. Despite these advances, AI diffusion across the broader economy is still in its early stages, and many sectors have yet to fully capitalise on AI.

- In **healthcare and pharmaceuticals**, AI holds significant promise for enabling personalised and predictive medicine. Its deployment is expected to enhance diagnostic accuracy, support decision-making by doctors and surgeons, and improve overall hospital efficiency[176].
- In **cultural and creative industries** AI is used to enhance creativity, image and sound generation and it also supports copyright management by automatically attaching copyright metadata to creative works, making tracking and licensing easier[177].
- In the **agri-food** sector, AI is being used for applications such as weather forecasting and supply chain management. AI is expected to play a key role in addressing labour shortages and automating tasks such as crop irrigation and harvesting.

Blockchain technologies applications are relevant for many sectors, with notable maturity in **finance** and **public administration**. Distributed ledger technologies (DLTs) are increasingly recognised for their ability to enhance transparency, efficiency and trust in digital systems. While cryptocurrencies and decentralised finance remain dominant narratives, blockchain's application is expanding to self-sovereign identity, digital credentialing, supply chain traceability, and secure data management in public services and healthcare. Use cases are maturing especially where interoperability, automation and provenance are critical.

Cloud-Edge-IoT facilitate seamless and real-time data processing and efficient data management, moving data processing closer to the edge. This contributes to services across a broad range of application areas, although the maturity level varies significantly. The market is on the one hand expected to grow substantially in the coming years, but there are multiple challenges to address for wider deployment, including addressing infrastructure limitations, security needs, standardisation protocols and ease of use for customers. While Cloud-Edge-IoT is enabled by low latency, 5G and the growing adoption of AI, it is expected to offer increasing relevance in various application areas, such as **healthcare** (such as real-time medical monitoring, remote diagnostics), industry/**manufacturing** (i.e. industry 5.0, industry automation), **mobility** (i.e. autonomous driving/mobility), **energy** (i.e. remote monitoring of environmental data and energy consumption, smart grids etc), **retail** (i.e. advanced analytics and supply chain optimisation), **agriculture** (i.e. smart farming, precision farming), **finance** (i.e. integration of FinTech) and **public administrations** (data collection and processing, service delivery).

[175] European Commission (2025). SWD(2025) 12 - Second annual report on key findings from the European Monitor of Industrial Ecosystems (EMI) accompanying the 2025 Annual Single Market and Competitiveness Report
[176] See also: https://health.ec.europa.eu/ehealth-digital-health-and-care/artificial-intelligence-healthcare_en
[177] See in European Commission (2022). Study on copyright and new technologies – Copyright data management and Artificial Intelligence by Technopolis Group, Crowell&Moring, IMC University of Applied Sciences Krems, Philippe Rixhon Associates, and UCLouvain, https://data.europa.eu/doi/10.2759/570559

Cybersecurity is considered more and more to be a common denominator that decides whether other digital applications can succeed. In **finance**, banks have begun swapping today's RSA keys for post-quantum algorithms while pairing them with AI fraud-detection engines that flag abnormal payment patterns in real time. **Hospitals** and **pharma** companies are segmenting networks into "zero-trust" zones so that ransomware outbreaks are confined to a single ward or lab. **Automotive** and **mobility** firms are pushing secure over-the-air updates to millions of vehicles and using on-board anomaly detection to catch malicious code before it reaches the drivetrain.

Data analytics are relevant basically for all industries and economic sectors, although some is more of a priority from a societal perspective such as healthcare, finance or media. According to the European Data Market Study 2024-2026[178], enterprise software industry remains the top market covered, with 35.2% of the data companies active, 13.5% in marketing and 13.2% in health.

- In terms of data spaces, the sectors of application include **agriculture** (e.g., of use case: enabling the sharing of data collected via digital technologies on farms, such as through precision farming applications), **cultural heritage** (e.g., of use case: preserving diverse assets through 3D digitisation, ensuring increased access and visibility, and their availability for future generations), **energy** (e.g., of use case: data space will help the further integration of renewable energy sources, increase the energy system efficiency, and ensure a smooth and competitive transition towards the electrification of sectors such as heating and transport), **finance** (e.g. of use case: providing innovative financial companies with access to synthetic data of national supervisors to test new applications and train AI/ML models), **health** (for example use cases of cross-border infrastructure for the exchange of health data, cancer images and genomics related data spaces), **manufacturing** (e.g., of use case: secure, fair, sovereign, responsible and cost-effective data sharing in dynamic asset management, predictive maintenance and agile supply chain management in the European manufacturing sector), **media** (e.g., of use case: helping media organisations of all sizes in fighting misinformation and provide better audience analysis), **smart cities and communities** (e.g., of use case: enabling secure, interoperable data sharing among urban stakeholders to drive sustainable development, efficient public services, and citizen-centric innovation). In the field of **mobility**, the Mobility Data Space[179] brings together companies, organisations and institutions: those who need data for innovative mobility solutions.

High-performance computing is becoming a key enabler across multiple scientific, industrial, and societal domains such as climate science, ICT, energy, life sciences, engineering, and finance. Its capacity to support large-scale simulations, advanced modelling, and real-time data processing is driving its uptake in these sectors.

- In the **ICT** sector, HPC is increasingly being combined with AI techniques to accelerate computation and improve decision-making. At the same time, research is advancing toward integrating HPC with quantum computing, which will further boost processing capabilities.
- In climate, weather, and earth sciences, it improves the accuracy and reliability of forecasts, enabling governments and research institutions to model extreme weather events and develop effective climate-adaptation strategies.
- In **life sciences, medicine, and bioinformatics**, HPC supports personalised medicine, large-scale genomic analysis, advanced medical imaging, accelerated drug discovery, and complex biological modelling.

Microelectronics underpin a wide range of critical applications across major industrial and societal domains. Microelectronics serve as the foundational layer for innovations in automotive, defence, telecommunications, healthcare, and industrial automation. In particular, the demand for microelectronics is growing in step with the increasing complexity and

[178] https://ec.europa.eu/newsroom/repository/document/2024-47/D41_First_EU_Data_Landscape_Report_FINAL_CzClBGPmPsorKyihsfJsG5kJo8c_110109.pdf
[179] https://mobility-dataspace.eu/

digitisation of products and services, particularly where real-time data processing, energy efficiency, and device customisation are required.

- The **automotive sector** remains Europe's largest semiconductor consumer. The transition to electric and autonomous vehicles is driving demand for both cutting-edge and mature-node chips[180], including microcontrollers, Insulated-Gate Bipolar Transistors, and AI accelerators. Europe's automotive firms are actively adopting chiplet architectures and RISC-V-based designs to enhance customisability and reduce vendor dependence.
- In **telecommunications**, Europe's positioning in photonics and RF semiconductors, together with initiatives like PIXEurope, supports future competitiveness in high-speed telecom systems.
- For applications in the industrial **manufacturing** sector, Europe's strengths lie in power electronics and sensors critical for industrial automation and efficiency gains.
- In **health**, European actors are active in biosensing and medical IoT, with growing interest in organ-on-chip systems and ultra-low-power designs for wearables.
- In the **energy-intensive** industry domain, European firms are leaders in power electronics and are expanding capacity to meet demand for electrification and grid modernisation.

Next Generation Internet (NGI) and extended reality (XR) technologies are increasingly being deployed across a range of sectors, driving innovation in immersive environments, and open-source alternatives. Applications span from immersive training and simulation to open-source infrastructures and decentralised platforms, supported by cross-fertilisation with areas such as edge AI and emotion AI, brain-computer interfaces, quantum networking, or synthetic biology.

- Applications are seen in **healthcare** (e.g., immersive therapy, diagnostics), **education**, **tourism**, and **retail**, while use cases continue to expand into **gaming**, **cultural and creative industries**, **mobility**, and **defence** domains. These applications are in early adoption stages and show high impact potential in terms of operational efficiency, workforce upskilling, and collaborative innovation.
- NGI and XR are applied in the **education** sector to create immersive, interactive learning environments, enable real-time collaboration across distances.

Photonics technology is increasingly central to Europe's strategic value chains, playing a crucial role in enabling high-speed communication, precision sensing, imaging, and advanced manufacturing processes. Its versatility and cross-sectoral relevance make photonics foundational for both established and emerging digital applications.

- Photonics plays a critical role in high-performance and quantum computing particularly in fields such as photonic integrated circuits and quantum optics, as well as in next-generation digital infrastructure by enabling high-speed data transfer and low-latency networks. It also underpins advances in extended reality, healthcare, mobility systems, and space technologies, highlighting its broad systemic impact. For instance, Europe benefits from a fully independent value chain in infrared imaging, with key players active in the field.
- Photonics is also a key enabler for optical interconnects and sensing applications, contributing to enhanced performance and miniaturisation in **electronic** systems.

Quantum technologies are gaining traction across several sectors, with short-term use cases in quantum sensing, such as target acquisition and inertial navigation, and longer-term prospects in quantum communications and computing, including secure communications and decryption.

- The **security and defence sector** is emerging as a prominent area for early adoption, particularly for quantum sensing in navigation and target acquisition.
- **Healthcare** and related research are also frequently cited in relation to quantum sensing and simulation-based applications. Quantum computing holds promise for drug discovery

[180] https://www.yolegroup.com/market/automotive-semiconductor-market-share/

and biological modelling, while quantum sensing may enable advanced imaging and diagnostic tools. These applications are still largely within the research phase but are gaining interest across the health sector.

Robotics demonstrates the strongest adoption in **manufacturing**. For example, the **automotive** industry is traditionally the main adopter of industrial robots, together with plastic and chemical products industry, metal and machinery sectors. Various other sectors have integrated or are starting to integrate advanced robotic and automation solutions. In **agri-food**, for example, adoption of robotics encompasses full automation of factory farms including harvesting and in-field operations—along with food product manufacturing. The **construction** industry benefits from factory modular construction with on-site assembly, robots for building inspections. Robotics in **health and pharmaceutical** sectors include lab automation and expanded non-medical hospital applications (e.g., soft robots). In the **space sector**, for example, robotics can be incorporated for mining and in-orbit construction, as well as planetary robotics for extraterrestrial building and excavation.

Technologies for interoperability & GovTech: GovTech and technologies for interoperability encompass the use of technology interoperability assets across a wide range of **public administration functions and services**. In **healthcare**, GovTech is supporting the deployment of AI-driven diagnostic tools that can integrate with national health systems. These applications also serve to enhance interoperability by connecting data across hospitals, labs, and digital health records. GovTech is also transforming **public administration** through interoperable digital verification systems, enabling seamless interactions between citizens and services across borders and agencies, supporting secure access to benefits, digital document storage, and multilingual services powered by AI translation. In terms of finance, the public sector's adoption of interoperable digital payment platforms is growing, particularly for disbursing welfare, tax refunds, and subsidies. Governments are also increasingly using interoperable remote sensing technologies, such as geolocation data and satellite imagery, for urban planning, environmental monitoring and emergency response.

Table 17 Applications and use cases of digital technologies across sectors

Sector	Examples of key applications and use cases
Digital and ICT	• **Advanced connectivity**: Self-organising and self-healing 5G/6G networks, network slicing automation, and intent-based networking for dynamic quality of service • **AI**: Network optimisation, fault detection, fraud prevention, AI-enhanced 5G, personalised services, AIaaS. • **Blockchain**: use of smart contracts and secure, verifiable transactions for data integrity and decentralised infrastructure, including integration with digital identity wallets • **Cybersecurity**: Zero-trust service meshes for cloud & data-centre traffic, Confidential-computing enclaves in EU sovereign-cloud nodes. • **HPC**: real-time data analytics, simulation, and AI model training at scale, supporting the development of digital twins and secure, sovereign computing infrastructure • **Microelectronics**: 5G/6G base stations, optical networks, and mobile devices, RF front-end modules, DSPs, optical transceivers, and network processors. • **Photonics**: Optical communication systems used in digital infrastructure, supporting high-speed data transfer and low-latency networks
Security & defence	• **AI:** surveillance, geospatial intelligence, autonomous weapons, cyber defence, strategic threat analysis, C3 decision support. • **Blockchain:** exploration of blockchain for identity, data security and decentralised systems in secure communication and procurement. • **Cloud-Edge-IoT**: Technologies for local communication and distributed intelligence for autonomous vehicles and drones (i.e. drone swarms) and threat detection at the edge • **Cybersecurity:** Quantum-resistant key management for classified networks, High-assurance roots-of-trust in defence systems • **HPC:** simulations for threat detection, mission planning, and real-time operational modelling

Sector	Examples of key applications and use cases
	• **Microelectronics:** radiation-hardened processors for space, high-frequency RF and microwave chips for radar and communications, and neuromorphic processors for autonomous systems such as drones • **Photonics:** infrared imaging, secure communications, and photonic sensors for surveillance and situational awareness • **eQuantum:** secure communications using quantum key distribution (QKD) and high-impact computational capabilities for decryption and simulation via quantum computing, quantum sensing in navigation and target acquisition.
Aerospace	• **AI**: predictive maintenance, UAV navigation, air traffic optimisation, defect inspection, autonomous control, structural monitoring. • **Cybersecurity**: Secure OTA update pipeline for avionics software, Intrusion-detection in aircraft cabin networks • **HPC**: advanced design and simulation for aircraft and space systems, including computational fluid dynamics for performance optimisation and structural analysis, earth observation applications and services • **Photonics**: high-reliability optical systems for space exploration, satellite communication, and onboard data handling
Mobility, Transport and Automotive	• **Advanced connectivity:** V2X communication, cooperative autonomous driving, smart traffic management, and in-vehicle optical networks for real-time sensor data transfer • **AI:** autonomous driving, driver assistance, predictive maintenance, smart traffic management, intelligent public transport and logistics. • **Cloud-Edge-IoT**: Edge processing and cloud storage for autonomous mobility and smart traffic management and • **Cybersecurity:** Secure over-the-air firmware for connected vehicles, In-vehicle intrusion-detection and isolation • **HPC:** simulation of complex mechanical systems and the optimisation of vehicle performance and fuel efficiency, relevance for AI integration in autonomous driving applications • **Microelectronics:** Europe's largest semiconductor consumer, with chips embedded in engine and power management, safety systems, ADAS, infotainment, and electric drivetrains • **Photonics:** optical sensors, lidar systems, and advanced lighting solutions used in autonomous driving and vehicle safety
Health and pharma	• **Advanced connectivity**: Telemedicine optimisation, remote surgery, real-time medical imaging, and wearable IoT integration for continuous monitoring and diagnostics • **AI**: medical imaging, predictive analytics, robotic surgery, virtual assistants, drug discovery, clinical trials, personalised medicine, supply chain optimisation • **Blockchain**: Blockchain-based electronic health records (EHRs) for secure, portable, and patient-controlled health data; emphasis on privacy-preserving architectures using eID and zero-knowledge proofs • **Cloud-Edge-IoT**: Remote patient monitoring and personalised healthcare through seamless and real-time data processing • **Cybersecurity**: Zero-trust network segmentation to limit ransomware spread in hospitals, EU digital-identity wallet for cross-border e-prescriptions • **HPC**: bioinformatics, personalised medicine, medical imaging, and accelerated drug discovery, support to genomic analysis and biological modelling at scale • **Microelectronics:** imaging systems, diagnostics, wearables, and implantables, chips used range from FPGAs and sensor interfaces to AI accelerators and microcontrollers, organ-on-chip systems and ultra-low-power designs for wearables. • **Photonics**: imaging technologies such as X-ray, CT, and MRI for diagnostics, as well as in optical biosensing – applications supporting more accurate, non-invasive, and earlier medical diagnoses • **Quantum**: Quantum computing also holds promise for drug discovery and biological modelling, while quantum sensing may enable advanced imaging and diagnostic tools

Sector	Examples of key applications and use cases
	• **Tech for interoperability**: connecting data across hospitals, labs, and digital health records paving the way for faster, more accurate diagnoses and more efficient public health management
Research and innovation	• **HPC** is critical to a wide range of scientific domains, including materials science, fundamental physics, and other data-intensive research projects, underpinning many Centres of Excellence and research infrastructures. • **Quantum:** simulation-heavy research, such as materials science and fundamental physics, where quantum advantages could offer substantial performance improvements
Electronics	• **Cloud-Edge-IoT**: Seamless integration and processing of data from devices and components, improving efficiency and reducing latency • **Cybersecurity**: Secure-by-design sensor chips produced in EU fabs, Continuous monitoring agents for industrial robots • **HPC**: enabler for nanoscale simulation for electronic and quantum devices, support for miniaturisation and innovation beyond conventional CMOS technologies • **Photonics**: optical interconnects and sensing applications, contributing to enhanced performance and miniaturisation in electronic systems.
Public administration	• **Advanced connectivity**: Smart city applications (e.g. traffic, lighting, emergency response), e-government services, and public-safety networks on demand for disaster recovery • **AI**: AI chatbots, service design, fraud detection, budget forecasting, risk analysis, policy support, transparency and audit tools • **Blockchain**: Digital identity and credential management through self-sovereign identity (SSI); applications include e-voting, welfare distribution, land registries, and digital citizen services such as Estonia's e-Residency programme • **Cloud-Edge-ioT**: Enabling seamless and real-time data collection and analysis for public administrations • **Cybersecurity**: digital-identity wallet integration for citizen portals, Ransomware-resilient back-up policies for municipalities • **NGI & XR**: open-source alternatives for software infrastructures, support open source access (NGI solutions), co-creation of solutions for real-world challenges through digital twins, extended reality (XR) and AI (CitiVerse projects) • **Technologies for interoperability**: interoperable digital verification systems facilitating online voting to cross-border healthcare, supporting secure access to benefits, digital document storage, and multilingual services powered by AI translation, interoperable, privacy-preserving systems that comply with eIDAS regulation and function across borders, interoperable remote sensing technologies, such as geolocation data and satellite imagery, for urban planning, environmental monitoring and emergency response
Logistics	• **Blockchain**: real-time tracking, provenance verification, customs clearance automation, and fraud prevention through tamper-proof ledgers; platforms such as TradeLens and Everledger illustrate the impact. • **HPC**: optimisation models for supply chains and routing, helping reduce costs and improve operational efficiency • **Quantum:** optimisation problems and secure communication - practical deployments remain limited at this stage but are expected to grow
Energy renewables and clean tech	• **AI**: smart grids, fault prediction, energy consumption optimisation, renewable forecasting, carbon monitoring, oil & gas exploration • **Cloud-Edge-IoT**: Real-time monitoring of energy systems and consumption, improved resource allocation and enabler of smart grids • **HPC**: multiscale modelling of energy systems, including wind and nuclear power, solar photovoltaics, grid management, and material design for storage solutions • **Photonics**: monitoring and optimisation of energy systems through precision sensors and laser-based measurement tools used in solar and wind installations

Sector	Examples of key applications and use cases
Education and training	• **AI**: Adaptive learning, AI tutors, curriculum planning, plagiarism detection, assistive tech, immersive virtual classrooms, personalised learning, tutoring systems • **Blockchain**: potential use in digital credentialing and portable skills recognition, supported by open badge frameworks • **Data**: Student performance tracking, curriculum optimization. • **HPC**: support advanced technical training and interdisciplinary education in modelling, simulation, and AI
Finance	• **Advanced connectivity:** real-time fraud detection at the network edge, latency-aware routing for trading, secure financial transactions through quantum-safe communications, and AI-driven micro-trading at the 6G edge • **AI**: Fraud detection, algorithmic trading. • **Blockchain:** fast, low-cost and transparent financial transactions via cryptocurrencies, DeFi platforms, tokenised assets, and smart contracts for lending and trade finance; development of central bank digital currencies (CBDCs) • **Cybersecurity:** Bank-wide migration to quantum-safe PKI, AI-driven fraud and anomaly detection in payment streams • **Data Analytics**: Customer segmentation, risk modelling. • **HPC:** high-frequency trading, risk modelling, and real-time market simulations, enabling financial institutions to manage large volumes of sensitive data efficiently • **Robotics**: Robotic Process Automation (RPA) for back-office tasks. • **Technology for interoperability:** disbursing welfare, tax refunds, and subsidies - systems aim to be inclusive, secure and cross-compatible, laying the groundwork for integration with digital identity systems and potentially central bank digital currencies
Agriculture and food	• **AI**: precision farming, crop and livestock monitoring, disease detection, automated irrigation and harvesting. • **Cloud-Edge-IoT**: Smart farming, precision farming • **Data Analytics**: Yield prediction, supply chain optimization. • **HPC**: simulations for climate impact modelling on crop yields and precision agriculture applications, supporting development of sustainable farming strategies • **Photonics**: optical quality control, soil analysis, and precision farming, photonics supports more sustainable and efficient agricultural practices • **Robotics**: Autonomous tractors, robotic harvesting
Energy intensive industries	• **AI**: Efficiency optimisation, emission prediction. • **Data Analytics**: Load forecasting, energy usage analysis. • **Microelectronics**: Power semiconductors are vital for renewable energy systems, EV chargers, and smart grids. SiC and GaN-based devices are used for high-efficiency power conversion. • **Robotics**: Equipment maintenance in hazardous environments.
Cultural and creative industries	• **AI**: Generative art and music, content creation and production, interpretation and preservation of cultural heritage and museum curated experiences, digital restoration of art, IPR management and auditing. AI is used in news media for content creation, personalised engagement, audience analytics, distribution optimisation. • **Data Analytics**: Audience tracking and engagement, content recommendation and distribution; B2B data exchange platform for fact checking and news content. • Cloud: European Collaborative Cloud for Cultural Heritage. • **Robotics**: Interactive installations, museum guides, cultural heritage restoration.
Manufacturing	• **Advanced connectivity**: Smart factory networks enabling downtime prevention, predictive maintenance, real-time quality control via digital twins and edge AI, and secure segmentation of Industrial IoT

Sector	Examples of key applications and use cases
	• **AI:** predictive maintenance, quality control, supply chain and warehouse optimisation, AI-based experimentation, assembly automation, generative design • **Cloud-Edge-IoT**: Real-time data processing at the edge and industry floor, data management and security, decentralised data processing, smart manufacturing and predictive maintenance • **Microelectronics** power PLCs, motor drives, industrial sensors, and smart factory systems - applications include rugged microcontrollers and analog ICs, often used in long-lifecycle and harsh conditions • **NGI & XR**: predictive maintenance, immersive design collaboration, and AR-based workforce training, "holodeck"-style spaces for remote product engineering
Construction	• **AI**: AI-driven BIM-based construction site analytics • **Data (analytics):** data analytics for construction waste management and collection • **Robotics:** Self-driving bulldozers, excavators, and dump trucks for site preparation and earthmoving also drones and ground robots for surveying, mapping, and monitoring construction progress
Tourism	• **AI:** Personalised travel recommendations, chatbots for customer support. • **Data Sharing/Analytics:** Tourist behaviour tracking, real-time demand forecasting. • **Robotics:** Service robots in hotels and airports.
Retail	• **AI**: recommendations, chatbots, also retail enterprises use AI in marketing and sales, with businesses leveraging AI to personalise customer interactions and optimise campaigns • **Data**: the use of data and data analytics (on product flows, consumer purchasing habits etc.) can be useful for mitigating some environmentally relevant issues, e.g. reducing packaging • **Robotics**: One of the most visible applications of robotics in the retail sector is the deployment of robotic informational guides. These robots, often equipped with friendly human-like features or appealing designs, roam store aisles, ready to assist customers
Textiles	• **AI**: Predictive maintenance for machinery, product quality control via computer vision. • **Data Analytics**: Trend forecasting, customer behaviour analysis. • **Robotics**: Automated sewing, dyeing, and material handling.

Source: Technopolis Group (2025) based on Delphi survey and foresight workshops

3.4.2 Unmet application sectors' needs and challenges for the deployment of digital technologies

The application of critical digital technologies across sectors faces important barriers that hinder effective deployment and scale-up of new technologies. These challenges stem from a combination of technological, organisational, regulatory and market-related factors that slow adoption and limit impact. The following section with a zoom-in to each technology area outlines the main gaps and obstacles and highlights where investments are most needed. It provides a summary based on the stakeholder consultations, the Delphi survey, expert interviews and desk research.

Advanced connectivity: The deployment of these technologies face various challenges including the diverse needs of vertical sectors that make it difficult to align infrastructure development with sector-specific requirements. These sectors often do not prioritise connectivity within their innovation strategies, despite its foundational role in enabling digital transformation. Strong interdependencies between connectivity technologies and domains such as AI, cloud computing, and semiconductors create uncertainty around future capabilities and investment, leading to a gap between technological potential and real-world adoption. Progress is further constrained by slow infrastructure rollout, particularly in fibre and non-terrestrial networks, limited public funding and private investment incentives, fragmented regulation and spectrum policies across EU Member States, weak development of sovereign cloud and edge infrastructure, and the lack of mature AI-driven network management for automated, self-organising networks.

Artificial Intelligence: Despite accelerating adoption, several barriers continue to hinder AI deployment across the EU-27. A major constraint lies in the limited availability of AI-optimised hardware, such as AI chips, and a growing gap in data centres and cloud infrastructure. To meet demand, Europe's data centre capacity needs to triple by 2027, reaching approximately 22,700 MW[181]. This shortfall poses significant risks to the EU's ability to maintain technological sovereignty and global competitiveness. Another critical barrier is the lack of return on investment (RoI) for internal AI initiatives. Many AI projects demand substantial upfront investment with benefits that may only materialise over the long term. At the ecosystem level, the uptake of AI in EU-27 is further hampered by fragmentation in talent, capital, and infrastructure. There is no sufficient concentration of key resources such as skilled professionals, investment capital, and advanced computing infrastructure.

Blockchain: Adoption remains limited due to remaining complexity, legacy infrastructure, lack of interoperability, and complex regulatory landscapes. The dominance of cryptocurrency applications distorts attention and investment away from other impactful areas. Public sector services struggle with the integration of verifiable credentials and common infrastructure, while industries face incompatible systems that hinder supply chain transparency. Healthcare deployment is constrained by stringent data protection requirements and the need for secure identity frameworks.

Cloud-edge-IoT: The wider deployment of these technologies faces numerous challenges. It necessitates the building of robust infrastructure to manage and process large quantities of data at the edge in a reliable, secure and scalable manner. Achieving this requires the construction of a network of distributed edge nodes located close to end-users to reduce latency and ensure performance. Edge computing requires edge orchestrators to manage, automate and coordinate the flow of resources between various types of devices, infrastructure and network domains at the edge of the network.[182] However, the EU is facing uneven rollout of the connectivity and computing infrastructure, a lack of common architecture and open standards, while also needing to ensure security and privacy. This also accounts for the need to find alignment within the broader ecosystem of EU telco and edge/cloud providers on industry practices, to facilitate the convergence across providers and in a cross-border context. In terms of the EU cloud market, it is exposed to a high-level of fragmentation, facing challenges in scalability, regulatory diversity and substantial competition from US hyperscalers[183]. Equally, while end-users ask for access to functionalities and tools that are easy to use, it is primarily the leading US cloud companies that offer the demanded integrated and widely covering services, increasingly with AI functionalities built in.[184]

Cybersecurity: The most pressing obstacle is the uneven maturity of Europe's user base. Large banks and telecoms can absorb zero-trust and post-quantum upgrades, while SMEs and local authorities still lack basic back-up discipline, incident know-how and capital to comply with the Cyber Resilience Act[185]. A large number of firms struggle with decades-old control systems that cannot be patched without shutting down production, and safe retrofit kits are still scarce. Deployment of advanced technologies (such as confidential-computing, AI-driven anomaly detection and hardware roots-of-trust) depends on cloud, chip and security-operations services that are dominated by non-EU vendors, raising cost and sovereignty concerns. Skills shortages are acute: Europe excels in cryptography research but has too few engineers who can translate those results into market-ready products, and the brain drain to the US and Israel persists. Also, data for training AI threat-detection models are siloed by sector and privacy rules, limiting accuracy and creating high false-alert fatigue.

Data analytics and data sharing: The widespread adoption of data analytics and data sharing technologies is hindered by several barriers. These include a lack of trust and universally accepted governance models for data spaces, persistent interoperability

[181] https://www.savills.co.uk/insight-and-opinion/savills-news/362723/european-data-centre-power-capacity-projected-to-rise-to-approximately-13-100-mw-by-2027
[182] https://op.europa.eu/en/publication-detail/-/publication/ff35c457-8f3b-11ee-8aa6-01aa75ed71a1
[183] https://eucloudedgeiot.eu/wp-content/uploads/2025/03/NexusForum_R-I_Roadmap-B.pdf
[184] https://ec.europa.eu/newsroom/repository/document/2021-18/European_CloudEdge_Technology_Investment_Roadmap_for_publication_pMdz85DSw6nqPppq8hE9S9RbB8_76223.pdf
[185] Regulation (EU) 2024/2846 (Cyber Resilience Act). https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=OJ:L_202402847

challenges, particularly between different data ecosystems, and a limited number of well-documented use cases that demonstrate the tangible benefits of data sharing. More specifically, some industries operate in silos, with different standards, platforms, and data formats. This fragmentation prevents seamless data exchange across stakeholders, regions, and supply chains. Also, organisations hesitate to adopt new data platforms due to the cost of migration, training, and integration. Existing systems may be deeply embedded in workflows, making transitions both financially and operationally daunting. Fear of business disruption during switching further discourages innovation uptake. Also, innovative start-ups with disruptive potential are often acquired by large multinational corporations. This can lead to consolidation of data power and reduced competition in the data services market.

High performance computing (HPC): HPC is critical for climate science, health, energy, manufacturing, finance, navigation, and more, but deployment varies in maturity and support across sectors. Many applications are developed under EU funding but lack long-term support, maintenance, or operational readiness post-project. SMEs and start-ups require tailored support, not generic HPC access; unmet needs risk discouraging commercial adoption. Industrial users need reliability and continuity, but current systems often lack business-grade support or pricing transparency. Strong software capability exists (e.g., in aerospace), but reliance on external providers for hardware remains a vulnerability. A coherent, forward-looking EU strategy is needed to balance HPC, AI, and quantum technology, focusing on integration, not competition.

Microelectronics: Microelectronics in the EU faces significant external dependencies, particularly for packaging, mature-node fabrication, and high-end chip manufacturing[186]. The 2020–2022 chip shortage exposed vulnerabilities in supply chains[187], especially in automotive and industrial sectors. Despite strong design and device capabilities, Europe's limited production capacity in back-end stages and high reliance on Asia for mature nodes (≥90 nm) remain major concerns. Microelectronics must also meet strict requirements for reliability in harsh environments, real-time performance, and energy constraints. Regulatory complexity in sectors like healthcare also delays market uptake of innovative microelectronic solutions such as implantable[188]. The defence sector represents an emerging opportunity for market expansion, though it remains largely untapped by many European semiconductor players due to significant entry barriers, including complex export control regulations[189].

Next generation internet technologies and XR: According to the Delphi survey, unmet sectoral needs are most prevalent in the case of cultural and creative industries and in education. To encourage wider adoption of XR technologies in the creative industries, it is essential to establish secure environments for sharing creative content and to ensure robust protection of intellectual property rights. Many organisations in the cultural, artistic, and humanitarian sectors still have a limited understanding of immersive technologies, often associating them primarily with gaming or entertainment, which creates a bias against exploring their broader potential. XR tools, however, can significantly enhance accessibility and inclusivity in education, help delivering high-quality educational experiences to remote areas, accommodating diverse learning needs, and enabling personalised, immersive learning environments.

Photonics: Despite Europe's strengths in segments such as instrumentation, defence, healthcare and mobility, unmet photonics application needs stem from an investment and scale-up gap that limits industrialisation and market uptake. Pilot-scale fabrication capacity remains scarce and poorly visible. A mismatch between vendor proposals and perceived economic opportunities (lack of visibility on RoI), conservative attitudes of large firms, slow funding decisions and fragmented research–industry collaboration further hinder deployment.

---

[186] European Court of Auditors. (2025). Special report 12/2025: The EU's strategy for microchips. https://www.eca.europa.eu/en/publications/SR-2025-12/SR-2025-12_EN.pdf
[187] https://www.forbes.com/sites/heatherwishartsmith/2024/07/19/the-semiconductor-crisis-addressing-chip-shortages-and-security/
[188] EFPIA (2025). The root causes of unavailability of innovative medicines and delay in access: Shortening the wait, https://www.efpia.eu/media/er5dshuq/cra-efpia-root-causes-of-unavailability-and-delay-final-2025-report-29-apr-2025-stc.pdf
[189] See also: https://www.csis.org/analysis/semiconductors-and-national-defense-what-are-stakes

Quantum: Quantum sensing is the most mature sub-area of the three main domains of quantum (sensing, communications, and computing), yet field deployment faces technical barriers, notably around miniaturisation, robustness, and adaptability to different conditions. In quantum communication, the main challenges include high implementation costs, lack of interoperability between systems, lack of key technological building blocks (like e.g. quantum memories), and low market urgency in sectors like finance, which do not yet fully recognise the risks posed by quantum threats. In quantum computing, several critical barriers persist such as high costs of acquisition and operation, limited software tools and algorithms, and uncertainty regarding the timeline for achieving quantum advantage over classical systems. Many components required for full-stack quantum computers are still under development, which slows scalability and commercialisation. Export restrictions and proprietary hardware requirements further complicate the ecosystem. For quantum sensing, testbeds that are agnostic to sensor type and certification schemes for precision and implementors will help build trust and comparability. In quantum communications, interoperability and open standards could be prioritised, alongside regulations mandating post-quantum protections for sectors handling sensitive data. In quantum computing, industries need broader access to quantum capabilities, including through HPC and cloud-based platforms[190]. Quantum metrological services are also needed for testing, benchmarking, validation and certification.

Robotics: The broader uptake of robotics is currently limited by several challenges. High capital and operational expenditures (CAPEX and OPEX), along with the relatively long-time horizon required for return on investment (an issue particularly acute for SMEs) are major financial barriers. Also, many robots are designed for highly structured environments and cannot easily adapt to dynamic, unpredictable tasks such as in agriculture or healthcare. Deployment also requires specialised technical expertise, making it inaccessible for organisations lacking in-house capabilities. In the workplace, workers may resist robotic automation due to fears of job displacement or disruptions to familiar workflows.

Technologies for interoperability & GovTech: A major barrier to broader GovTech deployment, particularly for AI applications, is the lack of clear and harmonised regulation[191]. Despite strong interest from public bodies and many promising use cases (including automating administrative processes or enhancing decision-making), efforts have stalled due to uncertainty around compliance, ethics and data usage. Interviewees highlighted that without clearer legal frameworks and operational guidance, public sector innovation risks stagnation, leaving many potential efficiency gains unrealised. Many public administrations across Europe continue to rely on outdated legacy IT systems that are siloed and poorly integrated[192]. These systems limit interoperability and make it difficult to adopt newer, more innovative GovTech solutions, particularly those requiring real-time data exchange or cloud-based infrastructure. Beyond the technical barriers, the culture within many public sector organisations favours risk aversion. This creates a challenging environment for innovation, where even pilot projects can struggle to gain traction without strong political or managerial backing. Interoperability solutions face barriers that set them apart from conventional technology deployments, primarily stemming from the complex multi-stakeholder coordination required across different national governments, regional authorities, and organisational cultures. These systems demand sustained collaboration and aligned governance frameworks, while stakeholders have struggled to see the long-term benefits of interoperability solutions (e.g. cross-border business operations, improved citizen mobility) against immediate implementation costs and risk. The challenge is further reinforced by governmental reluctance to engage in experimental cross-border systems, where failure carries diplomatic consequences and entails financial liabilities. This creates a coordination trap that requires simultaneous risk-taking and sustained partnership between public and private sectors across multiple jurisdictions. This level of collaborative governance is one that traditional procurement processes are not designed to support, particularly as technical demands evolve towards real-time synchronisation requiring ongoing operational coordination rather than static data sharing.

[190] See also: European Commission, Quantum Technologies Flagship (2024), https://digital-strategy.ec.europa.eu/en/policies/quantum-technologies-flagship
[191] https://www.brookings.edu/articles/the-three-challenges-of-ai-regulation/
[192] https://bradscholars.brad.ac.uk/server/api/core/bitstreams/f22363c5-d64b-46a4-85c4-9394dd2917d4/content

3.5 Digital infrastructures for the deployment of digital technologies

3.5.1 Digital infrastructures currently available for the deployment of digital technologies

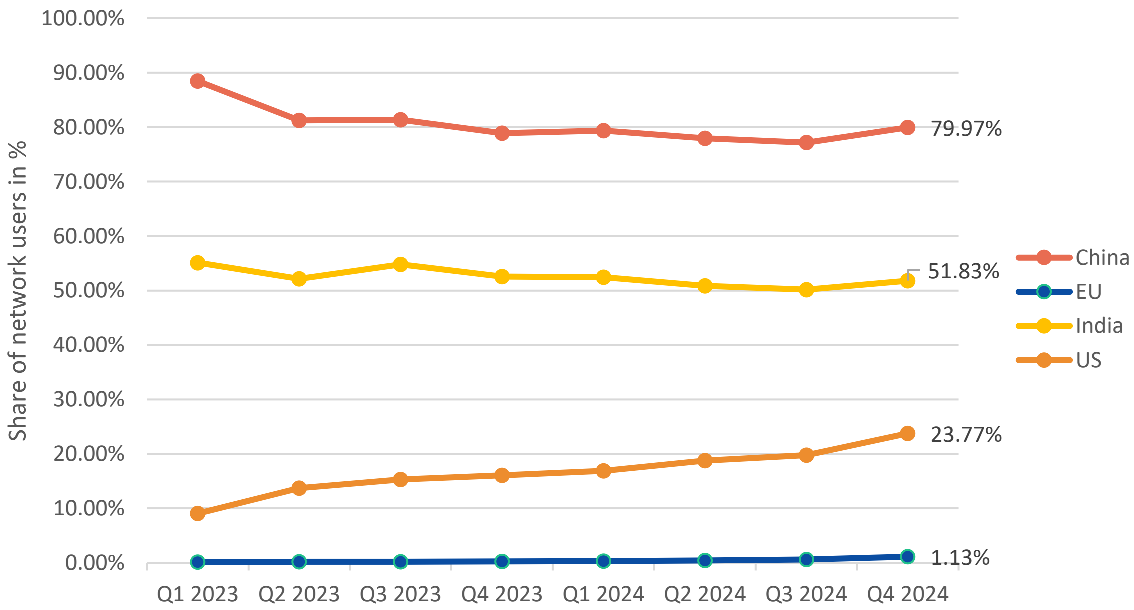
As reflected in the Digital Decade targets[193], Europe's digital leadership can only be built upon secure and performant sustainable digital infrastructures, including for hardware (microelectronics and photonics), but also compute capability (HPC, quantum), connectivity, data processing, and cloud/software. This requires significant investments to build, maintain, upgrade and enable cross-border access to these infrastructures. As part of the Digital Compass, the EU's ambition is that by 2030:

- All EU households have gigabit connectivity
- All populated areas are covered by 5G
- The production of cutting-edge and sustainable semiconductors in Europe is 20% of world production in value
- 10,000 climate neutral highly secure edge nodes are deployed in the EU
- Europe is at the cutting edge of quantum capabilities

The section below highlights the current initiatives and availability of digital infrastructures in each of the technology areas of the study.

Advanced connectivity and communication: The 2025 European 5G Observatory Report and Scoreboard[194] highlights steady progress in 5G rollout, with household coverage reaching 94.3 % across the EU by the end of 2024 and benchmarks deployment, spectrum allocation, and private network growth against global leaders like South Korea, Japan, and the US. The graph below illustrates the share of network users with 5G connection, illustrating that the EU considerably lags behind other world leaders in terms of advanced connectivity infrastructure deployment. This is also the case for fibre deployment.

Figure 39 EU-27 5G standalone deployment compared to other world leaders (2023-2024), Share of network users with 5G active devices who spend most of their time connected to 5G standalone networks (in %)



Source: Technopolis Group (2025) based on Speedtest, Ookla[195]
Note: 5G standalone sample shares are used as a proxy for 5G standalone availability

[193] https://digital-strategy.ec.europa.eu/en/policies/europes-digital-decade
[194] https://digital-strategy.ec.europa.eu/en/policies/5g-observatory-2025
[195] https://www.ookla.com/articles/europe-5gsa-2025

Artificial Intelligence: Several EU initiatives have been put in place to support the development and access to these infrastructures. The box below includes the main examples of critical infrastructure for AI deployment.

Box 4: Examples of critical infrastructures for AI

- **Cross sectorial AI Testing and Experimentation Facilities[196] (TEFs)** offer a combination of physical and virtual facilities, in which technology providers can get primarily technical support to test their latest AI-based software and hardware technologies (including AI-powered robotics) in real-world environments. Sectorial TEF projects include: "agrifoodTEF", "TEF-Health", "AI-MATTERS" (manufacturing) and "Citcom.AI" (Smart Cities & Communities).
- **Common European libraries of AI algorithms** have been established to facilitate transfers of knowledge from AI researchers and developers to businesses and public administration (also known as the AI-on-demand platform, or AIOD)[197]
- **Data Spaces**: provide secure and efficient frameworks for data sharing and enable access to diverse, domain-specific datasets -including proprietary industrial data - which are critical for GenAI developments. Data spaces offer strong foundations for data quality and relevance, key aspects for trustworthy and ethical AI. Beyond data sharing, data spaces bring up an ecosystem perspective, fostering innovation and collaboration among involved stakeholders, which can create value, form partnerships and generate new business opportunities. They also promote compliance with relevant EU regulations like the General Data Protection Regulation and the AI Act[198], thus, ensuring transparency, accountability, and adherence to legal obligations[199]. Achieving AI readiness is essential to ensure that organisations and public administrations have the infrastructure, skills, governance, and data capabilities needed to responsibly and effectively deploy Artificial Intelligence at scale.
- **European Digital Innovation Hubs (EDIHs):** provide businesses (especially SMEs) and the public sector, at their request, with expertise and testing options for the adoption of innovative digital (including AI) technologies. At least one hub in every Member State is required to have AI expertise.
- **The Important Project of Common European Interest on Next Generation Cloud Infrastructure and Services (IPCEI-CIS)**: Central to this initiative is the advancement of Artificial Intelligence (AI) and the development of decentralised digital infrastructure. AI plays a dual role within IPCEI-CIS: both as a technology that demands increasingly sophisticated compute capabilities and as a transformative force that enhances the functionality of cloud and edge systems.
- The **European Digital Infrastructure Consortium** (EDIC)[200]: It is an instrument provided to Member States under the Digital Decade Policy Programme 2030 to accelerate and simplify the setup and implementation of multi-country projects. It includes currently the ALT-EDIC on language technologies, the CitiVerse EDIC[201] that provides AI-based solutions to make urban planning smarter, more customisable and more participatory for cities and citizens, and the Europeum-EDIC for European Blockchain Partnership and European Blockchain Service Infrastructure that should further develop the existing ecosystem of the European Blockchain Services Infrastructure (EBSI).

Blockchain & distributed ledgers: Blockchain technologies, particularly those designed for enterprise or permissioned applications, rely heavily on cloud computing and edge computing.[27] Cloud computing provides the scalable storage necessary to handle the vast amounts of data generated by blockchain networks. It allows for flexible and on-demand access to computing power, which is crucial for running blockchain nodes and supporting large-scale blockchain applications. For use cases involving Internet of Things (IoT)-integrated blockchains, edge computing plays a critical role in reducing latency and enabling faster local decision-making. By processing data closer to where it is generated, edge computing allows

[196] https://digital-strategy.ec.europa.eu/en/faqs/testing-and-experimentation-facilities-tefs-questions-and-answers
[197] https://ec-europa-eu.libguides.com/ai-algorithms
[198] Regulation (EU) 2024/1689 (AI Act). https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=OJ:L_202401689
[199]https://dssc.eu/space/News/blog/380600324/The+new+%E2%80%9CGenerative+AI+and+Data+Spaces%22+white+paper+of+the+Strategic+Stakeholder+Forum+is+now+available
[200] https://digital-strategy.ec.europa.eu/en/policies/edic
[201]https://ldtcitiverse-edic.eu/

blockchain systems to operate more efficiently, especially in real-time applications like supply chain tracking, smart cities, and autonomous vehicles.[28]

Box 5: The European Blockchain Services Infrastructure

The European Blockchain Services Infrastructure (EBSI) represents one of the first public sector blockchain infrastructures in Europe.[202] Initiated in 2018, the EBSI was a collaborative effort involving 29 countries and the EU Commission, with the aim of creating a pan-European framework for secure, decentralised services. The EBSI supports the deployment of blockchain applications notably for cross-border public services, such as trust models to exchange verifiable documents or credentials and trust registries for anchoring services, offering a model for future blockchain-powered government solutions. This initiative highlights Europe's commitment to establishing a secure and interoperable digital infrastructure for blockchain adoption across Member States.

Cloud-edge and IoT infrastructures: The deployment of Cloud-Edge-IoT requires the development of an infrastructure combining cloud computing and edge computing resources for IoT applications and AI workloads. On one hand, this necessitates an infrastructure for processing and storing data through the cloud, and on the other hand, an infrastructure for managing and processing data at the edge of the network, with closer proximity to the IoT devices. Enabling seamless data processing in both centralised cloud and distributed environments imply the need for central and scalable cloud infrastructure and edge nodes closer to industries and users. While cloud computing is based on hardware (such as physical services), virtualisation, storage and networking, edge computing relies on more modular facilities closer to end-users. Facilitating real-time data processing in these computing environments calls for high-bandwidth, low-latency networks and fibre optics, and robust security measures.[203] The development of computing infrastructure and data centres should also address the increasing resource demands and energy grid challenge. Ensuring energy efficient and trustworthy edge and cloud infrastructures are at the core to secure sustainable edge and cloud computing technologies.

Box 6: Examples of policy and private initiatives for cloud-edge and IoT infrastructures

- **The Important Project of Common European Interest on Next Generation Cloud Infrastructure and Services (IPCEI-CIS)**: The IPCEI-CIS aims to develop an interoperable and openly accessible European data processing ecosystem based on a multi-provider cloud-to-edge continuum. To achieve this, it focuses on the development of data processing capabilities, software and data sharing tools for federated, energy efficient and trustworthy cloud and edge' data processing capabilities.
- **The European Alliance on Industrial Data, Edge and Cloud**: The alliance offers an industrial cooperation platform combining public and private stakeholders to develop investment roadmaps and public procurement rules for cloud. This alliance aims to shape the next generation of secure, low-carbon, and interoperable cloud and edge services and infrastructure.
- **EUCloudEdgeIoT.eu**: The initiative seeks to create a pathway for understanding and developing the Cloud, Edge, and IoT continuum by promoting cooperation among research projects, developers, suppliers, business users, and potential adopters. It emphasises developing new technologies and business models, contributing to the deployment ecosystem.
- **SIMPL platform**: SIMPL seeks to develop an open source, smart and secure middleware platform to support data access and interoperability across EU data spaces and other cloud-to-edge federations initiatives.
- **The Gaia-X Initiative**: Launched in 2019, it aims to develop a federated and secure data infrastructure for Europe, promoting European digital sovereignty by ensuring users retain

[202] https://ec.europa.eu/digital-building-blocks/sites/display/EBSI/Home
[203] https://zenodo.org/records/15259914

control over data access and usage. Gaia-X also plays a role in ensuring transparent and interoperable cloud-edge services, facilitating deployment within a trustworthy framework

- **Cloud and AI Development Act (CADA) - forthcoming:** The European Commission is set to propose the CADA during the end of 2025, with the aim to expand the EU's cloud computing and data centre capacity over the next 5-7 years. It is envisaged to propose a single EU-wide cloud policy for public administrations and public procurement, as well as to promote infrastructure deployment and public sector adoption, both key aspects of broad roll-out.

The current and projected deployment of edge computing in the EU has exhibited a strong trajectory of growth, with the Edge Observatory 4 Deployment Data Report from 2024 indicating that the deployment of edge node has grown from 498 in 2022 to approximately 1,836 in 2024.[204] However, EU's spending on edge computing still falls behind spending in the US, capturing more than 40% of the worldwide total share, while China and other regions outside the EU are expected to face the fastest spending growth[205]. Turning to cloud computing capacities, the situation points to a deficit for handling AI workload demands, while the EU cloud market is dominated by US cloud service providers (hyperscalers). According to a study of Synergy Research Group, the European cloud provider share of the local market for IaaS, PaaS, Hosted Private Cloud has fallen between 2017 and 2022.[206]

Cybersecurity and digital identity technologies: Europe has seen a range of emerging cybersecurity and digital-identity initiatives and infrastructures, from national cyber-ranges and training labs in various EU countries. The Digital Europe Programme supported the building up of 24 national Security Operations Centres (SOC) and 3 cross-border SOC platforms[207]. The key challenge is that as Europe remains dependent on non-EU intellectual property and cloud service providers, particularly hyperscalers. This dependence extends to infrastructure constraints such as the scarcity of local GPU capacity needed to advance AI-driven cybersecurity applications. Addressing this requires targeted investments in EU-based R&D, the expansion of sovereign cloud and high-performance computing infrastructure, and initiatives to promote adoption of local cybersecurity technologies throughout public and private sectors. The cybersecurity ecosystem also faces gaps in data availability and applicability, including a shortage of sector-specific datasets for training AI tools, and a lack of pan-European use cases that effectively connect cybersecurity research with industry requirements. Strategic funding in data infrastructure, collaborative pilot projects, and industry-research partnerships are essential to accelerate the translation of innovation into deployable solutions.

Data centres and data spaces: Europe's data centre industry is the backbone of European economic growth and digital sovereignty. It is critical that timely, insightful annual data with informed analysis provides a basis for industry assessment and performance into the future[208].

While enterprise data centres remain the most common in terms of numbers, scale colocation and hyperscale data centres have outgrown the enterprise market in terms of power years ago. Colocation and hyperscale facilities are typically more modern and provide higher power (kW) per rack compared to enterprise data centres. Between now and 2030, very strong growth is expected in all commercial segments, but most strongly in the scale colocation and hyperscale markets.[209]

In terms of infrastructure essential for the deployment of data spaces, in 2021, BDVA, FIWARE, Gaia-X and IDSA launched the Data Spaces Business Alliance (DSBA) with a common objective to accelerate business transformation in the data economy. The four European associations have developed an international network of national or regional 'Hubs'. Together a network of around 90 Hubs distributed over 34 countries is a key asset for the

[204] https://ec.europa.eu/newsroom/dae/redirection/document/109708
[205] https://my.idc.com/getdoc.jsp?containerId=prUS51960324
[206] https://www.srgresearch.com/articles/european-cloud-providers-continue-to-grow-but-still-lose-market-share
[207] https://www.euro-access.eu/_media/file/1008_Call_for_proposals_DIGITAL-ECCC-2026-DEPLOY-CYBER-10.pdf
[208] https://www.capacitymedia.com/article/eudca-report
[209] https://www.eudca.org/documents/content/lCO68CGFThKzAZ15oP6-LAo87?download=0

engagement of multiple stakeholders in the public and private sectors (in particular SMEs) and for the development and deployment of data spaces in Europe:[210]

Box 7: Examples of infrastructures for data centres and data spaces

- **Gaia-X Hubs** are the central, national contact points to inform about the Gaia-X Association. They act as independent think tanks, supporters or ambassadors and influencers for Gaia-X. The Association and the national Gaia-X Hubs cooperate in the areas of Gaia-X technologies, projects, and communication.
- **IDSA Hubs** incorporate all members, research organisations and companies that use IDS concepts and standards per country. The IDSA Hub is facilitated by a university, research organisation or non-profit entity. It enables communication between the Hub and the Association and drives forward the dissemination and adoption of the IDS standard.
- **FIWARE iHubs** are innovation hubs focused on the building of communities and collaborative environments to enable digital businesses to thrive at regional and global levels. Providing – such as private companies, public administrations, academia, and developers, among others. with tailored business development support, connection to FIWARE's global network, easy access to open-source technologies, marketing and community building training. FIWARE iHubs speed up innovation and digitalisation journeys.
- **BDVA i-Spaces** are trusted data Incubators and experimentation ecosystems accelerating the take up of data driven innovation in public and private sectors. i-Spaces offer secure data experimentation environment allowing Research, Education, and Innovation stakeholder to experiment and innovate with data, acting as hubs to connect different stakeholders at local and regional level. To become a BDVA i-Space, organisations need to go through an evaluation/labelling process.

HPC & Quantum computing: Since the Seventh Framework Programme (FP7) and even more so with the establishment of the EuroHPC JU, the EU has aimed to strengthen its position in HPC and Quantum Computing through targeted research and innovation programmes. A major component of the digital environment currently available is the deployment of pre-exascale and petascale computers. These supercomputers are hosted in national computing centres but operate under a pan-European access model, enabling researchers and industries from all EU countries to benefit from it. They operate at high utilisation rates, demonstrating strong demand, even though these are mainly used for research purposes at this stage. With the launch of the first exascale, JUPITER (Germany) entering on the 4th position of the TOP500 list[211] and two other entries in the Top10 of the fastest supercomputers worldwide, the EU is asserting its position in the HPC environment.

Box 8: Digital infrastructure for HPC

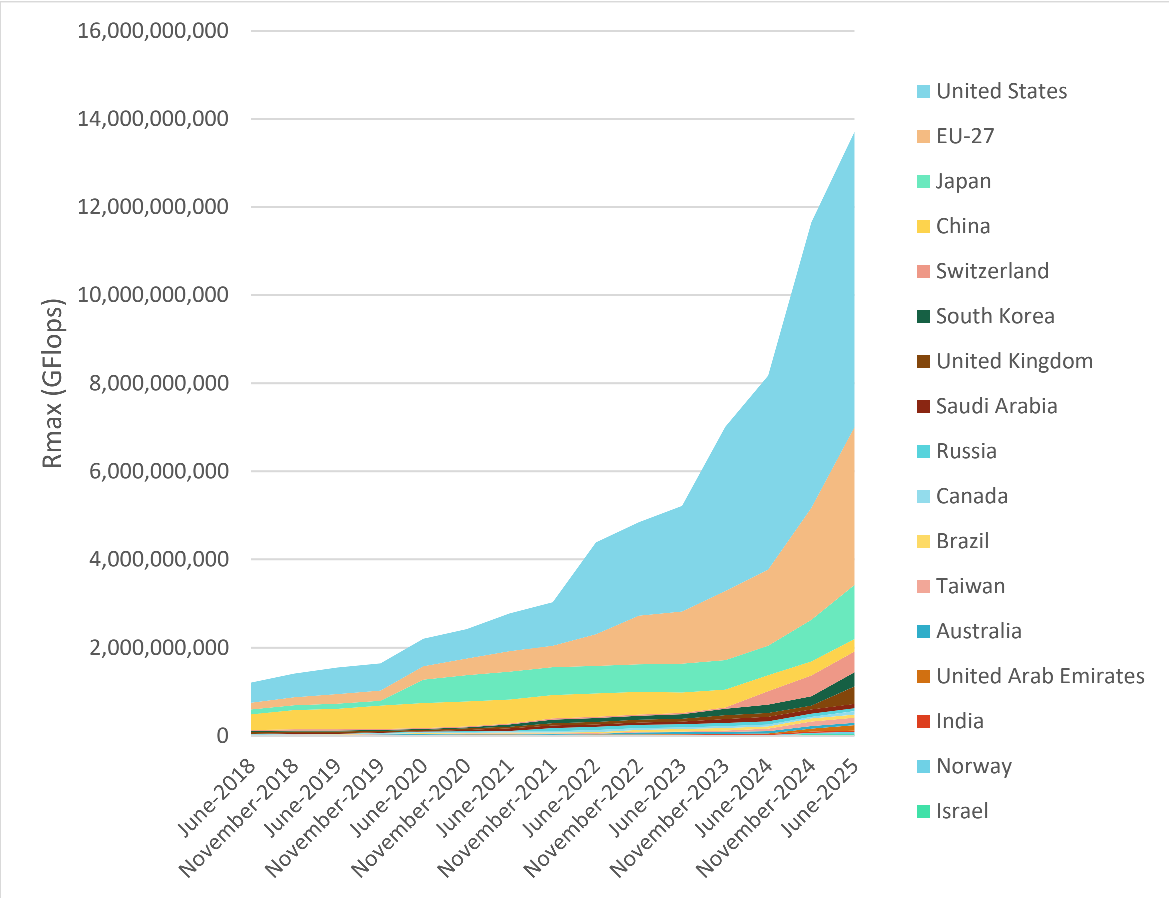
Currently available pre-exascale computers[212] include JUPITER Booster (Germany), HPC6, Italy, LUMI (Finland), LEONARDO (Italy), ISEG2 (Netherlands) MareNostrum 5 (Spain), CEA-HE, France
AI Factories[213]**:** These facilities harness the EuroHPC JU's supercomputing capacity to develop trustworthy, state-of-the-art generative AI models. These include AIF Austria (Austria), JAIF (Germany), Meluxina-AI (Luxembourg), MIMER (Sweden), BRAIN++ (Bulgaria), HammerHAI (Germany), PIAST AIF (Poland), LUMI AIF (Finland), Pharos (Greece), BSC AIF (Spain), AIF2 (France), IT4LIA (Italy), SLAIF (Slovenia)
AI Gigafactories: Up to 5 large-scale centres will be developed through the InvestAI Facility, focusing on developing and training next-generation AI models with trillions of parameters. Each Gigafactory will integrate over 100,000 advanced AI processors and prioritise ample power capacity, robust supply chains, high-speed networking, energy efficiency and AI-driven automation.

[210] https://data-spaces-business-alliance.eu/dsba-hubs/
[211] June 2025 | TOP500
[212] Based on https://top500.org/lists/top500/list/2025/06/
[213] https://digital-strategy.ec.europa.eu/en/policies/ai-factories

In addition, the EuroHPC JU has selected six sites across the EU to host the first European **quantum computers**. These include projects like LUMI-Q in the Czech Republic, EuroQCS-France, Euro-Q-Exa in Germany, EuroQCS-Italy, EuroQCS-Poland, and EuroQCS-Spain.

The figure below illustrates the EU-27's compute capacity as represented in the Top500 list of the world's highest-performing supercomputers. It highlights Europe's relatively strong standing, even as the gap with the United States has widened in recent years. This chart , however, does not distinguish the compute capacity specialised to support AI developments, also expected to increase in Europe with AI factories and gigafactories.

Figure 40 Total Rmax of Top500 supercomputers by key world economy (June 2018 to June 2025)



Source: Technopolis Group (2025) based on data from the June 2025 Top500 list (https://top500.org). The Top500 is released twice a year. Contributions to the list are voluntary, constituting a methodological limitation.

Note: As per OECD guidelines[214], "this figure should be taken only as a directional proxy metric for national compute capacity, with several caveats should be underlined. It does not consider the capacity of different supercomputers but the sum of supercomputers' performance by economy, (i.e., it treats different supercomputers as if they were the same, while significant variations in supercomputer capacity exist). In addition, as workloads cannot be run across multiple supercomputers, this measure should be viewed with limitations (e.g., 10 supercomputers that add up to the same sum of Rmax as a single supercomputer would not be equivalent). Further limitation includes the incomplete data available for China on its deployment of HPC.

Beyond physical supercomputers, the EU has supported numerous initiatives for the development of digital infrastructures. The GEANT project[215], a pan-European data network for research and education, has contributed to provide high-speed and secure connectivity for the transfer of large datasets between computing centres.

Some initiatives focus on advancing software modularity, processor development, energy efficiency, AI integration, and post-exascale computing, to be deployed into EuroHPC systems. A major strategic priority has been processor development and semiconductor sovereignty, particularly through the European Processor Initiative (EPI). The EuroHPC infrastructures have established a dense network across the EU, connecting computing centres, research

[214] https://www.oecd.org/en/publications/a-blueprint-for-building-national-compute-capacity-for-artificial-intelligence_876367e3-en.html

[215] https://geant.org/

organisations, and industrial actors to support uptake. However, concerns remain regarding access, as well as the timely updating and maintenance of these facilities.

Microelectronics and Photonics: Infrastructures support the entire cycle of microelectronics technologies development, including MEMS (micro-electromechanical systems) and 3D integration, optical MEMS, nano-optics, hyperspectral, integrated photonics, 2D materials, microfluids, piezo materials as well as superconductive and semiconductor technologies and interconnect technologies. They enable innovation, design, prototyping and characterisation of nano- and microelectronic components, up to small- to large-scale manufacturing. Several of these facilities, of various scale and focus, are available in Europe, including R&D cleanroom, pilot lines for semiconductors, integrated photonics, graphene and other superconducting technologies, sensor development and characterisation labs, photonics and optics characterisation, wafer-level testing and probing facilities. These infrastructures are often collaboratively used by research performing organisations and industry users, including semiconductor suppliers, but also large and small original equipment manufacturers in key sectors, including electronics industry, but also telecom, automotive, space & defence, healthcare, etc. They seek to offer equipment and services tailored to industry's needs in various application domains, covering for instance for lithography, implant, cleaning, metrology, deposition, etc.

Box 9: Pilot lines of the Chips JU

Recently, Europe has made targeted investments in pilot lines under the Chips Joint Undertaking (Chips JU), collectively funded by the EU, participating Member States and private partners (approx. €3.7 bn), including:

- **NanoIC** (imec, Belgium): Sub-2nm gate-all-around (GAA) process technologies for next-generation system-on-chip applications, with the aim to accelerate the innovation enabling future compute systems and bring new HPC technologies up to TRL 6.
- **FAMES** (CEA-Leti, France): 10nm and below FD-SOI for low-power and embedded applications.
- **APECS** (Fraunhofer, Germany): Advanced packaging and chiplet integration technologies.
- **WBG** (Tampere University, Finland): Wide-bandgap semiconductors (e.g. SiC, GaN) for power electronics.
- **PIXEurope** (ICFO, Spain): Photonic Integrated Circuit (PIC) pilot line offering open-access fabrication and packaging to support telecommunications, sensing, and quantum technologies.

A design platform is also being developed to provide SMEs and start-ups with access to EDA tools, IP, and financial support. This aims to lower barriers to chip design, reduce time-to-market, and help scale European design capabilities.

For photonics, some public programmes (e.g. Photonics21 PPP, EU funding for pilot lines like PIXEurope) exist, initiatives like PhotonixFAB address the gap between research and volume manufacturing by offering open-access pilot lines. Such facilities are vital for SMEs and innovators to scale without immediate reliance on non-EU fabrication.

Next generation internet and extended reality: the deployment of NGI/XR technologies requires infrastructures that support and combine efficiently different computation paradigms including high-performance computing, distributed computing, edge computing and cloud computing[216]. Accessibility to HPC centres is key to enable the further development and subsequent deployment of XR and NGI technologies. Additionally, the network of AI factories across the EU could also be exploited to support the deployment of XR and NGI technologies. On the other hand, digital twins and other simulation tools constitute digital infrastructures of key relevance for other technology fields.

Robotics infrastructures are crucial for the fostering the uptake of robotics by validating, testing and certifying robotics solutions. For example, the European Space Agency has established Internal Automation and Robotics Testbed. The testbed has been established to

[216] JRC (2023). Next generation virtual worlds: societal, technological, economic and policy challenges for the EU. Available at: https://publications.jrc.ec.europa.eu/repository/handle/JRC133757 (page 43).

demonstrate the benefits of Automation and Robotics (A&R) for payload operations and for familiarizing potential users, payload engineers and operators with A&R and to provide a development and testing environment for A&R technology[217]. In addition, ERL Consumer Service Robots has seven certified test beds around Europe where teams can test some Tasks and Functionality Benchmarks (e.g., ISRoboNet@Home Test Bed in Portugal and ECHORD++'s RIF @Peccioli in Italy). According to the technology centre mapping carried out for European Monitor of Industrial Ecosystems, there are 21 technology centres that focus on industrial and service robots in the EU[218]. Also, modern robotics, particularly mobile platforms rely on **fast, reliable communication and data processing** – often in real time – to coordinate their actions and connect with cloud services. 5G networks in particular have become a cornerstone for deployment of robotics, offering low latency (for real-time control), high bandwidth (for video and sensor streaming), and network slicing (for dedicated robot/drone communication channels). **Cloud** allows remote monitoring of robots, over-the-air updates, and centralised fleet management. **IoT** frameworks also provide the standards and architecture for connecting heterogeneous devices – sensors, robots, drones, infrastructure – into one networked system. Through IoT connectivity, for example, a swarm of drones or a fleet of factory robots can continuously report their status and receive commands.

Technologies for interoperability: a number of foundational digital infrastructure components are in place across Europe. Under the Digital Europe Programme, the Interoperable Europe action supported the development of EU critical interoperability solutions, with the overarching goal of reinforcing public sector digitalisation and interoperability[219]. These efforts enable public sector organisations to securely scale services across borders while maintaining compliance with EU regulations.

Box 10: Examples of infrastructures for interoperability

- The European Interoperability Framework (EIF) and associated European Interoperability Architecture provide guiding principles and reusable building blocks to align digital services across member states.220 These frameworks support semantic, technical, organisational, and legal interoperability. Interoperability architecture solutions such as EIRA / eGovERA guides public administrations to design modular, vendor-neutral and seamless digital public services[221]. The Interoperability Test Bed (ITB)[222] enables public administrations to test existing national systems as well as individual services or products, against a neutral, reliable and responsive reference test environment. SEMIC assets and specification such as the DCAT-Application Profile for data portals in Europe (DCAT-AP)[223] and Core Vocabularies deliver semantic interoperability through reusable vocabularies, metadata schemes, ensuring that systems understand and exchange data
- **Data sharing infrastructure** through **Common European Data Spaces**, which provide sector-specific environments for trusted data exchange[224]. These include health, mobility, and public administration among others, and are intended to facilitate cross-border digital services by ensuring shared standards, governance models, and technical specifications.
- In the health sector, the **eHealth Digital Service Infrastructure (eHDSI)** supports the secure exchange of electronic health records and ePrescriptions between EU countries[225]. This infrastructure is a cornerstone for cross-border care and the European Health Data Space, enabling a more connected and interoperable healthcare system. As well, the Interoperability architecture solution, developed the Interoperable Europe action of Digital Europe, are used to build a reference architecture for the health sector (eGovERA for Health project).

[217] https://www.esa.int/Enabling_Support/Space_Engineering_Technology/Automation_and_Robotics/Internal_Automation_and_Robotics_Testbed
[218] https://monitor-industrial-ecosystems.ec.europa.eu/technology-centre/mapping?search=&activities%5B0%5D=5824&activities%5B1%5D=5889&edit-activities-5824=on&edit-activities-5889=on&page=1
[219] More information can be consulted on the Interoperable Europe Portal, the EU's platform for promoting and supporting interoperability, collaboration, and knowledge sharing across public administrations, businesses, and citizens
[220] https://interoperable-europe.ec.europa.eu/collection/european-interoperability-reference-architecture-eira
[221] See also: Interoperability Architecture Solutions | Interoperable Europe Portal https://interoperable-europe.ec.europa.eu/collection/european-interoperability-reference-architecture-eira
[222] https://interoperable-europe.ec.europa.eu/collection/interoperability-test-bed-repository/solution/interoperability-test-bed
[223] https://op.europa.eu/en/web/eu-vocabularies/dcat-ap
[224] https://digital-strategy.ec.europa.eu/en/policies/data-spaces
[225] https://health.ec.europa.eu/ehealth-digital-health-and-care/digital-health-and-care/electronic-cross-border-health-services_en

eGovERA for Health facilitates data exchange between healthcare systems, and supports paving the way towards efficient and effective digital public services in the health sector. The Interoperability Test Bed has been used in the health sector in projects such as the European Digital Testing Environment and the European Health Data Space (EHDS), enabling seamless data exchange and cooperation, to support the creation of innovative health services and applications.

- In the higher education sector, the European Student Card Initiative (ESCI) enables the secure exchange of student mobility data among European higher education institutions through the Erasmus Without Paper (EWP) network. It also supports the roll-out of a standardised European student identity that enables students to authenticate their student status across the EU[226].
- Some countries use **on-premises software solutions,** such as interoperability test beds and national health information systems, which provide important testing environments and operational platforms tailored to national contexts[227]. While these systems can limit scalability, they play a critical role in meeting immediate institutional needs and aligning with local data handling requirements.
- The **IMPACTS-EDIC[228]** aims to connect public administrations to provide advanced public services across Europe in the context of the Interoperable Europe Act. The EDIC will provide an enabling environment for Member States to work together, jointly identify needs, and develop and deploy at large scale interoperability solutions for ensuring seamless cross-border digital public services.
- The **GovTech incubator[229]** represents a collaborative initiative aimed at accelerating digital transformation in the public sector while strengthening the European GovTech ecosystem. The incubator is set up through Specific Grant Agreements (SGA). Currently, the second SGA (GovTech4all 2.0), will deliver eight innovative digital government pilots, focused on reusing and scaling up existing digital solutions, launching startup-driven challenges, and exploring new models of public procurement that support innovation across a wide range of thematic areas.
- Cloud and edge computing capabilities are being strengthened through initiatives such as the cloud federation, which aim to ensure data sovereignty and interoperability between national and European cloud services.
- The Interoperable Europe Act mandates the establishment of easily recognisable label for certain interoperability solutions (Interoperable Europe solutions) to further promote reusability and enhance technological sovereignty[230].
- The **Public Sector Tech Watch[231]** (PSTW) monitors, analyses and disseminates the use of emerging technologies within the public sector in Europe; it hosts more than 1 800 cases, out of which more than 1 400 cases on AI.

3.5.2 Unmet digital infrastructures' needs and challenges for the deployment of digital technologies

With regards to the unmet needs for digital infrastructures in the EU, relevant for the deployment of advanced digital technologies, the below table highlights the main dependencies and needs, and the section below further specifies the type of needs and suggested investments for infrastructures, in each of the 13 technology areas in the scope of this study.

[226] https://erasmus-plus.ec.europa.eu/european-student-card-initiative
[227] https://interoperable-europe.ec.europa.eu/collection/interoperability-test-bed-repository/solution/interoperability-test-bed
[228] https://edics.eu/
[229] https://interoperable-europe.ec.europa.eu/collection/eugovtech/govtech4all
[230] https://eur-lex.europa.eu/EN/legal-content/summary/interoperable-europe-act.html
[231] https://interoperable-europe.ec.europa.eu/collection/public-sector-tech-watch

Table 18 Needs for infrastructure capabilities for the deployment of digital technologies

Technology & Capability/ infrastructure needs	Hardware	Compute	Data centres	Connect / network	Cloud computing, software and digital twins
Microelectronics		M	M	H	M
Photonics		M	M	H	M
HPC	H		M	M	M
Quantum	H		M	M	M
Artificial Intelligence	H	H	H	M	M
Data	H	H		H	H
Robotics			H	M	M
Cybersecurity	L	M	M	M	M
Cloud-Edge-IoT			M	H	
Blockchain and DL			M	M	H
Advanced connectivity	H		M		M
NGI & extended reality		H	H	M	
Tech for Interoperability			H	H	M

Source: Technopolis Group (2025) based on technology experts' consultations

Note: H: high need; M: medium need; L: low need for specific capabilities/infrastructures to enable the deployment of these digital technologies

More specifically, the infrastructure needs for each technology area has been assessed based on expert consultations and desk research:

Advanced connectivity: Connectivity gaps remain a key concern: the uneven rollout of 5G Standalone networks (41% of EU-27 population coverage versus over 90% in the US and Asia), scarcity of 6G test beds and under-developed digital-twin environments all impede real-time, decentralised AI and high-frequency chip workflows. Stakeholders therefore call for harmonised, cross-border 5G/6G deployment to ensure uniform coverage and ultra-low-latency fibre links, alongside secure metro and long-haul optical networks. They also stress the need to integrate AI-optimised edge computing nodes with central cloud clusters to support truly decentralised AI workloads. In addition, experts highlighted that funding programmes typically cover hardware acquisition but not the expert personnel and specialists in hardware selection, ongoing maintenance or licence renewals beyond an initial three-year cycle, and there is no clear continuation plan.

Artificial Intelligence*:* Europe currently holds only a small fraction of global **AI compute capacity**, underscoring a pressing need to expand AI-ready HPCs, cloud and edge platforms and establish AI Factories and Gigafactories. The proposed Cloud and AI Development Act[232] aims to triple data-centre capacity by 2032. While Europe's infrastructures for AI are promising, they remain fragmented: access outside major hubs is limited, many facilities lack interoperability or are ill-suited to applied AI needs, and sector-specific testbeds are scarce. In 2025, the Commission was upgrading 13 HPC supercomputer centres to turn them into AI factories[233], with the EuroHPC JU announced the launch of six additional AI Factories, located in the Czech Republic, Lithuania, the Netherlands, Romania, Spain and Poland.

Some specific challenges relevant for AI Factories and Gigafactories include:

- **Access to facilities**: for example, start-ups are sometimes reluctant to apply for access to the EU's supercomputers due to long and complex application processes. According to a

[232] https://www.eu-cloud-ai-act.com/
[233] https://digital-strategy.ec.europa.eu/en/policies/ai-factories

2024 report, 12% of start-ups found the bureaucratic effort to access the EuroHPC supercomputers too high, while 11% were uncertain about the specific benefits and considered waiting times to gain access to the EU's supercomputers were too long, and 8% were not sufficiently familiar with the EU's supercomputers[234].

- **Availability and price of the chips (GPUs):** Each gigafactory would require a number of cutting-edge AI chips. Obtaining these chips is difficult due to global shortages and export controls. Moreover, Europe currently relies on US vendors (e.g., NVIDIA) for such chips, exposing it to geopolitical constraints.
- **Obsolescence:** The AI compute race is evolving rapidly, therefore, there is an issue that hardware can become outdated in just several years.

The continent's **dependence on non-EU cloud**, semiconductor and platform providers further exacerbates challenges above, as does inadequate support for scalable, secure data storage and sharing. Beyond performance testbeds, there is a perceived need for **mission-oriented AI hubs** that integrate **ethical oversight,** civil-society co-design and long-term evaluation, particularly in socially sensitive areas. **Other challenges related to infrastructure include lack of scalable AI compute for both training and inference**, **specialised testing centres** for embedded AI in key sectors such as health, **trustworthy edge-AI infrastructures** with privacy-by-design and real-time capabilities.

Blockchain and distributed ledgers: For specific use cases of European importance, , stakeholders noted that there is a shortage of **blockchain-optimised cloud environments** that are also eIDAS-compliant. **Interoperability** is one of the key challenges facing blockchain deployment today[30]. Cross-chain communication protocols are essential for ensuring that different blockchain networks, whether public, permissioned, or consortium-based, can interact with each other. These protocols enable seamless data sharing and value transfer across different blockchain systems, which is critical for use cases like cross-border payments, supply chain tracking, and identity verification. The hosting of blockchain nodes requires **secure and resilient data centres** to ensure that blockchain networks remain operational and safe from cyberattacks.[31] For permissioned networks, reliable data centres are essential to host the infrastructure that supports these networks. This infrastructure must be designed to guarantee high availability, robust security, and compliance with local and international data protection regulations. Many blockchain deployments, especially in the private sector, rely on hyperscalers to host and scale their infrastructure.[32] However, some EU stakeholders have expressed concerns over Europe's reliance on non-European cloud service providers, suggesting the need to invest in sovereign EU capabilities. Importantly, stakeholders noted that connectivity remains uneven, with rural and remote areas lacking reliable, low-latency and high-bandwidth networks, which limits real-time blockchain applications. Moreover, stakeholders highlighted that fragmentation in infrastructure deployment across Member States leads to inconsistent access to decentralised compute and storage nodes, limiting unified EU-wide strategies.

Cloud and edge: Heavy reliance on non-EU cloud providers undermines data sovereignty, with several stakeholders calling for a stronger federation of HPC, cloud and emerging-tech platforms, and debate over federating existing infrastructures versus cultivating EU champions. Standardised interoperability protocols between various IoT devices, edge nodes, and cloud platforms (e.g. Dataspace Protocol, DCP), standards, and reference implementations, are seen as needed to accelerate deployment. Besides, the available cloud and edge infrastructures are often centralised, proprietary, or non-interoperable across borders and sectors. While growing, edge resources remain limited in rural areas across Europe. Decentralised edge computing entities (such as edge data centres, micro data centres, and distributed computational power) would facilitate more localised, real-time data processing. Stakeholders also report a lack of support for federated unified framework of cloud, edge and IoT environments that enable organisations to retain control over where and how data is

[234] https://www.europarl.europa.eu/RegData/etudes/BRIE/2025/769492/EPRS_BRI(2025)769492_EN.pdf

processed, stored, and shared, and which can seamlessly integrate devices, networks, and data across these domains.

Cybersecurity and digital identity infrastructure: Cybersecurity experts highlighted the lack of cohesive, large-scale and trusted environments for cybersecurity and digital identity deployment, noting that existing facilities are fragmented, poorly integrated across borders and often inaccessible to many users. They pointed out that compute bottlenecks (e.g., insufficient GPU and accelerator capacity reserved for security-oriented AI and digital-twin work) compound Europe's heavy dependence on non-EU hyperscalers for confidential computing and cloud storage, with few certified EU alternatives. There is no single, pan-European public-key infrastructure to serve as a trust anchor for quantum-safe certificates or device attestation, nor a pilot line for low-cost, secure IoT chip fabrication, which remains centred outside the EU. Limited zero-trust and post-quantum testbeds force companies to build bespoke environments, slowing deployment, while shared cyber-ranges for critical Operational Technology sectors (rail, aviation, healthcare) are few and edge-security sandboxes sparse, leaving SMEs unable to test secure update pipelines for smart-factory nodes. Uneven 5G security roll-out and differing Member State certification rules further undermine low-latency, high-throughput applications such as real-time IoT security monitoring, and SMEs lack affordable around-the-clock Security Operations Centre services (although now these services have been made available in 24 EU Member States). Finally, identity-wallet back-ends remain siloed, with large-scale, cross-border acceptance tests yet to begin, underscoring the need for federated testbeds, simulation environments and trusted, sovereign cloud infrastructure to validate secure digital-identity systems and AI-driven threat-response tools.

Data centres & data spaces: Data remains siloed and of uneven quality and there is more to do regarding the interoperability between data spaces, siloed by domain, and insufficient secure and high-performance storage constrain data sharing and hinders cross-border collaboration and large-scale experimentation.

HPC infrastructures: Seamless HPC **interfaces to commercial cloud platforms** remain underdeveloped, while they remain dominant for their ease of use and scalability. Stakeholders call for stronger collaboration between HPC centres and cloud providers, expanded access to cloud-based tools, and investment not just in hardware but also in the software ecosystems that enable flexible, efficient deployment. The **integration of data lakes and federated storage** into supercomputing environments is seen as essential. Stakeholders note gaps in data governance and urge coordinated efforts to ensure secure and long-term storage, curation, standardisation and seamless access, ideally within on-premise/cloud-hybrid models that address sovereignty and export-control concerns.

On **hardware**, Europe's heavy reliance on non-EU technologies, particularly NVIDIA GPUs, creates strategic dependency and limits the room for EU-grown solutions to scale. Many stakeholders call to support indigenous hardware development and to shape procurement policies that favour European technologies. Traditional building-based procurements limit flexibility. A move towards containerised modules, mixing CPUs, GPUs, quantum and neuromorphic units, would allow quicker, more scalable deployments and guard against vendor lock-in.

Europe has substantial HPC capacity, yet the uneven distribution of needs requires to shift **more compute towards edge nodes**. Secure fibre connections, distributed edge compute infrastructures, and expert-staffed data centres are needed to serve the needs of diverse geographical settings. In addition, seamless linkage among HPC, digital twins, 5G/6G test beds and data spaces are reported as vital for real-time experiments and low-latency workflows. Progress on federated infrastructures (e.g. EDUROAM–style connectivity) should be further supported, leveraging for instance the best practices from countries with deeper experience in hyperconnectivity. Beyond raw compute, interconnection should span data initiatives, processing capabilities and the wider microelectronics ecosystem (chip design, fabrication), towards a unified infrastructure that can accelerate the deployment of innovation across Europe.

In addition, as AI workloads grow more compute-intensive, the integration of traditional HPC with advanced technologies such as AI into **hybrid systems** becomes essential. This shift requires architectural redesign, software stacks' evolution and improved interoperability. For instance, despite its cutting-edge design, the Leonardo supercomputer still need to be better adapted for AI scale workloads[235]. Industry stakeholders have also signalled that AI-specific demands are often not reflected in infrastructures services offering.

Microelectronics infrastructures: Europe lacks **foundries especially at the most advanced nodes**, with only 7% of global semiconductor foundry capacity, primarily focused on mature nodes above 28nm. Most advanced chips are manufactured overseas, even when designed in Europe, due to **insufficient foundry capabilities** and absence of a **fabless ecosystem**[236]. In addition, Europe lacks cutting-edge and trailing-edge logic fabs, and only a small portion of its small total wafer capacity can be used to manufacture modern logic semiconductors. The majority of logic semiconductor suppliers follow a "fab-lite" business model and rely on foundries outside Europe. Projects such as Intel's €30 bn fab in Magdeburg faced delays[237], raising concerns over the EU's capacity to realise its semiconductor autonomy ambitions. To keep pace with improving manufacturing processes, fabs must constantly expand capacity and invest in the next generation of manufacturing equipment. In 2003, Europe was responsible for nearly 12% of all equipment spending, but in 2020, only 3% of equipment spending was in Europe.[238]

Most stakeholders stressed the quality of Europe's R&D facilities in this field, but many also mentioned a lack of direct industrial relevance and scalability of European existing pilot lines, with some exceptions**.** Several pilot lines are still at concept phase and not yet fully operational or geared for industrial deployment. While such research can serve as inspiration, even with accelerator support, the transferability to product development and large-scale manufacturing is reportedly limited. Ensuring that pilot line processes enable close to final development stages up to small scale manufacturing, is seen as essential for technology deployment. This would also strengthen research-industry collaboration further.

Additional concerns remain about the complexity of access modalities to these facilities, especially for SMEs and first-time users. Addressing regional disparities to ensure all key stakeholders have equal access to the advanced digital tools and services that enable the rapid deployment and scaling of microelectronics solutions is also seen as essential.

Despite existing pilot lines, gaps are reported by several stakeholders to ensure that pilot lines and scale-up facilities enable to bring research results to full industrialisation and support the transition from prototype to production. This is especially for sub-10nm digital nodes or high-frequency applications, facilities capable of testing emerging device architectures and advanced packaging techniques in close to market conditions, or facilities for advanced materials processing and integration, which are currently limited in Europe and drive the dependence on the US and China. The design ecosystem is fragmented and application-specific, making it difficult to design pilot lines or platform that would serve the needs of a community of users. Some stakeholders nonetheless stress the need for better availability of design tools for integrated photonics, and co-design of electronics and photonics.

Experts, however, identified the need for integrated digital design and simulation (digital twins), for rapid prototyping environments, reducing the design cycle, validating new architectures, and directly linking experimental results with large-scale deployment. They also highlighted several gaps in Europe's digital infrastructure for microelectronics. Tailored HPC platforms and high-performance cloud solutions to support chip design and simulation remain limited, while current workflows rely heavily on non-European cloud providers, raising concerns over data

[235] https://www.cineca.it/en/press-area/press-releases/eurohpc-joint-undertaking-awards-contract-lisa-upgrade-leonardo
[236] Semiconductor Digest, *Foundries in Europe 2024* (2025), https://www.semiconductor-digest.com/foundries-in-europe-2024/#:~:text=In%202024%20Europe%20control%207,as%20TSMC%2C%20or%20Samsung%20Semiconductor.
[237] Le Monde, *Germany's postponed microchip plant projects cast doubt on the merits of subsidies* (2024), https://www.lemonde.fr/en/economy/article/2024/09/07/germany-s-postponed-microchip-plant-projects-cast-doubt-on-the-merits-of-subsidies_6725175_19.html
[238] Interface, *The lack of semiconductor manufacturing in Europe* (2021), https://www.interface-eu.org/storage/archive/files/eu-semiconductor-manufacturing.april_.2021.pdf

sovereignty and strategic autonomy. Besides, connectivity constraints (e.g., delayed rollout of 5G SA networks and 6G test beds, and underdeveloped digital twin environments) hinder high-frequency chip deployment. Ultra-low latency connectivity is needed to support distributed design, real-time testing, and collaboration across Europe. Stakeholders also emphasised the importance of data security, standardisation, and interoperability, especially for integrated circuit design components (IP cores). Each IP must include all elements for safety assessment, supported by standardised APIs and data formats to ensure secure, effective sharing across the value chain.

NGI and XR: According to experts consulted, while cloud services are growing, Europe needs more scalable and high-performance cloud and storage solutions to support the intensive data requirements of NGI and XR applications. Despite the well-established network of HPC centres, some experts mentioned that those are only available to a limited number of research users. The unavailability of power grid capacity to deliver the consumption of large computer infrastructures needed for the extensive deployment of XR and NGI technologies also raises concerns. XR deployment requires to securely process data in real time, which is hampered by the uneven availability of advanced connectivity, despite recent efforts in improving high-speed connectivity (5G/6G) with low latency and interoperable platforms. Finally, the need for interoperable spatial data infrastructure is lacking spatial data which could be shared across sectors and applications. Enhanced interoperability of spatial data could help in the deployment of XR technologies as it will allow for better tailoring to users' needs.

Photonics: Europe excels in photonics research infrastructure, but transferring photonics technologies to industry and products is weak. In other words, Europe's main bottleneck is not a lack of equipment in photonics, but the lab-to-fab transition and commercialisation. Experts noted that dedicated pilot lines specifically for standard fibre-optic cables or laser transmitter components have not yet been established, although would be needed, for example pilot-scale processing of specialty optical fibres or packaging of high-power lasers. They also highlight a lack of field labs and demonstrators, where first-of-a-kind photonic systems (e.g. LiDAR platforms, imaging instruments, etc.) can be built and tested end-to-end before commercialisation. Another issue that has been stressed that while Europe boasts rich photonics R&D infrastructure, smaller companies often struggle to utilise it. Users have noted that the ecosystem could be more accessible. Additional pilot production facilities (even at national or regional scale) would help scale promising photonic chips into higher volumes.

Quantum computing: On **quantum-classical integration infrastructures**, stakeholders note that many large-scale quantum algorithms require shared queues and ultra-low latency connections to HPC centres. Europe's current digital backbone for hybrid quantum–classical workflows remains patchy: fibre links between quantum nodes, HPC facilities and end users often lack redundancy, causing data-transfer bottlenecks in time-sensitive applications. Public cloud and on-premise HPC providers typically enforce strict GPU/CPU quotas and offer few specialised APIs for co-processing, while storage platforms are not optimised for high-throughput experiment streams or secure quantum-key management. Essential middleware, such as federated identity systems, unified workload schedulers and end-to-end provenance trackers across distributed quantum resources, is still immature.

In the area of **quantum computing**, there is limited access to quantum computing time for industry. Key challenges related to increasing access are the skills needed to install and run these infrastructures, and the costs of installing and running quantum computers, while FTQC is still out of reach). Some stakeholders mentioned the necessity to have access to a diverse set of quantum computing technologies, with a robust benchmarking practice to prevent hypes and encourage hardware providers towards value creation.

Another key challenge is the **expectation of significant scaling up of chip fabrication requirements**, which cannot be met by the current fabrication facilities available in the EU. Europe does not possess a unified quantum foundry ecosystem: world-class cleanrooms and nanofabrication facilities for novel qubit materials are scattered and oversubscribed, slowing device prototyping. Cryogenic test centres with multi-platform support (superconducting, trapped-ion, spin) are limited, impeding cross-lab benchmarking and scale-up experiments.

Dedicated quantum metrology labs for coherence and gate-fidelity characterisation at scale are also limited. To bridge these gaps, stakeholders proposed the establishment of a European network of regional "quantum hubs" combining advanced cleanrooms, shared cryo-test rigs, and standardised metrology labs, linked by open-access protocols and co-funded by public-private partnerships.

In the area of **quantum communication**, no network constellation exists that makes the deployment of the technology practical. The cost of installing a large, useful network is currently high. Yet, several stakeholders call for more efforts such as the EuroQCI[239] and the establishment of such quantum network. In the area of **quantum sensing**, there is a lack of infrastructure for industry to test and certify their quantum technologies. One challenge relates to the high degree of specialisation needed for different kinds of tests.

Robotics: The success of robotics' deployment depends on the ability to test systems in progressively real environments over long periods of time with a high degree of consistency and control over the environment. Hence, the challenges in current robotics testing infrastructures warrant greater emphasis, particularly issues such as the lack of accessible and standardised testing environments, limited scalability, and the inability of existing testbeds to keep pace with rapid technological advancements. As testing moves to higher TRLs the sophistication of the benchmark and test environment needs to scale until it is near to real. Those testing environments need to be interdisciplinary and incorporate IoT, cybersecurity, human-machine interaction, etc. The need to protect IP and data during testing is also key. The sustainability of such testbeds in the long term (over 10+ years) with continuous upgrades as technology evolves is critical. Digital infrastructures, digital twins and simulations are increasingly used in robotics in parallel with the real physical environments and will become key enablers of efficiency gains and increased speed of robotics development and deployment.

Technologies for interoperability & GovTech: Stakeholders agree that the rollout of interoperable services across Europe remains hampered by fragmented and insufficient digital infrastructure. The European cloud ecosystem struggles to rival non-EU hyperscalers in trust, interoperability and seamless platform integration, particularly for platform-as-a-service offerings and collaborative software tools. Sector-specific shortfalls, such as limited high-resolution remote-sensing data for environmental and urban applications and underdeveloped self-sovereign identity infrastructures, further restrict innovation deployment. For interoperability solutions, this fragmentation is particularly problematic as cross-border data services require consistent, reliable infrastructure that can operate across different national technology ecosystem. Standardisation remains patchy, with inconsistent interfaces for emerging technologies, proprietary office suites and a dearth of non-copyleft licensing options. Stakeholders noted that many existing testbeds focus on single technologies, rather than testing how different components and technologies work together in full value or service chains. In particular, few sandboxes fully simulate legal, linguist and policy differences across EU MS, which are critical for interoperability. Experts noted that there was a need for sandboxes that supported multi-technology integration that tested the interoperability and integration of multiple technologies (e.g. AI, blockchain, digital ID) in a coordinated way. Indeed, the Interoperable Europe Act introduces interoperability regulatory sandboxes to facilitate the development and testing of innovative solutions before such solutions are integrated in the network and information systems of the public sector.

Energy infrastructures are critical enablers for the future deployment of advanced digital technologies. As digital tools such as AI, edge computing, cloud services, quantum technologies, and 6G networks become more used, their energy demands rise significantly. Data centres, sensor networks, and communication infrastructures require stable, high-capacity, and sustainable energy sources to function reliably and at scale. Moreover, digital technologies are increasingly integrated into energy-intensive sectors such as manufacturing, transport, and agriculture, amplifying the interdependence between energy availability and digital transformation. Without resilient, smart, and decarbonised energy infrastructures,

[239] https://hadea.ec.europa.eu/programmes/connecting-europe-facility/about/quantum-communication-infrastructure-euroqci_en

including grids capable of managing fluctuating loads and integrating renewable sources, digital innovation may face bottlenecks.

3.6 Skills and other capabilities for the deployment of digital technologies

3.6.1 Digital skills currently available for the deployment of digital technologies

Meeting the demand for tech talent is widely acknowledged as essential to maintaining and gaining leadership in key areas such as Artificial Intelligence or quantum technologies as was recently also stressed in the European Competitiveness Compass[240]. The EU faces major skills shortages, particularly in digital and advanced tech sectors, with nearly 80% of SMEs struggling to find qualified workers. Limited talent availability and mobility hinder business growth, putting the EU at risk of falling behind global competitors like the US and China.

As highlighted by the report on the Digital Decade[241], only 55.6% of the EU population had basic digital skills[242], and the number of ICT specialists is expected to reach 12.4 million by 2030, short of the 20 million target. Progress in 2023 was significantly below the needs[243]. The overall number of ICT specialists employed in the EU has been growing over time[244] but advanced at just one-third of the required rate, reaching over 10 million in 2024 (from 8.4 million in 2020). Germany accounted for the largest share (2.3 million or 22.1%), followed by France (1.4 million or 13.6%), Spain (just over 1 million or 10%), and Italy (0.9 million or 9.2%). The R&D Investment Scoreboard analysis found also that ICT software and services companies reduced employment, yet these sectors still represent a major share of US employment (37%), in contrast to only 14% in the EU. Media and digital literacy and critical thinking have been also highlighted in the Digital Decade report as essential soft skills that must complement technical digital competencies, enabling EU citizens to navigate digital environments responsibly, identify disinformation and misinformation, and fully participate in a secure and inclusive digital society.

In this report, the share of professionals with specific digital skills in the economy has been investigated using LinkedIn.[245] This data source enables insights into the share and distribution of professionals with specific technological skills such as Artificial Intelligence, advanced communications, or photonics. It captures both trends among professionals whose core roles involve tech skills and among a broader group of workers in non-IT positions for whom digital competencies are essential for effective technological deployment. Compared to highly resource intensive alternatives such as surveys it represents a more cost-effective alternative considering also the time needed for running surveys and the related survey fatigue. Nonetheless, the representativeness of LinkedIn needs to be taken into account and the indicators derived from the data need to be corrected for the under or overrepresented groups in the population which can be done using post stratification techniques. Further methodological considerations about LinkedIn have been included in the methodological annex.

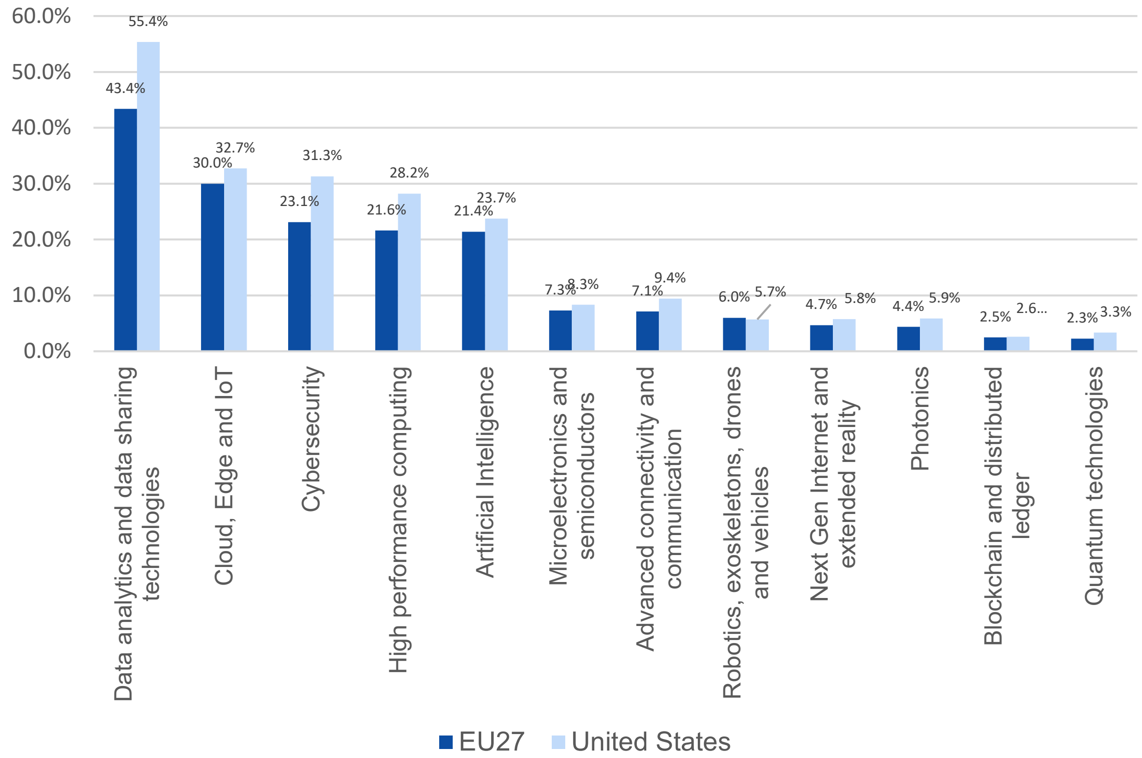
In 2025, there have been **3 276 706 professionals employed in ICT-related functions with relevant digital skills related to the 12 digital technology areas[246]** analysed, a relatively limited number given the scale of digital transformation, as found by the analysis of LinkedIn

[240] European Commission (2025). A Competitiveness Compass for the EU
[241] https://digital-strategy.ec.europa.eu/en/library/state-digital-decade-2025-report
[242] https://digital-strategy.ec.europa.eu/en/library/state-digital-decade-2025-report
[243] State of the Digital Decade 2025 report | Shaping Europe's digital future
[244] https://ec.europa.eu/eurostat/statistics-explained/index.php?title=ICT_specialists_in_employment#Number_of_ICT_specialists
[245] LinkedIn, as the largest professional networking platform, offers rich, up-to-date data on professionals' skills, job roles, and education, making it a valuable and cost-effective tool for tracking technology-specific skill trends, especially compared to traditional surveys. Its flexibility allows for analysis across skill combinations and geographic levels. However, its voluntary nature introduces self-selection bias, as users differ by location, sector, and education, affecting representativeness. Despite limitations like lack of access to raw data, potential inaccuracies in self-reported profiles, and mismatches with official statistics (e.g. Eurostat), LinkedIn remains a powerful source for skill monitoring, provided post-stratification techniques are applied to correct for biases.
[246] Given the horizontal nature of interoperability and related skills embedded in different functions, skills only to interoperability could not be scoped via keywords in LinkedIn.

data. When comparing this with ICT employment statistics, it represents **32% of all ICT and engineering specialists**.

In the EU in 2025, the largest share of ICT professionals had skills in **data analytics (43%), followed by cloud, edge, and IoT technologies (30%), and cybersecurity** (23%). The low share of professionals with skills in quantum technologies, blockchain, and photonics reflects the more limited current relevance and adoption of these technologies across the broader economy. As these fields are still emerging and have fewer mainstream applications compared to other digital technologies, supply of specialised talent remains relatively low.

Figure 41 Share of professionals with specific tech skills working in ICT and engineering functions within the total ICT professionals in the EU and the US



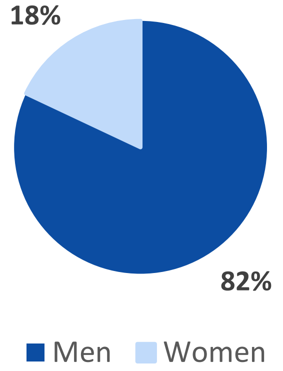
Source: Technopolis Group (2025) based on analysis of LinkedIn data

Across all technologies, the **share of professionals with specific digital skills within ICT and engineering functions has been systematically higher in the US than in the EU**. This reflects a more advanced digital ecosystem in the US, where the supply of high-level technological competencies is stronger. As a result, professionals in the US are more likely to possess and apply specialised skills in areas such as Artificial Intelligence, cybersecurity, data analytics, and other emerging technologies, contributing to the country's competitive advantage in digital transformation.

The gender gap is pronounced both in the EU and in the US given that 82% of the professionals with skills related to the 12 technology areas are men and only 18% are women, with similar percentages in both global regions. This is slightly below the general statistics for employed ICT specialists, where in 2024 only 19.5% of the workforce were women in the EU[247]. This percentage has not changed much over the past five years.

[247] https://ec.europa.eu/eurostat/databrowser/view/isoc_sks_itsps__custom_17014129/default/table?lang=en

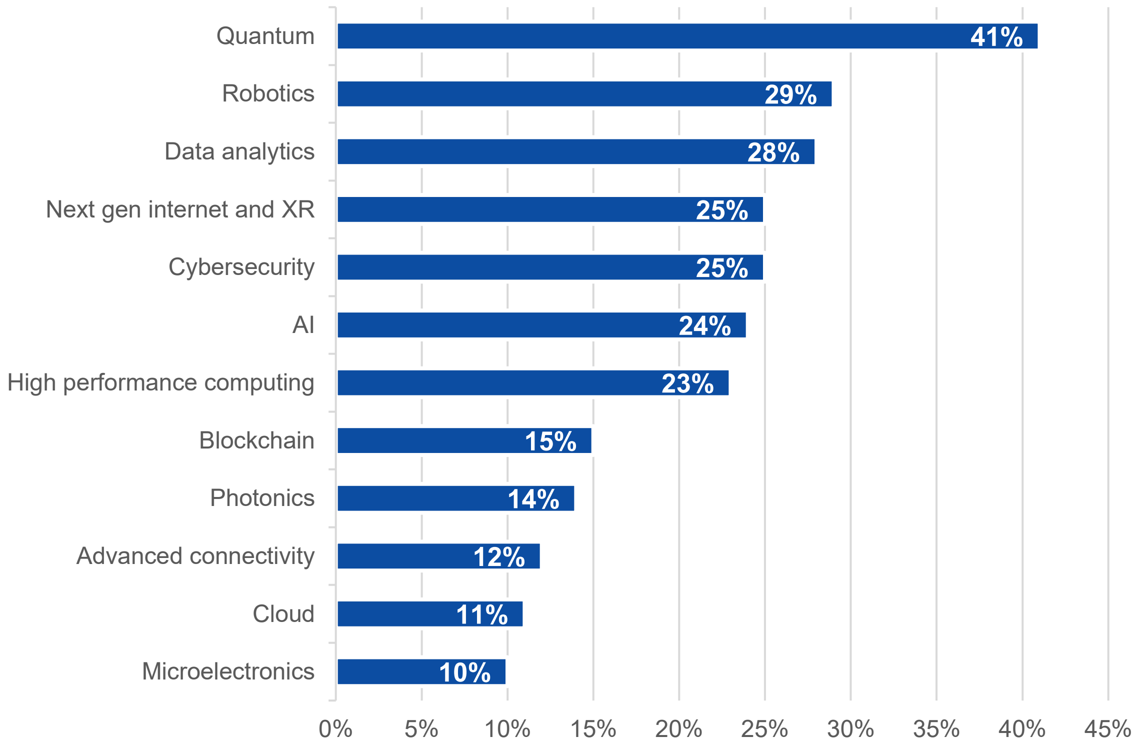
Figure 42 Share of professionals with specific tech skills in total ICT professionals in the EU and the US – men vs women



Source: Technopolis Group (2025) based on analysis of LinkedIn data

In terms of trends over time, the **most dynamic growth was observed in Quantum technologies, Robotics, and Data analytics technologies** in the number of professionals with digital skills in 2025. The total **number of professionals with AI-related skills in ICT and engineering functions increased by 24% over one year from May 2024 to May 2025**, indicating strong growth in this talent pool and reflecting rising demand for Artificial Intelligence expertise. More specifically, the EU's AI talent pool has grown significantly, notably 124% larger in 2024 than in 2016. While AI talent concentration has grown faster in the UK (150%) and US (136%), some EU countries such as Lithuania and Estonia have more than tripled their AI talent shares since 2016[248]. The lowest growth is observed in the case of microelectronics, cloud, edge and IoT and advanced connectivity.

Figure 43 Increase in the number of professionals in ICT and engineering functions with specific digital skills in the EU from May 2024 to May 2025



Source: Technopolis Group (2025) based on analysis of LinkedIn data

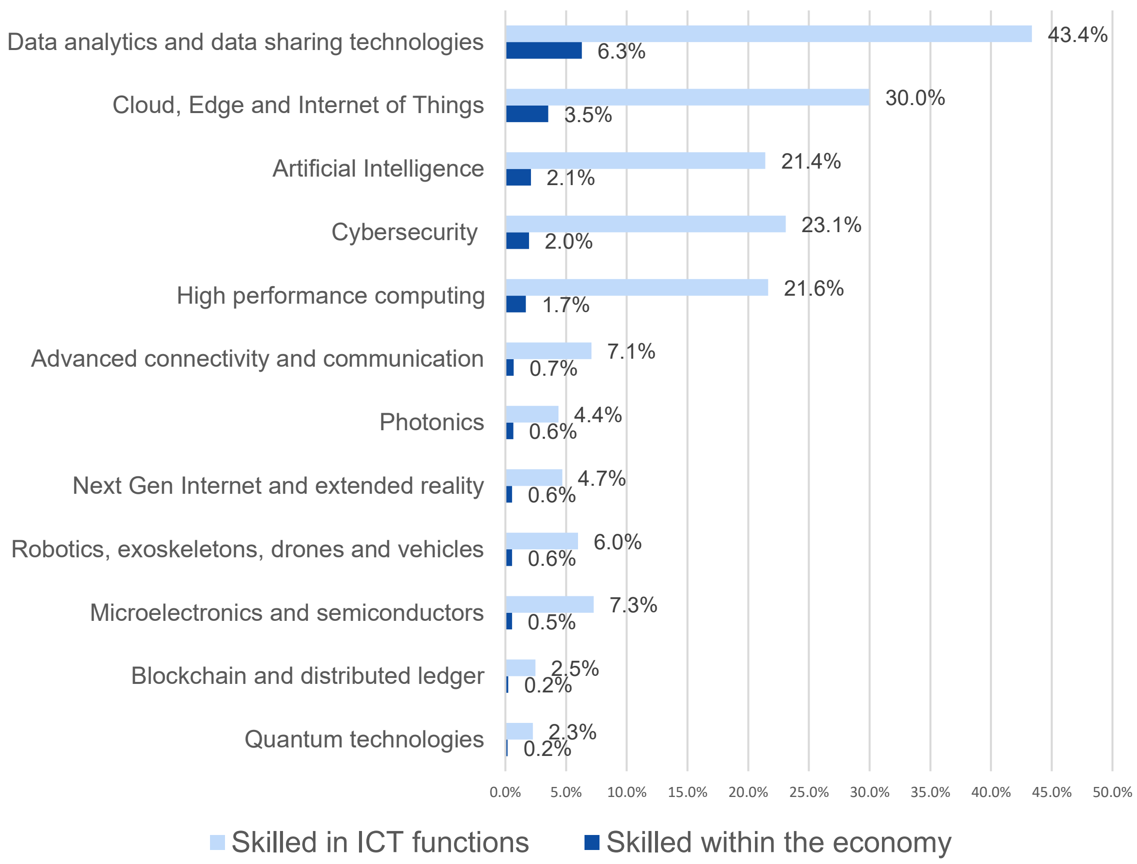
AI remains a key skills challenge, as hiring professionals for AI-related roles is difficult and takes time in the EU, posing a barrier to the rapid digital transformation of companies. There

[248] LinkedIn (2024). AI in the EU: 2024 Trends and Insights from LinkedIn

is a growing demand for specialised AI roles, such as machine learning engineers, including NLP and computer vision experts, as well as emerging positions like prompt engineers driven by the rise of Large Language Models (LLMs)[249]. However, the educational provision for these roles remains limited.

The uptake of digital technologies can be proxied by examining the share of professionals across various sectors and job functions who possess advanced digital skills[250]. This approach provides insights into how deeply digital competencies are embedded in different parts of the economy. Notably, **within the industrial sector, the proportion of professionals with advanced digital skills remains relatively low**. The highest levels of knowledge among professionals are found in areas such as data analytics (6.3%), cloud-edge-IoT (3.5%), and Artificial Intelligence (2.1%), while the lowest levels are observed in more specialised technologies like quantum computing, blockchain, and microelectronics (0.2-0.5%). This suggests that, despite ongoing digital transformation efforts, many industrial roles still lack the digital proficiency required to fully leverage new technologies, highlighting a potential gap in skills development and a barrier to innovation and productivity gains in the sector (see Figure below). It has to be noted though that quantum technologies or microelectronics are more relevant for specific industries and professions and have less cross-cutting role in the economy than for example AI.

Figure 44 Share of professionals with specific tech skills within ICT functions and in the broader economy in the EU



Source: Technopolis Group (2025) based on analysis of LinkedIn data

The limited share of **2.1% in the case of AI for the wider economy indicates a relatively low level of AI literacy across other roles** than ICT functions. Similarly, Cedefop (2025) recently found that understanding of AI remains low across the European adult workforce, with

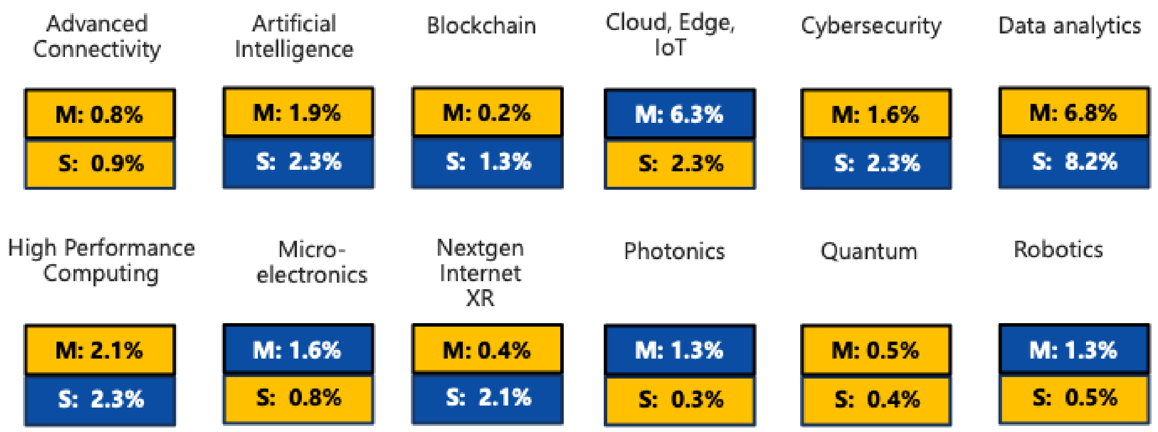
[249] ARISA (2024). AI Skills Strategy for Europe https://aiskills.eu/wp-content/uploads/2024/01/AI-Skills-Strategy-for-Europe.pdf
[250] The use of LinkedIn data is based on publicly available information and self-expression of individuals about their profiles, moreover, it is a certain part of the population that creates LinkedIn profiles, hence it does not fully represent the entire labor market and should be interpreted with caution regarding representativeness. The strengths and limitations of LinkedIn have been analysed in detail in a report prepared by Technopolis Group: https://op.europa.eu/en/publication-detail/-/publication/5976f0f1-308a-11ec-bd8e-01aa75ed71a1/language-en

around 40–60% of surveyed workers lacking knowledge about how AI functions or its broader societal implications[251]. Significant barriers exist to the take-up of AI technology in organisations, particularly for micro- and small and medium-sized EU enterprises, which often start from an unfavourable digital maturity position. To address these gaps, there is a need for strengthening the integration of AI literacy competences into initial and continuing vocational education and training curricula. The European Commission, in cooperation with the OECD, is currently working on the development of an AI Literacy Framework for primary and secondary schools. It will equip young people with the knowledge of how AI works, its societal impact and how to use it ethically in order to be prepared for a society and economy in the age of AI[252]. The updated Digital Competences Framework 3.0[253] also offers an updated set of competences ensuring a systematic and transversal integration of AI across the framework.

Certain digital skills align more closely with specific industrial activities. For instance, technologies such as **cloud-edge-IoT, microelectronics, photonics, and robotics are particularly relevant to manufacturing industries**, indicated by the higher share of professionals with these skills in manufacturing than in service industries. In these jobs, skilled employees support automation, process optimisation, and smart production systems. In contrast, **Artificial Intelligence, blockchain, cybersecurity, next-generation internet, and extended reality (XR) tend to have a stronger presence in service-oriented sectors**, reflecting their role in enhancing digital services, data management, and user experience. Some technologies such as advanced connectivity, quantum computing, and high-performance computing exhibit a more balanced distribution across sectors, indicating their broader applicability and cross-sectoral importance.

The higher presence of AI skilled professionals in services indicates that AI is not yet well-exploited in manufacturing industries in the EU although it has relevant applications. Similarly to cybersecurity, the lower share indicates vulnerabilities if the EU manufacturing industries are not well-prepared.

Figure 45 Share of professionals with specific tech skills in manufacturing and services in the EU-27 (M=manufacturing, S=services)



Source: Technopolis Group (2025) based on analysis of LinkedIn data, blue colours highlight when the share of professionals with the specific technology skill is higher than in the other sector of the economy

The main AI skills gaps in the EU stem from a significant mismatch between current skill offerings and the dynamic demands of an AI-driven economy. This situation is driven by a surge in demand for AI-related expertise that is quickly outpacing the current supply of qualified professionals. A recent Cedefop survey (2025)[254] found that while half of EU adult workers recognise the need to upgrade their digital skills, only about a quarter are in training due to lack of appropriate training courses and lack of time. Low participation in AI-specific training is evident, with only 15% of workers having participated in education or training to develop their AI knowledge and skills in the past year, despite large existing skill gaps. In this regard, the

[251] Cedefop (2025). Skills empower workers in the AI revolution First findings from Cedefop's AI skills survey
[252] Home | AILit Framework
[253] https://joint-research-centre.ec.europa.eu/projects-and-activities/education-and-training/digital-transformation-education/digital-competence-framework-digcomp/digcomp-30_en
[254] https://www.cedefop.europa.eu/en/projects/vocational-teacher-survey

Union of Skills and STEM/Basic Skills[255] strategic plans aim to strengthen Europe's workforce by promoting education and training initiatives that enhance foundational digital, STEM, and soft skills, ensuring citizens are equipped for the demands of the evolving digital economy.

3.6.2 Unmet digital skills' needs

The skills challenge has been further explored through workshops organised with key experts in each technology area. In this section, we provide a summary of the main findings.

In **Advanced Connectivity** the following skills challenges have been highlighted throughout the stakeholder consultation process:

- There is a pressing demand for cloud-native & AI engineers and general AI specialists, particularly those proficient in both telecom network functions and cloud technologies like OpenStack, AWS, Kubernetes, and network function virtualisation. A shortage of cybersecurity specialists and, more specifically, post-quantum specialists or post-quantum crypto specialists is also noted. The deployment of 5G-Advanced/6G is constrained by a lack of people such as certified fibre-and-tower techs, edge-integration experts, and good RF engineers
- Lack of interdisciplinary and holistic expertise: As technologies like 6G, edge computing, and AI-integrated networks become more prominent, the workforce will need to be equipped not only with technical knowledge but also with interdisciplinary skills that bridge software, hardware, and systems integration. The industry seeks more holistic experts who understand a system end-to-end. The sector requires more professionals with a technical background combined with project management and business acumen, who have a good understanding of business models.
- Systemic challenges: Several experts noted that finding qualified employees is very challenging, especially when hiring is restricted to European citizens. The demographic shift is expected to exacerbate the shortage of skilled workers, and despite efforts in gender equality, there remain significant disparities in interest and participation in technical fields among women from different countries.

The deployment of **Artificial Intelligence** faces the issue of a lack of interdisciplinary expertise that can combine technical skills with legal, ethical, and domain-specific knowledge.

- As AI systems increasingly interact with sensitive institutional environments such as healthcare, legal topics and public services, there is a need for AI specialist who can navigate technological deployment and regulatory issues. To close this gap, EU requires new training programmes that integrate technological skills with socio-technical systems thinking. These should be developed through strong partnerships across academia, industry, and public bodies.
- EU faces a shortage of AI engineers with advanced IT and data analytics expertise. More specifically, EU lacks AI translators, connectors, and business-focused developers who can bridge R&D with commercialisation, showcase use cases, and drive adoption in non-tech industries.
- AI specialised skills vary by profession, for example, the AI competencies required for doctors differ from those needed by professionals in chemistry, physics, tourism, and other fields.

In **Blockchain,** successful deployment is increasingly constrained by the availability of relevant digital skills. Interviews with stakeholders consistently highlighted the need for more advanced competencies to support both the development and implementation of these technologies.

- SMEs and public sector actors often lack in-house capabilities to deploy blockchain solutions for use cases like credential issuance, traceability, and identity verification. In addition there is deficient training on tools like smart contract auditing, data provenance visualization, and ESG traceability via DLT.
- Blockchain and crypto-specific skills are not adequately integrated into existing education and training systems. Skills required include developers and architects proficient in specific blockchain platforms like Ethereum, Hyperledger Fabric, Corda, etc, and skilled smart contract programmers with a strong understanding of security best practices.
- In terms of non-professional and business skills, there is a shortage of blockchain-literate business strategists, technical project managers, and legal/compliance experts familiar

[255] https://education.ec.europa.eu/news/basic-skills-and-stem-action-plan-to-support-education-and-training

with DLT regulation (e.g. MiCA, GDPR) and professionals who understand business needs and translate them into effective blockchain solutions.
- The lack of formalised crypto and blockchain education leaves many European citizens vulnerable to scams and misinformation, which in turn undermines public trust in digital currencies and blockchain applications. Additionally, many citizens currently have low digital skills and limited understanding of key blockchain concepts such as wallets and private keys, further emphasising the need for comprehensive educational efforts to improve awareness and safe usage.
- The challenges are particularly pressing in the public sector, where the adoption of blockchain-based solutions for public service delivery is being considered.

In **Cloud-Edge-IoT deployment** requires the ability to integrate open-source solutions and libraries into the ecosystem, recognising these as unique and highly desirable competencies.

- With the increasing prominence of AI, there is a need to understand and leverage AI for infrastructure development. This also includes the ability to integrate AI models into existing applications.
- There is a need for professionals who can holistically bridge cloud, edge, IoT, and hardware layers, often referred to as systems engineers. This comprehensive understanding, encompassing both software and hardware, is increasingly critical for optimal efficiency and performance.
- Expertise is vital in orchestration & automation, interoperability & open standards, and lifecycle management & DevOps for distributed cloud systems. For future networks, specifically 6G, stronger AI capabilities are anticipated, requiring skills to proactively provide better services, including non-terrestrial components and standard edge-cloud capabilities. The establishment of a Unified API layer is also proposed as a crucial standardisation initiative to simplify transitions between cloud providers and enable a potential "AI continent", requiring developers who can work with joint APIs across technology stacks.

In the field of **Cybersecurity**, skills gaps are particularly critical in the current global context. Main issues include[256]:

- Severe talent shortages exist across critical cybersecurity roles, especially cybersecurity implementers, incident responders, driven by rising threats and compliance pressures.
- Emerging technical skills in AI security, cloud security, and threat analysis are increasingly in demand, alongside core IT skills like network management and system integration.
- Soft skills and organisational capabilities, such as risk management, communication, and project management, are underdeveloped in current training offerings, highlighting the need for more holistic education and industry collaboration.

In the field of **Data analytics and data sharing**, the AI Skills Needs Analysis conducted by the ARISA consortium in 2023[257] highlighted the needs and gaps concerning data scientists, data engineers, data analysts, as well as data product managers.

- Concrete skills include e.g., "business intelligence, systems and architecture, process automation and technology & business topics", "traditional ICT topics like databases and SQL", and, for instance for data engineers "mathematics & statistics and machine learning algorithms". In addition, the report highlights the ability to work in teams, business development and project management competences.
- In relation to data sharing, key skills highlighted in interviews and focus groups also include expertise in relation to privacy and data protection, as well as further regulatory and legal compliance, and the ability to apply them in ICT context.

In **High Performance Computing**, Europe is facing a talent gap. While young people tend to pursue careers in finance, management, and general AI, fewer are specialising in HPC, leading to a shortage of domain experts capable of optimising supercomputing systems that sets also limitations for deployment.

- Most SMEs lack in-house HPC expertise, and many professionals are unfamiliar with batch computing, scaling, or job scheduling. There is a need for upskilling programmes tailored

[256] https://cyberhubs.eu/addressing-europes-cybersecurity-skills-gaps-findings-from-the-latest-cyberhubs-needs-analysis-report/
[257] https://aiskills.eu/resource/europes-most-needed-ai-skills-and-roles/

to non-specialists, particularly in fields like manufacturing, healthcare, and energy, where HPC can have transformative impact.

- While technical expertise exists within specialised research centres, in industry there is a lack of skills to integrate and use HPC effectively. There is a shortage of application engineers, system administrators, and data scientists who can deploy HPC solutions, manage complex systems, and tailor them to business or operational needs.
- Missing competencies in HPC-cloud integration, data stewardship, security, and energy-efficient computing operations hinder deployment. Initiatives like the EuroHPC EVITA[258] academy are promising, but need scaling-up, better industry linkage, and modular content that matches real use cases. Applied digital skills, business model innovation, and awareness campaigns are also needed to promote uptake beyond research institutions.
- HPC system cybersecurity: Effective data management, regulatory compliance, and security remain central to this ecosystem, ensuring ethical use, privacy protection, and adherence to EU standards for secure and responsible HPC deployment and operation.

In the field of **Microelectronics**, the EU faces a projected shortage of over 75 000 technical professionals in the semiconductor sector by 2030, particularly in hardware and software engineering, technician roles, and data specialisation[259]. As found by the interviews conducted in the framework of this study, key challenges include:

- Semiconductor companies are experiencing difficulties recruiting qualified talent, particularly in Analog Mixed-Signal Design and Test Engineering. Despite the strategic importance of these roles, student interest in these specialised areas remains low.
- While Europe educates a reasonable number of analog designers, there is a significant gap in digital design, which is a much larger field with more complex requirements. Universities often lack the funding required for proper digital design 'take-outs', leading to insufficient numbers of digital designers being educated.
- Overall, less and less students are interested in studying microelectronics. A major bottleneck is the lack of compelling communication about the excitement and opportunities in hardware and technical roles. More effort is needed to spark interest not only among students but also among future technicians and vocational professionals.
- Hardware engineering and related fields, such as material characterisation, are undervalued and perceived as less attractive compared to software engineering. There is a disproportionate focus on software engineering in educational programmes.
- Despite the EU having excellent universities and engineering programmes in various countries (e.g., the Netherlands, Germany, France, Spain), a strategic, data-driven estimation of future workforce needs is lacking. There is no clear forecast of how many engineers and technicians will be needed in the next 5–10 years, which is crucial for effective educational planning and policy design.

In the field of **Next Generation Internet and XR,** skills gaps are present in the following areas as identified during the Delphi survey and interviews:

- There is a cross-disciplinary skills shortage, notably few professionals are trained in both emerging technologies and applied sectors (e.g. healthcare, education), with additional gaps in UX, human-centred design, and XR content creation.
- Decision-makers often lack the digital literacy and combined technical-strategic skills needed to drive adoption and value creation, especially in sensitive sectors.
- Low awareness of open technologies: Non-technical professionals and SMEs often overlook open-source models and standards, limiting collaborative innovation.
- Broader digital literacy remains insufficient to support XR and NGI uptake.
- Skills are lacking in XR rendering, simulation, generative AI, and interface design (e.g. gesture recognition, cultural responsiveness), hindering adaptive, user-centric experiences.

In **Photonics**, despite growing demand, the industry faces a severe skills shortages. Interviews conducted as part of the market survey in this study highlighted that most photonics employers struggle to fill positions with qualified workers, along the following lines:

[258] https://www.eurohpc-ju.europa.eu/research-innovation/our-projects/evita_en
[259] Electronic Components and Systems (2025). ECS Strategic Research and Innovation Agenda 2025. https://ecssria.eu/ECS%20SRIA%202025_Global%20version%20final.pdf

- Limited educational programs: Few universities offer dedicated photonics degrees, especially at the undergraduate or technician level.
- Vocational training (technician certificates, apprenticeships) lags demand. As the Photonics21 (2021-2027)[260] roadmap notes, the European photonics sector needs "academic and vocational training in photonics [to] be a priority," implying it is not adequately addressed today. Without such programs, entry-level technician roles in assembly, packaging and testing go unfilled.
- Industry training burden: Because formal programs are scarce, firms compensate with on-the-job learning.
- Geographic imbalance: Training facilities and photonics clusters are concentrated in a few regions (e.g. Netherlands, Germany), leaving other areas underserved.

The deployment of **Quantum** technologies is constrained by several key skills gaps:

- In general, a 'quantum literacy' is needed in the market, as potential end-users are not aware of the different quantum technologies and their capabilities.
- While quantum software development presents a key opportunity area for the EU, there is a lack of incentive for talent to join this field e.g. salaries are low compared with AI software development, and the quantum software market is still too uncertain to justify higher salaries.
- Industry adopters need access to people skilled in the installation and operation of quantum technologies, especially where the technology is poised to scale up significantly e.g. logical qubits. In many cases, these people need certified capabilities. However, there is no standard certification system that can ensure that providers are 'trusted', at the technology or the skilled personnel level. There are also not enough technicians/engineers for the growth expected in the next 5-10 years.
- PhD graduates in quantum move to the quantum industry with a research-focused mindset that values flexibility, while companies require a more product-driven approach with specific timelines and deliverables.

In **Robotics**, one of the major bottlenecks is the skills gap at the intersection of robotics and AI. Modern robots increasingly rely on AI and machine learning for perception and decision-making, yet many robotics engineers lack AI expertise.

- There is growing demand for cross-disciplinary engineers who can design robotic systems and also develop or deploy AI algorithms. Implementing autonomous robots requires understanding data analytics and machine learning to imbue machines with adaptive behaviour.
- Another critical area is industrial data communication and interoperability skills, such as proficiency in standards such as the Asset Administration Shell (AAS) and other robot–machine–IoT protocols. Engineers and technicians will need to master such protocols (along with frameworks like OPC UA or MQTT) so that robots can easily integrate into smart factories and Industrial Internet of Things (IIoT) environments.

In the case of **Technologies of Interoperability and GovTech**, the skills' deficit is especially pressing. Interviewees noted that many public sector officials lack basic digital literacy and IT skills, making the prospect of integrating new and emerging technologies such as AI an impossibility. A shortage in multidisciplinary profiles within the public sector that combined blockchain, AI, cloud architecture and public administration expertise as a key challenge for the sector.

- Recruitment and retention of skilled digital professionals also remains a structural challenge. Public administrations often struggle to compete with the private sector on salary and offer slower, more bureaucratic hiring processes. For instance, Italy's data protection authority recently reported difficulties in hiring AI experts due to these constraints, an issue reflective of broader talent shortages across the region.
- Compounding these gaps is the limited availability of structured, cross-government training and career development pathways. While a number of EU initiatives such as the Digital Europe Programme and Big Data Test Infrastructure (BDTI) are designed to upskill civil servants, these efforts often remain fragmented and underutilised. In many Member

[260] https://www.photonics21.org/download/ppp-services/photonics-downloads/Europes-age-of-light-Photonics-Roadmap-C1.pdf

States, digital skills development is not yet embedded as a strategic, system-wide priority, limiting institutional capacity to scale successful GovTech solutions.

- In the coming years, interviewees and focus group participants expect that the demand for hybrid digital capabilities will intensify, not only technical skills like coding, cloud computing, and data analytics, but also adaptive skills such as problem-solving, creativity, and digital leadership. These competencies are critical for designing user-centred services, managing AI adoption ethically, and navigating increasingly complex regulatory and cybersecurity environments.

Europe is facing a growing talent gap in interoperability. While frameworks such as the European Interoperability Framework (EIF) set a common direction, many administrations lack professionals able to translate these principles into practice. Skills in data architecture, API management, and semantic interoperability remain limited, particularly at regional and local levels. There is also a shortage of multidisciplinary experts who can combine knowledge of ICT, data governance, legal frameworks, and public administration processes related skills essential for building interoperable and secure digital services.

Recruitment and retention challenges mirror those seen across the digital sector: the private sector attracts most data and IT talent, leaving public bodies reliant on external contractors and fragmented outsourcing models. Upskilling programmes, such as those offered through the Interoperable Europe Academy, are promising but need scaling, stronger industry linkages, and alignment with national training systems. Awareness campaigns and modular training on data governance, API standardisation, and cross-border service design could help build the applied digital skills needed to embed interoperability in day-to-day public sector operations.

3.7 European digital ecosystem relevant for the deployment of technologies

Digital ecosystems are essential to provide the adequate conditions, expertise, infrastructure, and coordination needed for the successful deployment of digital technologies. They are characterised by several unique features as discussed in the related academic literature[261]: they focus on delivering integrated goods and services rather than solely products. They leverage network effects, where the ecosystem's value increases as more users participate, and shift value creation from individual firms to a collaborative network of providers and consumers. They can exhibit winner-takes-all dynamics, allowing dominant platforms to capture significant market share, and foster openness by balancing accessibility and control to encourage innovation. Digital ecosystems also enable collaboration across companies, industries, and organisations, while optimising the use of idle assets to support sharing and access-based consumption. In this study, these conditions have been investigated by the stakeholder consultations and expert interviews complemented by further research.

The current composition of the European digital ecosystem is seen well-suited only to a moderate or a limited extent for the deployment of digital technologies in most technology areas and by most of the technology experts. The figure below shows the results of the technology expert survey (Delphi round 1), highlighting the quality of the current European digital ecosystem.

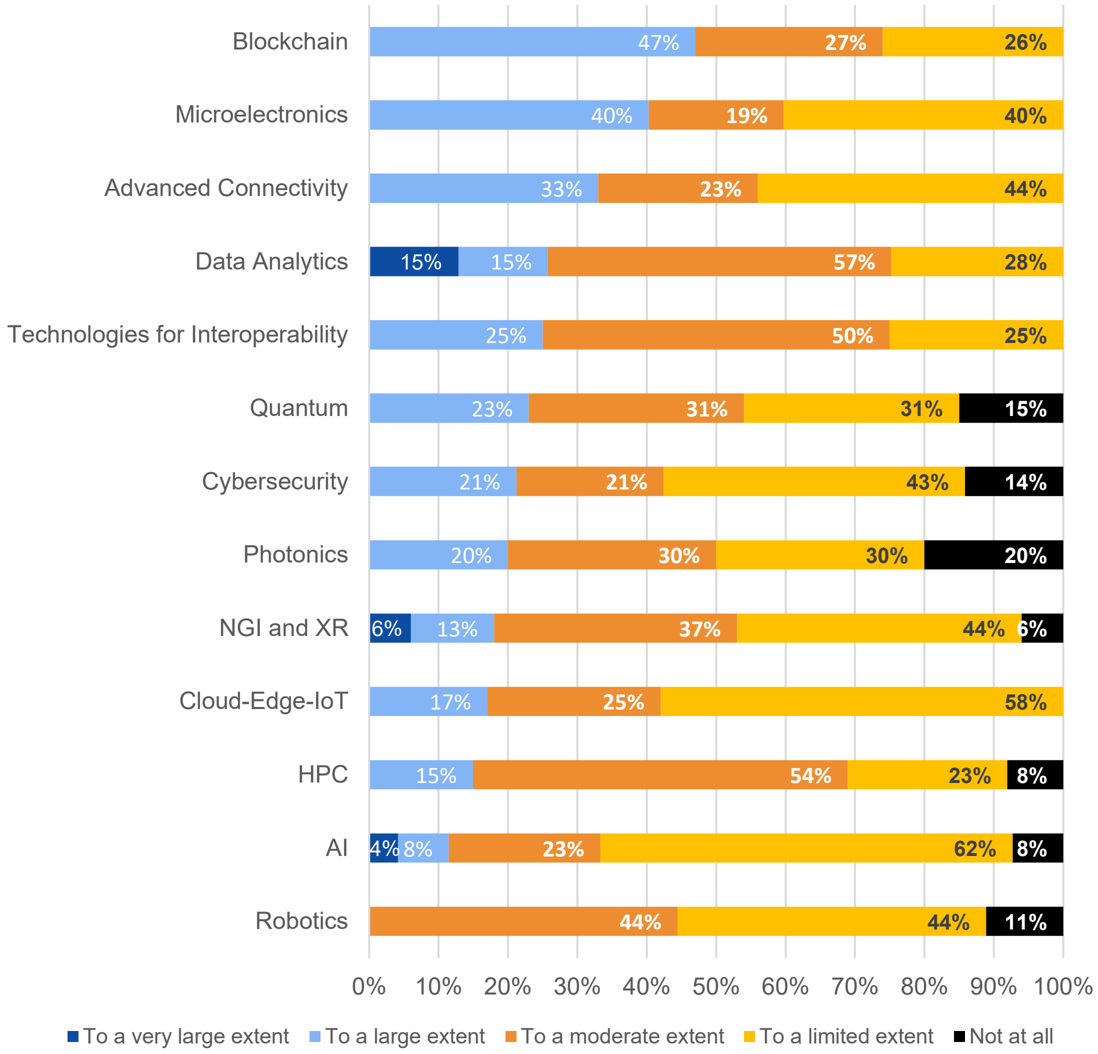
Most challenges are concentrated in Robotics and Artificial Intelligence, where experts consider the European ecosystem only moderately suitable for deployment. This indicates that more should be done to strengthen European value-chains and fill gaps in most technology fields. The picture is more mixed in the field of Quantum, Cybersecurity and Photonics where experts had diverging opinion with 18-23% rating it to a very large extent suitable while at the same time 15-18% stating that not at all. The best conditions are seen in the case of Blockchain and Advanced Connectivity.

The expectations as stated via the Delphi survey are that **the European ecosystem will evolve rapidly toward greater consolidation and vertical integration in various technology areas** such as AI or Data Analytics, aiming to strengthen EU autonomy, expand capabilities, and enhance resilience. Increasing regulatory pressure on circularity, carbon accounting, and supply chain transparency will drive the adoption of digital tools for traceability

[261] Koch, M., Krohmer, D., Naab, M., Rost, D., & Trapp, M. (2022). A matter of definition: Criteria for digital ecosystems. Digital Business, 2(2), 100027. https://doi.org/10.1016/j.digbus.2022.100027

and risk management. In the field of Quantum technologies, the ecosystem is projected to mature from niche R&D toward commercialisation, with a focus on integrated solutions, cost efficiency, and seamless software interoperability. Collaboration, sustainability, and talent development in cross-disciplinary areas will be key enablers of this transition. It is also expected that collaboration among all actors in the supply chain around digital technology deployment will be enhanced in Europe offering advanced digital solutions to key industries and sectors with data valorisation and access to new, international markets.

Figure 46 Current composition of European ecosystems as enabler of technology deployment [Is the current composition of the European digital ecosystem in the respective technology areas well suited to enable the deployment of advanced technologies?]



Source: Technopolis Group (2025), based on Delphi results round 1, n=170

The section below highlights the main ecosystem challenges identified by stakeholders in the different technology areas.

Advanced digital communications and connectivity: Key challenges discussed in the expert consultations include first the fragmentation of the European market, which limits the ability of companies to scale and compete internationally. The fragmentation extends to public-sector initiatives and permits, where small-scale, nationally siloed pilots fail to send clear, continent-wide signals of demand. In addition, according to the analysis of Connect Europe[262], total telecom investment has declined (€59.1 bn in 2022 to €57.9 bn in 2023), yielding lower returns (RoI falling from 6.6% to 5.9% since 2017) below the cost of capital. Per-capita investment lags peers (€118 vs. USA €226)[263]. Ambitious targets, such as 99% FTTH (fibre to

[262] https://connecteurope.org/insights/reports/state-digital-communications-2025
[263] ibid

the home) coverage requiring an additional €109 bn by 2030, or doubling 5G Standalone networks, require strategic, large-scale funding[264]. Yet current models often expect partial private contributions even where market failures exist, deterring operators from investing in underserved areas and advanced infrastructure (e.g. cloud RAN, Open RAN).

The role of telecom operators was debated, with some arguing that they have become passive infrastructure providers rather than active innovators. This shift, driven by cost pressures and intense competition, has weakened their ability to shape technological development. **Standardisation** is another area of concern. The process is currently dominated by large global players, making it difficult for smaller European companies and vertical industries to participate meaningfully. In addition, **Europe's digital connectivity ecosystem remains heavily reliant on non-European suppliers for critical network technologies**, posing challenges to digital sovereignty and security. Infrastructure gaps, including **limited fibre coverage, delayed 5G standalone rollout and edge node deployment** hinder the deployment of digital technologies. In the space and satellite communications domain, the IRIS² initiative represents a bold step towards a sovereign European Low Earth Orbit (LEO) communication infrastructure. However, the programme remains in its early stages and is currently overshadowed by the rapid deployment and commercial momentum of non-European systems like Starlink and Amazon's Kuiper.

Europe remains reliant on non-European providers for critical components: chipsets for 5G/6G hardware, cloud platforms (AWS, Azure, Google Cloud), and high-frequency pilot lines. This dependency hinders technological sovereignty and poses risks amid geopolitical tensions. Regulatory fragmentation and slow spectrum assignment a hamper timely deployment. Differing national rules on permitting (e.g., for masts or fibre trenches) and varied compliance requirements delay roll-out of 5G/6G and related infrastructure. The absence of harmonised, streamlined EU-wide frameworks for experimentation and deployment constrains large-scale testbeds and public procurement of new services. Stakeholders also note that the public sector's role as strategic buyer is underutilised, with small-scale, fragmented initiatives in rail, healthcare and other domains fail to create stable demand signals. Coordinated, long-term public procurement could de-risk investments and drive large-scale deployment of advanced connectivity in critical sectors (defence, secure communications, smart infrastructure). Such coordination would also help align research outcomes with market needs.

Artificial Intelligence: Europe's ecosystem features numerous specialised vendors (e.g. Mistral, iGenius, Aleph Alpha) focusing on domain-specific needs and regulatory compliance. While this aligns with European values and offers a contribution to EU's digital autonomy, the **absence of large, flagship AI firms limits scale and global reach**. Many start-ups address particular sectors (finance, healthcare, industrial AI), but the overall ecosystem remains dispersed across Member States, reducing cohesion and slowing the emergence of pan-European champions. Major corporates such as Bosch, Siemens, Airbus and Bayer integrate AI into manufacturing, robotics and predictive maintenance, underlining Europe's positioning in industrial AI applications. Yet broader adoption lags. SMEs often face hurdles in awareness, resources and risk appetite, while public-sector uptake varies by country, reflecting uneven readiness and limited trust architectures or collaborative deployment frameworks.

Although Europe hosts active VCs and public funds, total AI investment remains low[265]. High-profile funding rounds (e.g. Mistral's Series A/B) demonstrate potential, but overall private investment in AI scale-ups is modest. Stakeholders also stress that public procurement mechanisms for AI solutions are under-utilised, depriving SMEs of stable demand signals. With regards to geographic distribution, many regions remain behind in AI adoption, with disparities in talent, funding access and infrastructure, hampering a unified single market for AI innovation. Europe has strong research expertise, but wider AI literacy among industry and public-sector decision-makers is lacking. Beyond cloud and hardware dependencies, experts consulted also stressed that Europe must improve access to AI-ready compute (including HPC+AI environments) and interoperable platforms. AI factories/gigafactories are emerging but need

[264] https://connecteurope.org/sites/default/files/2025-01/State%20of%20Digital%20Communications%20%282025%29.pdf
[265] See results of the venture capital investment analysis presented in Chapter 2.

clearer interfaces and support for SMEs. Ensuring pan-European access to testbeds and data spaces would help innovators validate and scale AI solutions.

Blockchain and distributed ledgers: The EU blockchain ecosystem comprises numerous isolated innovation centres, start-ups, consortia and pilot projects with limited coordination across sectors and Member States. This dilutes resources and hampers the emergence of pan-European champions. While some regions (e.g. Germany, France, the Netherlands) host many intermediaries and integrators, others lack critical mass, leading to uneven capacities and missed opportunities for cross-border collaboration[266]. In addition, despite substantial EU-funded projects (e.g. Digital Product Passport pilots), awareness among public and private stakeholders remains limited, undermining trust and slowing adoption. Many traditional industries also cite unclear business cases and interoperability concerns, resulting in slow experimentation and limited deployment beyond proof-of-concept. The financial sector and public services show interest (e.g. traceability, faster settlement) but often proceed cautiously, awaiting clearer frameworks and demonstrable RoI. Bringing together stakeholders in finance, healthcare, logistics and public administration can develop tailored solutions and reusable standards, accelerating adoption. Clear return on investment needs to be showcased.

As for the other digital technology areas in Europe, venture capital availability is limited, investor confidence is low due to technology complexity and early-stage risk, and few specialised investors exist. This constrains start-ups from scaling and deters large-scale pilots. Besides, divergent rules across Member States create legal uncertainty for blockchain deployments, hindering cross-border solutions and deterring investment. Insufficient standards and limited interoperability between networks impede integration, making it harder to develop reusable frameworks and broader ecosystems.

Many EU blockchain solutions also depend on non-EU cloud platforms for off-chain storage and BaaS offerings, and on protocols developed outside Europe. This raises digital sovereignty concerns and centralisation risks beneath a decentralised façade. Core protocols (e.g. Ethereum, Bitcoin, Hyperledger) and many open-source libraries are governed outside the EU, limiting influence over updates and standards. Validator nodes and governance mechanisms for public chains are often concentrated in non-EU jurisdictions, reducing control over critical consensus infrastructure.

Cloud-Edge-IoT: The ecosystem in this technology area comprises a broad range of actors, including: providers (edge providers, cloud providers, data centres, mixed types), vendors (hardware vendors, power & cooling infrastructures, semiconductors and chip manufactures), users (cloud service users (private and public), AI service users (private and public), public administrations (regional, national, EU), regulatory bodies, investors, academic institutions and research centres, and industry associations and business networks. Collectively they contribute to enhance digital transformation, foster innovations and strengthen technological sovereignty in the context of cloud, edge and IoT technologies.

At a more granular level, a group of technology vendors are involved in producing the underlying advanced technologies, such as hardware components, software paradigms, and platforms for the Cloud-Edge-IoT continuum. This includes the development of processors, IoT devices, and software for distributed architectures and solutions. While Europe currently has a substantial dependence on non-EU providers (i.e. hyperscalers) for large-scale cloud infrastructure, there is a focus on developing European capabilities, for instance through the IPCEI-CIS to establish state-of-the-art cloud-edge infrastructure in Europe with significant investment. RISC-V is a key next-generation open-source Instruction Set Architecture offering an alternative for European processors. However, it is observed in the market that US hyperscalers, which have a dominant position in the EU's cloud market, are increasingly integrating AI services into their solutions, offering better functionalities, more user friendliness and overall better services, than EU counterparts. In addition to this, the cloud computing capacity in the EU is foreseen to be insufficient to handle the growing demands of AI workloads (i.e. for AI inference, AI training).

[266] See also: https://blockchain-observatory.ec.europa.eu/publications/eu-blockchain-ecosystem-developments-3_en

Intermediate suppliers and technology integrators (Atos, Dassault Systems, etc) are involved in integrating diverse technologies into products, solutions and platforms for deployment across sectors (manufacturing, healthcare, mobility, etc). This segment focusses, among others, on smart middleware for European cloud federations, sectoral and cross-sectoral open platforms for edge computing and enabling interoperability. The technology transfer intermediaries support the uptake of technologies through research, innovation, and overall by bridging the gap between foundational R&I and market deployment. They focus on roadmaps, standardisation, open-source, among others, helping to enable cross-border use cases. It covers both initiatives (such as AIOTI, NexusForum.EU, European Alliance for Industrial Data, Edge, Cloud, SIMPL, IDSA) and RTOs (e.g., Fraunhofer, IMEC, TNO, Tecnalia, RISE, Polimi). Drawing on the stakeholder feedback, there is still much work to do to ensure common standards and protocols across borders.

Further to this, end-users, which represents the demand-side, deploy and utilise Cloud-Edge-IoT technologies to generate value by adopting technologies (i.e. predictive maintenance, supply chain optimisation, remote monitoring, autonomous mobility), as well as sector-specific uses in manufacturing, healthcare, energy, and smart cities. Several financial actors assume a role in driving the technology adoption. The funding combines public funding programmes and initiatives (such as IPCEI-CIS) and private investments for the development and deployment of Cloud-Edge-IoT technologies.

In **cybersecurity**, the growing integration of connected systems, including cloud, IoT, and operational technology, has significantly expanded the cybersecurity attack surface, making robust protections essential. The European cybersecurity market, valued at approximately €57 bn, relies heavily on public investment (around 53%), unlike the US, where private funding dominates. Regulatory frameworks such as NIS2, the Cyber Resilience Act, and eIDAS 2.0 are shifting cybersecurity from voluntary to mandatory, emphasizing supply chain integrity, product certification, and incident reporting. The EU's technological sovereignty initiatives, including GAIA-X and the Chips Act, encourage adoption of EU-based solutions to reduce dependence on non-EU providers. Market pressures, especially from critical sectors like finance, energy, and defence, drive demand for verifiable cybersecurity standards and zero-trust architectures. Additionally, emerging technologies such as 5G, edge computing, IoT, and smart manufacturing create new infrastructure layers that require scalable, interoperable, and certifiable cybersecurity solutions.

Data analytics: Deployment is hindered by differing national standards and regulations, making cross-border scaling difficult. Lack of a unified "data union" framework has slowed the deployment of Europe-wide solutions. In addition, small businesses and local administrations often lack the capacity or incentives to adopt new data technologies. More specifically, SMEs often do not have in-house data scientists or IT teams to implement new tools. As a result, even when affordable tools exist (e.g., open source or as-a-service), SMEs may not know how to integrate them into their business processes. Also, small manufacturers or service providers might fear disrupting their operations with a new analytics system. The culture of data-driven decision making is not uniformly present. Many SME owners are not aware of what data analytics could do for them, indicating a need for awareness and demonstration. According to some of the consulted experts, procurement rules favour established players, making it hard for start-ups or EU-built tools to gain market traction[267].

In terms of data sharing, there is lack of trust. In operational settings, companies and sectors hesitate to share data (concerns over IP, privacy, liability). Additionally, industry stakeholders are increasingly recognising the strategic value of their data and, as a result, are becoming more reluctant to share it. This growing hesitancy underscores the need for stronger regulatory frameworks and incentive mechanisms to promote **open data practices**. Also, there is a pressing need to advance research in synthetic data generation. Efforts like common European data spaces (health, mobility, etc.) are nascent attempts to enable secure data exchange, but uptake remains slow due to governance and interoperability challenges. Sovereignty considerations pose another ecosystem challenge.. Deployers in Europe rely

[267] https://digital-skills-jobs.europa.eu/en/latest/news/commission-publishes-2024-state-digital-decade-report#:~:text=The%20report%20shows%20that%20significant,digital%20skills%20and%20talent%20development

heavily on foreign cloud and AI platforms due to lack of domestic alternatives. The absence of large European platform players means less capacity to deploy home-grown analytics at scale. There is also a lack of clear and **compelling business cases** for data sharing, which could promote its widespread adoption. Finally, there is a need to ensure interoperability between deployed data spaces. While SIMPL – an open source, smart and secure middleware platform – has been designed to support data access and interoperability among European data spaces, the platform is in the early development stages.

In **HPC**, research institutions account for 63.5% of the combined performance of the Top500 supercomputers, highlighting a clear disparity between usage volume and performance concentration[268]. Numerous public/academic supercomputing centres (e.g. Jülich, CINECA, BSC, CSC, GENCI/TGCC) offer petaflops-scale compute, yet coordination across Member States varies, and national HPC strategies may differ in scope and implementation. Hardware vendors and components (CPUs, GPUs, accelerators) are predominantly sourced from global suppliers (NVIDIA, AMD, Intel, HPE, Lenovo, Fujitsu). Hardware dependence is another critical concern. Of the 37 co-processors used in the Top500 systems, 28 are supplied by Nvidia (USA), with others coming from AMD and Intel—also US-based. Similarly, the 27 generations of processors used include Intel Xeon chips (China/USA), AMD (USA), and a few Japanese and Chinese alternatives, underlining the limited diversity of suppliers and the EU's strategic vulnerability in this area. Notably, all Top500 supercomputers operate on Linux, originally developed in Finland, reinforcing the role of open-source software in HPC. [269] European initiatives (e.g. European Processor Initiative[270]) seek sovereign alternatives, but current capabilities remain limited and behind leading-edge nodes.

The ecosystem comprises many SMEs and research bodies, fostering agility and innovation, but lacks large-scale "champion" companies to drive market adoption and coordinate demand. System integrators largely assemble global-sourced hardware; true EU-based vendors with large market share are scarce. The HPC software stack in Europe is largely open source (Linux, MPI libraries, Slurm, container platforms), with strong academic contributions to portability and emerging architectures. However, there is a lack of EU-based software companies to ensure long-term support, industrial adaptation, and maintenance of research outputs. This can deter industry from adopting HPC solutions, as commercial software markets remain dominated by legacy platforms ill-suited to new architectures. Applications developed in EU-funded R&D often remain at low TRL and require further optimisation, support and updates to be viable for industrial use. Although some cloud HPC offerings exist (AWS, Azure NVIDIA DGX in EU regions), adoption remains lower compared to on-premise systems; or many companies still turn to expensive non-EU cloud services.

Academia and large research institutes are heavy HPC users via PRACE[271] and EuroHPC calls, but industrial users, particularly SMEs, often lack awareness or find infrastructures too complex. Large corporations may partner with national centres, but smaller enterprises need simpler access models, tailored training and supportive pricing strategies. Europe collaborates globally (US, Japan, South Korea), but geopolitical uncertainties and restrictions (e.g. on China cooperation) require hybrid approaches. Financial support for international partnerships is essential but complex to navigate. Heavy reliance on non-EU suppliers for processors, accelerators and software frameworks underlines the need for alternative options. Yet, fully self-sufficient solutions are not immediately viable, so pragmatic, well-funded international collaboration is critical.

Microelectronics: The EU leads or has a strong position in selected segments of the semiconductor value chain (e.g., analog/mixed-signal, power semiconductors, photonics, equipment/materials such as lithography), but depends strongly on non-EU players in key areas (e.g., leading-edge logic, memory, advanced processors, packaging) as highlighted by the interviews. In terms of business models, global buyers demand scale. Fabless design is in the US and manufacturing is in Asia, while the EU is strong in equipment/materials and selected chip niches, supported by world-class R&D centres (e.g., imec, CEA Leti, Fraunhofer)

[268] https://top500.org/statistics/list/
[269] https://top500.org/statistics/list/
[270] https://www.european-processor-initiative.eu/
[271] https://prace-ri.eu/

and strong clusters (Grenoble, Dresden, Leuven). While Europe benefits from a well-coordinated ecosystem, the semiconductor industry serves a global market. It has important gaps across the value chain. Working with non-European partners, such as foundries in Korea, Taiwan, the US or Canada is essential to cover those gaps, yet it can be difficult due to regulatory and IP protection concerns. While European stakeholders align effectively through various EU and national programmes, involving these external partners from non-EU countries in collaborative projects can reportedly prove to be challenging. In addition, stakeholders voiced that Europe's focus remains so far heavily oriented toward R&I, with insufficient attention to deployment and industrialisation. The high investment required for design and scale-up manufacturing prevents some European companies from engaging/innovating in new technologies, leading many to rely on existing solutions, which are often not European. Nonetheless, stakeholders recognise the value in getting industry involved early on in the R&I process to co-shape the research focus and ensure alignment with their needs. In addition, sustainability remains a priority for many actors of the semiconductor industry, with a focus on sourcing raw materials responsibly and exploring greener semiconductor manufacturing processes. The importance of cost competitiveness and reducing Europe's dependency on external providers for critical materials and technologies is also crucial. Maintaining a strong semiconductor value chain in Europe is essential to prevent research investments from being industrialised elsewhere, and several experts point out to Europe's design capabilities that could be strengthened.

Next generation internet and extended reality: Europe's NGI and extended reality ecosystem is also marked by fragmentation across regions, sectors and actors. Although many SMEs and research groups throughout the EU develop innovative ideas, they often lack interoperable platforms, aligned governance or shared infrastructure to scale solutions beyond national borders. This fragmentation makes it difficult for European XR developers, mostly small firms with fewer than 15 employees, to compete against larger non-EU players with established hardware and platform offerings. In NGI, smaller providers of open-source or niche solutions struggle to gain traction when global incumbents (e.g. major browser or communication platforms) dominate the market or acquire promising start-ups.

A key challenge for XR vendors is the near-total reliance on non-European hardware and foundational engines. Very few EU-based AR/VR hardware manufacturers exist (with some notable exceptions like Varjo Technologies), and software developers depend on external 3D engines, cloud infrastructure and device platforms. This dependency undermines digital sovereignty and hampers the ability to optimise end-to-end solutions. In NGI, although much software is open source, many initiatives fail to reach widespread adoption, and public institutions do not subsequently deploy or endorse these home-grown alternatives.

End-user involvement is also limited. XR uptake depends on co-design and participatory processes to tailor immersive experiences to real sector needs (healthcare, education, industry), yet these are not strongly engaged in solution development. Similarly, NGI solutions developed under public funding frequently lack a clear deployment pathway.

Besides, venture capital backing for NGI and XR in Europe lags behind other regions, and EU/national grants tend to favour established institutions over small companies with novel solutions.

In **Photonics**, the European ecosystem is focused on specialised R&D and niche manufacturing, but lacks scale in mass-market segments and presents supply-chain vulnerabilities from offshore manufacturing (including chip fabrication, assembly/packaging in Asia). More specifically, Europe has a strong position in high-precision, B2B segments (e.g. industrial machine vision, scientific instruments), yet remains weak in large-volume consumer markets such as display panels and photovoltaics. Dependencies on raw materials and components (e.g. rare elements sourced from China, specialised tools from US/Japan) reinforce these vulnerabilities.

In addition, European companies often struggle to attract the capital needed to scale innovations and manufacturing capacities. Compared with North America and Asia, this limits progress from pilot or R&D stages into larger production, reinforcing dependency on non-EU investors and partners. Stakeholders highlight the limited private investment in start-ups, and the market fragmentation, which in turn prevent scale-up. In contrast to well-funded international peers, European start-ups often remain small. The photonics landscape comprises numerous SMEs alongside a handful of larger vendors. This fosters innovation but may impede coordination and the investment scale needed for mass-market production or global competitiveness in volume-driven segments. In addition, many vertical industries remain unaware of how photonics technologies can solve their problems, with an important communication and outreach gap between the sector and potential users.

Besides, the EU photonics industry is export-intensive, selling roughly half its output abroad, far above the export rate for EU manufacturing overall (photonics exports equal 51% of production vs. 27% for manufacturing on average)[272]. Though this underlines competitiveness, it also means high exposure to external market fluctuations and partner policies. China's rapid rise in photonics (from ~10% to 32% of the global share[273]) places pressure on EU players.

Quantum: The European ecosystem remains fragmented, marked by parallel developments across Member States, leading to some duplication of capabilities. Many SMEs and research spin-offs work on similar technologies in isolation, underlining the need for stronger EU-wide coordination and consolidation. There is also a dominance of SMEs and absence of flagship players, with most SMEs founded in the last 5–10 years, employing tens to a few hundred staff. While this dynamism drives innovation, the lack of large, anchor firms means that start-ups face challenges in scaling and securing sufficient resources.

In addition, developing quantum hardware entails substantial upfront costs. European public grants (e.g. EIC Accelerator) seed initial development, but private VC rounds in Europe remain modest compared to US levels. Growth projections (from ~€1 bn in 2024 to ~€12 bn by 2032[274]) depend heavily on scaling VC funding. The timeline for achieving practical quantum advantage remains unclear, affecting investor appetite.

End users, typically large corporates, often look abroad to non-EU QaaS providers with more mature offerings, further emphasising the funding disparity. Early adopters are predominantly large firms in automotive, pharmaceuticals, aerospace and finance. While they supply significant VC funding for quantum companies, they frequently turn to non-EU providers (e.g. D-Wave, Google, IonQ) for computing services. This reflects both technology maturity abroad and the attractiveness of QaaS models to multinationals, and highlights the risk that EU-based suppliers may lose strategic engagements.

Besides, quantum computer developers currently encompass multiple roles, from chip fabrication to firmware integration and QaaS delivery, placing heavy demands on single SMEs. Stakeholders note the supply chain must evolve towards specialist roles (e.g. dedicated foundries, firmware integrators, QaaS platforms), similar to classical computing ecosystems (e.g. NVIDIA/Intel in firmware and GPUs). As qubit counts grow, scalable fabrication capacity will be essential, requiring larger facilities and more focused supply-chain segments. Stakeholders also highlight quantum software as a promising European strength, given relatively lower development costs and the critical role of algorithms in realising quantum benefits. Key clusters exist in Germany (quantum computing, sensing, communication; strong Fraunhofer/Max Planck support; major corporate adopters), France (hardware providers Alice & Bob, Pasqal; adopters like Airbus, EDF), Finland & Sweden (superconducting hardware, QKD with Nokia/Ericsson), Spain & Portugal (communication and algorithm development), Benelux and Austria/Czech Republic (computing and software), and Italy (computing via Cineca). While these clusters underpin regional excellence, fragmentation across them points to the need for better inter-cluster collaboration and knowledge sharing.

Robotics: Robotics deployment is uneven across member states, with differing regulations and standards. In general, the regulatory environment in Europe is complex and still evolving – leading to uncertainty in both R&D and deployment. Robotics sits at the intersection of many regulations: machinery safety, product liability, functional safety standards, data protection (GDPR), and now AI-specific rules (the EU AI Act). Navigating multiple regulations across the

272 photonics21.org
273 https://www.marketresearchfuture.com/reports/china-photonic-integrated-circuit-market-46949
274 https://www.fortunebusinessinsights.com/europe-quantum-computing-market-107725

EU is challenging, especially for start-ups and smaller developers who do not have large compliance teams.

There is also insufficient private investment and scale-up capital for robotics firms. In addition, the use of robots among European SMEs is limited, with large firms have higher adoption rates. The barriers for this include high upfront costs and uncertain return on investment that make advanced automation hard to justify for smaller companies. Many SMEs also lack the technical know-how or resources to integrate robots into their processes. Another barrier is affordability and customisation. Off-the-shelf industrial robots or automation solutions may not fit the scale or needs of a small manufacturer or farm, and customising solutions is costly. Integration often requires hiring specialists or consultants, which is a hurdle for SMEs with limited budgets.

Many promising start-ups and established companies were acquired by non-European companies such as the Danish Universal Robots[275]. Therefore, there is a need for public-private investment mechanisms that support deployment at scale. In terms of specific sectors, there is a low uptake of new robotics solutions by industry, especially outside manufacturing. Sectors such as healthcare, agriculture or services lack awareness and processes to integrate robots. As indicated above, the infrastructure for deploying robots is key. However, there is a lack of accessible test environments and pilot facilities for deploying robots in real or simulated operational settings. Regulatory sandboxes and “living labs” are scarce, making it hard to trial robots in public spaces or critical sectors under safe conditions. Also, deployment requires access to high-quality data and compute (edge/cloud), which end-users might lack.

Robotics is a hardware-intensive domain, and Europe’s ecosystem faces challenges in accessing some of the advanced facilities and materials required for building robots. This includes high-end components (motors, sensors, gearboxes, specialised materials), microelectronics (embedded AI chips, power electronics) and the raw materials (e.g., rare earth metals for motors). Europe relies on imports for many advanced sensors and actuators. For example, precision reducers in robot joints, LiDAR scanners, or chips are often sourced from suppliers in Asia or North America. This dependency can become a bottleneck. Supply chain disruptions or export restrictions can delay European robotics projects or make robots more expensive to build and maintain.

For **Technologies for Interoperability and GovTech**, a core challenge is the fragmentation: interoperability efforts and pilots are scattered across Member States, sectors and projects, often lacking common design from the outset. National digital platforms tend to be siloed, with uneven digital maturity between regions. Even where sector-specific data-exchange initiatives exist (e.g. health or transport), they frequently rely on bespoke standards rather than sector-neutral frameworks, hindering scalability. Although legislation (Interoperable Europe Act, European Interoperability Framework, Data Act) provides a foundation, they are still evolving, with countries progressing a different paces in aligning with technical/legal standards. This dispersion weakens network effects, and stakeholders voiced that without stronger coordination or a pan-EU “marketplace” for interoperability components and expertise, knowledge sharing and resource pooling remain suboptimal. For example, the EU higher education sector still requires sustained support to deploy critical digital capacities, despite important progress made in recent years. Through the European Student Card Initiative (ESCI), nearly 4 000 higher education institutions across Europe are now able to exchange student mobility data securely and efficiently, which is a major achievement in creating a common digital infrastructure for student mobility. However, this foundational progress must be seen as a starting point, not a final destination. Building on the ESCI’s interoperable frameworks and tools such as the Erasmus Without Paper network, the European Student Card Router and the European Student Identifier, digital transformation across the sector must be deepened and scaled up. This includes enhancing cybersecurity, improving data governance, ensuring full system interoperability, and fostering digital leadership and capacity within higher education institutions. Another difficulty lies in ecosystem composition: most specialised interoperability start-ups struggle to gain visibility amid dominance by large ICT integrators and incumbent vendors. Smaller firms may lack the resources to participate in large cross-border procurements or to maintain long-term support for standards-based platforms.

[275] https://www.crunchbase.com/organization/universal-robots

Public sector risk aversion and complex procurement procedures favour established integrators over innovative newcomers, slowing the emergence of EU-based champions in interoperability.

This study identified significant challenges in **GovTech**, notably addressing EU agencies and public organisations' data handling capabilities, particularly where siloed data systems remain prevalent. The standardisation landscape presents considerable complexity, with different departments and entities across Europe maintaining unique preferences for data formats. This diversity complicates efforts to achieve machine readability at scale. The challenge is further intensified by the rapidly evolving nature of data structuring standards and approaches in this advancing sector, creating a clear need for coordinated guidance and leadership at the European level. Overall, the deployment of GovTech and interoperability solutions across Europe faces a complex web of regulatory, technical, cultural, and infrastructure challenges that collectively impede the realisation of the EU's digital transformation ambitions.

Dependencies further complicate matters, much of the middleware, cloud platforms and certain protocols originate from non-EU providers, limiting Europe's control over foundational layers. While Europe contributes to standards (ETSI, CEN/CENELEC, W3C, OASIS), implementation often relies on imported technologies and services. Talent pipelines for specialists in data integration, API design or secure cross-border exchange can be uneven, with risk of brain drain to better-funded ecosystems. Finally, the ecosystem's ability to translate R&D into deployable, scalable solutions is hampered by short-term funding cycles and a lack of structured support for start-ups focusing on interoperability. Although EU programmes fund cross-border e-government projects, the path from prototype to sustained service is unclear, and end-user engagement can be limited.

3.8 International collaboration for the deployment of digital technologies

3.8.1 Overview of collaboration dynamics for the deployment of digital technologies

3.8.1.1 International collaboration patterns in EU programmes

At the policy level, the EU fosters a strong regional and bilateral digital cooperation with partners through Ministerial **Trade and Technology Councils** (with the US and India), **Digital Partnerships** (with Japan, South Korea, and Canada), as well as **Digital Dialogues** (Brazil, Mexico, Argentina, Australia and Western Balkans). In addition, it has targeted **Cyber dialogues** (with India, Japan, the South Korea, Brazil, United States, Ukraine and the UK), and digital issues are part of tailor-made Comprehensive and Strategic Partnerships (with Tunisia, Egypt and Jordan). Digital is also a part of the EU's cooperation with Enlargement and Neighbourhood Countries, as well as the New Pact for the Mediterranean (under development). Finally, the EU has specific digital trade agreements with Singapore, with Korea and Japan. Looking forward, the European Commission and the European Parliament have recently launched a joint communication on '**International Digital Strategy for the European Union**'[276], positioning digital as a core element of the EU's external action. The Strategy has the following objectives:

- To boost the EU's tech competitiveness through economic and business cooperation
- To promote a high level of security for the EU and its partners
- To shape global digital governance and standards with a network of partners

The main current programme for digital deployment in the EU, the Digital Europe Programme, is explicitly targeted at EU countries, extended through a targeted association policy. The current status of association to Digital Europe[277] allows for participation of :

- the three EEA/EFTA countries (Norway, Iceland and Liechtenstein),

[276] https://digital-strategy.ec.europa.eu/en/policies/international-digital-strategy
[277] https://ec.europa.eu/info/funding-tenders/opportunities/docs/2021-2027/digital/guidance/list-3rd-country-participation_digital_en.pdf

- Acceding countries, candidate countries and potential candidates (Albania, Bosnia and Herzegovina, Kosovo, Montenegro, North Macedonia, Moldova, Serbia, Türkiye and Ukraine)
- European Neighbourhood Countries (currently no interest)
- Switzerland (signed in November 2025)

EEA/EFTA countries can fully participate in Digital Europe, while Specific Objective 3 (Cybersecurity) and Specific Objective 6 (Chips) are not accessible for the other associated countries. In contrast to Horizon Europe's Association Policy, Digital Europe is not designed to be 'open to the World', and as such no third countries (apart from Associated Countries) receive funding although they can participate in the programme in some instances. For procurement, restrictive and safeguarding measures may also apply to companies from third countries (or owned by third country entities). As such, there is relatively limited international cooperation in the context of Digital Europe.

There is a growing international cooperation on digital in the context of the Global Gateway, including support to connectivity in the Arctic and Latin America and the Caribbean, Global AI for Public Good activity, Cooperation on talent with India for attracting semiconductor talent, cooperation with Japan on hybrid Quantum-HPC algorithms, a EU-LAC community of practice on Cybersecurity, Dialogue with Japan, India and Singapore on interoperability between EU eID Wallet, supporting the Open Internet Stack, etc[278].

International cooperation in other programmes supporting deployment of digital technologies is equally limited. ERDF has some limited cooperation through its INTERREG programmes[279] in which also associated countries and third countries can participate. However, this is limited to a select number of countries (and specific regions within them), such as Amazonia (Suriname, Guyana, Northern Brazil), Next MED (Regions in the Mediterranean), Indian Ocean (e.g. India, Australia, South Africa), Mozambique Channel (Mozambique, Madagascar, Comoros), Caribbean (Mexico, Colombia etc.) and Madeira-Azores (including Ghana, Senegal etc.). These tend to be relatively small funding amounts focus on specific local cooperation challenges and opportunities. In CEF, only Moldova and Ukraine participate[280].

Stakeholders participating in the various consultations of this study called for more collaboration regarding digital technologies with neighbouring countries such as Ukraine . They highlighted opportunities for partnership in areas where Ukraine demonstrates strong capabilities, such as Artificial Intelligence and cybersecurity. International collaboration patterns of EU-based companies

As digital technologies evolve, European firms rely on partnerships both within and beyond their national borders to access markets, raw materials, talent, capital and complementary expertise. International trade in high-tech products has grown steadily over the past decade, boosting competitiveness through both imports and exports as shown by trade statistics[281]. Understanding where and how these collaborations take place sheds light on Europe's position in global value chains, the balance between dependence on non-EU providers and the pursuit of strategic autonomy, and the opportunities for strengthening the EU's innovation ecosystem through international collaboration.

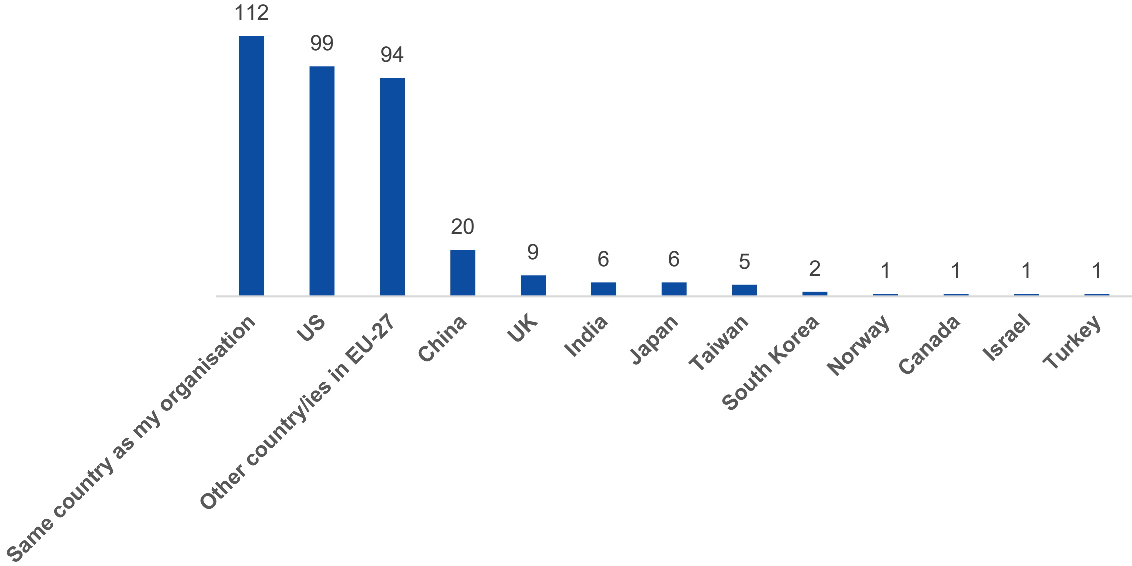
From 2014 to 2024, extra-EU trade in high-tech goods including digital technology-based products expanded by an average of 6.6% per year, with their share of total trade rising from 15.1% to 19.5%[282]. In 2024, China was the EU's leading source of high-tech imports, while the United States the main destination for EU high-tech exports.

European companies that participated in the telephone-based market survey indicated that they source their key supplies and materials related to the critical technology they develop or

[278] Annex 1 to the Joint Communication of the European Parliament and the Council, International Digital Strategy for the European Union.
[279] https://interreg.eu/programmes/
[280] https://ec.europa.eu/info/funding-tenders/opportunities/docs/2021-2027/cef/guidance/list-3rd-country-participation_cef_en.pdf
[281] https://ec.europa.eu/eurostat/statistics-explained/index.php?title=International_trade_and_production_of_high-tech_products
[282] https://ec.europa.eu/eurostat/web/products-eurostat-news/w/ddn-20250924-2

adopted mostly from the same country where they are located followed by the US. Many also source key supplies from other EU countries and from China (see Figure below).

Figure 47 Collaboration in terms of sourcing key supplies, materials and technologies (From which EU and non-EU countries does your company primarily source key supplies, materials, technologies or high-tech solutions/products leveraging digital technology?)



Source: Technopolis Group (2025) based on market CATI survey results, n=380

The main collaboration partners vary by technology area. For **AI, HPC, Blockchain, and Microelectronics, organisations surveyed indicated that they most often collaborate with partners from the United States**. For Robotics, Photonics, and Quantum, the main partners are typically located in other EU-27 countries. For all other technologies, collaborations are primarily domestic, involving partners from the same country as the organisation.

Table 19 Main collaboration partner to source key supplies, materials and technologies

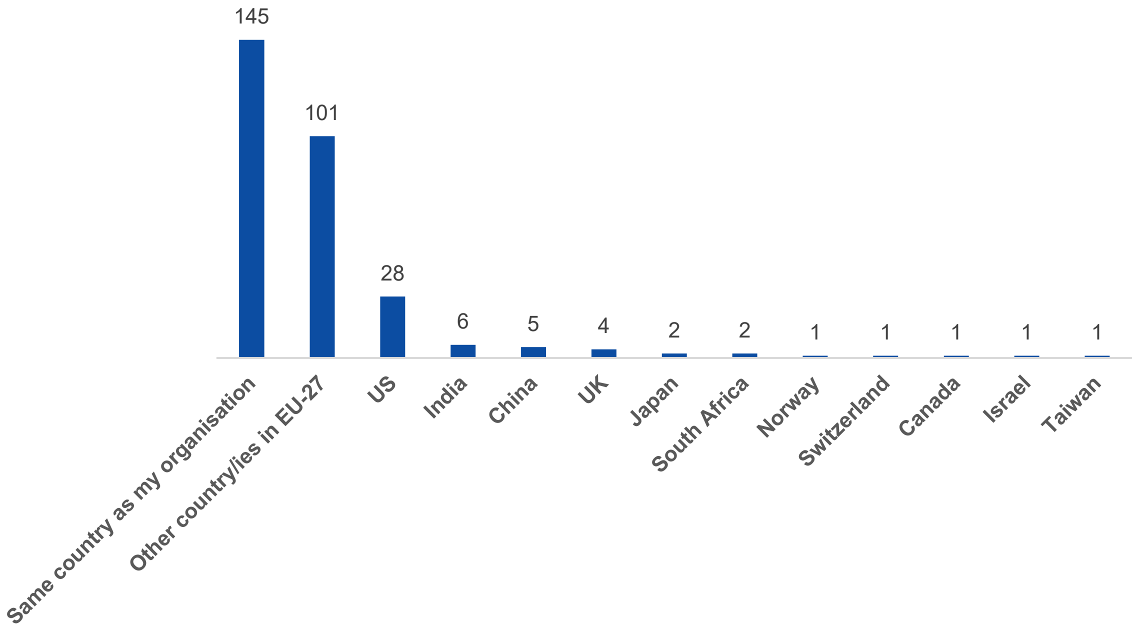
Technology	Main collaboration partner
Advanced digital communications and connectivity	Same country as my organisation
Artificial Intelligence	US
Blockchain and distributed ledgers	US
Cloud, Edge, Internet-of-Things	Same country as my organisation
Cybersecurity technologies and digital identity	Same country as my organisation
Data analytics and data sharing technologies	Same country as my organisation
High-Performance Computing (HPC)	US
Microelectronics	US
Next-generation internet and extended reality	Same country as my organisation
Photonics	Other country/ies in EU-27
Quantum	Other country/ies in EU-27
Robotics	Other country/ies in EU-27

Technology	Main collaboration partner
Technologies for interoperability	Same country as my organisation

Source: Technopolis Group (2025) based on telephone based market survey results, n=380

In terms of sales partners, the surveyed companies primarily sell their products to organisations within their own country, followed by other EU-27 countries. This may indicate that EU tech companies, as well as their products and services, are focused more on domestic and intra-EU markets rather than on international expansion. The US, UK, India, and China also feature as important international markets.

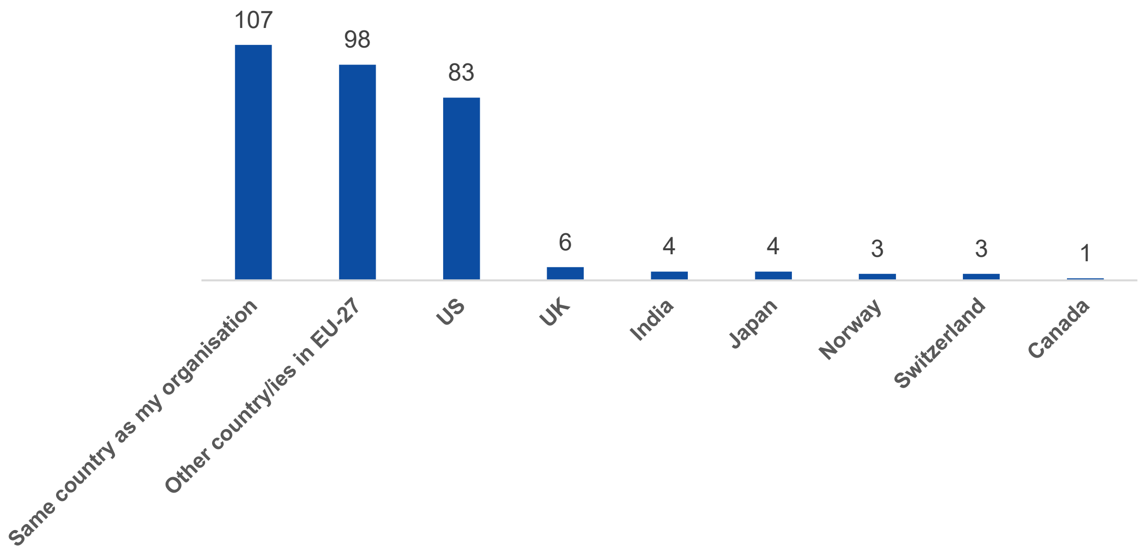
Figure 48 Collaboration in terms of selling partners (To which EU and non-EU countries does your company primarily sell key supplies, materials, technologies, access to infrastructure, or high-tech solutions/products leveraging critical digital technologies?)



Source: Technopolis Group (2025) based on telephone based market survey results, n=380

Interestingly, companies see their main competitors actually coming from other EU countries or the same country within the EU-27 and much less internationally related to research and adoption of critical digital technologies, which indicates that European research is still seen as strong within Europe. Other competitors come from the US, UK, Japan and India as indicated by companies participating in the survey.

Figure 49 Origin of main competitors of companies related to the research & adoption of critical digital technologies (From which EU-27 and non-EU countries do your main competitors come from, related to the research & adoption of critical digital technologies?)



Source: Technopolis Group (2025) based on telephone-based market survey results, n=380

3.8.2 Dependencies and reverse dependencies of the EU related to the deployment of digital technologies

Understanding the EU's dependencies and its emerging reverse dependencies in the deployment of digital technologies is essential for assessing Europe's strategic position in global value chains. These interlinked dependencies shape the EU's ability to develop, adopt, and scale key digital infrastructures and services, while also influencing its resilience, competitiveness, and technological sovereignty. In this section, dependencies have been investigated by expert and stakeholder interviews, complemented by desk research.

Experts reviewed the level of dependencies of the EU on other global actors, as well as reverse dependencies (see Tables below). **The overall perception is that the EU is more dependent on others than vice versa.** This is particularly the case for the value chains for sourcing raw materials as well as advanced digital components, or specific sections of the value chain. All areas note a high dependency in terms of digital infrastructures and software. Dependencies on testing and experimentation facilities, advanced skilled workforces and R&D actors are considered less pronounced. Reverse dependencies are notable in technology excellence, specific sections of value chains, and specific actors in the R&D ecosystem.

Different patterns emerge per technology area. The areas of Data Analytics and Technologies for Interoperability, with Photonics, Quantum, Robotics show a net dependency of more than three types. All other areas have a net dependency rating[283] of more than four, with Advanced Digital Communication and AI being the most dependent areas.

[283] Calculated as Total number of dependencies rated high – total number of reverse dependencies rated high

Table 20 Level of international dependencies of the EU in digital technology deployment

Technology	Sourcing raw/advanced materials	High-tech digital components, products and solutions[284]	Technology excellence	Testing and experimentation facilities for R&D	Digital infrastructures and software[285]	Advanced skilled workforce	Specific actors in the R&D ecosystem	Specific sections of the value chain	Overall Dependency
Advanced Connectivity	High	High	High	Some	High	Some	High	High	6
AI	High	High	High	High	High	Some	High	High	6
Blockchain	Some	High	High	High	High	High	High	High	7
Cloud	High	High	Some	Some	High	Some	Some	High	4
Cybersecurity	High	High	High	Some	High	Some	Some	High	5
Data	High	High	High	Some	High	Some	Some	High	5
HPC	High	High	High	Some	High	Some	Some	High	5
Microelectronics	High	High	High	Some	High	Some	Some	High	5
NGI	High	High	High	Some	High	Some	High	High	6
Photonics	High	High	Some	Some	High	Some	Some	High	4
Quantum	High	High	Some	Some	High	Some	Some	High	4
Robotics	High	High	Some	Some	High	Some	Some	High	4
Technologies for Interoperability	High	High	Some	High	High	Some	Some	Some	4

Source: Technopolis Group (2025) based on the cross-analysis of the Delphi survey and the market CATI survey

Table 21 Level of reverse dependencies of the EU in digital technology deployment

Technology	Sourcing raw/advanced materials	High-tech digital components, products and solutions	Technology excellence	Testing and experimentation facilities for R&D	Digital infrastructures and software	Advanced skilled workforce	Specific actors in the R&D ecosystem	Specific sections of the value chain	Overall Reverse Dependencies
Advanced connectivity	Some	Some	Some	Some	Some	Some	Some	Some	0
AI	Some	Some	Some	Some	Some	Some	Some	Some	0
Blockchain	Some	Some	High	Some	Some	High	High	Some	3
Cloud	Some	Some	Some	Some	Some	Some	Some	Some	0
Cybersecurity	Some	Some	Some	Some	Some	Some	Some	Some	0
Data	Some	High	High	High	High	High	High	Some	6

[284] e.g., processors, memory chips, sensors, radio frequency components, etc.)
[285] (e.g., cloud, connectivity, compute, security, etc.)

Technology	Sourcing raw/advanced materials	High-tech digital components, products and solutions	Technology excellence	Testing and experimentation facilities for R&D	Digital infrastructures and software	Advanced skilled workforce	Specific actors in the R&D ecosystem	Specific sections of the value chain	Overall Reverse Dependencies
HPC	Some	Some	Some	Some	Some	Some	Some	Some	0
Microelectronics	Some	Some	Some	Some	Some	Some	High	High	2
NGI	Some	Some	Some	Some	Some	Some	High	Some	1
Photonics	Some	Some	High	Some	Some	Some	Some	High	2
Quantum	Some	Some	High	Some	Some	Some	Some	Some	1
Robotics	Some	Some	Some	Some	Some	Some	Some	High	1
Technologies for Interoperability	Some	Some	High	Some	Some	Some	High	High	3

Source: Technopolis Group (2025), results from the Delphi survey, market CATI survey and expert interviews

This high-level analysis is corroborated by the specific list of main dependencies across all the technology areas (see Table 21). In terms of raw materials, the EU is highly dependent on rare earth and critical materials (in particular China). In terms of high-tech components, there are dependencies both ways, with both third countries (China, South Korea, Taiwan) and the EU holding critical positions in the microelectronics value chains. Overall, however, experts judge that the dependencies are more numerous and deeper than the reverse dependencies.

Similarly, as part of the dimension of technology excellence, it was mentioned that **Europe relies to a significant extent on non-EU providers and platforms across digital technologies, that create economic vulnerabilities**. For example, many IP in semiconductors manufacturing and design (particularly for high-end chips), cloud technologies (data access, encryption keys), blockchain protocols, or XR platforms are controlled outside the EU. The gaps are the most apparent in digital infrastructures. In the field of cloud, AI and advanced chips manufacturing, the EU is currently almost fully dependent on other countries, with alternatives (e.g. IPCEI CIS) not yet gaining enough traction as highlighted by interviews and the stakeholder consultation. NVIDIA leads the AI chip market with a 92% market share of GPUs (2025)[286] creating critical dependencies.

Regarding reverse dependencies, **currently, the EU excels in AI semiconductor equipment, particularly in advanced lithography and manufacturing tools**, with companies such as ASML leading the world in cutting-edge chip fabrication technology. The EU is considered to have a strong edge globally in safety, ethical technology, as well as in green technologies. EU standards also have an effect beyond the EU. For example, the EU has strong global standards in privacy, data protection, and AI governance (via GDPR, the AI Act, and ePrivacy), which are now further developed towards a business-friendly, flexible regulatory model, prioritising competitiveness, innovation, and regulatory simplification[287].

Experts stressed that non-EU countries are dependent on the EU in several key areas related to Artificial Intelligence, particularly in AI research. Moreover, AI ethics, and regulation also set an example. Europe is a leader in the development of AI frameworks and regulatory standards, including GDPR for data privacy and AI ethical guidelines, which are highly influential globally.

[286] https://carboncredits.com/nvidia-controls-92-of-the-gpu-market-in-2025-and-reveals-next-gen-ai-supercomputer/
[287] https://digital-strategy.ec.europa.eu/en/news/commission-collects-feedback-simplify-rules-data-cybersecurity-and-artificial-intelligence-upcoming

Europe's strong emphasis on sustainability and circular economy models positions it as a key global player, with non-EU countries increasingly turning to European expertise to address challenges in recycling, raw material reuse, and the reduction of electronic waste in AI hardware.

Table 22 Key dependencies and reverse-dependencies of Europe on non-EU countries

Category	Dependencies on other countries	Reverse Dependencies on the EU
Raw Materials	Rare Earth Materials (Chips/AI/HPC) Critical Materials: Lithium, Cobalt (Chips), Helium (Quantum) Purified Materials (Quantum)	
High-tech digital components, products and solutions (e.g., processors, memory chips, sensors, radio frequency components, etc.)	AI Chips / GPUs / FPGAs Processors RF components Sensor Systems (AI), AI-powered sensors Sub-THz operational chips (for 6G) Wafer Starts (5nm/3nm) HBM/NVM Memory Rare-earth/superconducting magnets Security Chips Batteries Lidars Crystals/Fibers for Lasers and Materials for Detectors (Photonics)	ASML Extreme Ultra-Violet photolithography machines High-tech components for chips High-end sensors (STMicroelectronics) High-tech Photonic Components, GaN and SiC semiconductors Advanced Optics Automotive Chips (Infineon) Manufacturing robotics / industrial automation Biorobotics/Exoskeletons High quality chemicals for chips (BASF)
Technology excellence & Intellectual Property	IP blocks/tooling for system-level integration (memory and I/O controllers, EDA tool suites) Interoperability frameworks Software and hardware core IP for 6G Key Blockchain Protocols (Ethereum) Opensource standards (Kubernetes, Spark) XR Headsets and Software	ARM-based and RISC-V R&D on processor architecture and design Neurosymbolic/hybrid AI Ethical/Trusted approaches (AI) Health/Green Tech (AI, Blockchain) Standards for 6G SIM/eSim technology Simulation frameworks for climate/health/material science Modular supercomputing architecture (e.g. MSA)
Technology infrastructures for R&D	Quantum computing	IMEC (Photonics) OTIC Labs for Open-RAN testing CERN
Digital infrastructures and software (e.g., cloud, connectivity, compute, security, etc.)	Advanced Fabrication capacity for <7nm chips Packaging and edge-HPC integration (HPC) Cloud Platforms (Cloud/AI) for storage and computing Cloud Hyperscalers (Cloud/AI) Foundational AI models /LLM Software such as OpenAI and Llama (AI, Cybersecurity)	

Category	Dependencies on other countries	Reverse Dependencies on the EU
	AI Frameworks (TensorFlow, PyTorch) Satellite (and launch capabilities) Orchestration Software (e.g. Kubernetes, OpenStack) for Cloud HPC software stack Threat Intelligence Feeds (Cyber) Smartphone Operating Systems	
Human Capital / skilled	Shortage of young talent – recruitment from outside EU Shortage of skilled staff – recruitment from outside EU	High level of talent in academia/RTOs Brain drain of EU talent to US
Leading Companies	Cloud: Microsoft (Azure), Amazon (AWS), Google Chips: TSMC, Samsung, Nvidia, Intel, SK Hynix Full stack integrators working in verticals Leading Cyber Firms (Palo Alto Networks, CrowdStrike, Fortinet) IBM, HPE (for HPCs) Google and Apple for Smartphone Operating Systems	ASML (Chips) Nokia/Ericsson (5g/6g) Siemens (IoT) SAP (ERP Software) ABB/KUKA/Staubli (Robotics/Industrial Automation)
Leading R&I Investors	Alphabet/Google on cloud, AI, data analytics Meta (AI and NGI XR) Microsoft in cloud, AI etc	Linked to R&I investors in key application sectors such as Volkswagen in automotive, ASML in electronics,
Intermediate Supplier	Strong dependence on processors, GPUs	ASML Extreme Ultra-violet photolithography machines
Final Consumers/Users	Na	Large and developed customer base
Private Investments	FDI US/ China	Investments in key application sectors such as automotive, telecommunications, etc
Risk Capital	US investors investing in advanced digital tech companies in the EU	none
Other	Na	Regulatory Frameworks (AI, Blockchain, GDPR) EUDI/eIDAS Frameworks Compliance markets / Safety Standards (CE/ETSI)

Source: Technopolis Group (2025) based on Delphi survey results

The EU faces key strategic dependencies across several digital technology areas, particularly related to **hardware components, computing infrastructure, digital services and critical raw materials**[288]. Many of these dependencies stem from the dominance of the US in services and software, and reliance on global supply chains especially in Asia for hardware inputs.

First, **the lack of domestic capabilities in microelectronics poses a significant strategic dependency risk for the EU**, affecting many other digital sectors. Despite ambitious policy initiatives like the **European Chips Act**, the Europe Union remains a **net importer of**

[288] See also European Commission. (2023). Report on the state of the Digital Decade 2023 (COM(2023) 570 final). Publications Office of the European Union.

semiconductors and key inputs, with estimates suggesting that EU production currently represents significantly less than 20% of global semiconductor output and could reach only around 8% by 2030 without major capacity expansion, highlighting persistent gaps in domestic fabrication and advanced manufacturing capabilities[289].

At the same time, critical raw materials essential for chips, batteries, and other digital technologies, such as lithium, cobalt, nickel, and rare earth elements, are overwhelmingly sourced outside the EU, with China providing all of the EU's supply of heavy rare earths and major shares of other critical metals, and the EU currently supplying only around 1% or less of some of these critical materials domestically[290].

A dominant concern is the **EU's overreliance on non-European chips and accelerators** that underpin modern data centres and high performance computing. The risk is amplified by substantial supplier concentration in GPUs and AI accelerators. Analyst tracking of add-in board/discrete GPU shipments shows NVIDIA at 92% share in Q3 2025, with AMD around 7% and Intel 1% (figures vary by quarter but consistently show overwhelming NVIDIA dominance)[291]. Market research has also described NVIDIA holding around 80% revenue share in AI-focused data-centre chips/accelerators.[292] Even where estimates differ by methodology (units vs revenue; "AI chips" definitions; inclusion/exclusion of CPUs), the consistent conclusion is that Europe's AI compute capacity is largely mediated through a single non-EU vendor stack. Discrete GPUs are not only consumer graphics components; they are the accelerators for AI training/inference, simulation, cryptography workloads, and advanced analytics. When one supplier controls the vast majority of this market, downstream ecosystems (cloud, research, defence suppliers, finance) become constrained by that supplier's roadmap, availability, and pricing power.

This dependency not only constrains long-term technological sovereignty but also limits innovation in other sectors such as defence or finance. When the dominant supplier, in this case largely US-based, is subject to export controls, European users feel the effects. For example, in October 2022 and subsequent 2023–2024 revisions, the US government imposed restrictions limiting the export of advanced AI accelerators and training chips (e.g., H100) to certain customers/regions, including 17 EU Member States[293]. As a consequence, some European companies and governments had to request special licenses to import the very chips they needed for data centres, advanced research, and defence applications[294].

Several publicly reported European defence R&D or secure computing efforts have explicitly sourced NVIDIA accelerators because alternatives were unavailable at the required performance level. When it comes to High Performance Computing, multiple EU-funded supercomputers, including Leonardo, MareNostrum 5, MeluXina, Karolina, Vega, and Deucalion, are built around NVIDIA GPUs (A100, H100, GH200)[295]. These systems are accessible to European researchers and industry clients for HPC and AI workload. As also flagged by CEPS, AI factories planned across the EU will be "entirely reliant on Nvidia" processors due to lack of alternatives and that this reliance may create rigidities and strategic risk for the EU's goal of technological sovereignty[296].

---

[289] European Court of Auditor (2025). Special report 12/2025: The EU's strategy for microchips-reasonable progress in its implementation but the Chips Act is very unlikely to be sufficient to reach the overly ambitious Digital Decade target. Available at: https://www.eca.europa.eu/ECAPublications/SR-2025-12/SR-2025-12_EN.pdf

[290] European Commission Joint Research Centre. (2020). Critical raw materials for strategic technologies and sectors in the EU: A foresight study (ISBN 978-92-76-15336-8; Catalogue No. ET-04-20-034-EN-N). Publications Office of the European Union. https://doi.org/10.2873/58081

[291] Carbon Credit (2026). Nvidia controls 925 of the GPOU market in 2025.Available at: https://carboncredits.com/nvidia-controls-92-of-the-gpu-market-in-2025-and-reveals-next-gen-ai-supercomputer/

[292] JPR (2025). Global add-in board market. Available at: https://www.jonpeddie.com/news/global-add-in-board-market-8-8-billion-in-q325-with-a-cagr-of-0-7-to-2029/

[293] Science Business (2025). European AI ecosystem worried about new US export restriction. Available at: https://sciencebusiness.net/news/ai/european-ai-ecosystem-worried-about-new-us-export-restrictions?

[294] European Parliament (2025). US export controls of AI chips: debate with the Commission. Available at: https://www.europarl.europa.eu/news/en/agenda/plenary-news/2025-02-10/6/us-export-controls-of-ai-chips-debate-with-the-commission

[295] More information available at: https://www.eurohpc-ju.europa.eu/supercomputers/our-supercomputers_en

[296] CEPS (2025). EU plans for AI (giga)factories:sanctuaries of innovation, or cathedrals in the desert Available at: https://www.ceps.eu/ceps-publications/eu-plans-for-ai-gigafactories-sanctuaries-of-innovation-or-cathedrals-in-the-desert/

Other examples include government-funded aerospace and defence labs using NVIDIA GPUs for secure simulation and cryptography workloads where domestic silicon was not yet mature. In some cases, special export licenses were required, introducing program delays.

Despite strong revenue growth among European cloud providers, the EU cloud market remains overwhelmingly dependent on US hyperscalers, such as Amazon Web Services, Microsoft Azure, and Google Cloud[297]. While European providers more than tripled their revenues between 2017 and 2024, the overall European cloud market expanded six-fold to €61 billion in 2024, meaning their collective market share fell from 29% in 2017 to around 15% and has since stagnated. In contrast, Amazon, Microsoft and Google captured the bulk of this growth and now account for roughly 70% of the European cloud market[298]. No European provider exceeds a 2% market share, underscoring the EU's structural reliance on U.S. cloud infrastructure for digital services and data-intensive workloads. Recent data confirm rising concentration in the global cloud infrastructure market. Amazon, Microsoft and Google accounted worldwide for 63% of enterprise cloud infrastructure spending in 2025[299]. Overall, market growth has reinforced dominance at the top rather than diversified global cloud supply.

EU communication equipment, such as radio base stations and switching centres used in 5G and next-generation connectivity, is powered by components (including secure processors and critical semiconductors) that are mainly designed and made outside the EU[300]. When it comes to computing power and data hosting capacities, the EU relies heavily on the United States, with its hyperscalers dominating 85% of the market.[301] In addition, although the EU operates its own testing and experimentation facilities, it remains **dependent on AI models developed abroad**. This vulnerability is most pronounced in the case of foundation models,[302] with 73% coming from the United States and 15% from China.[303] Consequently, the EU occupies a delicate position in the global AI ecosystem, balancing its own capabilities with significant reliance on technologies and resources from abroad, prompting some experts to stress the need to closely track its technological sovereignty in AI.[304] Additionally, the **memory hardware essential for AI data processing is also concentrated**, with SK Hynix, Samsung, and Micron dominating both high-bandwidth memory (HBM) and standard DRAM chips, making them critical suppliers in the AI supply chain[305]. **The generative AI market is largely led by US companies,** with major players including Meta, Anthropic, and xAI[306], while OpenAI stands out as the dominant frontrunner. Companies operating in this layer have built competitive advantage by developing models with high performance, versatility, and adoption, often leveraging scalable cloud compute and advanced hardware. In 2025, **US organisations remained the global leader in AI model development[307], with China rapidly closing the quality gap and Europe still trailing behind in both volume and performance**. While the US continues to lead in volume, Chinese models have quickly caught up in quality, with performance gaps on key benchmarks like MMLU and HumanEval narrowing from double digits in 2023 to almost equal in 2024. European companies often focus on fine-tuning and deploying external models rather than building foundational ones, reinforcing a reliance on foreign technological cores despite strong domestic scientific capacity[308].

---

297 Institute Jacques Delors (2025). Over-dependencies in services: A blind spot in the EU economic security strategy? in "Turning the Tide: Towards Open Economic Security – Ten Reflections", Brussels Economic Security Forum, EPC, 5 June 2025.

298 Synergy Research Group (2025). European cloud providers's local market shares now holds steady at 15%. Available at: https://www.srgresearch.com/articles/european-cloud-providers-local-market-share-now-holds-steady-at-15

299 Synergy Research Group (2025). Cloud Market Share Trends - Big Three Together Hold 63% while Oracle and the Neoclouds Inch Higher. Available at: https://www.srgresearch.com/articles/cloud-market-share-trends-big-three-together-hold-63-while-oracle-and-the-neoclouds-inch-higher

300 European Commission. (2021). Strategic dependencies and capacities (SWD(2021) 352 final). Accompanying the Communication Updating the 2020 new industrial strategy: Building a stronger Single Market for Europe's recovery (COM(2021) 350 final)

301 https://www.mckinsey.com/capabilities/quantumblack/our-insights/time-to-place-our-bets-europes-ai-opportunity

302 Experts' consultation (workshops)

303 https://carnegieendowment.org/research/2025/05/the-eus-ai-power-play-between-deregulation-and-innovation?lang=en

304 Experts' consultation (interviews)

305 https://introl.com/blog/ai-memory-supercycle-hbm-2026

306 https://x.ai/

307 Stanford University (2025). The 2025 AI Index Report https://hai.stanford.edu/ai-index/2025-ai-index-report

308 Based on expert interviews

For NGI and XR applications, while open platforms and ecosystems such as the European based Godot exist, they currently lack the popularity and market adoption of **dominant platforms like Unity and Unreal Engine**. As a result, developer communities tend to gravitate toward these established platforms, where a wealth of resources, tutorials, and support already exists. This creates a dependency on popular platforms, because the availability of existing assets, 3D models, libraries, plugins, and tools is critical for rapid development and prototyping. However, transferring these assets across platforms is technically challenging, which limits interoperability and makes it harder for alternative or open-source ecosystems to scale.

3.8.3 Mitigation strategies to address resilience and global positioning challenges

For raw materials, potential mitigation strategies include the pursuit of a diverse set of strategic trade agreements with key global partners, promoting exploration and exploitation of critical materials in the EU (e.g. recent Lithium discovery in Sweden, Helium in France), a well as continued investment in recovery of materials building on leading expertise in the EU.

In case of high-tech digital components, the development of EU micro-electronic fabrication capabilities will also create spill-over effects for upstream suppliers. Maintaining a unique position in some high-tech components will help the pursuit of trade agreements with strategic partners. However, full autonomy in all components would be highly costly.

In terms of technology excellence, the critical challenge is to ensure better translation of excellence in science and R&D into strategic IP and leadership in development and deployment of standards and protocols. This could be mitigated by better upscaling and coordination of existing excellence.

In terms of technology and digital infrastructures, the main mitigation measures would be to heavily invest in large-scale infrastructure in HPC/AI and Cloud, as well as the promotion of strong EU private actors in these spaces.

In terms of human capital, both promotion of better working conditions for technical talent (to reduce brain drain and improve attraction of talent) as well increasing the talent pool (through traditional education as well as reskilling and upskilling) could be mitigating measures.

3.9 Other framework conditions relevant for the deployment of digital technologies

The deployment of digital technologies depends on a set of enabling framework conditions that determine the speed and scale of adoption. These can include the availability of and access to digital infrastructure, as well as favourable demand-side conditions that incentivise uptake by businesses and public administrations. The cost of adoption, access to finance, related costs, and the ability to manage regulatory, and operational risks can all play a decisive role. As found in a recent research[309], firms' adoption of advanced digital technologies is shaped by a combination of technological, organisational and environmental factors: they are more likely to adopt when technologies are perceived as useful, reliable, compatible with existing systems and aligned with business strategy, and when firms have sufficient skills, leadership support and financial resources to manage risks and high upfront costs. External conditions, such as clear regulation and standards, competitive pressure, customer demand, access to infrastructure (e.g. digital connectivity), trusted networks and government support, also play a critical role, particularly given the greater uncertainty, complexity and investment intensity associated with cutting-edge technologies.

In this study, the most relevant framework conditions supporting deployment were explored via the a stakeholder survey. The Figure below presents the feedback from the stakeholder survey as regards the kinds of framework conditions that need to improve to foster deployment.

The most widely reported challenge relates to the speed of the technology adoption process. 77% of survey respondents (to a 'very large extent' or 'to a large extent') consider the process of market uptake to be very much slower than it ought to be. The second most important condition is seen in the independency from non-European technologies,

[309] Jibril, H., & Roper, S. (2025). Factors influencing firms' adoption of advanced technologies: A rapid evidence review. Innovation and Research Caucus. Updated 22 August 2025.

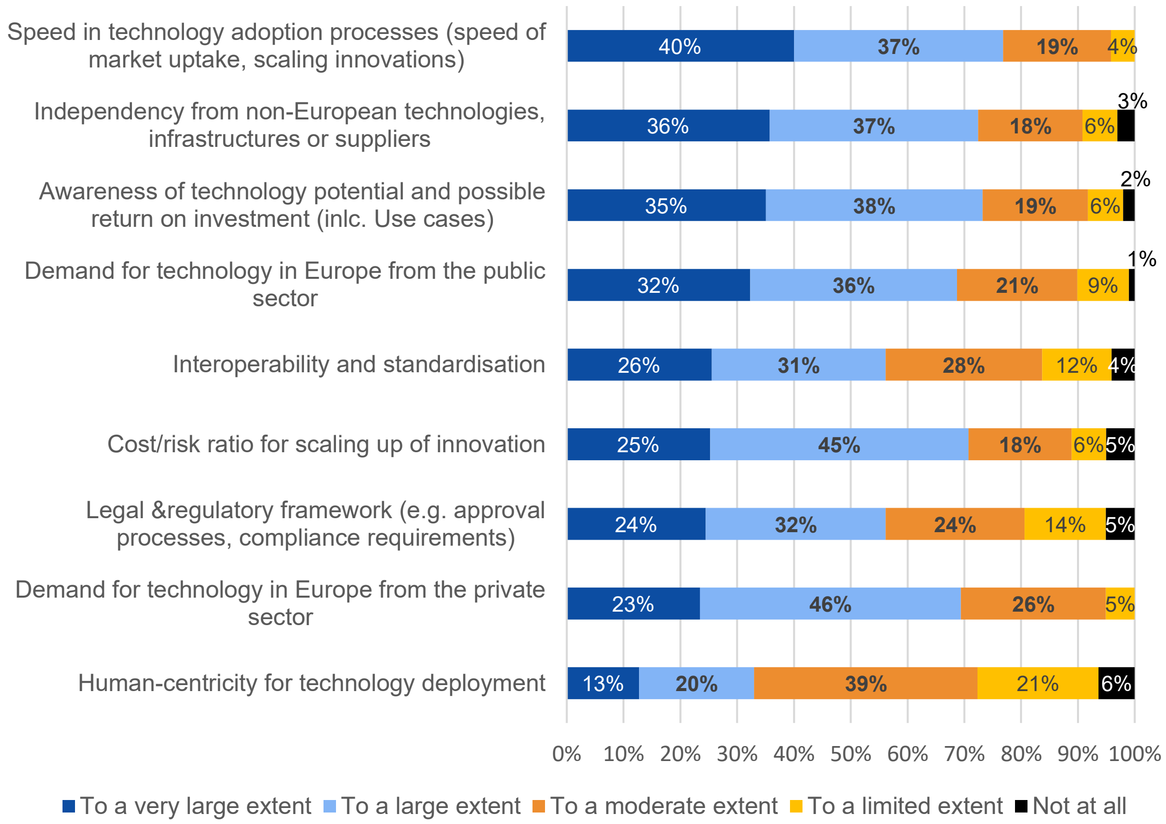
infrastructures and suppliers. The cost–risk ratio is less widely viewed as a decisive barrier, although it remains one of two closely related factors for which 45% of respondents agree to a 'large extent' that a barrier exists. Another factor is private-sector demand, as companies typically require a favourable cost–risk assessment before committing to investment. In parallel, disinformation and information integrity are emerging as critical components of digital resilience, particularly with the rise of AI-generated content, adding a new layer of complexity to ensuring trust in digital systems.

On the role of the EU regulatory framework, which is considerably more prominent in the EU than in other parts of the world, stakeholders display a duality of opinions. On the one hand, changes and additions to regulatory parameters, for instance for AI-powered medical devices, present considerable compliance challenges for European companies (e.g., those seeking certification in both EU and US markets). On the other hand, while creating such hurdles, the EU's stringent regulatory environment also offers **protective advantages, safeguarding European markets from external competition and ensuring a level playing field in the Single Market**. For example, Europe's strength in data privacy, security, and ethical AI is recognised as providing competitive leverage, particularly through the development of **specialised AI solutions for high-risk sectors**.

The framework conditions which respondents see few or no issues ('to a limited extent' or 'not at all') were human centricity (27%) and legal frameworks (19%).

Overall, the expert interviews also indicate that in order to establish a rapid adoption and scaling ecosystem, one needs to bring together demand-side measures (such as innovation-driven public procurement and lead market initiatives), awareness raising measures and access to testing and validation facilities (including regulatory and technical sandboxes).

Figure 50 Framework conditions for the deployment of digital technologies [What are the most important framework conditions relevant for the deployment of digital technologies?]



Source: Technopolis Group (2025) based on Delphi survey results (aggregated data across technology areas)

3.10 Cross-cutting considerations

Human centricity places human needs, characteristics, motivation and experiences at the centre of design, development, and implementation of technological solutions and organisational practices that enhance human well-being, capabilities, skills, and working, as defined by the recent ERA Industrial Technologies Roadmap on Human-Centric Research and Innovation[310]. Central to the Industry 5.0 vision[311], it reflects the recognition that digital transformation succeeds only when people are empowered, included, and supported throughout. The stakeholder survey conducted in the framework of this study found that **77% of the respondents think it is 'to a very large extent' or 'to a large extent' important to take into account human centricity** (user-focus, targeting societal needs) for the design and implementation of a future EU programme on the deployment/adoption of digital technologies. In line with this, the EU has already set the objective that technology should work for the people and digital economies should be fair and inclusive[312].

In Industry 5.0, humans take on an active and integrated role within cyber-physical systems[313]. Human-centric design, embedding human cognition, skills, and adaptability into automation and technologies is fundamental to achieving seamless and symbiotic collaboration between people and machines. Close human–robot cooperation and the sustainable, intelligent use of resources through advanced digital and cognitive technologies are essential. By leveraging AI and cognitive systems, these environments enable empathetic, adaptive machines that assist human decision-making from real-time operations to long-term strategy. A key challenge remains ensuring effective human integration into industrial cyber-physical systems through user-centred design.

Despite its importance, implementation of human-centric digital technology faces challenges including high costs, need for customisation, lack of standardised frameworks, cultural resistance, and shortages in leadership and multidisciplinary expertise[314]. Addressing these barriers through skills development, inclusive leadership, and structural support will be essential to ensure Europe remains a competitive and values-driven leader in the next wave of digital transformation.

Trust in technology is a key feature of human-centricity and has become a foundational requirement for successful deployment. In Europe, the emphasis on human-centric and responsible technology reflects an understanding that trust is not a by-product, but a design principle. Citizens and businesses are more likely to adopt digital tools from cloud services to AI and digital identity solutions when they believe they are accountable, fair, secure, and beneficial. According to a recent survey of Pew Research Centre[315], public trust in AI regulation differs sharply across global powers. The EU enjoys the highest confidence: across 25 countries, a median of 53% trust the EU to regulate AI effectively, compared to 34% who do not. Trust is even higher within the EU itself, where a median of 54% of respondents express confidence, versus 48% in non-EU countries. In contrast, trust in the United States is lower and more divided: a median of 37% trust the US to regulate AI, while 48% do not. Confidence in China is lowest of all, with only 27% expressing trust and 60% expressing distrust in its ability to oversee AI responsibly.

Nonetheless, trust is still a challenge. For example, low trust in data sharing reflects business concerns about data protection, intellectual property, liability and competitive risks. As a result, many firms hesitate to share data, limiting collaboration and slowing the uptake of data-driven innovation as found by expert interviews.

---

[310] ERA industrial technologies roadmap on human-centric research and innovation for the manufacturing sector, Publications Office of the European Union, 2024, https://data.europa.eu/doi/10.2777/0266
[311] https://research-and-innovation.ec.europa.eu/knowledge-publications-tools-and-data/publications/all-publications/industry-50-transformative-vision-europe_en
[312] https://international-partnerships.ec.europa.eu/policies/digital-and-infrastructure/responsible-digitalisation_en
[313] Piardi, L., Leitão, P., Queiroz, J., & Pontes, J. (2024). Role of digital technologies to enhance the human integration in industrial cyber–physical systems. Annual Reviews in Control, 57, 100934. https://doi.org/10.1016/j.arcontrol.2024.100934
[314] See also: https://www.forbes.com/sites/karlmoore/2025/05/09/the-human-centric-approach-to-digital-transformation/
[315] Jacob Poushter, Moira Fagan and Manolo Corichi (2025). Trust in the EU, U.S. and China to regulate use of AI, available at https://www.pewresearch.org/2025/10/15/trust-in-the-eu-u-s-and-china-to-regulate-use-of-ai/?gad_source=1&gad_campaignid=23163891359&gbraid=0AAAAA_c1WRnwLF3oRPcdz_MH1BMbeNlIY&gclid=Cj0KCQjwgpzIBhCOARIsABZm7vFq0u28TFuC-4JWHhTqcmd9dOoEXCCMmFag4OOFkGxr3fNppSyecvcaAvktEALw_wcB

Techno-optimism should be also balanced with environmental considerations, which are essential to ensure that human-centric technological development remains sustainable and responsible. Digital technologies come with a significant environmental burden. The environmental costs of generative AI stem from its entire computing lifecycle from material extraction and chip fabrication to data centre operation and end-of-life disposal. These processes consume significant energy, water, and raw materials, producing emissions that harm ecosystems and human health[316]. The training and operation of large-scale generative AI models such as GPT-4 requires vast amounts of electricity, leading to high carbon emissions and pressure on power grids. Moreover, data centres, which host and run these models consume substantial energy and water for cooling[317]. Water use for thermal management threatens local ecosystems, while the manufacturing and transportation of HPC hardware add further indirect environmental impacts. The frequent retraining and upgrading of ever-larger models exacerbate waste and energy intensity[318]. Sustainability assessments must extend beyond carbon metrics to include broader indicators such as resource depletion and toxicity. Additionally, indirect or system-level effects such as reinforcing energy-intensive technologies, increasing consumption, or spreading misinformation add to the long-term sustainability costs of Gen-AI, underscoring the need for holistic, multi-impact evaluation frameworks[319]. Besides AI, HPC, quantum, cloud and edge infrastructures are also extensively energy-intensive, hence the focus on sustainability becomes both an imperative and an opportunity. The growing energy demand places increasing pressure on power grids and raises concerns about environmental impact. Consequently, the focus on sustainability becomes not only an imperative for reducing carbon footprints and ensuring long-term operational viability, but also an opportunity to drive innovation in energy-efficient architectures, renewable-powered data centres, advanced cooling solutions, and more sustainable deployment models.

Energy optimisation in data centres and high-performance computing facilities is a central pillar of sustainable digital transformation. Optimising energy consumption in HPC, Cloud and data centres involves integrating renewable energy sources, exploiting natural cooling conditions, and developing smarter workload management systems that balance computational performance with energy use[320]. Moreover, fostering collaboration between service providers and users enables dynamic optimisation, increasing awareness of workload impacts and supporting transparent energy accounting. Extending hardware lifetimes, adopting green procurement, and embedding lifecycle and carbon footprint analyses in infrastructure planning are also critical to reducing embodied emissions and electronic waste. This way, energy optimisation becomes not only a technical challenge but a core dimension of human-centric, environmentally responsible digital innovation.

Cross-technology practices can also offer a solution. For example, energy efficiency in computing can be greatly enhanced through photonics, which replaces traditional electron-based processing with light-based data transmission. By using photons instead of electrons, photonic systems significantly reduce heat generation and power consumption while enabling ultra-fast, high-bandwidth data transfer[321]. This shift not only overcomes the physical and thermal limits of conventional electronics but also supports sustainable, scalable, and real-time data processing. As a result, photonics offers a transformative pathway toward greener, faster, and more efficient computing infrastructures for AI, data centres, and cloud systems. Another example in the case of Artificial Intelligence, spintronic technologies respond to the new need for real-time, energy-efficient AI at the edge[322]. Spintronics enables ultra-low-power, scalable, and high-performance AI inference through in-memory processing and non-volatile, quantum-

[316] Bashir, Noman, Priya Donti, James Cuff, Sydney Sroka, Marija Ilic, Vivienne Sze, Christina Delimitrou, and Elsa Olivetti. (2024). The Climate and Sustainability Implications of Generative AI. An MIT Exploration of Generative AI, March. https://doi.org/10.21428/e4baedd9.9070dfe7
[317] https://news.mit.edu/2025/explained-generative-ai-environmental-impact-0117
[318] https://news.mit.edu/2025/explained-generative-ai-environmental-impact-0117
[319] Bashir, Noman,et al. (2024). The Climate and Sustainability Implications of Generative AI.
[320] Silva, C. A., Vilaça, R., Pereira, A., & Bessa, R. J. (2024). A review on the decarbonization of high-performance computing centers. Renewable and Sustainable Energy Reviews, 189(Part B), 114019. https://doi.org/10.1016/j.rser.2023.114019
[321] https://news.mit.edu/2024/photonic-processor-could-enable-ultrafast-ai-computations-1202
[322] EpoSS. (2025). Artificial Intelligence at the edge: A joint European roadmap for Edge AI. European Technology Platform on Smart Systems Integration (EpoSS). https://www.smart-systems-integration.org/publications/edge-ai-roadmap

level efficiency, addressing key Edge AI challenges such as latency, energy use, and device miniaturisation.

3.11 EU's strength, weaknesses and opportunities for the deployment of digital technologies

As digital technologies are becoming even more a central pillar of the EU's competitiveness, innovation, and societal development, this study's research offers a reflection on the EU's notable strengths but also weaknesses as evidenced by statistical data and experienced by stakeholders, companies, research organisation and the public sector.

The EU is seen strong in terms of several aspects that are applicable across all technologies:

- A **trusted regulatory framework and strong data protection standards** make the EU globally recognised for promoting interoperability and safety. As outlined in the policy context chapter, initiatives such as the Digital Single Market and the EU's commitment to ethical standards in Artificial Intelligence and cybersecurity further strengthen its role in shaping global digital norms.
- **Open source** is seen as a strength and a potential strategy to close gaps where Europe lags behind global competitors, particularly the US and China. In areas like software, open source could provide a more agile and collaborative route to innovation.
- **Advanced research and innovation networks** in the EU are seen as a general strengths with a well-developed ecosystem of universities, research institutions, and innovation hubs that foster collaboration between academia, industry, and the public sector. These networks support cutting-edge research, accelerate the development of emerging technologies, and enable knowledge sharing across borders, driving scientific excellence and technological leadership.
- **Green digital solutions are seen an opportunity** to pursue since the EU is considered as a global leader in promoting environmentally sustainable technologies, integrating digital innovation with climate goals.

The stakeholder consultation identified a **number of key EU strengths but also pointed out weaknesses per technology area** which are described in detail in the technology annexes and are summarised in the Table below. **Cross-technology opportunities are key** to seize and invest in across several technology areas as presented below. The summary is based on desk research, the discussions at two Delphi workshops and the validation workshop organised on 9th July 2025 in Brussels with the involvement of 180 experts and technology stakeholders.

Table 23 EU's strengths to seize and critical weaknesses to be addressed for the successful deployment of critical digital technologies

Technology Area	EU strengths and opportunities	EU critical weaknesses and threats to address
Advanced digital communication & connectivity	• Strong role in **next-generation networks** • Critical communications expertise: **leadership in systems for rail transport, emergency response, and security services** • **Testing and certification capacity**: home to respected telecom laboratories and certification bodies. • **Potential in green digital technologies**: strong position to develop sustainable infrastructure. • Values-based approach: commitment to privacy, openness, and interoperability as a global differentiator. *Cross-technology areas:*	• Technology developed in Europe and acquired by non-EU entities • Commercialising 6G • Open RAN, which relies heavily on commercial off-the-shelf (COTS) hardware, face challenges in scaling to large-scale, carrier-grade deployment

Technology Area	EU strengths and opportunities	EU critical weaknesses and threats to address
	Leadership in **photonic components**, GaN/SiC semiconductors, power-efficient RF front-end modules, and digital twinning for 6G.	
Artificial Intelligence	• **Trustworthy AI technologies** and tools (can generate a market in itself) • Deployment of **foundation models** • **AI agents**, multi-agent systems • **Explainable** AI • **Frugal AI and Green AI** movement and push for more efficient AI in relation to energy-and water usage *Cross-technology areas:* • Edge AI • Quantum machine learning	• Global position of key players might change very fast (apart from US and LLMs) • Lack of groups developing frontier AI models in EU • EU is not investing in breakthrough technologies rather following existing trends without too much strategic reflection • Lack of service-oriented 'killer app' mindset - too little front-end and user + market sensitivity • Trustworthy AI costs and impact on performance • Lack of middleware platforms and scalers for data and AI and lack of centralised efforts to support and connect decentralised alternatives
Blockchain	• **Decentralised identity technologies** • **Strong position in blockchain for IP protection thanks to robust legal framework (**blockchain enhances IP protection and management, enables automated rights enforcement **)** • Supply chain: **real-time tracking of goods**, verification of provenance, and reduction of fraud • **Zero-Knowledge Proofs** (ZKPs) for privacy-preserving disclosures, in particular EU strengths in digital identity and privacy-first applications (however it has to be also noted that commercial leadership and product-level innovation would require much more effort in order to unlock potential)	• **Ecosystem dominated by cryptocurrency** use cases – making it more difficult for other sectors to gain attention, investment and regulatory clarity • **Decreased interest in blockchain**: little or no demonstrations of blockchain projects, limited awareness of blockchain applications • **Weak scalability**, especially in public blockchain • While regulations is seen as a strength, inconsistent implementation across Member States and evolving and complex requirements for compliance are considered as a weakness.
Cloud-edge-IoT	• **Energy-efficient computing continuum**, to optimise the entire IT provisioning stack. • **Integration of RISC-V Hardware** in the Cloud-Edge providing open, energy-efficient processors with the potential of reducing Europe's dependence on hardware providers • **Advance of photonics** towards energy efficient computing that can power the massive data demands of cloud infrastructure • Seamless secure computing continuum and confidential computing • Computing continuum enabled by interoperability between cloud-edge-IoT, and HPC, within AI factories. Interoperability with HPC/AI factories	• Lack of bringing EU cloud alternatives to same level as non-EU ones – again 'as-a-service-mindset is missing

Technology Area	EU strengths and opportunities	EU critical weaknesses and threats to address
Cybersecurity & digital identity technologies	• Cybersecurity is recognised as the paramount importance of all tech areas. • **The EU sets global standards** on data protection (GDPR), trust services (eIDAS), and network security (NIS2). • EU hosts world-class research institutions in **cryptography, privacy, and cyber resilience** (e.g., Politecnico di Torino, KU Leuven). • Growing **ecosystem of cybersecurity SMEs and start-ups**, especially in France, Germany, the Netherlands, and Romania. • Increasing integration of cybersecurity considerations in EU-level programmes. • The EU boasts technological strengths in **cryptography, confidential computing, and has key opportunities in developing the European Digital Identity Wallet**. *Cross-technology:* The maturing RISC-V chip ecosystem with links to cybersecurity.	• The EU has several weaknesses such as the varying cybersecurity maturity and implementation across Member States. • Critical reliance on non-EU technology providers (cloud, end-point protection, threat detection software) and dependence on non-EU IP. • Academic talent is solid, but hands-on cybersecurity skills remain scarce • Short-term funding periods when cyber technologies need at least 10 years • US & China dominate large rollouts
Data analytics and data sharing	• **Datasets of quality and relevance for specific sectors** (yet untouched) such as cancer image dataset initiative, data for space observation etc. • Europe is **generating huge amounts of data** given its population and industrial fabric • **Data spaces** with high opportunities • EU MS are trusted for **data hosting**	• **Data governance** is not optimal • Datasets are still **not sufficiently prepared to plug into AI** models • Interconnections between **dataspaces and AI platforms** and tools to allow the creation of AI-data value ecosystems • **Access to real-time data** remains limited, especially for SMEs and the public sector • **Lack of must-have use cases for data** sharing and that shows the real benefit
HPC	• **Increasing integration with AI, quantum, and simulation environments**, positioning HPC as an enabling layer. • **Strong public investment in next generation exascale systems**.	• User-friendliness and software stack (e.g., middleware, developer tools) still lag global competitors.
Microelectronics	• The areas where Europe remains globally significant are upstream segments such as **semiconductor manufacturing equipment**, where Dutch firm ASML is the global leader in extreme ultraviolet (EUV) **lithography**. This position is complemented by firms such as ASM International, BESI, Carl Zeiss SMT, and Soitec, which supply critical equipment and materials. EU holds a strong position in the **equipment segment and is leading in**	• Limited IP core presence in EU-27 • Missing advanced-node foundries (<22 nm) limits Europe's role in high-end logic and AI chips • Weak position in EDA tools and dependencies on non-EU vendors for design and simulation software. • Packaging & assembly mostly outsourced to Asia, with little domestic capacity in Europe for advanced packaging or chiplet integration.

Technology Area	EU strengths and opportunities	EU critical weaknesses and threats to address
	specialised machines for wafer and semiconductor manufacturing[323]. • The EU also holds global strength in specialised **chip segments like discrete, analog, and optoelectronics**, with companies such as Infineon, STMicroelectronics, Bosch, and Osram supplying essential components for automotive and industrial applications. • European firms also hold global leadership positions in several specialised **chip segments, including Power components, Microcontrollers, MEMS** (Micro-Electro-Mechanical Systems), and Security integrated circuits. These areas of strength reflect the continent's deep industrial base and longstanding expertise in automotive and industrial technologies. • Presence of advanced R&D ecosystems and Pilot Lines (through the Chips JU) *Cross-technology:* • Good positioning in nascent technological sectors (e.g. quantum technologies, neuromorphic computing, Edge AI)	
NGI & extended reality	• Advanced focus on ethics, privacy, ownership, and legal aspects	• Reliance on non-EU XR hardware (e.g. VR headsets) as well as non-EU XR authoring software
Photonics	• Global competitiveness in **industrial lasers, 3D/IR sensors, optical components, and medical diagnostics**. • Strong capabilities in compound semiconductors, diverse materials platforms, and photonic integrated circuits (PICs) • Industrial photonics systems, high-power lasers • High-end optics, laser sources, and optoelectronics • The EU has strengths in applying Photonics in the healthcare & biophotonics domains. • Another sectoral application strength is automotive photonics with LEDs, laser headlamps, LiDAR, and driver-assistance optics	• Limited silicon photonics foundries and weak EDA/PDK ecosystem mirrors microelectronics shortcomings
Quantum	• The EU **has high-quality research and early-stage innovation**, with strong universities and spin-offs. • **Quantum key distribution** provides secure key exchange, is relatively mature and already demonstrated over	• High interdependency (and synergy potential) between different quantum technologies, e.g. developments in quantum repeaters are needed for distributed quantum computing.

[323] See also in European Commission: Joint Research Centre, Bonnet, P., Ciani, A., Molnar, J. and Nardo, M., *EU's strengths and weaknesses in the global semiconductor sector,* Publications Office of the European Union, Luxembourg, 2025, https://data.europa.eu/doi/10.2760/6302476, JRC141323.

Technology Area	EU strengths and opportunities	EU critical weaknesses and threats to address
	fibre channels. Quantum random number generation is similarly considered ready for deployment in cryptographic systems.	• Many QTs are at lab scale but need further development e.g. miniaturisation etc. to be market ready. • Satellite quantum technologies need more focus. • Many promising quantum technologies remain confined to academic environments. The transition to market requires stronger support for technology transfer, prototype validation, and industrial co-development.
Robotics	• EU vendors strong in **industrial robotics and collaborative/service robots**, moreover developing **safe robotics** and human-centric robotics. • The EU has a **fast-growing robotics market** that underpins deployment. • EU has strengths in fields such as rehabilitation exoskeletons and **biorobotics**. *Cross-technology areas:* • Physical AI and AI for robotics opportunities	EU is falling back in the number of robots in use behind China. There is a growing shortage of robotics engineers, especially in areas like AI integration and embedded systems.
Technologies for interoperability & GovTech	• Expanding digital infrastructure, through initiatives like Gaia-X and EuroHPC, positions the EU to deliver **secure, standards-based platforms for critical applications**, including AI and data-sharing in government. • Ongoing efforts to ensure a secure, sovereign digital ecosystem comprising critical, reusable interoperability solutions, as well as systems such as the Once-Only Technical System (OOTS) and the EU Digital Identity Wallet create the foundation for seamless, cross-border public services. In addition, the Interoperable Europe Act[324], part of the Digital Europe Programme creates a common framework for EU public administrations to share data and services seamlessly. These initiatives can be scaled and replicated across sectors, as seen with successful EU-wide platforms like digital vaccination certificates. • **The EU offers a strong foundation for the growth of GovTech and interoperability solutions** supported by robust digital infrastructure and coordinated policy efforts. Core digital building blocks, such as eIDAS, eSignature and eDelivery provide secure, standardised mechanisms for cross-border interactions. T • The regulatory environment is another key strength, with the EU playing a leading global role in setting standards	Reliance on non-EU technology providers Legacy IT systems in many administrations that are inflexible and siloed Fragmentation in the implementation of cross-border services despite regulations Siloed national approach to technology, particularly in the deployment of interoperability technologies

[324] https://eur-lex.europa.eu/EN/legal-content/summary/interoperable-europe-act.html

Technology Area	EU strengths and opportunities	EU critical weaknesses and threats to address
	around data protection, digital markets, and emerging technologies such as AI.	

Source: Technopolis Group (2025) based on desk research, data analysis and stakeholder consultation

3.12 Problem definition: key challenges identified for digital technology deployment in the EU

The table below characterises the main types of problems impacting the adoption of advanced digital technologies, limiting the extent to which innovative solutions are taken up and generally holding back the digital transformation in Europe. These barriers are similar, in broad terms, to the challenges that affect the rates of diffusion of technological advances more generally, however the complexity, intersectionality and dynamic nature of digital technologies compound the classic market and system failures and may result in a much flatter and more extended diffusion curve[325] with the early majority following the innovators and early adopters many years later when the solutions and their use cases have reached a high degree of maturity.

The problem identification takes into account that many early-stage commercial value chains are in the process of formation, resulting in a strong reliance on a limited number of critical inputs, such as highly specific expertise, suppliers and specialised infrastructure. Although the system may appear linear and straightforward, **it is in fact a tightly coupled and fragile network, where the absence or failure of one essential component within this pipeline can disrupt the whole system**. This illustrates the degree of dependence on bottlenecks and the inherent vulnerability of technological solutions prior to their evolution into more diversified and resilient industrial ecosystems.

Table 24 Problem tree for the deployment of digital technologies

Focus area	Problem drivers	Problems/challenges identified	Stakeholders affected	Likelihood of persistence of the problem
Technologies for deployment	Solutions can be complex and costly to implement	Use cases may not be sufficiently developed **to make the economic case** Implementation roadmaps are too simple and generic	The great majority of prospective adopters, **outside advanced users for which the tech is 'business critical'**	High
Applications & sectors	Many sectors struggle with **limited internal capability, tight budgets and a need to be cautious**	Public sector, especially local government, is **slow to adopt** Smaller firms lag larger firms on average Large parts of the **services industry and agri-food lag other sectors**	Smaller and less sophisticated organisations in both the public and private sectors	High
Infrastructures	Limited numbers of **demonstration facilities or early adopters**	Adopters may struggle to find **facilities where they can see technologies demonstrated or visit peers that have implemented solutions successfully and can**	Organisations located in smaller member states with less well-**developed infrastructure and ecosystems**	High

[325] Rogers, E. M. (1983). Diffusion of innovations (3rd ed.). Free Press.

Focus area	Problem drivers	Problems/challenges identified	Stakeholders affected	Likelihood of persistence of the problem
		explain the success factors and risks		
Skills	Technological advances can **move faster than educational programmes** Graduates are attracted to higher paying sectors Employers may struggle to invest / release staff for ongoing training	Adopters may struggle to recruit people with the **necessary skills and experience to implement / maintain systems optimally** Existing staff may struggle to **adapt quickly to the new systems and may not be able to exploit the full potential of the investments**	All organisations, including developers and early adopters	High
Ecosystem	Digital technology start-ups can **struggle to find the funds and people to grow into mature tech service providers** Intermediaries and business-support organisations can struggle to **keep up to date with advances in technology**	Prospective adopters may struggle to find **providers of an appropriate scale and experience to meet their particular requirements**	Most organisations other than the larger and more advanced corporates for which these are business critical **solutions and with the in-house capability and resources to review / adopt / optimise**	High
International positioning and resilience	Limited or non-existent local developers and suppliers	Heavy dependence on international suppliers can **make investments more uncertain and subsequent account management more fragile**	Any and all organisations, depending on the technology More likely to affect **smaller and less advanced users in both public and private sectors**	High
Framework conditions	Regulations **do not reward capital investment**	Underinvestment in innovative tools and procedures	More likely to affect smaller and less advanced users in both public and private sectors	High

Source: Technopolis Group (2025)

4. Future investment scenarios and assessment

This section provides information on the investment needs to support the deployment of advanced digital technologies and capabilities in the EU, stemming from the data collected and analysed in the previous sections.

4.1 Contextual factors influencing the investment scenarios

The study's horizon scanning identified a long list of contextual factors relevant for the deployment of digital technologies. The list was reduced in a foresight workshop to 11 key factors expected to impact the future European Digital Ecosystem and the development and deployment of advanced digital technologies within it. A short description of each priority factor is provided in the following table, presented in alphabetical order, which were used subsequently to reflect on the implications for the specific investment options.

Table 25 Key contextual factors likely to influence the deployment of digital technologies in Europe

Factor	Description
Access to critical materials	Reliable access to critical raw materials (CRMs) is considered crucial for producing key components of high-tech products, renewable energy technologies, and advanced manufacturing. Materials such as rare earth elements, lithium, and cobalt play a critical role in the production of electric vehicles, batteries, and digital devices amongst others. Given that a significant share of CRMs is sourced from outside the EU, supply chain dependencies, trade policies, and geopolitical developments influence availability. Any changes in supply presents challenges for industrial production, innovation cycles and technology development
Climate change adaptation & mitigation	Climate change continues despite efforts to reduce human-induced emissions, with rising temperatures and shifting climate patterns. Increasingly severe weather events impact ecosystems, infrastructure, human safety and health. Environmental degradation, including pollution and the depletion of water, land, and other natural resources contributes to lasting ecological and economic disruptions. Climate change mitigation efforts are being implemented to reduce greenhouse gas emission, while adaptation strategies are playing a growing role in addressing the degree of exposure and vulnerability to ongoing impacts. As environmental limits are increasingly reached or exceeded, established lifestyles, belief systems, and business practices face scrutiny and are subject to ongoing transformation, particularly in high-income societies.
Cohesion of the European Union	Misinformation and declining public trust in institutions contribute to political polarisation and social fragmentation, further complicating the EU's attempts to strengthen cohesion. If unaddressed, increasing political divides could lead to a 'multi-speed' Europe, where integration levels vary significantly among member states. Discontent with traditional political elites, combined with economic grievances, drive marginalised communities to support radical political alternatives, making consensus-building within the EU more challenging. These dynamics may influence future governance models, institutional stability, and the EU's capacity to maintain unity while navigating diverse political and economic interests.
Demographics & Digital skills in Europe	Digital skills and literacy are increasingly important for the European Union's competitiveness, sustainability, and social inclusion. Beyond employment, digital literacy plays a role in civic participation, critical thinking, and the ability to navigate information, including distinguishing facts from misinformation. However, demographics influence the varying levels of digital skills and literacy among policymakers, citizens, scientists, and communicators, highlighting disparities across age groups, education levels, and regions. These gaps are additionally widened by the exponential use and deployment of AI, which calls for urgent actions to boost AI literacy across all segments of the population.
Energy security	Global energy consumption continues to rise, with renewable energy sources playing a growing role as their costs decline. However, energy supply disruptions and price fluctuations may impact economic stability, particularly in energy-intensive sectors. Ongoing investment in fossil fuel infrastructure coexists with efforts to transition to greener energy sources, while factors such as the availability and cost of critical raw materials and grid capacity constraints affect the pace of this shift. Disparities in access to energy services become apparent.
Ethics, standards & law	The integration of emerging technologies is shaped by ethical considerations, influencing their development, deployment and societal acceptance. Balancing between fostering innovation and implementing safeguards is crucial to mitigating risks while enabling progress. Particularly significant in the field of Artificial Intelligence (AI), the AI Act serves

Factor	Description
	as a key regulatory framework designed to address ethical concerns surrounding AI development and deployment. Standardisation plays a vital role in this process, providing clear guidelines and technical benchmarks that promote transparency, interoperability, and accountability in ICT.
Geopolitical reconfiguration	Geopolitical alliances continue to evolve in a multipolar world shaped by competition for resources and emerging technologies, influencing the European Union's strategic positioning. Regional conflicts and shifting international dynamics contribute to adjustments in the EU's foreign policy approach. In response to a changing global landscape, the EU engages in diplomatic efforts and explores new alliances that support democratic norms and values. Cooperation with ASEAN countries, African nations, and other global partners reflects an interest in diversifying strategic relationships.
Global digital currency system	The global payment landscape is changing driven by digitalisation. The use of cash is steadily declining as online shopping, and digital payments through new service providers (outside the traditional bank sector) are becoming more prevalent. Cryptocurrencies built on distributed ledger technologies are becoming more and more popular and there is a growing global interest among central banks to develop central bank digital currencies. The EU is introducing the digital euro – an electronic form of central bank money to complement traditional banknotes and coins. These developments point to the potential emergence of a global digital currency system, which could enhance transaction efficiency, reduce currency exchange costs, simplify international trade, and promote financial inclusion beyond national borders. However, this potential shift could come with challenges, including regulatory complexities, political considerations, and concerns related to privacy, control, and security.
Global health challenges	Biodiversity is globally declining and environmental degradation is accelerating. Biodiversity loss undermines critical ecosystem services, including pollination, water purification, and climate regulation. The degradation of these services can lead to reduced agricultural productivity, increased vulnerability to climate change, and compromised human health, which are particularly concerning for the EU's food security and public health systems. The risk of a global health crisis is growing ever stronger, driven by the emergence of pandemic-level infectious diseases, increasing antimicrobial resistance and deteriorating and unequal conditions in access to health care. Increasing intergenerational inequality, unregulated social media, insecure employment and the climate crisis (eco anxiety) are worsening the global mental health state particularly among youth. The European One Health approach addresses this issue across a broad range of policies by highlighting the interplay of people, animal and ecosystem health. Digitalisation has been shown to affect mental health, human cognition, and emotional processing, with studies indicating both potential harms such as increased anxiety, reduced attention spans, and altered emotional regulation and opportunities for cognitive stimulation and digital mental health support.
Shifts in global trade and value chains	Over the past 30 years, the stability of the global economic and trade regime, coupled with advancements in digitalisation, has led to the proliferation of globally dispersed value chains. Their stability is challenged by recent disruptive developments, from pandemics to security and military threads. In response, governments are implementing measures to mitigate risks related to science, technology, and innovation (STI) interdependencies. Such efforts include enhancing industrial performance through targeted investments and strengthening international STI alliances among like-minded economies. These shifts in global value chains and international scientific collaboration potentially contribute to reshaping long-established trade and innovation networks.
Social disparities within Europe	While the number of people living in extreme poverty has declined globally, economic inequalities persist as the distribution of wealth shifts and concentrates in an ever-smaller group of people. Environmental challenges also influence economic stability. Beyond financial disparities, factors such as access to education, healthcare, technology, and intergenerational equity shape social inclusion. Issues related to climate justice, democracy and equal opportunities affect different groups in distinct ways. In Europe, variations in social and economic conditions among and within Member States contribute to ongoing tensions on cohesion and democracy.

Source: Technopolis Group (2025) based on foresight workshop

Having identified these 11 factors, a Delphi survey was used to collect expert opinion on their expected impact on the deployment of each digital technology under review, in both the medium term (from 2028) and longer term (from 2036), the analysis of which is presented in Tables 26 and 27.

In this study, expected impact has primarily been interpreted as anticipated negative effects, that is, contextual factors that may hinder technology deployment. However, several of these factors can also generate positive outcomes. For example, skills shortages can act both as a barrier and as a catalyst: if firms are unable to recruit sufficient workers with digital capabilities, they may accelerate investment in digitalisation and automation to compensate. In such cases, increased use of digital technologies can deliver productivity gains and expanded service offerings while partially offsetting demographic pressures through workforce restructuring. At the same time, this shift may inadvertently heighten reliance on imported technologies and global providers, reinforcing external dependencies.

Table 26 Expected impact of contextual factors on technology deployment in 2028

2028	Expected impact on technology deployment												
Context factor	**Microelectronics**	**Photonics**	**HPC**	**Quantum**	**AI**	**Data**	**Robotics**	**Cybersecurity**	**Cloud-Edge-IoT**	**Blockchain**	**Adv. dig. com. & con.**	**NGI & XR**	**Tech for Interoperability**
Access to critical materials	High	Very high	High	High	High	Medium	High	Medium	Medium	Medium	High	High	Medium
Cohesion of the European Union	High	Medium	High	High	High	High	High	High	High	High	High	High	High
Demographics & Digital skills in Europe	High	High	High	High	Very high	High	High	High	High	High	Very high	High	High
Energy security	High	High	High	High	High	High	Medium	High	High	High	High	High	High
Ethics, standards & law	Medium	Medium	High	Medium	High	High	High	High	High	High	High	High	Very high
Geopolitical reconfiguration	Very high	High	High	High	High	High	High	High	High	High	High	Very high	Very high
Global digital currency system	Medium	Medium	Low	Low	Low	Low	Low	High	Medium	High	Medium	Medium	High
Global health challenges	Medium	Low	Medium	Low	Low	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium

2028	Expected impact on technology deployment												
Shifts in global trade and value chains	High	High	Very high	High	High	High	High	High	High	High	High	High	High
Social disparities within Europe	Low	Medium	Medium	Medium	Medium	Medium	Low	Medium	Medium	Medium	High	Medium	High
Climate change adaptation & mitigation	Low	Medium	Medium	Low	Medium	Medium	Medium	Medium	High	Medium	High	High	Medium

Source: Technopolis Group (2025) based on Delphi survey

Table 27 Expected impact of contextual factors on technology deployment in 2036

2036	Expected impact on technology deployment												
Context factor	**Microelectronics**	**Photonics**	**HPC**	**Quantum**	**AI**	**Data**	**Robotics**	**Cybersecurity**	**Cloud-Edge-IoT**	**Blockchain**	**Adv. dig. com. & con.**	**NGI & XR**	**Tech for Interoperability**
Access to critical materials	Very high	Very high	Very high	High	High	Medium	High	Medium	High	Medium	Very high	High	Medium
Cohesion of the European Union	High	High	Very high	High	High	High	High	High	High	Very high	High	Very high	Very high
Demographics & Digital skills in Europe	Very high	High	Very high	Very high	Very high	High	Very high	High	High	Very high	Very high	Very high	High
Energy security	High	High	High	High	Very high	High	High	High	High	High	High	Very high	High
Ethics, standards & law	Medium	Medium	High	Medium	High	High	High	High	High	Very high	High	High	Very high
Geopolitical reconfiguration	Very high	High	Very high	High	High	High	High	High	High	High	High	High	Very high
Global digital currency system	Medium	Medium	Medium	Medium	Medium	Low	Low	High	Medium	Very high	Medium	Medium	Very high

2036	Expected impact on technology deployment												
Global health challenges	Medium	Low	Medium	Medium	High	Medium	Medium	Medium	High	Medium	High	High	High
Shifts in global trade and value chains	High	High	Very high	High	High	High	High	High	High	High	High	High	High
Social disparities within Europe	Medium	Medium	Medium	Medium	Medium	High	Medium	Medium	High	High	High	High	High
Climate change adaptation & mitigation	Medium	High	High	Medium	Medium	Medium	Medium	Medium	High	High	High	Very high	High

Source: Technopolis Group (2025) based on Delphi survey

From the figures some stark differences can be observed. For example, there is a strong difference in expected impact for the "Global digital currency system" which is expected to have a low or medium impact in most technology areas with the exception of blockchain and interoperability where it is expected to have a very high impact on deployment. This can be understood from the application of these technologies in the finance sector. "Social disparities within Europe" is expected to have a low or medium impact on the deployment of most technologies in 2028, while it is expected to have a high impact on the deployment of advanced digital communication and connectivity. On the long term, this contextual factor is expected to have a higher impact on the deployment of other technologies as well. A similar contrast can be observed for "Climate change adaptation and mitigation" which is for some technologies expected to have a low impact on deployment, while for those more pervasive, energy-intensive digital technology applications like cloud and next generation internet, climate mitigation measures are expected to have a high or very high impact beyond 2028. For 2036 the impact increases, likely due to the assumption that the efforts to mitigate climate change will need to become more restrictive in the longer term.

The top 5 contextual factors that are expected to have the highest impact on deployment across all technologies in both 2028 and 2036 as per experts' views are:

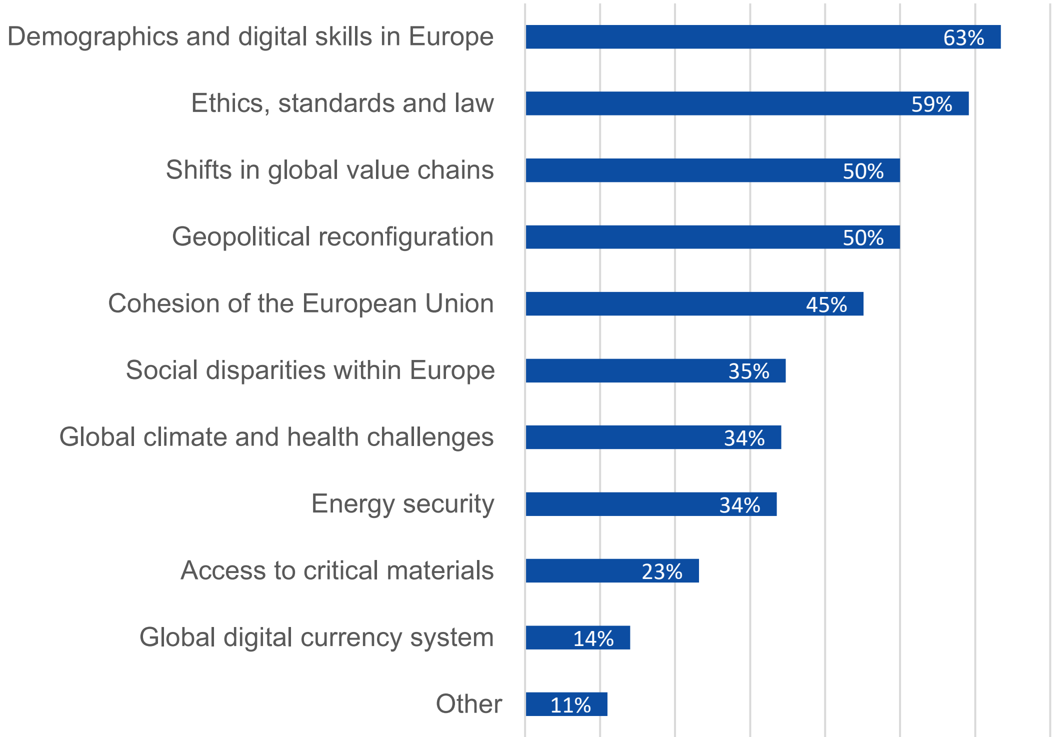
1. Demographic & digital skills in Europe (same expected impact in 2036)
2. Shifts in global trade and value chains (lower expected impact in 2036)
3. Geopolitical reconfiguration (same expected impact in 2036)
4. Cohesion of the European Union (higher expected impact in 2036)
5. Energy security (same expected impact in 2036)

The horizontal bar chart below presents the views of a wider pool of stakeholders, as regards the most important barriers to the deployment and adoption of advanced digital technologies in general. The technology experts' ranking is almost the same as the views of wider stakeholders, with the exception of regulatory issues (which the experts are less concerned about) and energy security which they rate much more highly than the wider group. From this feedback, we can see that the top 5 contextual factors that are expected to have the highest impact on deployment across all technologies are:

1. Demographic & digital skills in Europe
2. Ethics, standards and law
3. Shifts in global trade and value chains
4. Geopolitical reconfiguration
5. Cohesion of the European Union

The top two factors, loosely skills shortages and regulatory obligations, stand apart from several other much-discussed topics such as the dependence on global value chains, or the shifting balance of economic and technological power to the East, and the unevenness of Europe's single market. Societal challenges like climate, energy security and social disparity are even less widely seen as a key barrier to the deployment of these various advanced digital technologies (they may even be a driver of deployment).

Figure 51 Challenges/barriers to digital technology adoption/uptake efforts in Europe



Source: Technopolis Group (2025) based on the stakeholder survey results, n=164

4.2 EU added value and objectives

Stakeholders advocated a long-term EU strategic plan, with a clear 10-year vision, and coordinated priorities across technologies and sectors to guide investment and innovation.

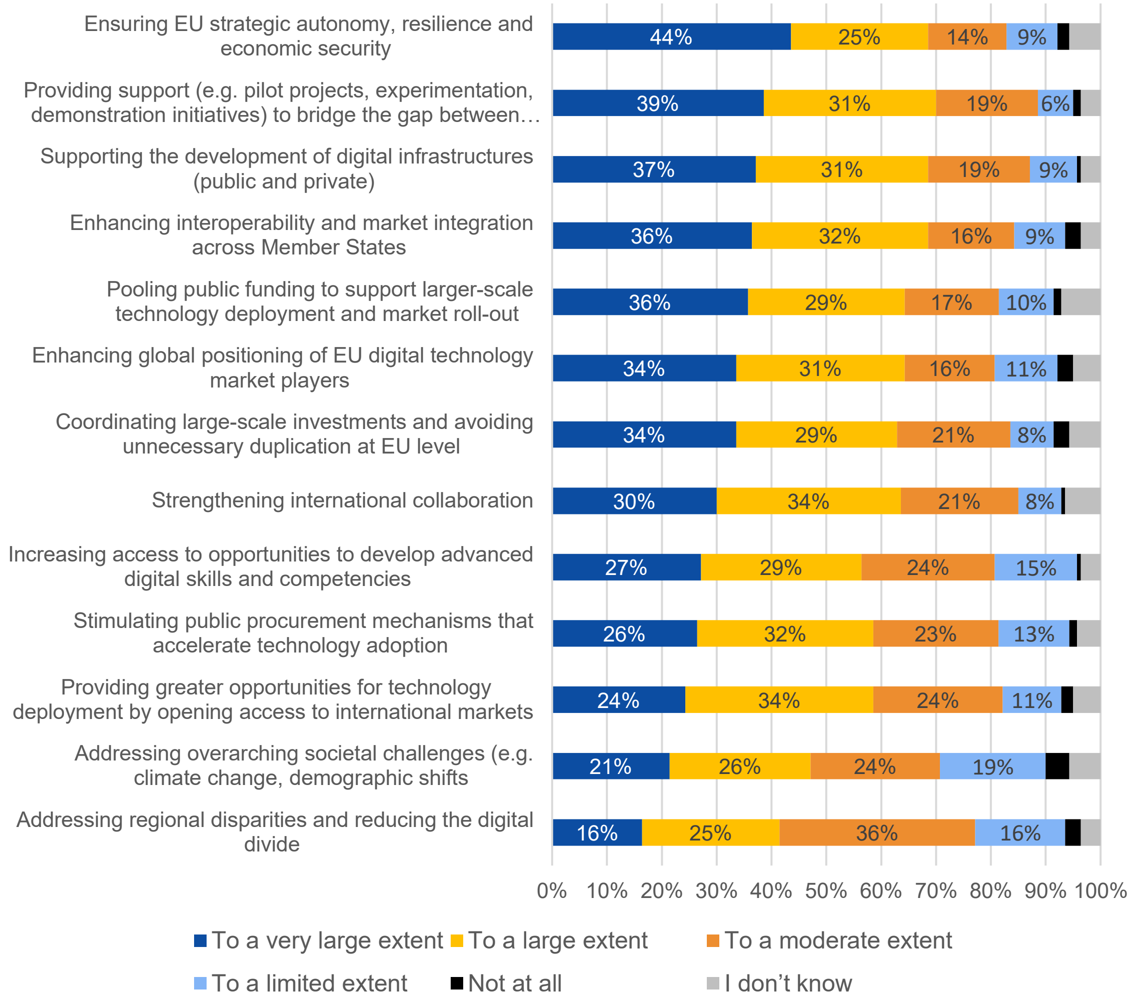
The analysis of the previous sections point to the need for the EU to continue investing in all critical digital technology areas, if Europe is not to become even more dependent on other countries for next generation digital solutions. A growing international dependency may lead to a weakening of the relationship between technology developers and their users in Europe, which could in turn impact the relevance of available solutions, the competitiveness of prices, and the quality of available support.

4.2.1 EU added value to support the deployment of digital technologies

Feedback from the stakeholder consultations shows widespread endorsement of EU interventions to complement the efforts of the private sector and Member States, to support the deployment of digital technologies and accelerate the digital transition. The Figure below shows that there is support for EU actions across all dimensions, from infrastructure to talent. **The highest added value of an EU programme is seen in ensuring EU strategic autonomy, resilience and economic security**. This dimension is followed by bridging the gap between research and real-world market applications. The least added value is seen in addressing overarching societal challenges and regional disparities.

According to the stakeholder feedback, EU-level support has been pivotal in accelerating the adoption, deployment, and scaling of digital technologies across Europe by enabling cross-border collaboration, large-scale experimentation, and shared infrastructure that national or private funding alone could not sustain. Examples mentioned where EU-level support made a significant difference focused on the adoption/uptake of digital technologies include projects and partnerships under DIGITAL, CEF but also Horizon Europe such as data spaces development, EuroHPC, LUMI AI factories, Destination Earth, SNS JU 6G[326], the EuroQCI, CyberHubs[327], the EDIHs, AI4Manufacturing, EUCAIM[328] or INDICATE[329].

Figure 52 Added value of an EU programme for the adoption/uptake of digital technologies compared to national/regional and private efforts [To what extent is a future EU programme supporting the adoption/uptake of digital technologies expected to provide larger added value compared to funding at national/regional level or private efforts in 2028?]



Source: Technopolis Group (2025) based on stakeholder survey, n=133

The stakeholder survey results underline the special importance of several types of European added value, which can be grouped into three categories:

- **Setting agendas and defining standards**. This reflects the ability of EU programmes to bring together public and private actors to focus their efforts on common strategic objectives, bringing together their respective resources to address the most pressing issues.
- **Pump-priming investments to crowd-in wider funds and achieve critical mass**. The EU's ability to implement large-scale, cross-border platforms such as the IPCEIs provides a bedrock of funding – capital and recurrent – that pool resources and capabilities, to reach a scale of investment few individual actors can deliver. The scale and strategic intent of these platforms gives confidence to other investors and can crowd in additional funding from both public and private sources. This can be decisive

326 https://smart-networks.europa.eu/
327
328 https://cancerimage.eu/
329 https://indicate-europe.eu/

in delivering breakthroughs and match or exceed the rate of progress achieved by the leading players globally.

- **Accelerating diffusion by sharing the insights and lessons learned at the cutting edge with most actors that adopt digital innovations only gradually.** While a key aspect of deployment is concerned with the early application of breakthrough technologies, the majority of European businesses, public bodies and households depend upon the creation of affordable solutions developed for their specific applications and sectors. These followers look to their more adventurous peers to give them confidence in moving forward with investments in novel systems as they look to realise the kinds of productivity and service enhancements promised by these fast-moving digital technologies. The EU's ability to co-fund communities of practice and more general innovation diffusion platforms helps greatly with shortening the diffusion curve, within sectors, across sectors and across borders.

4.2.2 Objectives of public intervention to support the deployment of digital technologies

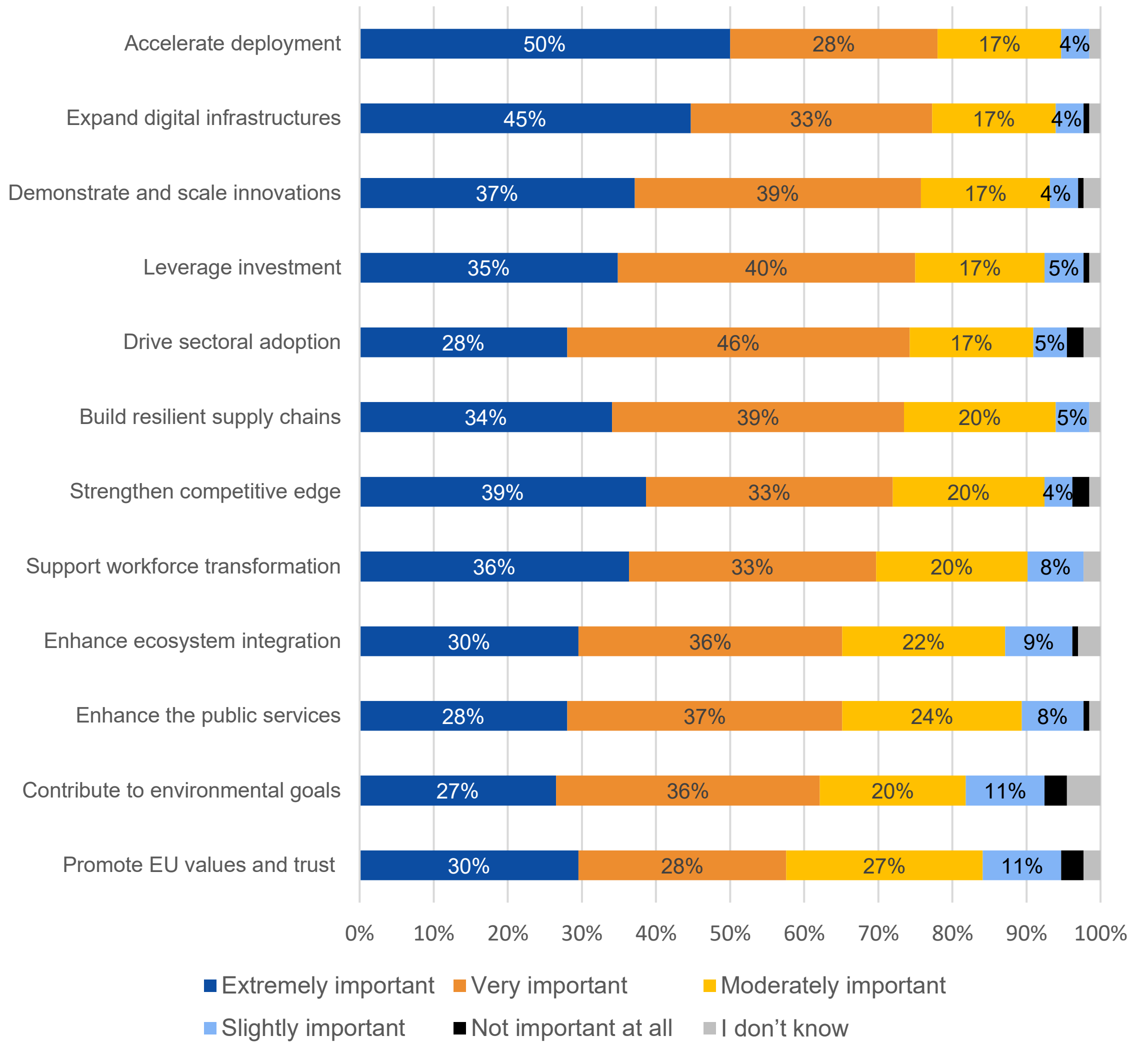
Feedback from the stakeholder consultations shows widespread endorsement for EU interventions across a broad range of objectives relating to the deployment of digital technologies, from support measures (e.g., preparing use cases and offering advice on adoption) to reducing dependencies (e.g., providing advice to public procurement specialists on various sovereignty measures like smaller contracts or evaluation criteria that give credit to local suppliers. Other ideas include targeting support to European startups and scaleups, where those firms are developing alternatives to global services.) through to ensuring better and more cost-effective services for citizens (e.g., expanding provision of European test beds and demonstrators).

There is strong support for each objective tested through the survey, with every aim rated as 'very' or 'extremely important' by more than 50% of respondents. The results suggest that there is relatively more support for objectives relating to the acceleration of the digital transition, the development of digital infrastructures and the creation of more resilient supply chains. There is marginally less support (<60% rating the objective as 'very' or 'extremely important') for leveraging technologies to promote transparency and inclusivity, creating digital ecosystems, or supporting more cost-effective services across borders and sectors.

Regarding the importance of dimensions to prioritise, 78% of stakeholders view as 'very' or 'extremely important' to accelerate deployment and to expand digital infrastructures. They also emphasise the importance of promoting the shift to European alternatives[330], and fostering the large-scale uptake of open source software and services. The future EU programme for the deployment and adoption of digital technologies is also expected by stakeholders to focus on bridging the gap between innovation and real-world impact by addressing not only technological readiness, but also organisational, regulatory, and skills-related barriers that often delay adoption. Large-scale demonstrators, testing environments and simplified access to digital infrastructure for SMEs are seen as critical in this endeavour. Stakeholder interviews highlighted the need for a stronger focus on workforce transformation, promoting upskilling and reskilling programmes that combine digital skills with sector-specific expertise.

[330] For example, the website https://alternativeto.net/ offers alternatives for various applications filtered by country of origin

Figure 53 Dimensions to prioritise in the next EU programme for technology deployment [Please assess the level of importance of the following dimensions for a future EU programme supporting the deployment & adoption of digital technologies (2028-2034)?]



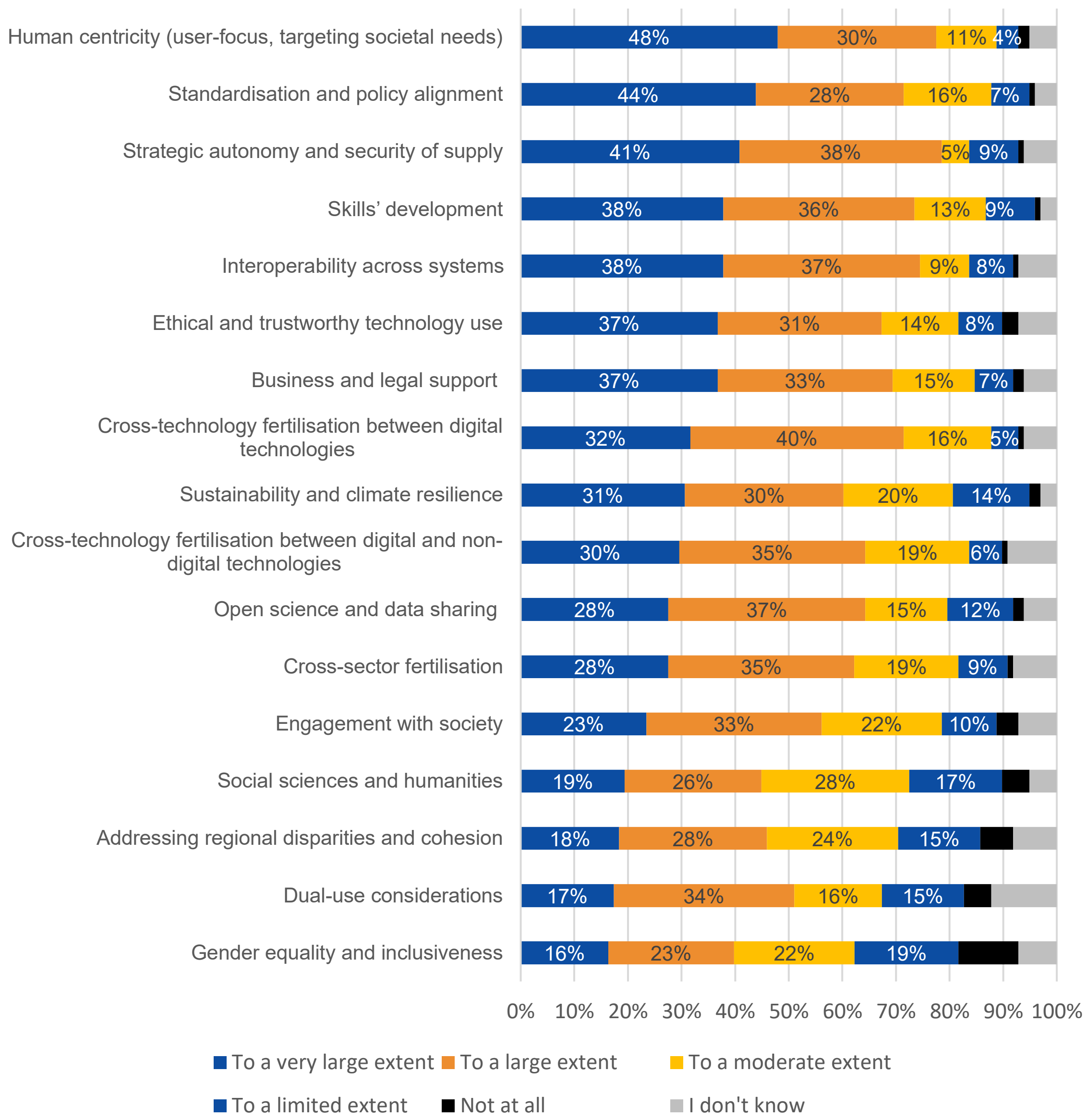
Source: Technopolis Group (2025) based on stakeholder survey, n=132

Regarding programme design, in almost every case, the alternative design constructs attracted similar proportions of support from stakeholders (selective and inclusive; leading and lagging; early adopters and followers; sector specific and sector agnostic), **reflecting the breadth of investment needs and the ambition levels** of consultees. The only design concept that attracted notably less support was the suggestion that a future programme should be entirely open and bottom-up. That suggests stakeholders appreciate the need to be strategic, given the finite funds available, and the need for the activities supported to have a clear European logic, to ensure investments add value over what Member States or even the private sector are able to fund.

Overall, 48% of survey respondents rated human centricity as essential 'to a very large extent', and respectively 44% and 41% of respondents rating standardisation and policy alignment and strategic autonomy very high. Other highly rated dimensions included skills development, cross-technology fertilisation between digital technologies, and standardisation and policy alignment. Dimensions such as business and legal support, ethical and trustworthy technology use, cross-technology fertilisation between digital and non-digital technologies, and open science and data sharing also received strong support, with around two-thirds of respondents (between 64% and 69%) considering them important 'to a very large' or 'to a large extent'. Between half and two-thirds of respondents, which remains a significant share but lower than that of the previous dimensions, considered cross-sector fertilization, sustainability and climate resilience, engagement with society, and dual-use considerations to be essential.

Finally, addressing regional disparities and cohesion, social sciences and humanities, and gender equality and inclusiveness ranked lowest, with a higher proportion of respondents rating them essential only 'to a moderate extent' or 'to a limited extent' (between 40% and 45%).

Figure 54 Essential dimensions to take into account for the design and implementation of a future EU programme on deployment and adoption of digital technologies [To what extent are the following dimensions essential to take into account for the design and implementation of a future EU programme on the deployment/adoption of digital technologies?]



Source: Technopolis Group (2025) based on stakeholder survey results, n=113

4.3 Overview of Investment Options

The study has created a series of technology reports that document expected medium and longer-term trends in key digital technologies and applications within a broad domain as well as detailing past investment levels and judging EU strengths and weaknesses. These area reports are a primary output from the study and each of these substantive documents will be a critical input for the European Commission when determining the priorities for future digital work programmes.

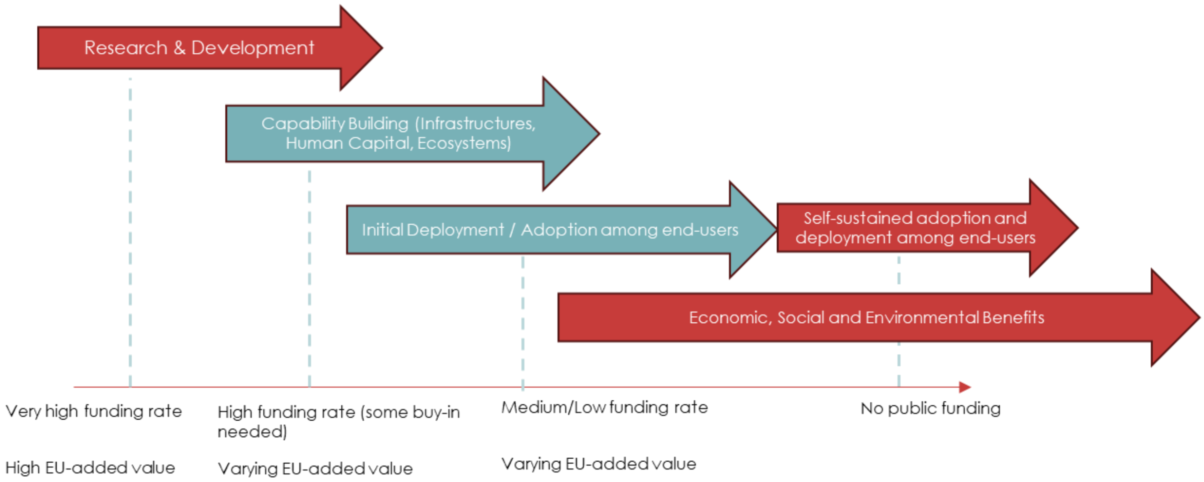
To bring together these individual reports into an investment strategy for the programme overall, other issues need to be considered, such as the **total funding envelope available** and **the most appropriate distribution of investment across domains.** To support the EC in its thinking about the best mix, the study team has prepared a series of four stylised

Investment Options, each of which has a particular focus, such as productivity or strategic autonomy, and which is then used to **prioritise technologies within and across domains**. The Options have also been used to propose a **mix of investment types**. In both cases, the mix has been determined by the study team, based on evidence from our consultations and desk research, to be optimal for the specific scenario under review. The cross-tabulation of technology areas with broad investment types has led us to add one further 'technology area,' which we have labelled cross-cutting: this is a recognition that many infrastructure or ecosystem investments are relevant to many digital technologies, like the EDIHs.

4.3.1 Key concepts for designing investment options for deployment

Before characterising each of these Investment Options, it is relevant to recap the general logic for public funding of technological deployment. From a highly simplified perspective, once R&D in a technology area has progressed beyond a specific point and evidence of clear application potential emerges, governments can choose to invest in **capability building**, such as technology infrastructures (such as pilot lines, testing facilities), ecosystems (networks, standards etc.) and human capital (education and skills). While these already indirectly support technology adoption among end-users, the public sector may also directly support adoption through **deployment programmes** focused on specific applications and target groups. At some points, technology adoption becomes self-sustained through market or regulatory forces. It is important to note that economic, social and environmental benefits only emerge from the point of adoption and application onwards.

Figure 55 Technology development phases – stylised overview (in blue the focus of this study)



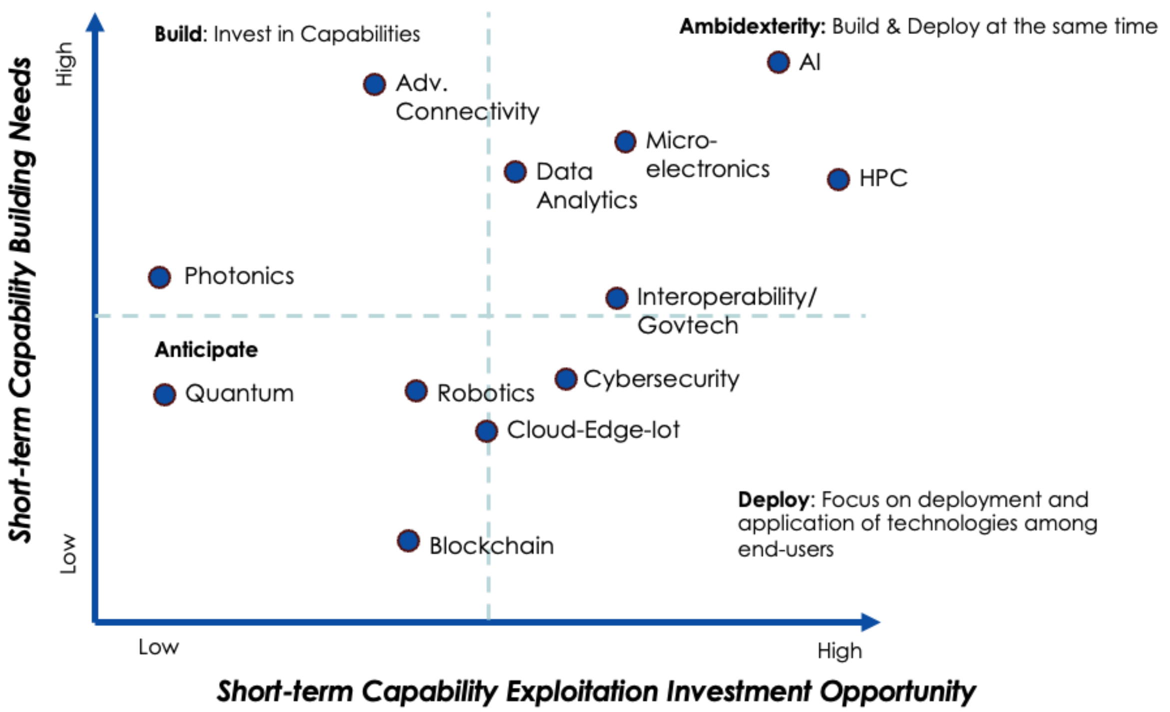
Source: Technopolis Group (2025)

The distinction between **capability building** and **technology deployment** is a critical aspect when designing investment options, as they are associated with different investment types, funding rates and intervention level. Capability building (infrastructure, ecosystems and skills) typically need high funding rates as appropriability of results is relatively low and direct economic return is still far away. A degree of co-funding is still relevant to ensure buy-in of relevant public and private sector stakeholders. EU-added value is typically high due to the shared nature and high degree of spillovers of such capabilities (e.g. a large-scale technology infrastructure can be used by end-users from different MS), although the case is less clear for large-scale investment in human capital programmes at EU-level[331]. Deployment programmes typically have lower co-funding rates due to higher appropriability of results, as also reflected by state aid principles[332]. Direct EU-added value is more nuanced and is mostly realised by directly tying in deployment programmes to the aforementioned capabilities (access to (cross-border) technology infrastructures, learning in networks, standards).

[331] There is a case for ecosystem activities related to skills, such as reference frameworks for skills, joint curricula development. In addition, mobility programmes have a clear EU-rationale, and some specific niche areas may work better at European scale. Nevertheless, most human capital building related to digital technologies is expected to be taking place at MS or regional level.
[332] For discussion see for instance Haucap, Justus; Schwalbe, Ulrich (2011) : Economic principles of state aid control, DICE Discussion Paper, No. 17, ISBN 978-3-86304-016-1, Heinrich Heine University Düsseldorf, Düsseldorf Institute for Competition Economics (DICE), Düsseldor

The stylised linear logic of Figure 55 is, however, too simple. In reality, technology areas are in constant flux, with new technology trends emerging at varying paces. These new trends require the constant rebuilding of capabilities, while at the same time the existing capabilities are **exploited** to deliver application and economic, societal and environmental benefits. This brings us to a two-dimensional frame (Figure 54) that helps to orient investment by investment type and scale. On the Y-axis, it maps the short/medium-term investment needs for technology areas in terms of (re)building capabilities for current and upcoming technology trends. On the X-axis, it presents the opportunities present in terms of exploiting the currently available capabilities, such as for instance technology infrastructures (HPC, TEFs, AI Factories) and EDIH-networks set up in the current Digital Europe Programme, It shows some technologies are in the 'build quadrant', where there is a need to primarily build technologies and exploitation investment potential is currently limited. In the 'deploy' quadrant, those technologies are present where significant capabilities are already available, and there is a need to invest primarily in deployment at scale. In the top-right quadrant, a high intensity of both building and exploiting is needed, requiring more complex programme/intervention approaches, also known as 'ambidexterity' in an organisational context[333]. In this quadrant, a relatively fast cyclical approach is needed where feedback from use is fed back to new or updated capability development and application (i.e. innovation). Finally, some technologies are either still primarily in R&D-phase (e.g. Quantum) or their exploitation opportunity is not fully revealed (e.g. Blockchain). In such technologies, an 'anticipation' approach allows for small-scale building of capabilities while waiting for technological or contextual changes. Such small-scale investment can still pay off in a strategic portfolio, as building capabilities from a low level is much faster than starting fully from scratch, and monitoring the emergence of new opportunities itself is hard without any capabilities.

Figure 56 Capability Building & Exploitation[334]



Source: Technopolis Group (2025)

333 For an overview see O'Reilly CA., Charles A., and Michael L. Tushman. "Organizational ambidexterity: Past, present, and future." *Academy of management Perspectives* 27.4 (2013): 324-338.

334 Positioning based on experts' views on current capabilities (see 1.9) and experts' / stakeholders' views on uptake potential (see also 1.9).

4.3.2 Investment options

Four stylised investment options have been formulated, each with a particular signature that is evident in the study's problem analysis and objective definitional work.

Investment Option 1 is concerned with competitiveness and productivity above all else while Investment Option 2 emphasises the strategic need to increase Europe's resilience and strategic autonomy in digital technologies. Investment Option 3 shows an approach where the investment strategy is focused around a core technology, in this case AI, in line with the recent AI Continent Action Plan[335]. Investment Option 4 presents a plan built bottom-up around stakeholder needs in a broad sense. These stylised investment options have been used to define priorities for funding allocations between technology areas and for the mix of investment types.

Table 28 Overview of the Investment Options

Investment Options	Main sources for prioritisation	Impact on prioritisation of technologies and instruments
Investment Option 1: (Competitiveness/ Productivity)	• Expected impact on uptake and productivity of different investment levels (Delphi survey).	• **Technology areas:** focus on areas where exploitation potential is high, less on (just) building capabilities (AI, Data, GovTech/Interoperability, Cybersecurity, etc.) • **Investment type mix:** High on Deployment support services, Medium/Low on Infrastructure development, Medium/Low on Ecosystem
Investment Option 2: (Competitiveness/ Resilience)	• Impact on dependencies of different investment levels per technology area (Delphi survey) • Impact on reverse dependencies (Delphi)	• **Technology areas:** More focus on areas where dependencies are high (AI, Cyber, etc.) • **Investment type mix:** High on building capabilities (Infrastructures, Medium/Low on Ecosystem)
Investment Option 3: AI Continent	• High investment needs for AI (technology report) • Cross-fertilisation with other technology areas (Delphi survey)	• **Technology areas:** Central focus on AI and other areas where synergies with AI are very high (e.g., HPC, Cloud, Microelectronics, Data etc.) • **Investment type mix:** High on Deployment and High on Infrastructure, Medium on Ecosystem
Investment Option 4: Stakeholder priorities	• Investment priorities of private / public sectors (stakeholder survey) • Current level of capabilities of infrastructures in EU (Delphi survey).	• **Technology areas:** More focus on areas where stakeholders are prioritising investment (AI, Cyber, Data, Interoperability, etc.) • **Investment type mix:** High on Deployment support services, Medium on Infrastructure development, Low on Ecosystem

Source: Technopolis Group (2025)

It is important to note that these Investment Options are stylised presentations and are not fully-fledged policy options. As such, they contain no detailed analysis of funding and implementation modalities.[336] In the following sections, each Investment Option is presented individually. Subsequently, the four options are compared with one another and against the baseline to highlight their respective strengths and weaknesses.

Investment levels

Our consultations considered four funding scenarios, as follows:

- 25% of current funding levels (low)

[335] https://commission.europa.eu/topics/competitiveness/ai-continent_en
[336] A horizontal analysis of recommendations for implementation modalities for the next MFF are presented in Section 4.10.

- 100% of current funding levels (continuation)
- 150% of current funding levels (High)
- Optimal investment level, as defined by experts: (150-350% per technology)

Given that the 2025 ECF proposal suggests a €51.5 bn investment for digital through the Digital Leadership window, a fivefold increase on the current combined DIGITAL and CEF funding, we have presented a series of investment options based on the 'optimal investment' scenario. This has the following rationale:

- Experts argued for a flexible budget ready to address emerging needs, based on new upcoming trends that can move very fast, or changes in the external environment (such as value chain disruptions) that are best addressed at EU level. However, on the other hand, Member States and regional bodies also call for stability and the ability to execute long-term planning to effectively design co-funding mechanisms and build a pipeline of activities, although they also agree with the intrinsic need for flexibility[337]. As such, ideally a new programme will **combine stability and flexibility** in its design from the start.
- While the current programme has invested heavily in infrastructure and ecosystems, and the feedback from users is positive and is already empirical quantitative evidence of impacts for several instruments (in particular EDIH and digital skills), there is **due to the timing no full evidence yet** for other key instruments/investments (e.g. AI Factories, TEFs, Euro HPC facilities) whether these infrastructures and the current approaches supporting their exploitation are effective at creating impact for end-users. While many of the activities are expected to be impactful, it would be logical to allocate further investment to proven models, in order to generate higher public returns on investment.
- Ecosystem investments (development of standards, improvement of framework conditions, collaboration networks, mobility and coordination, etc.) are essential components of a broad deployment programme. However, these activities generally benefit from scale efficiencies in larger programmes, meaning that the relative allocation would decrease for a larger overall budget.
- According to the experts, as well as the interim evaluation of the Digital Europe Programme, there is a need for more diverse instruments, including wider use of financial instruments as well as demand-side measures (e.g. vouchers, end-user pilots, etc.). **Such demand-side measures are intrinsically less predictable in terms of allocation by technology area**, as they depend on incipient demand and existing financial capital available.

Each option has different priorities and investment criteria for both fixed and flexible budgets. For the flexible budget, the following would be the priority for each of the investment options:

- Option 1: (Competitiveness - Productivity): Prioritised for rapid scale-up of proven effective interventions and to stimulate infrastructure use and deployment services uptake via demand-side measures.
- Option 2: (Competitiveness - Resilience): Prioritised for contingency measures to rapidly invest in areas where there are supply chain disruptions, emerging vulnerabilities and strategic strengthening of emerging reverse dependencies.
- Option 3 (AI Continent): Prioritised for rapidly following up on AI and related technologies developments, new technology trends and/or application areas.
- Option 4 (Stakeholder priorities): Areas of emerging demand as identified through our consultations with stakeholders from public and private sectors.

Investment ratios between investment types

Investment ratios between investment types are determined based on several factors:

- The allocations in the baseline (current MFF)

[337] Digital Europe Interim Evaluation, Policy Workshop

  - In line with the terminology of the proposals for the next MFF, Digital Infrastructures and Technology Infrastructures (including Testing Facilities etc.) have been consolidated into 'Technology Infrastructures'
  - Skills investments are integrated with 'Ecosystem' investments.
- The recommendations of the experts in the Delphi survey, in terms of prioritisation in the new MFF. We have aggregated this feedback into an overall assessment of "importance," with each technology-investment pairing being located somewhere on the importance scale, from high to low.
- The positioning in terms of capabilities (based on an assessment of capabilities by experts, see Table 28.) and exploitation potential (based on the stakeholder assessment and expert expectations of uptake, informing the 'quadrant'.
  - Infrastructure and Ecosystem are considered capability building.
  - Deployment support services are considered exploitation.
- The investment option chosen and its focus on building capabilities vs exploiting them (for instance, the productivity option is more focused on exploiting capabilities, whereas the resilience option is more focused on building capabilities.
- The current ratios take into account the findings of the interim evaluation of the Digital Europe Programme (high capability building successfully implemented, now need for (also) more exploitation, e.g. for instance HPC and AI Factories have seen large-scale investments in facilities already, which allow for better/faster exploitation in the next years).
- Taking into account certain saturation points (see discussion above on investment levels).

Framework conditions and stress-testing

Each option is assessed in terms of the necessary framework conditions as well as sensitivity to positive and, in particular, negative scenarios. The analysis of framework conditions is based on the Delphi survey (see Table 29), workshops and qualitative evidence. The stress-testing took place in the expert workshops (second round), at the technology area-level.

Table 29 Need for improvement of framework conditions

Technology	Advanced connect.	AI	Blockchain	Cloud	Cybersecurity	Data	HPC	Interoperability	Microelectronics	NGI	Photonics	Quantum	Robotics
Cost/risk ratio for scaling-up of innovation	LE	LE	VLE	LE	LE	VLE*	LE	VLE	LE*	LE*	LE*	VLE	LE*
Demand for technology in Europe from the private sector	LE	LE	VLE	LE	LE	VLE	VLE	LE	LE*	LE	LE*	VLE	LE*
Demand for technology in Europe from the public sector	LE*	LE	VLE	LE	LE*	VLE*	LE	VLE	LE*	VLE	LE*	VLE	LE*
Awareness of technology potential and possible return on investment (incl. use cases)	LE*	LE	VLE	LE	LE*	VLE	VLE	LE	VLE	VLE	LE*	VLE	LE

Technology	Advanced connect.	AI	Blockchain	Cloud	Cybersecurity	Data	HPC	Interoperability	Microelectronics	NGI	Photonics	Quantum	Robotics
Human-centricity for technology deployment	ME*	ME*	LE	LE	LE*	LE*	ME*	VLE	ME	LE*	ME*	ME*	LE*
Interoperability and standardisation	LE	LE*	VLE	LE*	LE	VLE*	LE	VLE	LE*	LE	ME*	VLE	LE*
Independency from non-European technologies, infrastructures or suppliers	VLE	VLE*	LE	VLE	LE*	VLE	VLE	VLE	LE*	VLE*	LE*	LE*	LE*
Legal & regulatory framework (e.g., approval processes, compliance requirements)	LE	VLE	LE	LE	ME*	LE*	LE*	LE	LE	LE*	ME*	ME*	LE*
Speed in technology adoption processes (speed of market uptake, scaling innovations)	VLE*	LE*	VLE	VLE	LE	VLE	LE*	VLE	VLE	VLE*	LE*	VLE	LE*

*Source: Technopolis Group (2025) based on Delphi survey, Note: LE = To a large extent; VLE = To a very large extent; ME = To a moderate extent; the * symbolises considerable divergence of opinion amongst experts*

4.4 Investment Option 1: Competitiveness: Productivity

Main policy objectives

Investment Option 1 (IO1) recommits to the central objectives of the current Digital Europe Programme, expanding substantially the level of investment overall, while maintaining support for both deployment and capability development across all technology areas and sectors.

The central aim is the enhancement of European competitiveness through measures to accelerate the digitalisation of all sectors, public and private, and to support the earlier deployment of frontier technologies among advanced users. It is in line with the ambitions of the Draghi report on EU competitiveness (2024) and President von der Leyen's plan (2024) for Europe's sustainable prosperity and the call to invest record amounts in new technologies to drive the green and digital transition.

This investment option will continue to mirror the dual funding strategy of the current programme, with investment being directed to two specific objectives:

- Advancement of digital capabilities in critical sectors: Support to Europe's strategic industries and their access to and use of next-generation solutions across all areas of digital technology, including AI, advanced communications, semiconductors and quantum technologies, robotics, etc.
- Deployment of digital solutions generally. Support for the diffusion of digital technologies across the whole economy through for example skills development for both the existing workforce and new joiners, technology demonstration and ecosystem initiatives that facilitate peer learning and knowledge transfer within and across sectors.

4.4.1 Investment priorities

Table 30 Prioritisation table Option 1

	Priority: Productivity impact potential*	Most dominant mode	Deployment	Technology Infrastructures	Ecosystem & Skills	Total
AI	**VH**	**Build & Exploit**	VH	VH	H	23%
Advanced Digital Comms	**VH**	**Exploit**	H	H	L	6%
Blockchain	**L**	**Anticipate**	L	L	L	1%
Cloud-Edge-IoT	**H**	**Build & Exploit**	H	H	MH	7%
Cybersecurity	**VH**	**Exploit**	VH	H	H	15%
Data	**H**	**Exploit**	M	H	MH	5%
HPC	**H**	**Exploit**	VH	H	MH	10%
Interoperability/Govtech	**VH**	**Exploit**	VH	M	MH	12%
Microelectronics	**H**	**Exploit**	H	H	MH	7%
NGI	**H**	**Anticipate**	H	M	MH	3%
Photonics	**L**	**Anticipate**	M	M	M	1%
Quantum	**L**	**Build**	M	M	L	2%
Robotics	**M**	**Build**	M	M	M	2%
Crosscutting	**H**	**Exploit**	H	L	MH	6%
Total			50%	30%	20%	100%

Source: Technopolis Group (2025) based on Delphi survey

Implications for prioritisation of technology trends and application areas

Investment Option 1 acknowledges that there will be developments in all areas of digital technology of great importance to the future of European industry and society more generally, and as such, all 13 technology areas should continue to be covered under the new programme (each with a much larger budget compared with the current Digital Europe Programme). However, the proposed funding distribution is skewed in favour of those **technology areas with the greatest potential for delivering advances in competitiveness and productivity.** The priorities reflect the feedback from the Delphi survey on the potential impact of the widescale deployment of each of the 13 broad technology areas on European productivity by the mid-2030s. The top five areas, in descending order (where AI was ranked first), are:

- AI (e.g., AI Agents / Multi-agent systems)
- Interoperability (e.g., Platform Neutrality)
- Cybersecurity (e.g., Ransomware & Extortion Protection)
- Advanced digital communications (e.g., Mobile networks [5G, 6G])
- Data (e.g., Advanced data analytics (prescriptive), real-time analytics and implementing AI in Data Analytics)

Moreover, cross-cutting activities also have strong potential to impact productivity, including actions with a broad or technology-agnostic focus, such as many of the European Digital Innovation Hubs or digital skills initiatives.

The deployment of these productivity-boosting applications is expected to be driven by various economic sectors from advanced manufacturing through high value services to public administration, with these early adopters supporting the development of applications and the wider rollout to other sectors like construction, retail or tourism. Interoperability is a foundation stone, playing an important role in the digitalisation of public services and those enhanced and more cost-effective systems can in turn contribute to the EU's wider competitiveness.

We have also used the feedback from stakeholders to reflect on the mix of investments, with the understanding that IO1 will continue to provide support through the same types of investments to those used under the current programme.

A degree of rebalancing of the overall funding is proposed in favour of the deployment line, in recognition of the substantial investments directed to the creation of new infrastructure and networks under the current programme. Under this investment option, deployment activities account for 50% of the total available budget.

It is further assumed that a future programme would invite its wider partners and stakeholders – at European and MS levels – to identify complementary policy interventions to maximise (system-wide) synergies, whether that is ad hoc collaborations, like InvestAI, where the EC and EIB are planning to invest €20 bn in the creation of four new AI Gigafactories, or Member States' own efforts to support the digital transformation, whether that is major investments in national infrastructure (e.g., extending the roll-out of 5G) or fiscal measures (tax breaks) to accelerate adoption of key digital technologies.

4.4.2 Benefits and Drawbacks

Key Benefits

The principal benefits from this investment option will be to help maintain current rates of adoption of frontier digital technologies by Europe's advanced users and to boost the rates of diffusion of digital technologies within the wider economy. The former will help to underpin the international competitiveness of Europe's strategic industries, while the latter should deliver small but useful productivity gains across tens of thousands of European businesses in every sector that engages with the programme, including government. This should deliver wider economic benefits through the protection of jobs for example in critical industries and the improvement of prices and service quality (from productivity gains) that will be shared in part at least (through market forces) with other businesses and consumers.

Given the new programme can build on the past investments of DIGITAL (e.g., new infrastructure has been created and is ready for use), there should be a substantial increase in the numbers of end-users that are being reached by the programme (indirectly, in a majority of cases still) and achieving a critical mass of adopters could trigger a groundswell of investment (unfunded by the programme) as competitors emulate the actions of their peers.

The investment option will likely deliver few major benefits in terms of reduced technological dependencies because of its design parameters: the scale of investment, the balance of support across both general deployment and frontier technologies and a commitment to support developments in every technology area. In short, it will deliver small benefits for the many rather than deep benefits for the few.

These impacts are summarised in the following table using a standard set of impact types and these have then been rated by the study team, in very broad terms, based on the evidence from the study. We have used a simple, 7-point scale where three pluses is a 'very high impact', +/- is neutral and three negative signs is a 'very low impact.' We have briefly explained our ratings in the description and the key to the scale is shown below this.

Table 31 Summary of high-level benefits and impacts: Investment Option 1 (productivity)

Benefit types and impacts	Description	Rating
Adoption of digital technologies, including for SMEs	Higher than baseline, as productivity is the primary focus of the option, but framework conditions may constrain extent of the transition	++
Productivity benefits for adopters, including for SMEs	Higher than baseline, as productivity is the primary focus, and it will be further driven by an expansion in overall investment and the ability to take advantage of existing infrastructure established under the current programme to reach a larger number of users	+++
Reduced dependencies	Neutral, as it is not a primary focus and while there will be an increase in investment it will favour deployment	+/-
Reverse dependencies	Neutral, as it is not a primary focus and while there will be an increase in investment it will favour deployment	+/-
Economic impact	Higher than baseline, as there will be increased investment and sharper focus on deployment for productivity	++
Social impacts	Somewhat negative, as it is not a primary focus and while there will be an increase in investment it will favour productivity advances over social impacts	-

Benefit types and impacts	Description	Rating
Environmental impacts:	Somewhat negative, as it is not a primary focus and while there will be an increase in investment it will favour productivity advances over environmental impacts	-

Rating	Description of gradation
+++	Extremely high
++	Very high
+	Somewhat high
+/-	Neutral
-	Somewhat low
--	Very low
---	Extremely low

Costs/Drawbacks

There are several drawbacks to the option, with the most obvious being that an investment option directed to a broad set of productivity-boosting applications may fail to deliver on Europe's ambitions to achieve strategic autonomy in various critical digital technologies, such as semiconductors, where the US, China and the Far East dominate global markets and where this study suggests the leaders are increasing the gap with the second and third tier. A productivity-led strategy would emphasise broad support for all digital technologies and all applications and sectors, which would necessarily reduce the intensity of investments within the context of a finite programme budget, possibly below the levels needed to sustain or establish European leadership in a critical technology. Moreover, a commitment to catalysing widespread deployment of advanced digital technologies would be complicated and possibly be undermined by the inclusion of conditionalities regarding the origin of those digital solutions: European-developed solutions may not match international offerings or may not be sufficiently widely available.

A primary focus on delivering productivity gains may mean there is less capacity to invest in deployment activities that prioritise social or environmental benefits, so for example, concerns about the digital divide among certain socio-economic groups or regions would be a lower priority here. Likewise, the option's commitment to accelerate the rate of adoption of the most powerful cloud-based solutions across industry and government would add to pressures on Europe's energy systems with a potential increase in emissions as a result. In both cases, it is conceivable that calls for proposals could target productivity boosting activities that also deliver social or environmental benefits. However, such conditionalities are unlikely to be appropriate in all cases.

4.4.3 Framework conditions & stress-testing

Framework conditions

The study suggests that for most European organisations, across both the public and private sectors, digitalisation is hampered by uncertainty as regards the relevance of solutions and the balance between the evident risk and any future rewards. For many organisations, the adoption of new digital solutions tends to happen through their periodical investment in and replacement of existing systems and equipment. Deployment programmes can accelerate digitalisation – even where it is embodied in other products and services – by showcasing solutions that are already in use by one's peers or presenting use cases that explain 'the what and the how' of adoption for specific digital solutions along with a concrete analysis of the costs / risks / rewards of needed investments.

Investment Option 1 has the capacity to change the conversation about digital skills, albeit it may need to change focus, moving beyond the creation of new skills in deeply specialist areas like HPC PhDs, to persuading employers of the benefits of reskilling or supporting training providers with updated curricula or other pedagogic tools. The programme does not have the spending power to plug the skills gaps itself and would be better placed coordinating developments alongside Member States (education is primarily a Member State competency) and employers. Nonetheless, it has a position within the EU ecosystem to help Member States and others reduce skills shortages and improve the functioning of labour markets.

While Investment Option 1 is well placed to address the classical market failures of uncertainty and information asymmetry at the level of individual adopters, it may do less well with the emerging contextual issues of disinformation and trust. This may be a suitable topic for sector or technology specific studies, however, at this point, it would likely require a much bigger multilateral push by governments across the EU and globally to arrive at protocols and codes of conduct that can begin to build back trust.

The study has also looked at the issue of regulation and its potential to drive or hold back the digital transition in Europe. Some contend that over-regulation, especially in tech, is contributing to the EU's poor growth and weakening global competitiveness of both the tech industry and wider industrial sectors. Consumers are potentially disadvantaged too, where global tech firms withhold innovative services from their European consumers as a result of EU laws. Moreover, competitor countries like the UK and the US are taking a deliberately permissive approach to regulating newer technologies like Artificial Intelligence. Others insist on the need to maintain stringent regulatory frameworks that respect fundamental human rights and point to the EU AI Act as a piece of legislation that could turn Europe into a global hub for 'trustworthy' AI. With its focus on deployment, Investment Option 1 could be an important catalyst for accelerated adoption of AI solutions reducing uncertainty, championing high standards and directing would be adopters to make more informed choices about what systems they invest in and how those tools are used.

Stress-testing in different scenarios (from workshops)

Investment Option 1 should provide a reasonable degree of robustness were Europe to confront a severe worsening of external circumstances, with its broad focus offering a level of flexibility where the area-specific strategies and annual work programmes can be reframed and rebalanced in response to new developments.

While there are limits to what can be achieved, depending upon the severity of the events in question, the recent experience with the global chips' shortage (where the pandemic triggered a spike in demand while also restricting supply), suggests this option has the breadth to allow the EC to rebalance investments to address major new policy requirements. The crisis exposed vulnerabilities in the strategies of most industries around the world, with the shortages causing major social and economic disruption, and triggering a political rethink about external dependencies. The EU Chips Act (2023) was a direct response to the crisis, and the current Digital Europe Programme was able to refocus on this new challenge helpfully launching new initiatives and rebalancing its funding within an annual cycle to begin to strengthen the EU's semiconductor ecosystem and supply chains. DIGITAL is consolidating and extending EU capabilities in areas of existing strength, and in parallel, the EU RDI Framework Programme is supporting advanced research in next generation technologies like quantum.

The risks have not been eliminated, however, and this area remains under pressure with European technology companies facing a difficult and uncertain geopolitical environment (e.g., the ongoing conflict in Ukraine and global trade tensions) and exploring all options from switching suppliers to reshoring production. A dramatic increase in tariffs would bring additional pressure for Europe's remaining semiconductor industry and its global price-competitiveness, while Europe's technology companies may confront substantial price rises (for key imports). That could in turn improved EU demand for European sourced hardware, software and services, albeit many digital products and services produced in Europe will tend to have a high global content that would be hard to replace with equivalent technologies, and there is a wariness of pivoting from US to Chinese technology.

War in Europe is entirely possible within the next five years, extending beyond the conflict in Ukraine, and Member States are rethinking their domestic policies on defence and dual use technologies, which may in the near term lead to an expansion in national investment in digital technologies and a willingness to co-fund a larger number of pan-EU initiatives, including those launched through the digital strand of the proposed European Competitiveness Fund. However, should there be further conflict, through for example, Russian incursions into Finland or the Baltic States, it may be that the attention – and finance – of all Europe would move to operational matters away from research and innovation. The possibility of conflicts further afield, in the Middle East or Far East, may be less disruptive financially but could be deeply challenging for global supply chains as has been shown by the war in Ukraine and the pandemic before that. Likewise, there is an expectation that Europe and the world will be subject to a growing number of more sophisticated cyberattacks, with AI-powered attacks bringing things to a new level and the scope of both public and private vulnerability grows with the progression of the digital transition.

There are many other external factors challenging the precarity of public finances, from ageing populations to living with climate change, and these chronic issues could easily worsen, exacerbated by various other threats.

Investment Option 1's prioritisation of deployment would be a good response to these wider developments, which would tend to trigger shortages and drive-up prices. A productivity focus would help contain inflation and sustain competitiveness, protecting employment and consumers. This general sentiment may be especially important when it comes to supporting EU businesses and public bodies in their efforts to ride the AI wave and deliver gains in terms of service quality and productivity, to the benefit of Europe in general, whether that is through improving healthcare or transforming transport and mobility.

Overall, Investment Option 1's diversified strategy does provide it with intrinsically higher levels of flexibility and a readiness to adapt to major changes in external threats or opportunities.

4.5 Investment Option 2: Competitiveness: Resilience

Main policy objectives

Investment Option 2 echoes the general objective of Investment Option 1, with a primary focus on strengthening EU competitiveness. It differs from Investment Option 1, and the current DIGITAL programme in its ambition to deliver **greater strategic autonomy and resilience in critical areas.** It still has considerable thematic breadth, in terms of the range of technology areas covered, however it is more differentiated in terms of its investment levels with several **major funding uplifts specifically related to AI and Cybersecurity**.

This study's research has confirmed Europe's relatively weak position internationally in all 13 digital technology areas in scope. Within that overall picture of dependence, the experts judged the technology areas where there is the greatest current dependence as being in: AI, NGI, Blockchain, Cybersecurity, Microelectronics and Photonics. Reviewing the feedback on the likely level of future resilience under higher and lower funding scenarios revealed an expectation that Europe has the greatest potential to improve its resilience and strategic autonomy in the areas of AI and Cybersecurity, as well as NGI and Advanced Communications. In addition, stakeholders prioritised Cybersecurity (81%) and Artificial Intelligence (80%) in a future EU programme supporting the adoption and uptake of digital technologies.

Implications for prioritisation of technology trends and application areas

Investment Option 2's focus on a narrower group of selected technology areas that are critical to Europe's future competitiveness and where there is a chance to contain or reduce current high levels of dependence on global suppliers, will mean proportionately smaller increases in future investment in other technology areas like GovTech, Photonics or Blockchain. Likewise, the focus on these other technology areas will be reframed in some degree to support the resilience agenda, whereby future investments in the earlier deployment of advanced Microelectronics may focus on certain types of chips that deliver the greatest speed and efficiency for AI-specific applications. AI chips include graphics processing units (GPUs), field-programmable gate arrays (FPGAs), and application-specific integrated circuits (ASICs) that are specialised for AI. We might also see greater emphasis on RISC-V processors that use an open-source instruction set architecture (ISA) to allow innovators to develop processors without paying royalties. Similarly, while Interoperability / GovTech is not a primary focus of

Investment Option 2, this area can provide a helpful foundation to wider efforts to reduce Europe's dependencies. A future programme should continue to work hard ensuring the openness and interoperability of applications coming onto the market, for deployment in public services for example, which should improve resilience, inasmuch as those more open applications can be substituted more readily where a provider changes its prices, or terms and conditions or withdraws a product. Global technology firms tend to prefer closed ecosystems that create a level of lock-in for clients to maximise income and ensure the margins exist for the continuous improvement of their products and platforms. Those proprietary interfaces can have great benefits, however, they also bring dependencies and can have negative implications for digital sovereignty.

The funding distribution, compared with the current programme, reflects the areas singled out as being both strategically important for Europe's future competitiveness and an area of high dependency, as defined through the Delphi survey and workshops.

The changing levels of funding across technology areas are relative, however, as the substantial increase in the overall level of investment being proposed for the digital pillar of the European Competitiveness Fund will allow a future programme to invest in all these technology areas at similar or greater levels than was the case under the Digital Europe Programme.

Table 32 Investment prioritisation for Option 2

	Resilience priority	Dominant mode	Deployment	Technology Infrastructures	Skills & Ecosystem	Total	
AI	**VH**	Build & Exploit	VH	VH	H	21%	21%
Advanced Digital Comms	**H**	Build	MH	VH	M	10%	10%
Blockchain	**M**	Anticipate	M	L	L	1%	1%
Cloud-Edge-IoT	**H**	Build	MH	VH	MH	9%	9%
Cybersecurity	**VH**	Build & Exploit	VH	VH	MH	16%	16%
Data	**H**	Build & Exploit	H	H	MH	8%	8%
HPC	**M/H**	Build & Exploit	H	H	M	5%	5%
Interoperability/Govtech	**L**	Build & Exploit	MH	MH	L	5%	5%
Microelectronics	**M/H**	Build	MH	VH	MH	9%	9%
NGI	**H**	Build & Exploit	H	MH	M	4%	4%
Photonics	**L/M**	Build	L	M	M	2%	2%
Quantum	**M/H**	Build	M	MH	M	3%	3%
Robotics	**M/H**	Build & Exploit	M	MH	M	3%	3%
Crosscutting	**M/H**	Exploit	MH	M	MH	4%	4%
Total			30%	45%	25%	100%	100%

Source: Technopolis Group (2025) based on Delphi survey

Table 33 presents a list of indicative examples of technologies for selected sectors. The examples focus on AI and Cybersecurity, as these are particularly pertinent for Investment Option 2, with its emphasis on resilience and where our Delphi survey suggested these were especially critical. As a case in point, the study has identified considerable interest in the development of secure over-the-air (OTA) solutions that would allow safe and timely software updates of connected vehicles. This is an ambition in all transport modes, with the security issues being especially critical for more complex situations like aviation or rail.

Table 33 Indicative AI and Cybersecurity developments expected to be implemented in various sectors

Sectors	Examples of applications and use-cases
Aerospace	**AI**: predictive maintenance, UAV navigation, air traffic optimisation, defect inspection, autonomous control, structural monitoring **Cybersecurity**: Secure OTA update pipeline for avionics software, Intrusion-detection in aircraft cabin networks
Finance	**AI**: Fraud detection, algorithmic trading **Cybersecurity:** Bank-wide migration to quantum-safe PKI, AI-driven fraud and anomaly detection in payment streams
Health and pharma	**AI**: medical imaging, predictive analytics, robotic surgery, virtual assistants, drug discovery, clinical trials, personalised medicine, supply chain optimisation **Cybersecurity**: Zero-trust network segmentation to limit ransomware spread in hospitals, EU digital-identity wallet for cross-border e-prescriptions
Mobility, Transport and Automotive	**AI:** autonomous driving, driver assistance, predictive maintenance, smart traffic management, intelligent public transport and logistics **Cybersecurity:** Secure over-the-air firmware for connected vehicles, In-vehicle intrusion-detection and isolation
Public administration	**AI**: AI chatbots, service design, fraud detection, budget forecasting, risk analysis, policy support, transparency and audit tools **Cybersecurity**: digital-identity wallet integration for citizen portals, Ransomware-resilient back-up policies for municipalities

Source: Technopolis Group (2025)

4.5.1 Benefits and Drawbacks

Key Benefits

The principal benefits of this investment option would be a reduction in Europe's dependence on several of the most critical digital technologies, which would in turn support the realisation of several wider benefits, including greater cybersecurity, improved economic resilience through shorter and more robust supply chains and the increased international competitiveness and economic performance of several European technology sectors.

The Delphi survey explored the implications of higher and lower funding scenarios on Europe's strategic autonomy in digital, in both the medium and longer term. From this analysis we see that the experts anticipate that for every digital technology area, a substantial increase in available funding for that field, compared with the current programme, would tend to reduce the level of dependency and increase reverse dependences in some degree. By contrast, a substantial reduction in funding is expected to result in a worsening of Europe's dependence on international technologies. Europe's dependencies in Cloud, HPC and Microelectronics are judged to be relatively more sensitive to higher or lower funding scenarios – while it is less so for Photonics, Blockchain and Quantum. Given the ambition to improve strategic autonomy *and* drive competitiveness, it is proposed that option 2 should focus on two or three of the most critical and pervasive applications.

Given their pervasiveness, investing heavily in AI and Cybersecurity areas ought to result in relatively greater productivity gains for early adopters as well as greater strategic gains in terms of reduced dependencies in these areas at least. The relatively smaller levels of investment in other technology areas may reduce deployment and potential productivity gains in those technology areas, as compared with Option 1. However, the increased budget overall, should allow a future programme to match or exceed the investment levels and achievements of the current programme (the baseline) across the broad swathe of technology areas.

These benefits are summarised in the following table using a standard set of impact types rated by the study team, in very broad terms, based on the evidence from the study.

Table 34 Summary of high-level benefits and impacts: Investment Option 2 (Autonomy and Resilience)

Benefit types and impacts	Description	Rating
Adoption of digital technologies, including for SMEs	Higher than baseline, as investment will be higher and the selective focus on strategic digital technologies like AI and cyber which have widespread relevance across the public and private sectors	++
Productivity benefits for adopters, including for SMEs	Higher than baseline, as investment will be higher and technologies like AI will deliver productivity gains	+
Reduced dependencies	Higher than baseline, as investment will be higher and a sharper focus on selected critical technologies should promote autonomy	++
Reverse dependencies	Higher than baseline, as investment will be higher however the increasing investment of competing regions will constrain this	+
Economic impact	Higher than baseline, as there will be increased investment and a focus on critical technologies relevant to key European sectors	++
Social impacts	Somewhat negative, as it is not a primary focus and while there will be an increase in investment it will favour productivity advances over social impacts	-
Environmental impacts	Somewhat negative, as it is not a primary focus and while there will be an increase in investment it will favour productivity advances over environmental impacts	-

Costs/Drawbacks

There are several drawbacks to Option 2, with the most obvious being that an investment that is focused on a narrower set of technologies than was the case for the baseline (or Option 1) may fail to provide the necessary levels of support to the broader digital technology landscape and opportunities could be missed.

Perhaps the single biggest risk with Option 2 is the temptation to only support technologies developed in Europe, which may be short sighted where specific, globally sourced technologies are intrinsically better in performance terms and likely to be developed more quickly as a result of larger investments and larger user bases. Reversing dependencies is likely to take many years – if it is possible at all – and consume a disproportionate share of available public resources, meaning other areas may be underserved. There would need to be clarity of thought within the implementing bodies – and work programmes – to avoid choosing the wrong emerging technologies to promote. Such commitments could also have profound implications for end users adopting digital technologies that work less well than those being used by their competitors in other regions or become obsolete within one or two cycles.

A primary focus on resilience may mean there is less capacity to invest in deployment activities that prioritise wider social or environmental benefits, so for example, concerns about the digital divide among certain socio-economic groups or regions would be a lower priority here, as with Investment Option 1.

As an environmental drawback, Artificial Intelligence has significant environmental impacts due to high energy consumption, water use for cooling data centres, and growing electronic waste from hardware. Likewise, a commitment to promote the adoption of sovereign cloud may add to pressures on Europe's energy systems with a potential increase in emissions as a result. In both cases, it is conceivable that calls for proposals could target resilience activities that also deliver social or environmental benefits. However, such conditionalities are unlikely to be appropriate in all cases.

4.5.2 Framework conditions & stress-testing

Framework conditions

Expert feedback through the Delphi survey anticipates that many wider framework conditions, including EU cohesion, demographics, legal frameworks, geopolitical reconfiguration and shifts in global trade, will have a high impact (constraining) on the deployment of all digital technologies. Investment Option 2, with its strategy of funding two or three technology areas at a scale sufficient to deliver improved strategic autonomy will directly address several of these conditions, and in particular the implications of geopolitical tensions and shifting global trade. Investing selectively also means it should have the scale to address several other wider framework conditions, and in particular the issues of demographics and ethics.

The emphasis on AI and cybersecurity means it should be able to shape its investments to comply with and lead the application of key pieces of legislation, like the EU AI Act (2024), with its staggered implementation timelines, and the EU Cyber Resilience Act (2024), which will come into force from December 2027.

Stress-testing in different scenarios (from workshops)

Investment Option 2 has been conceived to address several major contextual factors, and in particular the vulnerability of the continent to the evident and worsening geopolitical tensions, rising cyber-crime and trade disputes between the US and China.

Investment Option 2's strategic focus on cybersecurity, is both a recognition of the growing threat (cyberattacks have become more frequent, sophisticated, and damaging) and market demand for solutions and an acknowledgement that many of the leading cybersecurity companies are not EU businesses, whether that is the pure players like Fortinet (US) or Darktrace (UK) or the big IT companies with a cybersecurity capability (Cisco, IBM, Microsoft). The fast-evolving landscape of cyber threats poses substantial risks for individuals, businesses, and governments around the world, necessitating robust cybersecurity measures and significant investments to protect digital assets and ensure the resilience of digital infrastructure. A deployment programme with a major strategic focus on cybersecurity could be hugely beneficial to helping businesses cope with this rising threat both through the development / roll out of strategies like zero-trust architecture and the creation of more sandbox environments to continuously check different types of vulnerabilities.

While much of AI relates to the deployment of software, its performance does rest on physical entities like AI chips or powerful data centres currently dominated by the US (AI GPUs) and China's control of rare earth elements. There is a question mark around timing, and whether the EU can move forward fast enough to create a much-expanded EU AI infrastructure ahead of possible major price rises or export restrictions. These trade barriers may also trigger larger and earlier inward investment – to the EU – by the leading global technology businesses looking to maintain access to large markets where pricing may be impacted negatively by tariffs or legal restrictions on the origins of certain types of digital services (e.g., pushing towards EU or sovereign cloud solutions). The much-discussed idea of a Digital Services Tax or reformed rules on corporation tax appear to have been postponed as the EU seeks to secure a trade deal with the US but were these to be put back on the agenda and introduced in the next 3-5 years, there would likely be additional costs for Europe's digital services companies as well as potentially a reduction in access to services of the global leaders.

4.6 Investment Option 3: AI Continent

Main policy objectives

Investment Option 3 takes the EU's AI Continent Action Plan,[338] launched in April 2025, as its inspiration applying an AI focus to all aspects of a future Digital Europe Programme. The Action Plan resonates strongly with the evidence we have derived from our desk research and consultations, pushing for the development of European-made AI models, ensuring access to high-quality data, training a skilled workforce, and supporting AI innovation more generally, while upholding human-centric values and ethical AI development associated with the European Social model.

The overall objective is to reinvigorate the EU's global competitiveness through continent-wide investment in all things AI, making Europe the leading AI continent by enhancing its computing and data infrastructure, fostering AI skills and talent, promoting the development and adoption of AI in strategic sectors, and simplifying regulatory compliance. It has a sharper focus on a single critical technology, albeit a pervasive one that intersects with most other digital technologies. It also differs in its commitment to invest at scale in both infrastructure

[338] https://digital-strategy.ec.europa.eu/en/library/ai-continent-action-plan

development and deployment, whereas Options 1 and 2 give greater weight to deployment, capitalising on the recent infrastructure investments under DIGITAL.

Implications for prioritisation of technology trends and application areas

Investment option 3 gives equal weight to two principal audiences: the EU's tech industry and the EU's users of AI solutions.

The sharp focus on AI means the programme will be able to invest at an unprecedented scale in all aspects of the deployment of AI technologies relevant to Europe's public and private sectors, addressing both major application areas (e.g., automotive, health, public administration) and supporting the EU technology companies developing and supporting the roll out of those applications.

Even with a substantially expanded budget for a future digital programme, Investment Option 3 will need to strike a balance between support for the creation of new technological infrastructure, like AI Gigafactories, and support for strengthening the AI capabilities of existing infrastructure. The previous programme has created a substantial portfolio of facilities that are bringing together developers with advanced users on the one hand and supporting awareness raising and adoption among smaller businesses on the other, and this is likely to be a more cost-effective route through which to ensure the optimal uptake of AI solutions. The big-ticket items are more likely to make the difference in terms of catalysing radical innovations of benefit to Europe's advanced users, however, each item is likely to be many times more costly, and time consuming to set up, than a very much larger number of investments in existing facilities.

This option includes relatively lower levels of support for other digital technologies at least for those aspects that do not have a strong interplay with the deployment of AI in the medium term.

The following table presents a funding grid that reflects both the importance of AI as a critical technology in its own right and as an enabler of performance enhancements in many other technology domains, where feedback from our stakeholders and Delphi experts has allowed us to weight the relative importance of the synergies between each broad technology areas and AI (see the left-hand column, AI Synergy Priority), with for example substantial increased investment in AI, Cyber, Cloud and Robotics. The distribution across the funding pillars has also been shifted slightly, to give greater weight to deployment and skills relative to the share of funding under the current programme and reducing slightly the level of support for infrastructure investments and ecosystem development, albeit these pillars would still see a substantial increase in absolute terms under this investment option.

The skewedness of the funding distribution towards AI overstates the degree to which other issues would no longer be considered for support within a digital deployment programme. Interoperability is a case in point, whereby the small share of the overall budget being earmarked for activities that are focused primarily on interoperability – sufficient to support the kinds of initiatives recommended by the European Commission's Apply AI Strategy[339] to build an AI toolbox for – does not preclude consideration of interoperability issues within the AI-first initiatives. Indeed, it is an aspect that should always be reflected upon in any call.

[339] European Commission. (2025). Communication from the Commission to the European Parliament and the Council: Apply AI strategy (COM(2025) 723 final). https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52025DC0723

Table 35 Investment prioritisation for Option 3

	AI Synergy priority	Dominant mode	Deployment	Technology Infrastructures	Ecosystem & Skills	Total
AI	VH	Build & Exploit	VH	VH	H	33%
Advanced Digital Comms	H	Build & Exploit	MH	VH	M	6%
Blockchain	L/M	Anticipate	L	L	L	1%
Cloud-Edge-IoT	H	Build & Exploit	H	H	M	8%
Cybersecurity	H	Build & Exploit	H	H	M	7%
Data	VH	Build & Exploit	VH	VH	L	10%
HPC	VH	Build & Exploit	VH	VH	M	10%
Interoperability/Govtech	M	Exploit	MH	M	M	2%
Microelectronics	M/H	Build & Exploit	H	H	M	6%
NGI	H	Build & Exploit	H	H	M	5%
Photonics	L/M	Anticipate	L	M	L	1%
Quantum	L/M	Anticipate	L	M	L	1%
Robotics	H	Build & Exploit	H	MH	MH	5%
Crosscutting	H	Build & Exploit	H	MH	H	6%
Total			50%	40%	10%	100%

Source: Technopolis Group (2025) based on Delphi survey

The following table presents a list of specific, AI-related technology development trajectories that our desk research and expert consultations have identified. It is split into a list of key technologies that are expected to be deployed in the medium term (left-hand column) and a list of technologies that are expected to require further research and more time before they come into general use (right-hand column). It is the medium-term needs (left-hand column) where our experts consider the ECF could accelerate the roll-out of new AI technologies and applications and catalyse earlier adoption among key sectors and across Europe more generally. As noted already, AI is a dynamic and fast-moving technology area that has potential application in every economic sector and often in combination with other technologies, and this indicative list must be understood in that light. It is highly likely that this priority list will look rather different in three years' time at the beginning of the ECF(2028).

Table 36 Key technology advances expected in the field of AI

High priority for deployment in medium term	Medium priority for deployment
Foundation models Explainable AI AI Agents / multi-agent systems Open-source AI Factual and Trustworthy AI Edge AI	Recurrent neural networks Convolutional Neural Networks (CNN) GenAI for generic text-, image-, or sound generation or domain-specific GenAI models) Biomimicry-based AI Non-silicon based new paradigms Quantum Computing and AI Artificial General Intelligence (AGI/ Strong AI) Supervised, unsupervised, reinforced, transfer learning, federated learning and causal machine learning Fairness and privacy and copyright-aware machine learning techniques AI for dedicated devices or networks such as Artificial Intelligence of Things (AIoT), Advanced Robotics and Control Novel AI-human interaction such as prompt engineering, natural user interfaces, speech recognition, intelligent personal assistants Causal AI Frugal AI / Green AI Neurosymbolic AI (former Hybrid AI) HPC for AI Multimodal (gen) AI Classic Symbolic AI

Source: Technopolis Group (2025)

4.6.1 *Investment priorities*

Following the insights derived from our AI roadmapping, we expect the specific objectives would comprise the following activities:

- Infrastructure Development: The dramatic improvement in AI capabilities has been driven in large part by scaling up existing AI systems rather than achieving scientific breakthroughs in human cognition or developing revolutionary algorithms. Assuming this principle will continue to hold, co-funding the building of ultra large-scale AI computing infrastructures, including AI Factories and Gigafactories, should provide the EU with the quality and volume of infrastructure necessary to transform AI development across the continent. While creating this infrastructure will be hugely costly, there are opportunities to build on existing investments in Europe's worldclass super-computers creating a network of AI Factories integrating massive computing power, together with energy-efficient data centres, and AI-driven automation to optimise AI model training, inference, and deployment. At the next level up, the EC has issued a call for expressions of interest in application focused (rather than research) AI Gigafactories (AIGFs) from consortia with an interest in principle in creating these €3bn-€5bn public-private partnerships.[340]
- Support for the validation of Sector-Specific Applications: The Digital Europe Programme co-financed the creation of four sector-related testing and experimentation facilities (TEFs) that are providing European SMEs in health, agri-food, manufacturing and smart cities with the means to test their latest AI-based technologies (Technology Readiness Levels 6-8) in close-to-real conditions. This investment option would follow the advice from our consultations and capitalise on past investments, by expanding their offer (increasing the range of services and volume of users that can be supported by existing TEFs) and extending the model to other strategic sectors such as energy, transport and public services. These mid-sized sector-specific facilities (hub and spoke models to extend the geographical reach of the facilities) would complement the big-ticket items (e.g., AIGFs), providing access to hundreds of smaller technology developers seeking to refine and validate their AI-based solutions in discussion with users and as a means by which to accelerate the rollout of workable and typically lower cost and more self-contained tools.
- Data Access: access to large, high-quality data sets is a crucial component for training and deploying effective AI models and there are major challenges associated with data fragmentation, access, formats, quality, all of which hinder AI models' ability to learn and produce accurate and insightful outcomes. Common European Data Spaces (e.g., the European Health Data Space, and European Data Space for Smart Communities) and European Digital Infrastructure Consortia (EDICs) will be critical actors in improving effective data quality and supporting the work of the various infrastructures already mentioned (AI Factories, TEFs, etc), ensuring a more distributed and universal infrastructure offering for EU applications developers.
- For a majority of organisations, in the public and private sectors, AI tools and systems will be embedded in other solutions that are bought rather than developed and these less sophisticated users may be encouraged to invest earlier and with a greater likelihood of success if there is good trustworthy advice available on the costs and benefits of implementation (use cases), some guidance as to the most appropriate solutions and possibly access to networks of early adopters among their peers. The European Digital Innovation Hubs have the competence to deliver these types of advice, albeit they may not have the capacity to address the intrinsic level of demand and may also need help with sector-specific issues. Working with industry and trade bodies could expand reach.
- Skills and Talent: Strengthening AI skills and talent development to ensure a workforce capable of developing and utilising AI solutions. Our desk research and consultations have confirmed the view that there are widespread skills shortages in every sector and that the skills gap acts as a brake on the deployment of AI solutions. Skills gaps are reported both for the small proportion of the workforce responsible for the development and deployment of new solutions within organisations and for the great majority of people whose roles will

[340] For more information, see https://www.eurohpc-ju.europa.eu

be enhanced or reframed by the technology. For the former there is a need to expand the total supply of specialists coming through both vocational and academic routes and, given the pace of development, there is a need for more and better online tools. For the non-specialists, employers need to do more to review the implications of AI for their operations / functions and the resulting need for skills development, targeted training programmes and learning. Likewise, the demand for talent (new joiners) is leading to an increase in supply, but education and training providers are struggling to match the explosion in demand and to support both those that are new to the workforce and existing workers. While the EC may not be best placed to deliver AI training at scale, it can support awareness raising among employers, training needs analysis, and the development of new pedagogic models and content for specific sectors and functions.

- AI Act Implementation: Working towards a streamlined and simplified implementation of the AI Act to create a clear and predictable regulatory framework for AI.

4.6.2 Benefits and Drawbacks

Key Benefits

Investment Option 3 should deliver a wide range of social and economic benefits, including both improved EU productivity, increased global competitiveness and reduced dependencies on the US and other global players for critical technologies. The types of benefits are widely reported in policy studies[341] and market research reports,[342] and these general concepts were confirmed through our desk research and expert consultations and are captured more fully in our AI technology area report. The specific expected benefits include:

- Acceleration in the rate of adoption of AI-enabled solutions across the EU and across all economic sectors, both public and private, and with a greater proportion of those solutions conceived and delivered by EU-headquartered technology firms
- Productivity benefits should follow from the acceleration in deployment, albeit the gains will differ across applications and sectors and will also reflect levels of market penetration
- Downstream economic benefits would then flow from the enhanced goods and services and productivity gains realised from accelerated deployment, with businesses, consumers and citizens potentially sharing in some fraction of those benefits through improved price-performance (market spillovers). Likewise, productivity improvements may enable EU-based organisations to compete more effectively with their international counterparts protecting and possibly even expanding employment in those sectors
- Expanding the EU market for AI-enabled solutions – and in particular supporting local development of sector-specific applications – should provide EU-based businesses with a stronger domestic marketplace that could boost their growth and reduce global dependencies in some degree. It may also lead to more global players establishing a serious presence within the EU, supporting high quality jobs and technology development
- Strengthening Europe's tech firms – through bigger markets and support for applications development – should underpin global competitiveness and secure leadership in certain niches generating higher reverse dependencies (of the rest of the world on the EU)
- Accelerating the digital transformation should deliver additional social and environmental benefits, through for example, the smarter management of major infrastructure (from transport to energy) that should result in systemic efficiency gains and a concomitant reduction in system-wide greenhouse gases.[343] Elsewhere, the further digitalisation of certain public services could deliver improved inclusivity among certain socio-economic groups that are currently under-served or otherwise disadvantaged.

---

[341] https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/europe-fit-digital-age/excellence-and-trust-artificial-intelligence_en. https://www.oecd.org/content/dam/oecd/en/publications/reports/2025/11/progress-in-implementing-the-european-union-coordinated-plan-on-artificial-intelligence-volume-1_bb04a5b6/533c355d-en.pdf

[342] https://www.mckinsey.com/capabilities/quantumblack/our-insights/the-state-of-ai

[343] Stern, N., Romani, M., Pierfederici, R. *et al.* Green and intelligent: the role of AI in the climate transition. Nature, *NPJ Climate Action* **4**, 56 (2025).

These benefits are summarised in the following table using a standard set of impact types rated by the study team, in very broad terms, based on the evidence from the study.

Table 37 Summary of high-level benefits and impacts: Investment Option 3 (AI Continent)

Benefit types and impacts	Description	Rating
Adoption of digital technologies, including for SMEs	Higher than baseline, as investment will increase and AI is almost universally applicable across public and private sectors. There are constraints however that may slow rates of adoption esp. for SMEs (e.g., internal capabilities, access to finance, skills)	+
Productivity benefits for adopters, including for SMEs	Higher than baseline, as investment will increase and AI is expected to drive major productivity gains	++
Reduced dependencies	Higher than baseline, as investment will be higher and the focus on AI deployment should create opportunities for EU deep tech	+
Reverse dependencies	Neutral, as while investment will be higher the investment of competing regions will match this and expanding EU demand will also present opportunities for international tech	+/-
Economic impact	Higher than baseline, as there will be increased investment and a sharper focus on the deployment of AI which has perhaps the greatest potential benefit for user productivity	++
Social impacts	Somewhat positive, as while it is not a primary focus there will be an increase in investment and the programme is likely to support applications of relevance to the public and private sectors with potential social impacts (e.g., distributional effects, ethics)	+
Environmental impacts	Somewhat positive, as while it is not a primary focus there will be an increase in investment and accelerated deployment should deliver environmental gains through system optimisation and through targeting energy-efficient AI solutions	+

Costs/Drawbacks

Investment Option 3's prioritisation of AI may result in lower levels of investment in other technology areas that have been found to be of critical importance through this current study. While AI is a cross-cutting technology that will benefit from advances in semiconductors or quantum computing, these are likely to be second order priorities and the total volume of funding for say AI chips designed in Europe would be very much less than a programme that was concerned primarily with regaining strategic autonomy in microelectronics.

There is also a risk that by accelerating the rate at which AI is deployed throughout the European economy, the EC will boost the domestic market for AI solutions, which could drive up imports of AI technologies and services. While EU AI businesses will benefit from a larger and more dynamic domestic market, they may not be able to scale quickly enough and international players may be able to strengthen their position, possibly even increasing global dependencies. This risk will be offset by the expected productivity gains in the wider economy, which should help to protect the competitiveness of other economic sectors and the balance of trade in those sectors.

Other risks might relate to the EC's ability to secure sufficient strategic and financial commitment from Member States and other actors (e.g., the EIB) to deliver on these ambitions and related to that there may be resistance from other actors including smaller Member States with less developed infrastructure and fewer actors with the necessary capability to play a significant role. An infrastructure led strategy could weaken cohesion, albeit that can be managed in part through the idea of different tiers of interventions (e.g., primary [AIGFs], secondary [TEFs] and tertiary [EDIHs]) that are more or less sophisticated and more or less widely distributed. Ultimately the biggest social benefits may derive from the transformation of all industry rather hosting a single AI factory.

Lastly, while there should be environmental benefits that follow on from the improved efficiency delivered by more widespread deployment of AI (e.g., more efficient logistics, optimised energy systems), many commentators foresee important environmental risks associated with the greatly increasing energy demand linked with the massive computational power required to deliver AI. The International Energy Agency's (IEA) report on Energy (April 2025) and AI suggests electricity consumption by data centres is likely to more than double by 2030[344]. The IEA report notes that while it is starting from a low base, as a share of total consumption, the predicted expansion in AI data centres is likely to be concentrated regionally and a future European programme may need to consider mitigation measures to minimise the reliance on fossil fuels rather than renewables.

4.6.3 Framework conditions & stress-testing

Framework conditions

Our desk research and consultations all point to the importance of the regulatory environment as well as other framework conditions such as dynamic labour markets (new industries mean new jobs and talent, but old industries need to reconfigure, rationalise and retrain) and investment conditions (AI infrastructure aside, the deployment of AI across all areas of the public and private sector will need huge levels of finance to support those capital investment programmes, whether that is internal finance, debt or equity).

The AI Act's insistence of human-centric, safe, ethical AI systems may push EU developers to arrive at solutions that are far more attractive and effective than those systems developed in a more permissive regulatory environment. However, there is a risk that a more stringent regulatory environment will hamstring EU-based developers, and the record-breaking investments talked about by the EC president, Ursula von der Leyen, will not deliver major breakthroughs and will largely leak out to other countries and regions directly through our strategic partners or indirectly through knowledge spillovers more generally.

Our experts flagged issues with other framework conditions, including for example connectivity, which is seen as a major bottleneck. The uneven rollout of 5G, limited fibre coverage, and the slow pace of 6G development will restrict the deployment of decentralised, real-time AI applications. According to the experts, without significant upgrades in broadband, mobile networks, and edge computing, Europe risks deepening the digital divide and excluding less urbanized regions from AI-driven innovation. Experts also argue that Europe's data infrastructure is fragmented, with limited interoperability, siloed datasets, and inadequate frameworks for secure, large-scale data sharing. High-quality, trusted datasets for critical areas like health, climate, and assistive technologies are scarce, and infrastructures for governance, security, and traceability are lacking. Without robust and interoperable data ecosystems, cross-border and cross-sector AI applications remain constrained.

Stress-testing in different scenarios (from workshops)

The desk research and surveys suggest that a major expansion in support for the development and deployment of AI throughout Europe is likely to be one of 'the answers' to most of the external development considered here, whether that is demographics, climate change adaption or health and environmental concerns. There are, however, risks to the Investment Option's sharp focus on AI, should there be a significant worsening in several external conditions, including the increasing geopolitical instability and shifting global trade or greater uncertainty around energy security (e.g., supply disruptions or price volatility).

While much of AI relates to the deployment of software, its performance does rest on physical entities like AI chips or powerful data centres currently dominated by the US (AI GPUs) and China's control of rare earth elements. The experts consulted for this study argued that Europe should focus on emerging technologies, like more efficient AI hardware, rather than seeking to challenge the US suppliers of mainstream GPUs, referencing Europe's strengths in photonics and neuromorphic computing. There is also a question mark around timing, and whether the EU can move forward fast enough to create a much-expanded EU AI infrastructure ahead of possible major price rises or export restrictions.

These trade barriers may also trigger larger and earlier inward investment – to the EU – by the leading global technology businesses looking to maintain access to large markets where pricing may be impacted negatively by tariffs or legal restrictions on the origins of certain types of digital services (e.g., pushing towards EU or sovereign cloud solutions).The much-discussed

[344] https://www.iea.org/reports/energy-and-ai

idea of a Digital Services Tax or reformed rules on corporation tax appear to have been postponed as the EU seeks to secure a trade deal with the US but were these to be put back on the agenda and introduced in the next 3-5 years, there would likely be additional costs for Europe's digital services companies as well as a possible narrowing in EU end users' access to the most innovative, AI-enabled services provided by the global platforms.

4.7 Investment Option 4: Stakeholder Priorities

4.7.1 Description and rationale

Main policy objectives

Investment Option 4 is constructed around the main stakeholder priorities identified through the study, which echo the objectives of the current programme, with its focus on the digital transition, global competitiveness and greater EU resilience around critical technologies and infrastructure. Stakeholders placed relatively greater emphasis on the need to accelerate deployment of digital technologies across all parts of the economy (78% judge this to be 'very' or 'extremely important'), to expand and enhance Europe's digital infrastructures thereby boosting access, connectivity and interoperability (77%) and to support the demonstration and scale-up of innovative digital products and services (76%). There was also broad support for a future programme with clear environmental objectives (61%) or EU values and trust (57%).

While stakeholders in the round recommend a primary focus on accelerating deployment, the stakeholder consultations confirmed a strong interest among policy makers – and citizens –in a future digital programme delivering social and environmental advances (see Section 4.2). These perspectives can be reconciled when one considers the types of applications being called for by end users, the great majority of which will deliver efficiency gains at both organisational and system levels, whether that relates to public transport, logistics or advanced manufacturing. Other policy commitments like industrial decarbonisation are also dependent upon digital solutions. Likewise, the further digitalisation of public services is expected to deliver improvements in both service quality and productivity as well as improved inclusivity among certain socio-economic groups that are currently under-served or otherwise disadvantaged. From this perspective, advancing the digital transition should deliver substantial social and environmental gains. For those concerned about the spiralling energy consumption of the growing number of data centres that underpin the digital transition, there is emerging evidence[345] suggesting that there will be a major net gain for net zero from the digital transition. Nevertheless, the feedback from stakeholders suggests that a large majority would expect a future programme to incorporate environmental – and social – considerations within its specific work programmes.

The stakeholder consultation also confirmed a broad agreement that an EU programme would provide greater added value as compared with a national or regional level initiative for most of the specific objectives, whether that was providing support for demonstration initiatives (where 70% of all respondents agreed to a 'large or very large extent' that an EU programme would add value), pooling public funding to support larger scale deployment (64%) or coordinating larger investments to avoid unnecessary duplication (62%). There were just two specific objectives where the stakeholders overall were less persuaded of the argument for inclusion within a future European digital programme, which concerned the need to address overarching societal challenges and addressing regional disparities (see Section 4.2 above).

4.7.2 Investment priorities

The investment grid has been developed based on the feedback from our Delphi survey where we invited experts to indicate the level of funding that would be appropriate for each technology area under a future programme. The support for skills has also been increased relatively to allow for a broader set of interventions to catalyse wider deployment of these critical digital technologies.

[345] A UK government report (2025) researched the impact of data centres – for certain use cases – on energy consumption associated with new digital services and the gains or losses when compared with the conventional service delivery models that are being displaced. The three use cases analysed all show a positive overall reduction in energy consumption with the move to digital. https://www.gov.uk/government/publications/impact-of-growth-of-data-centres-on-energy-consumption

Table 38 Priority Investments for Option 4

	Stakeholder priority	Dominant mode	Deployment	Technology Infrastructures	Skills & Ecosystem	Total
AI	**VH**	**Build & Exploit**	VH	VH	H	17%
Advanced Digital Comms	**MH**	**Build**	H	VH	M	10%
Blockchain	**L**	**Anticipate**	L	L	L	1%
Cloud-Edge-IoT	**H**	**Build & Exploit**	H	H	M	2%
Cybersecurity	**H**	**Exploit**	VH	H	H	10%
Data	**H**	**Build & Exploit**	H	H	MH	4%
HPC	**M**	**Exploit**	H	H	M	13%
Interoperability/Govtech	**VH**	**Exploit**	VH	H	MH	9%
Microelectronics	**L**	**Build & Exploit**	H	H	MH	6%
NGI	**MH**	**Build & Exploit**	H	H	MH	8%
Photonics	**L**	**Build**	M	M	L	1%
Quantum	**MH**	**Build**	MH	MH	MH	6%
Robotics	**H**	**Build & Exploit**	H	H	L	5%
Crosscutting	**H**	**Exploit**	VH	M	H	8%
Total			40%	40%	20%	100%

Source: Technopolis Group (2025) based on Delphi survey

As with Investment Option 1, **Investment Option 4 recognises there are developments occurring in all areas of digital technology that are of great importance to the future of European industry and our society more generally, and as such, all technology areas will continue to be covered within the new programme** (each with a larger budget compared with the current Digital Europe Programme). However, the proposed funding distribution is skewed in favour of those technologies that were prioritised (Very High or High) across a majority of stakeholders:

- AI (e.g., AI Agents / Multi-agent systems; Factual and Trustworthy AI)
- Interoperability (e.g., Semantic Data Interoperability, AI for Interoperability)
- Cloud and IoT (e.g., IoT Digital Twins, Modelling and Simulation Environments for efficiency, intelligence and optimised maintenance; Increasing Data Processing at the Edge contributing to a more resilient, green and secure computing ecosystem)
- Cyber (e.g., Ransomware & Extortion Protection; Embedded System Security)
- Robotics (e.g., Robot-AI integration; Human robots teaming and collaboration)
- Data (e.g., Advanced data analytics (prescriptive), real-time analytics and implementing AI in Data Analytics)

Priority Application Areas

The Table presents several indicative examples of applications for selected sectors, which have been identified through stakeholder surveys, workshops and desk research. It shows there is an interest to deploy digital technologies in every sector and for many applications, to support innovation, quality, competitiveness, productivity, and security.

Table 39 Digital technologies relevant for sectoral applications

Sector	Examples of applications and use-cases
Aerospace	• **HPC**: advanced design and simulation for aircraft and space systems, including computational fluid dynamics for performance optimisation and structural analysis • **AI**: predictive maintenance, UAV navigation, air traffic optimisation, defect inspection, autonomous control, structural monitoring. • **Cybersecurity**: Secure OTA update pipeline for avionics software, Intrusion-detection in aircraft cabin networks
Agri-food	• **AI**: precision farming, crop and livestock monitoring, disease detection, automated irrigation and harvesting. • **Data Analytics**: Yield prediction, supply chain optimization. • **Robotics**: Autonomous tractors, robotic harvesting • **Cloud-Edge-IoT**: Smart farming, precision farming
Construction	• **AI**: AI-driven BIM-based construction site analytics • **Data (analytics):** data analytics for construction waste management and collection • **Robotics:** Self-driving bulldozers, excavators, and dump trucks for site preparation and earthmoving also drones and ground robots for surveying, mapping, and monitoring construction progress
Cultural and creative industries	• **AI**: Generative art and music, content creation, interpretation and preservation of cultural heritage and curated experiences, digital restoration of art, IP management and auditing, etc. • **Data Analytics**: Audience tracking and engagement, content recommendation and distribution. • **Cloud**: new cloud-based networks and tools can connect cultural heritage institutions and professionals improving connections taking advantage of the digital transition. • **Robotics**: Interactive installations, museum guides, cultural heritage restoration.
Digital and ICT	• **AI**: Network optimisation, fault detection, fraud prevention, AI-enhanced 5G, personalised services, AIaaS. • **Advanced connectivity**: Self-organising and self-healing 5G/6G networks, network slicing automation, and intent-based networking for dynamic quality of service • **Cybersecurity**: Zero-trust service meshes for cloud & data-centre traffic, Confidential-computing enclaves in EU sovereign-cloud nodes.
Energy intensive industries	• **AI**: Efficiency optimisation, emission prediction. • **Data Analytics**: Load forecasting, energy usage analysis. • **Robotics**: Equipment maintenance in hazardous environments.
Energy renewables and clean tech	• **HPC**: multiscale modelling of energy systems, including wind and nuclear power, solar photovoltaics, grid management, and material design for storage solutions • **AI**: smart grids, fault prediction, energy consumption optimisation, renewable forecasting, carbon monitoring, oil & gas exploration • **Cloud-Edge-IoT**: Real-time monitoring of energy systems and consumption, improved resource allocation and enabler of smart grids
Health and pharma	• **Quantum**: Quantum computing for drug discovery and biological modelling, while quantum sensing may enable advanced imaging and diagnostic tools • **Artificial Intelligence**: medical imaging, predictive analytics, robotic surgery, virtual assistants, drug discovery, clinical trials, personalised medicine, supply chain optimisation • **Cloud-Edge-IoT**: Remote patient monitoring and personalised healthcare through seamless and real-time data processing
Logistics	• **HPC**: optimisation models for supply chains and routing, helping reduce costs and improve operational efficiency

Sector	Examples of applications and use-cases
	• **Quantum:** optimisation problems and secure communication - practical deployments remain limited at this stage but are expected to grow • **Blockchain**: real-time tracking, provenance verification, customs clearance automation, and fraud prevention through tamper-proof ledgers; platforms such as TradeLens and Everledger illustrate the impact.
Manufacturing	• **Artificial Intelligence:** predictive maintenance, QA, supply chain and warehouse optimisation, AI-based experimentation, assembly automation, generative design • **Advanced connectivity**: Smart factory networks enabling downtime prevention, predictive maintenance, real-time quality control via digital twins and edge AI, and secure segmentation of Industrial IoT • **Cloud-Edge-IoT**: Real-time data processing at the edge and industry floor, data management and security, decentralised data processing, smart manufacturing and predictive maintenance
Mobility, Transport and Automotive	• **AI:** autonomous driving, driver assistance, predictive maintenance, smart traffic management, intelligent public transport and logistics. • **Advanced connectivity:** V2X communication, cooperative autonomous driving, smart traffic management, and in-vehicle optical networks for real-time sensor data transfer • **Cybersecurity:** Secure over-the-air firmware for connected vehicles, In-vehicle intrusion-detection and isolation • **Cloud-Edge-IoT**: Edge processing and cloud storage for autonomous mobility and smart traffic management
Public administration	• **AI**: AI chatbots, service design, fraud detection, budget forecasting, risk analysis, policy support, transparency and audit tools • **Advanced connectivity**: Smart city applications (e.g. traffic, lighting, emergency response), e-government, public-safety networks on demand for disaster recovery • **Cybersecurity**: digital-identity wallet integration for citizen portals, Ransomware-resilient back-up policies for municipalities • **Interoperability and GovTech**: simplifying procurement processes, reducing time and cost for administration, improving citizen engagement mechanisms
Retail	• **AI**: chatbots, also retail enterprises use AI in marketing and sales, with businesses leveraging AI to personalise customer interactions and optimise campaigns • **Robotics**: A key application of robotics in the retail sector is the deployment of robotic informational guides. These robots, often equipped with friendly human-like features or appealing designs, roam store aisles, ready to assist customers • **Data**: the use of data and data analytics (on product flows, consumer purchasing habits etc.) can be useful for mitigating some environmentally relevant issues, e.g. reducing packaging
Security & defence	• **Quantum:** secure communications using quantum key distribution (QKD) and high-impact computational capabilities for decryption and simulation via quantum computing, quantum sensing in navigation and target acquisition. • **Cybersecurity:** Quantum-resistant key management for classified networks, High-assurance roots-of-trust in defence systems • **Cloud-Edge-IoT**: Technologies for local communication and distributed intelligence for autonomous vehicles (e.g., drone swarms) and threat detection at the edge
Textiles	• **AI**: Predictive maintenance for machinery, product QA via computer vision. • **Data Analytics**: Trend forecasting, customer behaviour analysis. • **Robotics**: Automated sewing, dyeing, and material handling.
Tourism	• **AI:** Personalised travel recommendations, chatbots for customer support. • **Data Sharing/Analytics:** Tourist behaviour tracking, real-time demand forecasting. • **Robotics:** Service robots in hotels and airports.

Source: Technopolis Group (2025) based on the study's stakeholder consultations and desk research

Implications for prioritisation of technology trends and application areas

Investment Option 4 gives relatively greater weight to the technology applications of particular interest to Europe's wider economy, which should have a positive impact on productivity and competitiveness in major application areas (e.g., automotive, health, public administration). That should also increase opportunities for the EU technology companies developing and supporting the roll out of those applications, albeit those new and expanding markets will also be open to global tech companies and the success of domestic players is not a given.

The Investment Option will also give relatively less weight to issues of strategic autonomy, as the transformation of whole sectors through the deployment of novel digital solutions will reflect the price-performance and provenance of those solutions rather than the origins of the technologies. The competitive dynamics within Europe's applications markets is unlikely to help incubate a European cloud or relaunch the EU microelectronics sector.

Benefits and Drawbacks

Key Benefits

The principal benefits from Investment Option 4 will be its support for the accelerated deployment of all digital technologies, boosting the rates of diffusion across the wider economy. This should deliver small but useful productivity gains across every sector including government, with associated improvements in price performance and competitiveness. Such a transformation should deliver wider social and economic benefits through the protection of jobs for example in critical industries and the improvement of prices and service quality (from productivity gains) that will be shared in part at least (through market forces) with other businesses and consumers.

These benefits are summarised in the following table using a standard set of impact types rated by the study team, in very broad terms, based on the evidence from the study.

Table 40 Summary of high-level benefit types and impacts: Investment Option 4 (Stakeholder priorities)

Benefit types and impacts	Description	Rating
Adoption of digital technologies, including for SMEs	Higher than baseline, as there will be greater investment available and the option will focus on user needs, including SMEs	++
Productivity benefits for adopters, including for SMEs	Higher than baseline, as greater investment available and the option will focus on user needs, including SMEs	+
Reduced dependencies	Neutral, as while there will be an increase in investment it will favour deployment and	+/-
Reverse dependencies	Neutral, as it is not a primary focus and while there will be an increase in investment it will favour deployment	+/-
Economic impact	Higher than baseline, as investment will be higher and there will be a sharper focus on user needs	++
Social impacts	Neutral, as it is not a primary focus and while there will be an increase in investment it will favour industrial advances over social impacts	+/-
Environmental impacts:	Neutral, as it is not a primary focus and while there will be an increase in investment it will favour industrial advances over environmental impacts	+/-

Costs/Drawbacks

The most obvious drawback or risk is that a focus on deployment may reduce the level of direct support available for Europe's tech firms looking to develop and demonstrate next generation digital technologies in collaboration with advanced users. The substantial increase in the level of funding for digital technologies under the ECF could mean there will be sufficient resources to satisfy the needs of both EU users and tech developers. However, accelerating deployment should help to create a bigger domestic market for EU tech firms and provide them with a set of client references from which to address global markets with greater confidence. As noted elsewhere, a bigger and more dynamic domestic market may also drive-up imports and the EU's leading tech businesses will need to compete effectively if they are to benefit substantially from an expansion in demand. The other potential risk is a programme that is committed to support all digital technology areas may mean that individual technologies do not get the level of support needed to ensure wider diffusion through the economy.

Framework conditions & stress-testing

Framework conditions

As noted above, expert feedback gathered through the Delphi survey indicates that many wider framework conditions, including EU cohesion, demographics, legal frameworks, geopolitical reconfiguration and shifts in global trade, will have a high impact (constraining) on the deployment of most digital technologies in the medium term and a very high impact in the longer term. The main exceptions, in terms of framework conditions as impediments, were global health, social disparities across Europe and the climate emergency. These are expected to have a low or medium impact on the rate of deployment of all digital technologies, with the exception of advanced communications technologies where social inequality is expected to have a limiting effect. The development of a global digital currency system is seen as being unlikely in the medium term, and as such will be of limited relevance for most digital technologies except for those applications of direct relevance to efforts to create such an international system: cyber and blockchain.

Investment Option 4's thematic breadth means that any future deployment programme with such a bottom-up character would need to consider how the actions it supports should be framed to contend with these framework conditions (e.g., demographics and skills issues may suggest greater attention is paid to the existing workforce alongside new joiners) or take advantage of them (e.g., climate change mitigation may encourage relatively more focus on cloud or advanced communications as a means by which to promote the optimisation of national and European energy systems). The more balanced investment across the three activity pillars (deployment, infrastructure, ecosystems & skills) will better equip the programme to address wider framework conditions as a point of principle, with calls for proposals and applications needing to openly address a wide range of systemic factors, from labour markets to regulation by way of access to finance.

Stress-testing in different scenarios (from workshops)

Investment Option 4 has a breadth and diversity that will provide a greater degree of flexibility in the face of major geopolitical or economic events as compared with the other three investment options. The continuing and substantial investment in all digital technologies would allow the EC to respond relatively quickly to external events, whether that is a major new piece of legislation or increasing energy security risks, rebalance investments across areas and reframing priorities for support through interactions with implementation bodies or through the annual work programmes. This bottom-up option would provide less scope intrinsically than Option 2 for the EC to address major geopolitical shocks or security issues, by virtue of its investments being more thinly spread and with many more implementing bodies.

4.8 Investment needs for deployment of digital technologies in the EU in 2028-2036/40

Besides the analysis of high-level investment options, the stakeholder consultation, foresight workshops, Delphi survey, interviews and desk research identified a list of high priority actions for digital technology deployment relevant for the shorter term by 2028 and by 2036/2040 that are summarised in this section and are presented more in detail in the technology annexes. Regarding deployment, stakeholders stressed that it is not the role of the public sector to take on the financial risks associated with early adoption and the private sector is more suited to experimenting with new deployments, especially if public co-funding is made available. Public funding for deployment can however create favourable conditions for technology adoption and should come with conditions, specifically, a commitment from beneficiaries to share lessons learned. This would help build a knowledge base that can guide future adopters and increase overall uptake.

Although investment needs are often technology-specific as they are outlined in the subsequent table, there are several common denominators, and many investment priorities cut across multiple technologies:

A key investment need lies in the establishment and scaling of regulatory and technical sandboxes that enable companies, particularly SMEs and start-ups to test innovative technologies in controlled, real-world environments under regulatory supervision. Such sandboxes reduce uncertainty by allowing innovators to experiment with AI, cybersecurity, data-sharing solutions, while ensuring compliance with EU legislation. Investment is required not only for the regulatory coordination and guidance mechanisms, but also for the underlying technical infrastructure, testing facilities, secure data environments, and expert support services.

A common shortcoming identified across all technology areas is the insufficient access of SMEs to relevant research infrastructure. Targeted investments to address this gap could unlock significant potential for more effective deployment of digital technologies.

Investment into enabling infrastructure such as secure and scalable cloud and edge computing services and interoperable data infrastructures underpins a wide range of advanced digital technologies. AI relies on high-performance computing and large datasets, virtual worlds and digital twins depend on low-latency processing and real-time data exchange, and innovations such as IoT, smart manufacturing, 5G/6G applications, and advanced cybersecurity solutions all require resilient, distributed, and trusted cloud and data infrastructure to function effectively at scale.

The acute skills shortage persistent across all technologies is a key area requiring continued investment. There is a shared understanding that a more strategic, long-term approach to education and workforce development is needed. This includes engaging students as early as middle school to generate interest in critical digital technologies. At the university level, more attention should be given to bachelor's and master's students, particularly in terms of providing them with exposure to industry. Many companies currently seek PhD-level candidates, but there is an opportunity to encourage earlier engagement through internships, apprenticeships, and in-house work experiences.

Deployment could be more effectively promoted by associated legislations which require the actual implementation of decentralised and secure technologies. Similarly, the Data Act and Open Data Directive drive the uptake of interoperable cloud, edge, and data-sharing infrastructures by establishing clear rights and obligations for data access and portability. A further example is the NIS2 Directive, which strengthens cybersecurity requirements for critical and essential entities, thereby stimulating investment in advanced cybersecurity solutions and secure digital infrastructures across the EU.

The prioritisation is presented by technology area in the Table below.

Table 41 Investment needs per critical technology (further details are in the technology reports)

Technology Area	Priority actions by 2028	Priority actions by 2036/2040
Advanced digital communication & connectivity	*Deployment:* • Mobile networks (5G, 6G) • AI-driven network management • Multi-access edge computing • Cloud-native networking • Optical communication technology • Advanced Non-Terrestrial Communication Systems *Infrastructure:* • Diversifying trusted suppliers; securing critical infrastructure • Create investment incentives, especially in underserved areas *Skills:* • Support the rollout of advanced connectivity by retaining domestic talent in telecom and digital infrastructure	*Deployment:* • Time sensitive networking and deterministic routing • Reconfigurable and Adaptive Wireless Technologies • Joint Communication and Sensing (JCAS) and Integrated Sensing and Communication (ISAC) *Infrastructure:* • Quantum technology for communication • Open Radio Access Network • Networks for AI • Ultra-dense networks • Network Function Virtualisation

Technology Area	Priority actions by 2028	Priority actions by 2036/2040
	• Address gender imbalance in the sector • Organise specialised bootcamps for skills in mobile networks, advanced non-terrestrial communication networks *Ecosystem:* • Spectrum harmonisation; More cooperation between competence centres across disciplines and Member States	
Artificial Intelligence	*Deployment*: • Foster the uptake of AI in manufacturing, automotive, aerospace (industrial AI, robotics) and their downstream services, leveraging EU's global competitiveness, with the development of sector-specific AI technology and GPUs • Energy-efficient AI/ Frugal AI • Proprietary and open-source foundation models • Trustworthy AI; • Physical AI (AI-Robotics integration) • Scale AI adoption in public sector *Infrastructure*: • Investing into AI middleware • Supporting access to sovereign AI infrastructures (chips, HPC, cloud, data centres, AI factories): • Compute vouchers for SMEs *Skills:* • Implement dual education and reskilling programmes in cooperation with technology firms focused on AI, focus on learning of specific AI technologies and tailor-made AI solutions • Leveraging the AI Skills Academy to deliver training opportunities • Development of interdisciplinary AI education programmes *Ecosystem*: • Support capital formation and funding access for AI ecosystems.	*Deployment:* • Edge AI • Quantum Computing and AI • Neurosymbolic *Infrastructure:* • Investing in addressing territorial gaps in AI infrastructure • Investing in fully sovereign AI value chain *Skills:* • Development of programmes where AI has been fully integrated across all education stages • Large-scale Public administration AI literacy / competency training • Programmes supporting career moves from Academy to Industry and vice versa *Ecosystem*: • Develop an AI Ethics "Trust Mark" for certified systems.
Blockchain	*Deployment:* • Foster the use of interoperability solutions • Greater investment in cross-border consortia; expand EBSI and harmonise cross-border services • Promoting and encouraging private sector investment to diversify EU blockchain deployment. Cross-technology: • IoT-blockchain integration • Privacy-enabling technologies (e.g. zero knowledge proofs) *Infrastructure:* • Network backbone infrastructure • Cybersecurity frameworks • Regulatory compliant infrastructure • Develop trusted nodes and integrate with sovereign cloud efforts • Sovereign cloud hosting solutions	*Deployment:* • Quantum resistant cryptography for blockchain • Cross-chain interoperability protocols • AI-blockchain integration • Layer 2 / 3 scaling solutions • Green blockchain technologies *Infrastructure:* • Quantum-safe infrastructure • Legacy system bridges • Regional blockchain infrastructure and hubs *Skills*: • Advanced blockchain architecture design • AI-blockchain integration skills • Advanced consensus design *Ecosystem:* • Global blockchain standards bodies and consortia • Industry-specific blockchain networks

Technology Area	Priority actions by 2028	Priority actions by 2036/2040
	Skills: • Education on blockchain technology awareness • Address the shortage of blockchain professionals by including blockchain in formal education and lifelong learning (e.g. CHAISE, DEP); train public sector and regulatory professionals *Ecosystem:* • Awareness raising of use cases in specific sectors • Platform for education and accessible resources • Blockchain for good • Platforms for engagement building • Ecosystem players collaborating on EU projects • Developed communities and hackathons	• Cross-border collaboration platforms • Regional blockchain networks
Cloud-edge-IoT	*Deployment:* • Support high-potential use cases, in particular in manufacturing, automotive, and security sectors • Promote the procurement of green energy by cloud providers *Infrastructure:* • Incentivise strategic placement of European data centres, efficient cooling methods, and heat reuse to strengthen green energy usage • Encourage domestic cloud providers to scale up sovereign cloud solutions • Connect capacities with pan-European cloud federation • Target critical capacities such as chips to reduce external dependencies Cross-technology: Facilitate mechanisms and instruments to foster HPC and Computing Continuum integration, including AI factories Continue rolling out fibre and 5G network *Skills:* • Invest in workforce upskilling and reskilling with additional trainings in Cloud-Edge-IoT tackling in-demand skills • Support industry-led training, public-private partnerships, and competence centres • Promote lifelong learning in Cloud-Edge-IoT *Ecosystem:* • Create an open innovation ecosystem where research and market actors actively collaborate • Address the fragmentation of the ecosystem Support the development of European cloud solutions	*Deployment*: Deploy large-scale public procurement contracts to stimulate demand for European technologies Set up a unified API layer to build a federated cloud easing the transition between providers Promote the use of European cloud service through "sovereign cloud credits" *Infrastructure:* Continue supporting the establishment of EU-based cloud computing capacities *Ecosystem*: Prioritise building a robust ecosystem enabling talent retainment and investment inflow Encourage the coordination of providers to facilitate their convergence towards common standards
Cybersecurity & digital identity technologies	*Deployment:* • Foster use cases for the deployment of quantum-safe encryption in energy and public-service systems. • Launch the EU digital identity wallet and ensure consistency across all Member States.	*Deployment:* • Use large digital twin models of power grids, transport and hospitals to stress-test cyber-resilience virtually. *Infrastructure*:

Technology Area	Priority actions by 2028	Priority actions by 2036/2040
	• Strengthen security operations centres and cyber ranges to improve early detection and rapid response. • Fund simple, affordable protection packages to facilitate compliance of SMEs with the new Cyber-Resilience Act. • Open test sites where companies can try quantum-safe and "zero-trust" security before full roll-out. • Foster the European production of secure chips for smart meters, sensors and connected cars. • Put proven AI threat-detection systems into daily use in banks, cloud providers and early adoption manufacturing facilities. • Incentivise adoption of EU-made cyber products • Support collaborative creation and sharing of anonymised sector-specific datasets within the cybersecurity ecosystem. • Continue investment in critical cybersecurity infrastructure and support to pan-European cyber security alert system *Skills:* • Expand cybersecurity education, upskilling, and reskilling programmes. • Support international talent attraction and retention initiatives while strengthening national talent pipelines. • Run intensive training courses on post-quantum crypto, secure coding and industrial incident handling. • Launch awareness campaigns for public sector and SMEs. *Ecosystem:* • Finalise EU standards and certification labels for product security and digital identities. Foster collaboration platforms connecting cybersecurity researchers with industry stakeholders.	• Finish a quantum-secure communications backbone that covers the whole EU. • Build a European "confidential-computing" cloud based on home-grown, tamper-resistant processors.
Data analytics	*Deployment*: • Support the adoption of data spaces by the public sector and society • Provide funding for the development and piloting of sectoral and cross-sector data spaces, including bases, pilots, and early deployments. • Improve SME access to advanced data analytics and AI-ready tools. *Infrastructure:* • Enhance data spaces with regulatory and technical sandboxes to support testing and innovation. • Ensure the integration of data spaces with connectivity and computing infrastructure. *Skills*: • Invest in specialised skills profiles, including engineers able to scale and operationalise models, experts in privacy-enhancing technologies, interoperability implementers	*Deployment:* • Create a large-scale EU data space consortium ("Data Airbus") to drive coordination, scale, and global competitiveness. • Establish long-term strategies and scaling funds for data spaces, including sustained EU-level funding mechanisms. • Embed ethics, trust, privacy, and security by design across all data space initiatives. • Develop sector-specific and multi-sector data space strategies, including media, finance, proximity and social economy. *Infrastructure*: • Support the rollout of connectivity and computing infrastructure. • Strengthen interoperability across domains, promoting the use of

Technology Area	Priority actions by 2028	Priority actions by 2036/2040
	(connectors, APIs, standards), and legal-tech hybrid profiles enabling compliance-by-design *Ecosystem*: • Establish dedicated funding programmes and EU-level collaboration forums to stimulate cross-border partnerships and knowledge exchange	common components, standards, and building blocks. *Skills*: • Establish EU-wide certification schemes and platforms, complemented by peer-to-peer learning opportunities. • Strengthen knowledge sharing and awareness, particularly for SMEs, on data sharing practices and data analytics technologies
HPC	*Deployment:* • High Productivity Programming & Language Models • Hardware / Software Co-Design • Specialised AI accelerators • Open-Source Software development *Infrastructure:* • Deploy hybrid HPC infrastructures integrating CPUs, GPUs, AI accelerators, quantum processors, and neuromorphic units; • Prioritise modularity and vendor diversification. • Begin coordinated investment in European microelectronics, processors, and accelerators with public-private risk-sharing models. *Skills:* • Create dedicated HPC/AI training programmes in NCCs, research centres, and industrial clusters; • Scale up EuroHPC to work more with universities and existing curricula • Launch targeted scholarships, mentoring networks, and fast-track programmes, especially for women in HPC/AI. • Expand industry-academia mobility schemes and target SMEs Ecosystem: • Pilot industrially oriented HPC/AI systems with service-oriented operating models tailored for SMEs and scale-ups (digital twins, pharma discovery, manufacturing pipelines). • Encourage co-development by research–industry–start-up consortia • Establish transparent pricing and cloud-like user interfaces. • Fund "last mile" support (maintenance, certification, long-term reliability)	*Deployment:* • Scale indigenous processor and accelerator supply chain. *Infrastructure:* • Mature hybrid systems combining HPC, AI, and quantum into operational infrastructure across Europe. • Ensure long-term continuity and interoperability of HPC infrastructure across Member States *Skills*: • Establish EU-wide collaborative talent hubs equipped with HPC/quantum facilities. • Scale continuous reskilling programmes across SMEs and research centres. *Ecosystem:* • Fully operationalise sector-specific HPC/AI platforms serving industries such as energy, automotive, pharma, climate research. Integrate digital factories optimised for sectoral KPIs. • Ensure EU-native platforms dominate industrial HPC services. • Secure data processing environments to comply with the requirements on the processing of health data (i.e. health sector)
Microelectronics	*Deployment*: • 3D stacking and wafer-level packaging for high-density integration • Chiplet and modular architecture for flexible system design • In-Memory Computing and Emerging Memories Technology • AI-Optimised semiconductor toolchains and software co-design • Novel transistor architectures beyond traditional CMOS • Open Instruction Set Architectures (e.g. RISC-V) for Custom Processor Design	*Infrastructure:* • Replace or upgrade existing pilot line equipment to maintain long-term operational readiness • Expand lab-to-fab capacities to accommodate emerging fields such as quantum computing *Skills*: • Establish long-term workforce forecasting and planning mechanisms to anticipate demand for engineers, technicians, and ICT specialists • Tie incentives and retention measures to Chips Act funding,

Technology Area	Priority actions by 2028	Priority actions by 2036/2040
	• Wide Bandgap (WBG) and Ultra-Wide Bandgap (UWBG) Material for high efficiency electronics *Infrastructure:* • Strengthen lab-to-fab transition capabilities to scale promising technologies into industrial production • Invest in pilot lines with flexible, upgradeable equipment to accommodate emerging technologies (e.g., quantum devices) and ensure long-term sustainability. • Ensure transparent and affordable access for SMEs and start-ups *Skills*: • Rebrand semiconductors as a strategic, high-tech career path • Launch EU-wide campaigns to raise awareness, attract students earlier, and promote diversity • Build dual-track pathways combining university education with vocational fab and assembly training • Expand EU-co-funded vocational schools and "Chip Academies" in hubs like Dresden, Grenoble, Eindhoven *Ecosystem*: • Support the growth of European fabless companies to strengthen design-driven demand and innovation • Encourage partnerships between downstream industrial users and semiconductor producers to consolidate demand across sectors (automotive, defence, healthcare.	ensuring mobility schemes and structured career path *Ecosystem*: • Maintain a critical mass of fabless and upstream companies to strengthen Europe's semiconductor value chain
NGI & extended reality	*Deployment:* • Digital twins and applications across sectors • Development of decentralised applications (dApps) • Industrial applications in health, pharma, education, aerospace, CCI • Enable rapid pilot deployment through local or governmental sandboxes and improving access to European-generated data *Infrastructure:* • Decentralised applications related platforms • Web 3.0 and 4.0 infrastructure that relies on privacy, security, interoperability *Skills:* • Awareness raising programmes and open-source alternatives. • Train the trainer programmes for XR • Large-scale national digital education campaigns • Virtual Worlds Skills Academy	*Deployment:* • Fog and cloud computing infrastructure • Humanistic agents • Automating virtual worlds production with AI generated contents • Public service immersive multi-user platforms Skills: • New model of educational institutions as hybrid hubs Ecosystem: • Create harmonised standards and design principles consolidating the needs of various involved industries.
Photonics	*Deployment:* • Foster pilot lines to industrial scale; • Support dedicated pilot lines specifically for standard fibre-optic cables or laser transmitter components	*Deployment:* • Invest in quantum photonic devices • Invest in unified European EDA & design kits; expand multi-material foundry access; scale 200 mm+ wafer capacity *Infrastructure:*

Technology Area	Priority actions by 2028	Priority actions by 2036/2040
	• Deploy photonic accelerators & neural networks for advanced computing • Foster the use of photonics in biomedical imaging and sensing • Deploy optical computing architectures in application areas such as high-performance computing and embedded intelligence • Deploy Photonic Integrated Circuits (PICs) in applications such as quantum photonics, LiDAR and AI infrastructure, and develop PIC design and simulation tools for their manufacturing • Invest in new materials and alternative platforms to enable the transition of heterogeneous integration from lab-scale innovation industrial deployment • Develop advanced packaging & co-integration capabilities *Infrastructure:* • Fund first-of-kind pilot lines for quantum, AI, and specialty fibres; support demonstrators for space and sensing applications *Skills:* • Expand academic & vocational training; regional training hubs; • Promote cross-technology skills in advances in AI, electronics and sustainability *Ecosystem:* • Foster growth capital for photonics SMEs	• Explore alternative platforms to silicon (such as oxide-based photonics) • Test photonics technologies in large-scale infrastructures in adjacent sectors (such as fusion energy)
Quantum	*Deployment:* • Develop quantum sensor technologies and applications/ Improvement of technologies that are fundamental to quantum sensing, communication and computation systems • Reduce error rates in quantum computers to the point of industrial viability • Develop key enabling technologies for the large-scale integration of qubits • Integration of classical and quantum computing to optimise the performance of and simplify interaction with quantum computers Improve access to quantum computing capability • Quantum metrology / related to standards and certification *Infrastructure:* • European foundries, quantum testbeds, specialised cleanrooms and metrology services, quantum computing infrastructures and cloud services *Skills:* • Target skills investments, awareness campaigns and demonstrators • Fund or promote technical degrees related to subjects like cryogenics and quantum software development	*Deployment:* • Application of quantum computing to address large-scale combinatorial problems • Application of quantum computing to model systems which cannot be efficiently simulated on classical computers • Application of Quantum Key Distribution • Improve stability and scalability in quantum information processing and storage • Quantum random number generators for the development of secure keys to protect against quantum decryption • Quantum networks *Infrastructure:* • Consolidated cloud service capabilities at EU scale and beyond • Consolidated metrological services/infrastructures, including cryogenic laboratories, quantum engineering centres, and next-generation fabrication and metrology facilities

Technology Area	Priority actions by 2028	Priority actions by 2036/2040
	• Fund and publicise demonstrations that showcase quantum technologies to a general audience *Ecosystem:* • Coordinated approach accounting for technology types and business maturity. E.g., SMEs receive support for regulatory testing, and scaleups receive access to export support and late-stage growth equity • Technology transfer, prototype validation and industrial co-development	
Robotics	*Deployment*: • Development of public-private investment mechanisms that support deployment at scale, particularly supporting SMEs and scale-ups. • Launch of sectorial regulatory sandboxes for real environment testing of robotic solutions. • Foster energy efficient robotics Support robot-AI integration across manufacturing and service-based industries. • Support actions increasing safety & dependability of deployed robots. • Focus on human-robot teaming and collaboration. • Foster the uptake of smart/advanced materials and energy efficient and energy conserving structures in deployed robots • Establish regulatory sandboxes for robotics (both technical and legal). Cross-technology: • Support the development of specialised chips for robotics • Develop end-to-end robotics platforms to train, develop, and deploy AI-enabled robots at scale. *Infrastructure:* • Support actions to strengthen simulation and computation infrastructures (HPC, robotics simulation, digital mirroring, virtual commissioning). • Development of large-scale, real-world environments where companies (especially startups and SMEs) can test and validate robotics solutions. *Skills:* • Launch of dedicated skills certification programmes in robotics. • Launch talent exchange programmes focused on robotics, leveraging existing programmes such as ERASMUS + *Ecosystem:* • Build industry-led platforms, exchanges, and leverage data spaces for robotics. • Focus on enabling sectors (construction, care homes, farming) for automation adoption. • Reframe European Digital Innovation Hubs (EDIHs) as robotics centres of excellence.	*Deployment*: • Dedicated measures to support reprogrammable / re-deployable robotics *Infrastructure*: • Reduce dependency on non-European technologies and supplies. *Skills:* • Introduce robotics classes across disciplines (CS, mechanical engineering, etc.). • Promote interdisciplinary teaching (CS, psychology, sociology, etc.). • Support school robotics competitions • Recognise pan-European certifications of skills focused on robotics *Ecosystem:* • Creating marketplace for second-hand robotics Reduce dependency on non-European technologies and supplies in robotics

Technology Area	Priority actions by 2028	Priority actions by 2036/2040
	• Advance standardisation across industries (e.g., vehicles, medical equipment, aviation).	
Technologies for interoperability & GovTech	*Deployment:* • Continue investment in interoperability solutions and support for GovTech cooperation mechanisms • Invest in broader and more frequent opportunities to experiment across technologies, including AI, blockchain and data-sharing solutions and across borders. • Increase investment in sandboxes and pilots that can accelerate learning, reduce regulatory uncertainty and support the safe scaling of interoperable GovTech solutions • Invest in standardised APIs, cloud migration, and interoperability frameworks, data integration platforms Infrastructure • Improve access to enabling infrastructure such as sovereign cloud infrastructure; domestic tech capabilities (including open source capabilities) Skills: • E-learning platforms, digital collaboration tools, targeted trainings for the public sector Ecosystem: • Demand-side initiatives from public authorities to support the emergence of start-ups and tech companies specialised in GovTech • Support the change in public procurement practices to favour interoperability and GovTech solutions	Deployment: Launch mission-oriented funding to encourage interoperability and GovTech Ecosystem: Initiate regulatory harmonisation initiatives

Source: Technopolis Group (2025) based on expert consultations and desk research

4.9 Strategic implementation and programme design

In broad terms, this study's overall findings suggest that **a future digital programme needs to be simpler, faster and more flexible than the current programme** to improve its effectiveness and its optimal ability to strengthen Europe's future prosperity and security[346]. The implementation modalities were discussed in the stakeholder consultation, in expert interviews, and assessed via desk research (e.g. interim evaluation of the Digital Europe Programme) and in-depth discussions with the European Commission and the implementation bodies involved in the implementation of Digital Europe.

Stakeholders throughout the consultation stressed **the need for greater agility in EU funding mechanisms** to broaden the appeal amongst smaller tech firms and users. This could mean reducing the burden of applying for support and by speeding up the process to better align with the high metabolic rate of innovation and deployment of innovative digital technologies.

Stakeholders argued that a future programme must do better in pursuing both its primary objectives: firstly, to encourage the early adoption of next generation digital

[346] As a note of caution, stakeholders have multiple viewpoints, and they are not always in agreement (e.g. end-users versus developers; private for profit businesses versus public research institutes), and the majority has a tendency to conceive of a future programme as something monolithic with a singular objective and a primary audience. The reality will be more multifaceted and is likely to warrant a more differentiated implementation strategy than was recommended by any single discussion partner or stakeholder group.

technologies and applications among advanced users; and secondly, to engage more broadly with organisations across the EU, in both the public and private sectors, to foster broad deployment of digital technologies.

To encourage engagement, stakeholders suggested the application process should be simplified and specifically that a two-step system should be used whenever it is appropriate. The first step is an outline use case or business case, enabling applicants to express interest at minimal cost and to receive early feedback as to whether their idea is relevant and has a chance of success within the second and final round of the competition. Applicants can test and either confirm or fail their ideas quickly. If positively received, the second step would involve applicants submitting a full proposal, but this process should remain agile, since the goal is deployment rather than research and innovation, so speed of processing remains important as does flexibility around the specific focus of the proposed activities (avoid being overly prescriptive in call documents) and a need to avoid the very low success rates typical of other programmes in the RDI space for example.

In terms of support for early adoption, stakeholders argue that the most innovative deployments should be prioritised, while acknowledging the administrative challenge of clearly defining and recognising substantive innovation potential. A minority suggested that the focus should be even sharper (not just major innovations) proposing that major innovations with dual-use applications (those with both civilian and security benefits) should be favoured, especially given current geopolitical considerations.

On the subject of making any future programme more strategic, stakeholders suggested setting measurable targets, such as increasing the yearly adoption rate of strategic technologies. Furthermore, stakeholders argued that the EC should consider introducing additional conditions or incentives to **encourage the use of European sourced technologies and solutions** within supported projects**.** The European Competitiveness Fund envisages several means through which an EU preference might be implemented practically, including for example requiring funded projects to source components or materials from other European entities as a means by which to secure their supply chains or to require that a project's decision-making process does not depend on a non-EU entity. These types of preferential conditions would need to be considered carefully, to ensure they are legally appropriate, and equally do not add complexity to the process, and thereby running counter to the most widely expressed desire of simplifying arrangements.

It was suggested that to strengthen the uptake of advanced, sovereign digital technologies, EU agencies, such as eu-LISA, should be strategically **used as testbeds, regulatory sandboxes, and early adopters of digital innovations**. By deploying European technologies in operational EU environments, these institutions can serve as trusted demonstration platforms, enabling Member States to observe their performance, assess their capabilities, and evaluate their interoperability in real-world contexts.

Paradoxically, when considering the trade-off between supporting a few champions versus promoting broad adoption, broad adoption is favoured by most stakeholders. This inclusive approach is seen as more effective for accelerating the digital transition across Europe. Stakeholders recommend that a future programme continue to support both the early adoption of state-of-the-art digital solutions involving EU tech firms and small numbers of advanced users and in parallel to support the broad adoption of more general purpose digital technologies by the great majority of organisations, public and private. This implies continuation of a bimodal strategy, as in the current Digital Europe Programme.

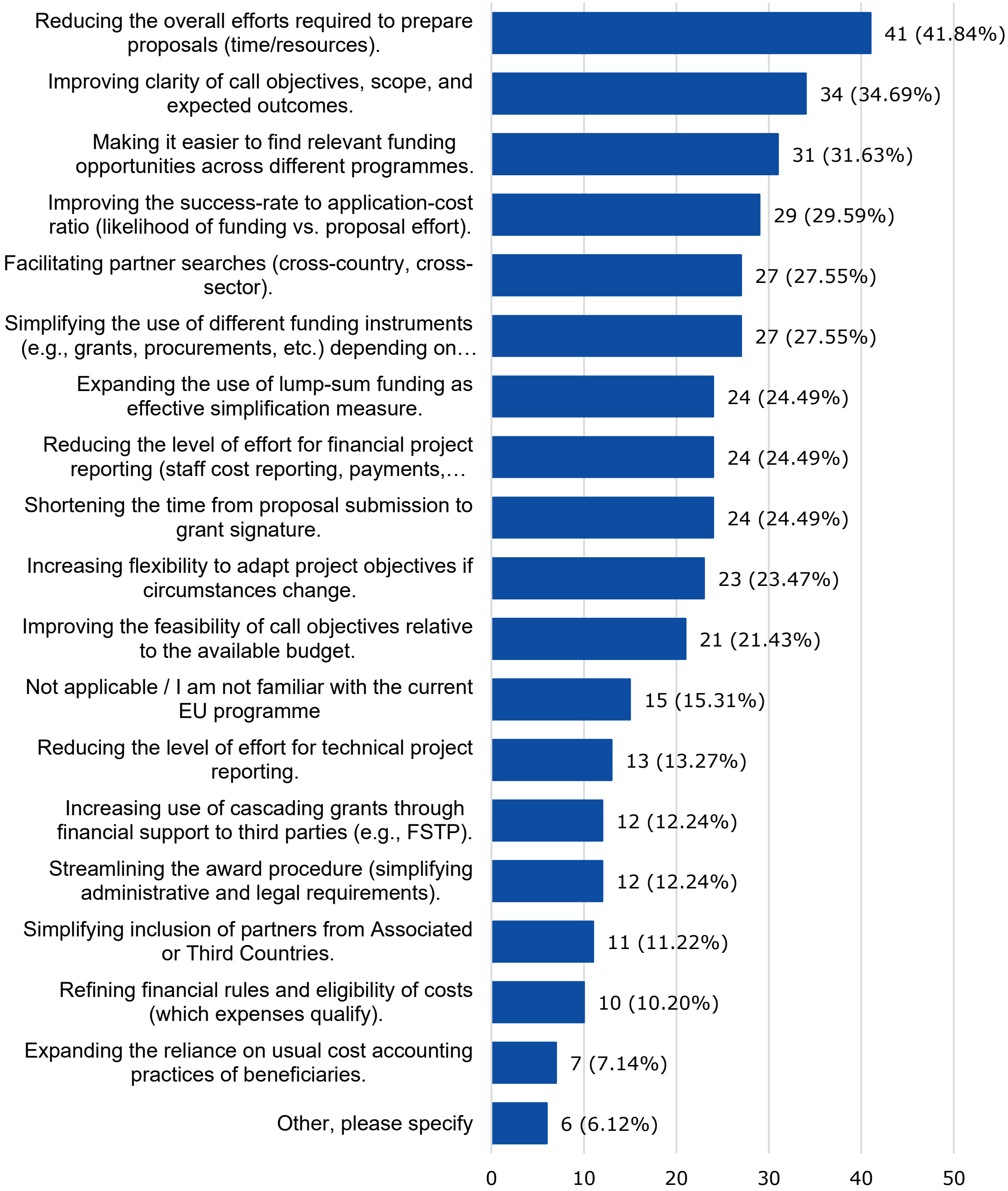
In terms of the types of projects to support adoption, stakeholders suggest that SMEs and end users need more and better access to testbeds or sandboxes, enabling these actors to experiment with new technologies in a lower-risk applications environment before full-scale deployment. This could be complemented by an expansion in the use of cascade funding (Financial Support for Third Parties) or micro-grants to ensure smaller businesses can more easily compete for access to small grants to underwrite some of the costs of their demonstration or scale-up ambitions. The change in the legal liabilities associated with this third-party funding model can reduce bureaucracy and expedite application processes as compared with bidding for Commission grants directly.

Stakeholders flagged the issue of **fragmentation in the implementation of the programme** and the potentially negative impact that can have on internal and external synergies**.** With regard to implementation, it was commented that the work programmes are currently being developed by different EU institutions or joint undertakings, which is not always optimal. Each work programme is prepared according to a distinct philosophy, structure, and logic. This distributed approach was said to be too fragmented, complicating implementation and reducing administrative efficiency while also causing delays and reducing the effectiveness of the portfolio overall.

The bar chart presents feedback from the stakeholder consultation as regards the potential benefits of simplifying future programme management arrangements for each of 17 performance dimensions, which ranged from the effort involved in preparing an application through to the ease with which future projects might include partners from associated or third countries. The chart ranks each of the dimensions in descending order of adjudged importance, based on the share of respondents that placed that particular issue amongst their Top 5. As already noted, the most widely support proposal for simplification related to the effort involved in preparing a proposal.

There were various other suggestions made that could improve the attractiveness of a future programme to a broader cross-section of beneficiaries. For example, around one-third of respondents highlighted the need to **better match call objectives to the available budget.** There was also a suggestion that there should be **greater contractual flexibility** with project officers being ready to use their discretion more often to allow beneficiaries to adapt project objectives where circumstances change, as this is a common occurrence in deployment projects rather than an occasional event as in the field of research and development. Such a possibility already exists, but stakeholders suggest a broader use. Other suggestions for simplification (to reduce burden and quicken processes) included shortening the time from proposal submission to grant signature, and expanding the use of lump-sum funding. Among the dimensions perceived to offer more moderate potential for simplification, were facilitating partner searches, reducing the level of effort for financial reporting, simplifying the use of different funding instruments depending on the call objectives, simplifying inclusion of partners from Associated or third countries, reducing the level of effort for technical reporting, and streamlining the award procedure by simplifying administrative and legal requirements. Actions that ranked lowest in terms of their expected potential to simplify a future programme were increasing the use of cascading grants through financial support to third parties (e.g., FSTP), refining financial rules and eligibility of costs (which expenses qualify for support), and expanding the reliance on usual cost accounting practices of beneficiaries, with less than 10% of respondents selecting them.

Figure 57 Margins for simplification for a future EU programme supporting the adoption and deployment of digital technologies [If you are familiar with the current EU programme supporting the deployment/adoption of digital technologies, please select up to 5 of the below items that would constitute margins for simplification for a future EU programme supporting the adoption/deployment of digital technologies?]



Source: Technopolis Group (2025) based on stakeholder survey, n=98

Working with the European Competitiveness Fund's (ECF) toolbox

The future 'Digital Europe' programme is expected to be part of one of the four policy windows (Digital Leadership) of the proposed European Competitiveness Fund (ECF)[347] and as such the new programme will be able to make use of a broader set of instruments than is the case for the current programme. As such, it will have access to the entire ECF toolbox of grants, procurement and industrial coordination alongside ECF InvestEU instruments, including

[347] EUR-Lex - 52025PC0555 - EN - EUR-Lex

financial support to start-ups and scaleups (Article 22) and Advisory Support to projects and businesses across the investment cycle[348]. This already exists under the DIGITAL programme but stakeholders suggest a further use. While this support can be accessed under the current programme, it is expected to be more extensive in future.

There are several important principles that resonate with the stakeholder feedback discussed above, including:

- The ECF should strive to create an investment culture that leverages public funding and crowds-in, de-risks private investment, to achieve funding at scale. The ECF regulation indicates an ambition to support more public-private partnerships as well as public-public collaboration. In the current programme, the 'simple grant', with a 50% co-financing rate, has been an important tool to leverage digital funding from Member States and stakeholders across the EU but has presented a challenge for some types of stakeholders, such as public administrations, universities and SMEs.
- The Toolbox should be based on simplified common procedures to reduce complexity and promote synergies between programmes at EU levels. This principle also suggests that the current programme's use of multiple implementation bodies is also likely to continue to ensure access to specialist capacities and networks and that the EC will not be required to bring all management and all sub-programmes under a single roof. Simplification will need to come through greater harmonisation in the implementation of tools and procedures, more trust based / risk sharing support and stronger shared administrative infrastructure.
- The choice of instrument should follow context, whether that is the nature of the issue at hand the nature of the industry or the stage of development or the particularities of the market failure. The use of a mix of instruments is also foreseen as a way to encircle a problem and ensure support across the investment lifecycle.

In addition to mainstream grants, procurement and coordination activities, the ECF regulation has introduced several new tools most of which are relevant to the needs of a future digital technology programme. The ECF InvestEU Instrument will provide for the use of budgetary guarantees and financial instruments. It will build on the existing procedures and features of the current InvestEU programme. The main novelty is that InvestEU, which is a demand-driven programme, will no longer be implemented as a seperate programme but implemented via annual or multiannual work programmes, e.g. under the digital policy window of the ECF. The following table provides a simple assessment of the relevance in principle of each new instrument in turn. The overall picture is one of greater strategic capacity and a legal ability to make large, market-making interventions that have the express intention of changing European competitiveness in strategic sectors. The strategic instruments are most relevant to the objective of supporting the development and early adoption of next generation digital technologies by Europe's most advanced users. The business support and skills development measures are also relevant to Europe's deep tech industry and advanced used and of especial significance to the wider deployment of digital technologies in pursuit of the digital transition.

Table 42 Main tools and their relevance to a future digital programme

Main tools in the ECF Toolbox	Relevance of tools to a future digital programme
Single Market value chains builder (Article 16) In order to foster resilient EU value chains, [ECF] work programmes may include dedicated value-chains scale up calls which shall support both project preparation and crowding in of additional public and private capital to integrate suppliers, manufacturers, and innovators from different Member States and diversify sources of supply.	Highly relevant to the objective to support the earlier adoption of advanced technologies to support EU competitiveness and resilience in strategic areas The current study has confirmed high levels of European dependence on global suppliers of critical digital technologies. A value-chain builder would be relevant in principle to all digital technology areas.
EU Tech frontrunners (Article 17) [ECF] work programmes may include dedicated two-stage bottom-up award procedures to identify and	Moderately relevant to the objective to support the earlier adoption of advanced technologies to support EU competitiveness and resilience in strategic areas

[348] See Chapters II and III of the REGULATION OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL on establishing the European Competitiveness Fund ('ECF'), SEC(2025) 555 Final.

Main tools in the ECF Toolbox	Relevance of tools to a future digital programme
support EU Tech frontrunners through industry-driven consortia leveraging on their role as innovation and export drivers to strengthen their global competitive position along with their European SME suppliers through investments in new solutions and identification of relevant partners. Project preparation as well as crowding in of additional public and private capital may be supported.	The current study has confirmed that leading European technology businesses can struggle to scale with smaller fragmented markets and lower levels of available scale up funding. A Tech Frontrunners scheme would be relevant in principle to all digital technology areas. Note: the overall feedback from stakeholders found the balance of opinion was in favour of supporting broader initiatives (supporting multiple businesses) rather than individual champions
Production Ramp up actions (Article 18) By way of derogation from Article 196(2) of the Financial Regulation, financial contributions may, where necessary for the implementation of manufacturing projects essential to support general resilience, or activities required to ensure the security, resilience or service continuity, cover actions that started prior to the date of the submission of the proposal for those actions.	Of limited relevance to either the objective to support early adoption of advanced digital technologies or the objective to accelerate deployment of digital technologies across Europe and among all sectors. The current study suggests there have been instances where external events (pandemic) have impacted demand (increased) and production (decreased) and where some additional support for manufacturing may have been relevant. The best example is the semiconductor crisis, but there may be others in for example, medicines and healthcare (i.e., non-digital)
Top Ups for IPCEIs (Article 19) The ECF may support projects directly participating in an Important Project of Common European Interest (IPCEI) conditional on national co-funding; and follow-on projects, based on results from IPCEIs, and also conditional on significant private investments.	Highly relevant to the objective to support the earlier adoption of advanced technologies to support EU competitiveness and resilience in strategic areas The current study has confirmed the three existing digital IPCEIs (in microelectronics, communications and next generation cloud and infrastructure services) with around €11.2bn in national state aid that are well regarded by participating companies and Member States. A top-up of IPCEI funding would be relevant in principle to the current digital IPCEIs and the provision of additional EU funds may also allow member states and private companies to launch new IPCEIs in other areas from AI to Quantum.
Accelerated and Targeted Actions for Competitiveness (Article 20) In order to create or facilitate the possibility of Union support to actions of imperative public interest or critical time-sensitivity, which could otherwise not be effectively implemented under the normal rules applicable to the Union budget or sectoral policies, the [ECF] work programmes may identify certain award procedures, under direct or indirect management, that may benefit from certain additions, exceptions, and derogations from applicable law, during the award procedure or implementation of the supported activities.	Highly relevant to the objective to support the earlier adoption of advanced technologies to support EU competitiveness and resilience in strategic areas The current study has confirmed high levels of European dependence on global suppliers of critical digital technologies. An Accelerated and Targeted Action would be relevant in principle to all digital technology areas , where for example there may be a need to anchor or complete a portfolio of strategic investments in a major new pan-EU infrastructure project (e.g., AI Gigafactories), inward investment (e.g., extending NVIDIA's support for regional cloud providers in France and Italy to other EU MS; or its AI Factory for Manufacturing in Germany) or flagship EU-based companies developing next generation digital technologies.
The ECF InvestEU Instrument: Support to scaleups and start-ups (Article 22) The ECF InvestEU Instrument shall serve as the Union's integrated platform for delivering targeted financial support to companies across all development phases start-ups, scale-ups, including those actively pursuing manufacturing, industrial and market deployment. It shall ensure that high-potential European companies developing or deploying innovative solutions can access the capital and resources to grow in the Union, thus strengthening	Highly relevant to the objective to support the earlier adoption of advanced technologies to support EU competitiveness and resilience in strategic areas The current study has confirmed that the EU tech industry struggles to a greater extent than their counterparts in the US to access to investment finance, with European funds favouring more mature technologies and businesses. The research also suggests that this challenging financial environment (and market conditions) mean that many deep tech businesses are now choosing to scale up outside

Main tools in the ECF Toolbox	Relevance of tools to a future digital programme
the integration of the Single market and the Savings and Investment Union.	Europe with implications for competitiveness, employment and resilience A scale-up fund would be relevant in principle to all digital technology areas.
EU for Business Network The "EU for Business" Network shall be established to help Union businesses [e.g., integrated business advice, brokering partnerships, gateway to tech infrastructures and access to finance] become more competitive and innovate, grow and scale in the Single Market and beyond, with a particular emphasis on SMEs, start-ups, scaleups and small mid-cap companies. The network shall have a Union-wide and geographically balanced coverage, taking into account the specificities of all types of regions in the Union, including the less developed regions and the Union outermost regions.	Moderately relevant to the objective to accelerate deployment of digital technologies across Europe and among all sectors. This study has confirmed that the network of EDIH's is working with tens of thousands of businesses and public bodies to raise awareness of and support deployment of digital solutions, and that these users are deriving benefits from that engagement. The scale of the problem is challenging however, with millions of businesses in every sector potentially in need of advice and support, and a bigger push in general business support could be positive for the digital transition. An EU for business network would offer greater reach than the EDIH's but there may be issues around the sectoral and thematic priorities of a 'competitiveness' network and some risk of duplication and rivalry with the nascent network of EDIHs.
Dedicated SME Actions to increase SME participation Each ECF window shall support dedicated, sector-specific actions targeting start-ups, SMEs and small mid-cap companies or calls for SMEs in strategic sectors with a view to fostering innovation, business acceleration, commercialisation and scaling-up.	Highly relevant to both the objective to support early adoption of advanced digital technologies or the objective to accelerate deployment of digital technologies across Europe and among all sectors. This study has found that SMEs (start-ups) are key players in Europe's deep tech sector, with a critical role to play in the development and deployment of advanced digital technologies in almost every technology area. A dedicated digital SME instrument could also catalyse digital transformation in more smaller companies (buying and adopting rather than developing technologies) to support new products and services, process innovations and general strengthening of their competitiveness. Note: this could overlap with the EDIHs
Support for skills development (Article 30) The ECF shall finance activities in support of skills development, in particular in the strategic sectors, building strong links between higher education, vocational education and training providers, applied research and businesses for an agile, innovative and competitive economy. This shall include support for a European Skills Guarantee to support value chain transitions in favour of strategic growth sectors or occupations across the labour market through upskilling and reskilling of the workforce and Vocational Education and Training (VET) partnerships to strengthen cooperation between VET providers and businesses, especially SMEs and connecting them with regional industrial ecosystems.	Highly relevant to both the objective to support early adoption of advanced digital technologies or the objective to accelerate deployment of digital technologies across Europe and among all sectors. This study has found that skills shortages are affecting Europe's deep tech sector on the one hand and the more general deployment of digital technologies on the other. This affects every area and relates to both new joiners and the existing workforce and that the issues of tight supply (of new people) and upskilling / reskilling are affecting both digital specialists and non-specialists that need to work with new digital applications. The challenges are also affecting all levels, from technicians through to post-graduates. The competition for AI talent has hit the headlines in recent months, with financial services companies offering base salaries in the many hundreds of thousands of Euros, which is having a knock-on effect on salary expectations more generally and raises affordability issues. The bigger problem – in terms of scale – is arguably the existing workforce (c. 200m people) that are not ICT specialists and yet need to adapt to these new systems and ways of working (products, processes and business models). Working with education and

Main tools in the ECF Toolbox	Relevance of tools to a future digital programme
	training providers to address both issues is hugely important, whether that is better forecasting of demand or the ability to develop online courses more quickly so they can reach more people and can be kept up to date and relevant. Note: the proposals are rather vague about what kinds of actions the EC can take a lead on in an area where MS still have the primary competence.

Source: Technopolis analysis of ECF legislation

Matching programme objectives and ECF tools

The figure locates the principal ECF tools in a simple 3x2 matrix where the columns reflect the three principal activities defined in the ECF regulation under the digital leadership policy that are of direct relevance to a deployment programme (Article 39 clauses 2b, c and d: respectively, ecosystems, deployment, and skills). We have not included the two other types of activities foreseen in the regulation, specifically research and innovation (clause 2a) and support for relevant legislation and policy (clause 2e) as we judged these to be out of scope, with research and innovation being seen as a focus for the digital strand of Horizon Europe 2028-2034. These three types of activity are then split by the two principal objectives that have been selected for this study and reflection about investment options, which are expected to continue to support both the early adoption of state of the art technologies amongst leading users and the encouragement of the widespread adoption of digital technologies that are new to the organisations concerned rather than new to the world.

The new ECF tools are all located in the grid, and we have included several of the existing instruments that have been used under the current programme, as these are still in scope and while they are not mentioned specifically in the ECF legislation, this is simply because they exist already. We have also included potentially other relevant instruments, which have been used previously in other EC programmes and that would be allowable under the new ECF rules. For example, the EC's public procurement of innovation (PPI)[349] tool is not mentioned explicitly, while public procurement could be particularly relevant for numerous public organisations seeking guidance and support to invest sooner in more ambitious digital solutions than they might otherwise feel confident specifying or purchasing.

Table 43 Relevance of new ECF tools for the three pillars of a future DIGITAL programme

Digital objectives / ECF strands	Ecosystems	Deployment	Skills
Development and early adoption of advanced technologies	Single market value chains builder Support to scale-ups and start-ups	EU Tech Frontrunners Accelerated and targeted actions IPCEIs [HPC clusters, AI Factories, EDICs, TEFs, etc.]	Support for skills development
Widespread deployment of digital technologies	EU for Business	Dedicated SME actions (e.g., EDIHs) Public procurement of innovation (PPI) Innovation vouchers	Support for skills development

Source: Technopolis Group analysis

349 https://research-and-innovation.ec.europa.eu/strategy/support-policy-making/shaping-eu-research-and-innovation-policy/new-european-innovation-agenda/innovation-procurement/public-procurement-innovative-solutions_en

5. Conclusions

EU policies are highly relevant for the deployment of digital technologies as they provide strategic direction, funding, and regulatory frameworks that enable faster adoption and scaling. By prioritising investments in digital infrastructure, critical technologies, supporting innovation and start-up ecosystems, and addressing skills gaps, they contribute to a supportive environment driving Europe's global competitiveness.

In the 2025 State of the Union and its Letter of Intent, President von der Leyen re-stressed that Europe must strengthen its autonomy and competitiveness. While Europe leads in research, a persistent challenge lies in scaling up innovation, making the deployment of frontier digital technologies (such as AI and quantum) essential to securing Europe's digital and economic future.[350] In her political guidelines[351], President von der Leyen announced a new plan for Europe's sustainable prosperity and competitiveness and quoted the Draghi report mentioning the motto "*Boost productivity with digital tech diffusion*". President von der Leyen also called to invest record amounts in new technologies for Europe to drive the green and digital transition, with the aim to build "a continent reconciled with nature and leading the way on new technologies"[352]. Public investments in advanced digital technologies have an important role to play in meeting those challenges, leveraging private investments and driving the sustainable and smart transformation of industry and society. Moreover, the recent Communication of the Commission on the Union of Skills[353] highlighted that Europe's competitiveness relies heavily on its human capital, yet faces major challenges including skills shortages, declining educational performance, and fragmented governance. The 2025 Strategic Foresight Report builds on this perspective by stressing that Europe's competitiveness will increasingly depend on achieving greater strategic autonomy in frontier technologies and the infrastructures that support them.

In our current political and market context, **Europe has both a range of key opportunities to take leadership in the technology race but also a critical underinvestment to address related to advanced digital technologies.** On average, European companies invest less than €50,000 annually in advanced digital technologies. In particular, company spending is generally modest in areas such as Artificial Intelligence, Data analytics, Advanced Connectivity, Cybersecurity, and Cloud–Edge–IoT, company spending. However, medium-sized enterprises show a strong engagement in advanced digital technologies relative to their size. They demonstrate agility in adopting digital solutions more often than smaller firms or larger corporations and are important building blocks of the future of digital technology deployment often missed by digital policies. Future private investments are projected to grow across all technologies most rapidly in the area of Artificial Intelligence. The deployment of Photonics, Quantum are also expected to be a future investment target by companies, but less so for High Performance Computing and Next Generation Internet.

The European start-up landscape that is underpinning technology deployment has shown remarkable progress over the past decade, marked by a strong rise in entrepreneurship and increased mobilisation of venture capital. However, Europe's next challenges revolve around not only accelerating the scaling of tech start-ups but fostering their growth-stage coupled with a stronger market and demand focus that enable the emergence of unicorns, while simultaneously maintaining a strong pipeline of new start-ups amid the slowdown in early-stage financing.

The EU's global position is suboptimal in most of the digital technologies and its deployment is lagging behind international competitors. For 2028, the EU's global position has been assessed as 'medium' for most technology areas, 'low' for AI, Blockchain, Microelectronics and NGI & XR and has not been considered 'strong' for any of the technologies, as concluded by experts participating in the Delphi exercise of this study, in particular in relation to the EU's expected position at the start of the next MFF (2028), and expected position in 2036 (+2 years after the end of the next MFF) in a scenario where the

[350] EC (2025), State of the Union 2025 – Letter of Intent, Online
[351] EC (2024), Europe's Choice, Political Guidelines for the next European Commission 2024-2029, July 2024, Online
[352] EC (2023) Ursula von der Leyen, *State of the Union Speech 2023*, Online
[353] https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX%3A52025DC0090

current level of EU support was to continue unchanged. However, while the EU is underperforming internationally on various metrics of digital technologies, it has opportunities to create value across many application areas.

The reliance on non-EU countries for digital products, services, infrastructure, and strategic investments poses high risks. This is why a stronger focus on EU digital technology, supply chains favourable to productive technology deployment, and protection of intellectual property would be essential to reduce vulnerabilities and capture greater economic value.

Insufficient investment in deployment is identified as the most important barrier for both large companies and SMEs. Digital transformation necessitates substantial upfront spending on infrastructure, software, and skills, but firms' investments are constrained because returns may take time to materialise or are difficult to quantify, which is compounded by limited access to finance via banks or other sources. The high cost of energy is also a significant financial barrier, particularly for high-tech investments in areas like microelectronics, quantum, or high-performance computing, making European investment less attractive compared to countries in Asia. Beyond financial concerns, market fragmentation remains a top challenge for company executives. Fragmentation stems from divergent national markets and regulatory systems, as well as differences in consumer preferences and economic conditions, which create substantial obstacles for digital businesses attempting to operate seamlessly across EU Member States. While regulation provides a clear and stable framework, it often creates hurdles and lengthy compliance issues. Regulatory complexity is especially challenging in highly regulated sectors like healthcare and finance, where fragmented rules across countries increase costs. Companies specifically highlighted that the EU AI Act introduces too many strict rules regarding transparency, risk classification, and compliance obligations, particularly for high-risk AI systems, contrasting with more flexible, industry-driven approaches seen in places like Japan. Furthermore, administrative bureaucracy and complex public tendering systems slow innovation, with SMEs and start-ups citing the complexity of the public procurement process as a key issue.

The shortage of skilled staff and the difficulty in recruiting talent is another key challenge for companies, as many existing employees are not accustomed to working with advanced technologies. Many companies struggle with legacy IT systems and the difficulty of integrating new advanced digital technologies, alongside the threat of cybersecurity issues and immature AI applications. Insufficient investment in digital infrastructure is identified as the third most significant barrier overall, demonstrating persistent gaps in high-speed connectivity, data infrastructure, and advanced computing capabilities. Would-be adopters often get stuck mid-cycle, struggling to find the time or service providers to run real-world trials after evaluating an innovation, which is often tied to uncertainty regarding the relevance or cost-effectiveness of innovative technologies. There is also a recognized need to better demonstrate the value of digital products and services, as a lack of awareness among citizens and SMEs about the benefits and accessibility of certain technologies, such as HPC or XR, hinders adoption despite their technical maturity.

The EU has several strengths and opportunities despite the above mentioned challenges and global competitive pressure. Advanced research and innovation networks in the EU are seen as a general strengths with a well-developed ecosystem of universities, research institutions, and growing entrepreneurial hubs around them across the EU that foster collaboration and commercialisation. These networks support cutting-edge research, accelerate the development of emerging technologies, and enable knowledge sharing across borders, driving scientific excellence and technological leadership. A trusted regulatory framework and strong data protection standards make the EU globally recognised for promoting interoperability and safety. Initiatives such as the Digital Single Market and the EU's commitment to ethical standards in Artificial Intelligence and Cybersecurity further strengthen its role in shaping global digital norms. Open source is seen as a strength and a potential strategy to close gaps where Europe lags behind global competitors, particularly the US and China. In areas like software, open source could provide a more agile and collaborative route to innovation. Green digital solutions are seen an opportunity to pursue since the EU is considered as a global leader in promoting environmentally sustainable technologies, integrating digital innovation with climate goals.

The current Digital Europe Programme has made significant investments across several investment types in the current MFF, with a relatively strong focus on digital Infrastructure and all other categories representing a relevant share, except skills which had a lower allocation. Under the current MFF (2021-2027), the total amount of targeted contribution from the EU for DIGITAL and CEF Digital together totals €9.8 bn, with €7.9 bn for DIGITAL and €1.9 bn for CEF Digital. CEF Digital is mostly supporting digital infrastructures and to a lesser extent testing facilities (AI Factories) in the areas of Advanced Connectivity, AI, Quantum and HPC, whereas DIGITAL is heavily investing in deployment, ecosystem activities, testing facilities and skills in the areas of AI, HPC, Microelectronics, NGI, Data, Interoperability and Crosscutting issues. Overall, areas such as Photonics, Blockchain and Robotics receive comparably less support.

This study outlined several investment options to test future potential scenarios that can address dependencies and adoption. These options can have different ability to address one or both of the principal challenges identified in this study, notably the high level of dependence on digital solutions that have been developed or are controlled by global (non-EU) players in almost every technology domain, which can increase prices impacting the competitiveness of Europe's goods and services vis a vis its international counterparts and create supply-chain vulnerabilities, and secondly the slow and uneven rates of adoption of digital technologies across the wider European economy, in both the public and private sectors, which constrains productivity growth and underlines service innovation and quality.

Four investment options were conceived as distinct funding mixes that amount to different, contrasting scenarios. Three of the four options emphasise one funding logic above all else (e.g., a sharp focus on productivity or strategic autonomy) while the fourth is more open and reflects the many and various priorities of all stakeholders. These stylised treatments are designed to draw out the strengths and weaknesses of particular funding strategies, with a view to a preferred option (likely a hybrid) that strikes the right balance across the specific objectives and benefit types. The four investment options are outlined below:

- **Investment Option 1: Competitiveness/Productivity**: Technology areas: More focus on areas where exploitation potential is high across the wider economy and less on expanding EU capabilities in the most advanced digital technologies/ Investment types: High on Deployment support services, Low on new Infrastructure, Medium on Ecosystem and Skills.
- **Investment Option 2: Competitiveness/ Resilience**: Technology areas: More focus on expanding EU capabilities in areas where EU global dependencies are high (AI, Cyber, etc.) and where there is potential to achieve substantial improvements in emerging / fast moving markets. Investment type mix: Medium/low on Deployment, High on building capabilities including new and expanded Infrastructures, Medium/Low on Ecosystem and Skills.
- **Investment Option 3: AI Continent**: Technology areas: Central focus on AI technologies in general and the intersection between AI and other technology areas where the synergies are expected to be very high (e.g., HPC, Cloud, Microelectronics, Data etc.). Investment type mix: High on Deployment, High on new and expanded Infrastructure, Medium on Ecosystem and skills
- **Investment Option 4: Stakeholder priorities**: Technology areas: More open support for all technology areas where stakeholders are prioritising investment (AI, Cyber, Data, Interoperability, etc.) Investment type mix: High on Deployment support services, Medium on Infrastructure development, Low on Ecosystem and Skills.

These four investment options have been compared one with another and with a baseline option, which is rooted in the current Digital Europe Programme. All four assume a substantial increase in funding for a future digital pillar under the European Competitiveness Fund. Following the analysis of costs and benefits, Investment Option 1 would deliver the greatest boost to the adoption of digital technologies across both the public and private sectors, including Europe's SMEs and this in turn is expected to deliver proportionately stronger productivity gains with resulting in high market spillovers and moderate social and environmental impacts. The expansion in demand for digital solutions will also support Europe's deeptech industries, however, it is likely to drive an increase in imports of digital technologies and services from the rest of the world, potentially exacerbating current dependencies and lowering resilience overall. By contrast, Investment Option 2 would provide a bigger boost for Europe's deeptech industries and advanced users compared with Investment Option 1, and the baseline, which should help reduce dependencies in selected key areas, but with less impact on adoption rates or more generalisable benefits of the digital transition for wider users and citizens. Investment Option 2 would be the most heavily focused option, given the scale of funding needed to begin to close the gap with the global state of the art in areas like AI or Cybersecurity Investment Option 3 offers the broadest set of positive outcomes across all benefit types, albeit without quite the scale and scope of impacts of Investment Options 2 on their primary objective (resilience). Investment option 4 mirrors the current programme, but with a very much larger budget, and would deliver positive impacts on most dimensions except strategic autonomy, where it is anticipated that less focus / lower effective funding levels would result in a continuation of current trends (with the EU continuing to fall further behind the cutting edge as defined by US and increasingly China). On a positive note, there are fewer risks of the EU underinvesting significantly in whole technology areas and it will support capability building across the continent: Investment Option 4 keeps open more options than do the others and has a higher level of flexibility intrinsically such that it would be able to pivot more quickly should wider events demand that, while its breadth means it must be less strategic absolutely within a given, finite budget.

In terms of implementation mechanisms, a future European digital programme needs to be simpler, faster and more flexible than the current programme to improve its effectiveness and its optimal ability to strengthen Europe's future prosperity and security. In terms of support for early adoption, stakeholders argue that the most innovative deployments should be prioritised, while acknowledging the administrative challenge of clearly defining and recognising substantive innovation potential. Some stakeholders also suggested that the focus should be sharper still (not just major innovations) but major innovations with dual-use applications, those with both civilian and security benefits, should be favoured, especially given current geopolitical considerations.

On the subject of making any future programme more strategic, setting measurable targets are necessary, such as increasing the yearly adoption rate of strategic technologies. Additional incentives could be introduced to strategically encourage the use of European providers and solutions, for instance by offering a higher funding percentage when European technologies are chosen.

Recommendations

Given the critical role of advanced digital technologies in the future competitiveness of the EU economy and taking into account the market and systemic failures that pose challenges to the wider and human-centric adoption of digital solutions in both the public and private sectors, a renewed EU commitment to a European digital programme fostering digital transition with more targeted interventions and a sharper focus on private sector leverage is essential.

Market orientation and a focus on viable business models is a key ingredient of technology deployment that needs to be addressed under the European Competitiveness Fund (ECF). A future programme should have a primary focus on the value that EU digital tech providers can generate for the EU industry and should accelerate the realisation of productivity gains and the delivery of service enhancements and market spillovers, both of which will help to secure the overall competitiveness of the EU in the medium term.

As concluded in this study, Europe should focus on domains of relative advantage and explore complementary or reverse-dependency strategies rather than chase areas where it is far behind. It should be also more protective of European technology and monitor carefully firms' offshoring of critical technology.

Technological strategic autonomy should be addressed selectively through support for uniquely European application-led challenges (and therefore first-in-the-world solutions) in areas such as public health or sustainable transport systems or even the energy transition. It is also important to recognise that Horizon Europe 2028-2034 will have more scope to work at scale with strategic industries on the development of emerging technologies, investing proportionately more of its total funds on nearer to market opportunities with a strong industrial logic. As such, the new digital pillar of the ECF does need to invest directly in applied research and technology development and should instead focus more sharply on the deployment of proven, breakthrough technologies.

Higher private leverage can be reached by focusing on framework condition specific actions that improve the situation of both start-ups and scale-ups and address the challenges of medium-sized companies with a potential to become unicorns and create impactful products with high economic value.

Future support measures should address a range of critical framework conditions both on the demand and supply side and make use of a comprehensive policy toolbox, in recognition that the barriers to adoption are often multi-factorial and support needs to be targeted within the specific context of industrial and societal application areas. Direct and indirect support such as high-quality advice and peer learning are both important as are measures addressing support services, infrastructure needs, ecosystem capabilities and regulatory framework conditions.

There is a need for a more systemic perspective with a different approach to continuity, whereby support to a given group of actors should at least consider the need for ongoing advice or continuity of support, as deployment advances and new issues arise.

Moreover, support to digital technology deployment should not be the end goal and the EU should defend its focus on productive and healthy industries, human-centric and a environmentally conscious digital transformation where digital technology serves our society and not vice versa.

More ambitious governance arrangements are recommended, providing both leadership and supervision, to the efforts of the core programme management team and its many delivery partners. This should focus on determining where interventions can shift the dial, what type and mix of support measures work best where and how to maximise potential synergies with other EU programmes and national efforts (recognising the challenge of co-funding in a straightened financial environment).

Fragmentation and limited coordination across Member States needs to be addressed with a stronger coordination mechanism that reduces duplication of efforts and inefficiency. Lack of VC funding and risk-aversion of the private sectors remain key limitations that complementary programmes such as the European Innovation Fund can address. Scale-up requires heavy investments which are often not available in Europe. In addition, gaps in European value-chain should be mitigated with clear long-term strategic positioning.

Blended EU-, national-, regional-, and private-funding is seen essential to scale pilots, sustain operations, and achieve real-world impact, particularly in strategic areas such as AI, Quantum, or HPC. At the same time, the lack of harmonised support structures across Member States risks creating uneven opportunities and deepening gaps in digital transformation.

Annex 1: Technology assessment scorecard

The table below summarises the EU technology assessment in terms of the deployment of critical digital technologies including main key performance indicators and recent trends for each digital technology in scope.

Table 44 Technology assessment scorecard for deployment

Dimension	Subdimension	Indicator for technology assessment Scorecard	Adv. Connectivity	Artificial Intelligence	Blockchain	Cloud-Edge-IoT	Cybersecurity	Data analytics	HPC	Microelectronics	NGI & XR	Photonics	Quantum	Robotics	Tech for Interoperability
Current level of investments															
Technology potential for deployment	Current scope of EU programmes for deployment and associated funding (EUR m)	Volume of funding targeted at area in Digital Europe & CEF (21-27). Includes grants, procurements, CA, FI. Excludes cross-cutting funding.	1 391	1 321	60	155	1 149	427	1 433	1 533	614	12	321	40	455
Technology potential for deployment	Private investments: VC investment into digital technologies (€m)	Volume of VC funding going into the technology areas from 2015	2 517	18 551	6 179	14 313	5 190	17 386	3 291	4 071	1 816	1 149	1 180	3 091	na
Technology deployment & infrastructure															
Market potential - applications and sectors for technology deployment	IPR	Total number of patent applications in 2022 in the EU27	38	1 439	125	74	112	44	17	1 960	210	1 408	162	711	100

Dimension	Subdimension	Indicator for technology assessment Scorecard	Adv. Connectivity	Artificial Intelligence	Blockchain	Cloud-Edge-IoT	Cybersecurity	Data analytics	HPC	Microelectronics	NGI & XR	Photonics	Quantum	Robotics	Tech for Interoperability
Market potential - applications and sectors for technology deployment	IPR	Total patenting in the EU 27 trend based (vs 3yr avg)	-27%	18%	-21%	-21%	-17%	38%	-53%	1%	5%	-2%	89%	1%	
Infrastructures	Current scope of EU programmes for deployment and associated funding (EUR m)	Scale of investments in digital infrastructures from EU programmes (Digital Europe projects '21-24)	-	1	.2	-	2	121	196	-	7	-	64	-	3
Current (2028) Global Position of EU for innovation and deployment	Position of Digital Infrastructures, Skills and Competences and EU Digital Ecosystem	Delphi analysis Expert opinion (Round 1 - to be validated)	Medi um	Lw	Low	Medi um	Medi um	Medi um	Medi um	Low	Low	Medi um	Medi um	Medi um	High
Skills															
Skills	LinkedIn	Share of professionals with specific digital skills within ICT total in the EU27	7.1%	21,4 %	2.4%	30%	23%	43,4 %	21%	7.3%	4.6%	4,3%	2,2%	6%	na
Skills	Current scope of EU programmes for deployment and associated funding (EUR m)	Funding allocated of current ('21-24) projects in DIGITAL (excludes cross-cutting skills investments)	-	40	3	5	52	14	31	313	19	5	14	5	15

Dimension	Subdimension	Indicator for technology assessment Scorecard	Adv. Connectivity	Artificial Intelligence	Blockchain	Cloud-Edge-IoT	Cybersecurity	Data analytics	HPC	Microelectronics	NGI & XR	Photonics	Quantum	Robotics	Tech for Interoperability
European ecosystem (tech developers - supply-side)															
Capability of the European ecosystem	IPR	Share of tech field within total volume of patents in EU27 (in 2022)	0.05%	1.91%	0.17%	0.1%	0.15%	0.06%	0.02%	2.6%	0.28%	1.87%	0.21%	0.94%	na
Capability of the European ecosystem	IPR	Share of tech field within total volume of patents in EU27 (Trend (vs 3yr avg))	-26%	19%	-21%	-21%	-17%	38%	-52%	2%	5%	-1%	90%	2%	
Capability of the European ecosystem	Standards	Total number of standards	IEEE (1366)	IEEE (114)	IEEE (39)	IEEE (50)	IEEE (129)	IEEE (45)	IEEE (2)	IEEE (6)	na	IEEE (10)	IEEE (4)	IEEE (24)	
			ISO (715)	ISO (309)	ISO (81)	ISO (241)	ISO (345)	ISO (2694)	ISO (21)	ISO (311)	na	ISO (262)	ISO (166)	ISO (125)	
			ETSI (8121)	ETSI (791)	ETSI (43)	ETSI (628)	ETSI (165)	ETSI (418)	ETSI (26)	ETSI (6)	na	ETSI (5)	ETSI (75)	ETSI (47)	
Ecosystem – global positioning (tech adopters - demand-side)															
Technology potential for deployment	Current scope of EU programmes for deployment and associated funding	Private sector leverage in % for grants (Private co-funding / EU Contribution, based on actual grants 2021-2024 in DEP)	0%	7%	50%	58%	32%	19%	10%	21%	40%	na	23%	16%	29%
EU competitive position globally	Trade	Trade balance by sub-technology area (only possible at highest level of aggregation, Level 1) (last year 2022)	-59.6%	-15.5%	na	-33.6%	na	na	-36.5%	-13.1%	na	-13.1%	na	-15.5%	na

Dimension	Subdimension	Indicator for technology assessment Scorecard	Adv. Connectivity	Artificial Intelligence	Blockchain	Cloud-Edge-IoT	Cybersecurity	Data analytics	HPC	Microelectronics	NGI & XR	Photonics	Quantum	Robotics	Tech for Interoperability
EU competitive position globally	Trade	Trade balance by sub-technology area (only possible at highest level of aggregation, Level 1)	2.04 %	- 3.75 %		2.08 %			- 1.37 %	- 15.9 %		- 15.9 %		- 3.75 %	
Overall dependency on non-EU	Raw Materials; High Tech Digital Components; Technology excellence; Testing and experimentation facilities; Digital infrastructures and software; advanced skilled workforce; specific actors in the R&D system; specific sections of the value chain)	Delphi analysis Expert opinion (Round 1 - to be validated): Number of subdimensions rated 'high' in dependency	6	6	7	4	5	5	5	5	6	4	4	4	4
Reverse dependencies on the EU	Raw Materials; High Tech Digital Components; Technology excellence; Testing and experimentation facilities; Digital infrastructures and software; advanced skilled workforce; specific actors in the R&D system; specific sections of the value chain)	Delphi analysis Expert opinion (Round 1 - to be validated): Number of subdimensions rated 'high' in reverse dependency	0	0	3	0	0	6	0	2	1	2	1	1	3

Dimension	Subdimension	Indicator for technology assessment Scorecard	Adv. Connectivity	Artificial Intelligence	Blockchain	Cloud-Edge-IoT	Cybersecurity	Data analytics	HPC	Microelectronics	NGI & XR	Photonics	Quantum	Robotics	Tech for Interoperability
EU competitive position globally	IPR	Global Ranking of Countries (Latest Year and. Long term 3 year average (2017/19-2020/22)	US (40.58%) 0.85 % increase	US (36.51%) 7.19 % decrease	US (27.94%) 14.94 % decrease	CN (37.50%) 20.77 % increase	US (31.87%) 13.16 % decrease	US (31.40%) 9.36 % increase	US (46.37%) 2.70 % decrease	JP (32.90%) 6.70 % decrease	US (36.65%) 1.35 % increase	EU-27 (24.53%) 1.79 % increase	EU-27 (33.47%) 54.66 % increase	CN (24.77%) 10.61 % increase	
			CN (25.22%) 41.38 % increase	EU-27 (18.98%) 14.31 % increase	CN (24.71%) 21.51 % increase	US (35.92%) 2.31 % increase	CN (21.46%) 11.84 % increase	CN (28.96%) 0.51 % increase	CN (31.28%) 2.29 % decrease	CN (24.03%) 18.97 % increase	CN (18.57%) 8.78 % increase	CN (23.18%) 21.55 % increase	US (27.07%) 42.43 % decrease	EU-27 (19.08%) 5.14 % decrease	
			EU-27 (11.01%) 31.76 % decrease	CN (17.53%) 10.08 % increase	EU-27 (11.23%) 16.83 % decrease	EU-27 (11.71%) 26.54 % decrease	EU-27 (18.21%) 13.78 % decrease	EU-27 (13.41%) 2.44 % increase	EU-27 (9.50 %) 0.09 % increase	US (17.31%) 2.37 % decrease	EU-27 (14.60%) 3.94 % increase	US (19.84%) 7.09 % decrease	JP (10.74%) 89.29 % increase	US (19.08%) 16.76 % decrease	
			JP (8.12 %) 9.61 % decrease	JP (7.40 %) 26.51 % decrease	GB (7.46 %) 38.81 % decrease	GB (2.53 %) 4.31 % increase	JP (9.43 %) 46.33 % increase	JP (5.79 %) 18.40 % increase	GB (4.47 %) 3.17 % increase	EU-27 (14.02%) 2.03 % decrease	JP (7.51 %) 4.86 % decrease	JP (17.33%) 16.27 % decrease	CN (9.09 %) 25.29 % increase	JP (18.76%) 14.39 % increase	

Dimension	Subdimension	Indicator for technology assessment Scorecard	Adv. Connectivity	Artificial Intelligence	Blockchain	Cloud-Edge-IoT	Cybersecurity	Data analytics	HPC	Microelectronics	NGI & XR	Photonics	Quantum	Robotics	Tech for Interoperability
				GB (4.43 %) 6.55 % decrease	JP (7.46 %) 39.36 % increase	JP (1.42 %) 28.53 % decrease	GB (4.07 %) 30.13 % decrease	GB (3.35 %) 59.35 % increase	JP (1.12 %) 34.39 % decrease	GB (1.13 %) 19.55 % decrease	GB (2.57 %) 1.02 % increase	GB (1.76 %) 7.68 % decrease	GB (7.02 %) 56.34 % increase	GB (3.27 %) 19.85 % increase	

Source: Technopolis Group (2025)

Annex 2 Methodology

The study was structured into four main tasks, each with a dedicated objective and aligned with the overall project framework. These tasks have been translated into specific research questions, as presented in the table below, which offers a clear overview of the study's objectives.

Table 45 Research questions guiding the study

Main topics	Objectives	Research questions
Scoping	**Identify the critical and emerging digital technologies, infrastructures and capabilities** essential for creating and strengthening digital ecosystems and building digital capacity across the EU; strategic and critical for addressing global challenges, ensuring EU industrial competitiveness as well as economic security and sovereignty	• What are the **strategic and critical digital technologies for deployment[354]** (high TRL) and the related **infrastructures** (e.g. quantum, supercomputing, AI) and capabilities (incl. **advanced digital skills development**), relevant for investments during the next MFF[355] (2028-2034)? • What are the future areas for deployment and adaptation of **emerging digital technologies** in the public and private sector (and related infrastructures and skills), relevant for investments?
European landscape	**Map the European ecosystem around each technology** based on their level of maturity in different application sectors, including levels of public and private investments and challenges, gaps and obstacles encountered for their scaling-up	• What is the **composition of the European digital ecosystems** around such technologies, incl. the types of actors involved, size, and market shares, geographical differences and Member States' engagement? • What are the **interlinkages and synergies** between these technologies and related infrastructures and skills, highlighting the compound effects of their combination to create digital ecosystems, including cross-sectorial dimension where digital can be transformative (e.g., energy, transport, health, environment, cultural and creative industries...)? • What are the **levels of public and private investments** in the deployment of digital technologies, infrastructures and other capabilities at EU, national and regional levels? What are the gaps and (multi-level) inefficiencies across the investment journey, and potential market distortions? • What is the **impact and added value** of current EU funding programmes addressing digital technology deployment, infrastructure deployment and capacity building? • What are the key **challenges, gaps and obstacles** faced for the deployment of those technologies and related infrastructures and capabilities (main market bottlenecks, skills and infrastructures' gaps, access to funding, sectorial incentives and needs, geographical differences)?

[354] Based upon: digital technologies funded under the Digital Europe Programme; as well as the technologies identified as critical in the Economic security strategy adopted in June 2023 and the follow up Recommendation of 3 October 2023, as well as the STEP Regulation; also building on the areas identified in the Digital Decade Policy Programme 2030 - Decision (EU) 2022/2481 of the European Parliament and of the Council of 14 December 2022 establishing the Digital Decade policy programme 2030, OJ L 323, 19.12.2022, p. 4–26

[355] Essential for creating and strengthening digital ecosystems and building digital capacity across the EU; strategic and critical for addressing global challenges, ensuring EU industrial competitiveness as well as economic security and sovereignty

Main topics	Objectives	Research questions
International landscape and EU positioning at global scale	**Analyse the global digital ecosystem surrounding each technology**, assessing the level of global competitiveness of the EU in the different areas of investments for both critical and emerging technologies, to identify the EU's strengths and unique competitive advantages, and assess dependencies	• Who are the **global technological leaders**, main competitors, market players in each of the technology areas? • What are the level and scope of **public investment programmes** for the deployment of those technologies by the global leaders and main competitors? • What is the relative **competitive advantage** of the EU against the global competitors identified: what are the technologies and infrastructures that the EU currently has in its portfolio, and which do not appear as strongly for global competitors (high investments in Europe versus global competitors in strategic technologies or for specific application areas) • What are the **dependencies/vulnerabilities and reverse dependencies** in the industrial value chains[356] and deployment of the selected technologies
Foresight	**Identify the foreseeable evolution of the digital technologies selected** (deployment, infrastructures and capability needs, market and societal trends, ecosystem, investments, EU global positioning), and feed into the development of strategic (investment) options that can support priority setting for an optimal design of the next digital technology deployment programme under the next MFF, covering a time horizon up to 2034 (end of the next MFF), with the idea that the insights provided can be relevant in the longer term and tested and revised in the course of the next programme	• What is the foreseeable **development of the digital technologies** selected in task 1 (future deployment, infrastructure, capabilities), including future market trends, investment needs and obstacles to market uptake? • What are the expected changes in the **composition of digital ecosystems** that can impact EU's competitiveness (e.g., gaps of infrastructures, services, competencies preventing scaling up and market uptake)? • What are the expected opportunities and challenges related to the **coordination of the EU, national and regional programmes**? • What are the foreseeable variations in **global technological leadership** incl. areas/sectors in which the EU could improve its competitiveness, and what are the areas/sectors where the EU is expected to lose or stand-by? • How are **global and horizontal contextual factors and megatrends** shaping digital ecosystems expected to influence future scenario, including global economic landscape, international cooperation and geopolitical factors, regulatory frameworks, environmental factors, ethical considerations, societal and demographical changes, etc.)?
Towards the next MFF: strategic recommendations for the next digital technology	**Develop a set of strategic considerations** to support the EU strategy for EU bringing-to-market and deployment of essential technologies[357], and **for the**	• Based on the evidence collected[358] and the policy priorities for the EU in the next MFF[359], what are the focus areas and **positive and negative priorities for investments**[360] in specific digital technologies for deployment (incl. essential and emerging)?

[356] Advanced digital technologies will allow a company to drastically improve its capability to undertake supply chain due diligence. Beyond helping it comply with sustainability due diligence legislation, this has merit in itself, as with better information, the company will be able to take more informed decisions and thereby increase its resilience.

[357] And to best deliver on the Digital Decade Policy Programme, taking into account the need for developing a strong ecosystem (including start-ups and scale-ups and the public sector), demand and market development, infrastructural needs for testing and scaling, and the potential for cross-sectorial spillovers

[358] Also considering Europe's economic security, competitiveness and technological sovereignty

[359] The analysis will further factor in considerations on how digital technologies can be deployed while respecting European values to promote equality, democracy and human rights, to further enhance security online, to propel competitiveness and support the digital transformation of the European society

[360] The Study will provide suggestions on different strategic investment scenarios covering a limited, moderate and/or large number of digital technological areas to prioritise in the next programming period, with a short and long term horizon

Main topics	Objectives	Research questions
deployment programme	**preparation of the successor of the Digital Europe programme,** including the objectives and EU added value of the future programme in light of the problems identified, as well as the development of options for the structure and priorities of the future programme, including the weight and focus that strategic digital technologies (critical and emerging) should have in the EU investment strategy to reach Europe's overall objectives	• What are the technology areas where the EU should craft its **international partnerships and cooperation** for the deployment of digital capacity? • What considerations should feed into the development of an **EU strategy towards the deployment and uptake** for these essential digital technologies (incl. ecosystem building, infrastructural needs, skills, potential for cross-sectorial spillovers), and to deliver on the targets of the **EU Digital Decade programme** while considering the subsidiarity and proportionality principles to maximise the impact of EU intervention? • What are the opportunities for **simplification** (incl. reporting) of the programme, including alternative **implementation modes and funding instruments** (incl. grants, procurement, financial instruments) to support the investment journey into digital technologies beyond TRL 8-9 and their wide uptake by industry and society? • How could **synergies** between EU, national and regional roadmaps and funding mechanisms be strengthened to support the deployment and capability building related to digital technologies, and what are the areas where the **EU adds value**, and those were **multi-country collaborations** could be envisaged? • What are the **costs and benefits** of the different options and structures, implementation modes and funding instruments, and what are their **expected impact**? • For each technology area identified as worth funding at EU level, what **set of indicators** (KPIs) can be developed to analyse impact (incl. to strengthen the twin transition in terms of stronger markets, industries and high-quality jobs)?

Source: Technopolis Group, 2024

Methodology framework

To develop our approach tailored to the needs of this strategic study, we have developed an analytical framework to feed into the development of the EU strategy for the deployment and adoption of critical and emerging digital technologies under the next MFF. The study was divided into two main phases, as described below.

Phase 1 – Scoping and landscaping

The first phase of the study, following the inception period, mainly consisted in the scoping and landscaping analysis.

- The scoping phase, combined with the horizon scanning exercise, enabled the team to list the critical and emerging digital technologies for deployment relevant for investment in the next MFF, which constituted the scope of the study.
- This list was enhanced through focus group discussions with technology experts and stakeholders, in synergy with the study on critical technologies for R&I investments, and through the Delphi process (especially for emerging technologies).
- The list of critical and emerging technologies was further enriched during the landscaping exercise, which provided a wide range of additional insights on technology trends (including maturity and application sectors), the structure and dynamics of the European ecosystem (including current levels of public and private investments at EU, national and

regional levels), and the positioning and competitiveness of the EU in the global landscape (including dependencies and resilience of European value chains).

- The results from the scoping and landscaping phases were discussed and enriched through multiple stakeholder consultation mechanisms, including with technology experts through the Delphi process, and through interviews.

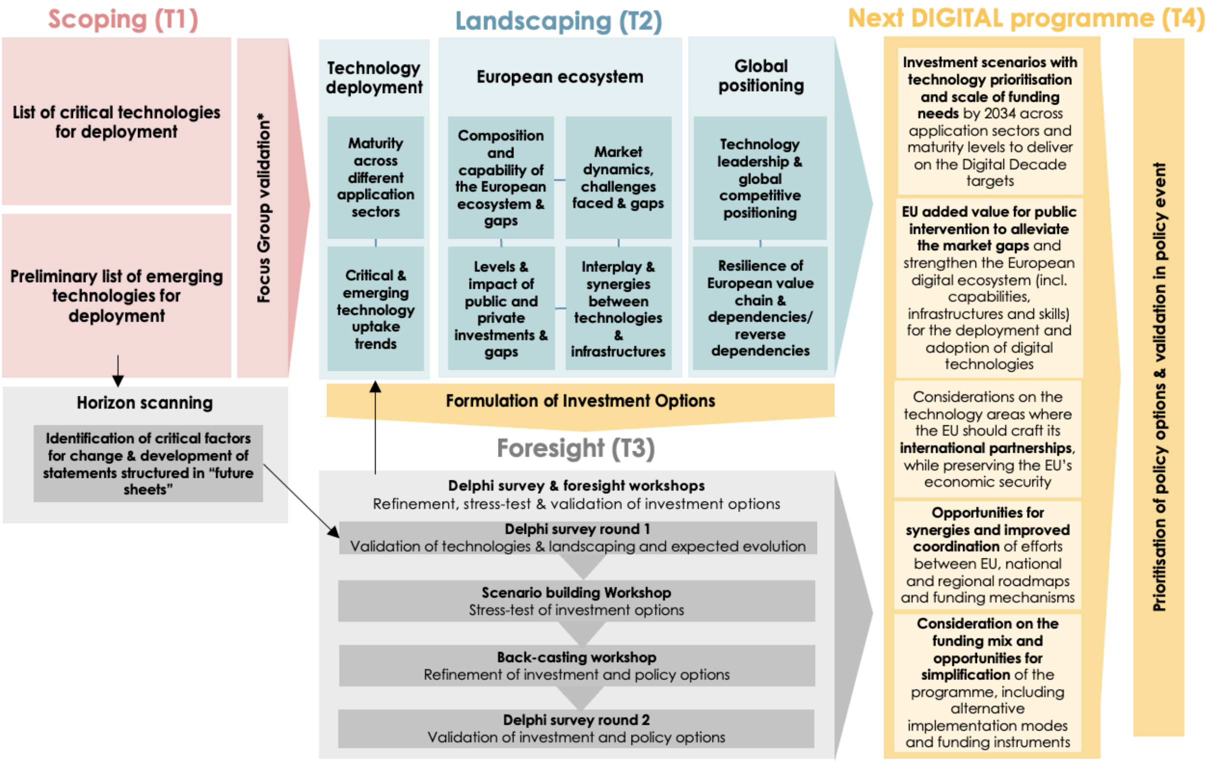
Phase 2 – Foresight and strategic considerations

The second phase of the study covered the foresight exercise and considerations for the next EU programme and strategy for the deployment of digital technologies.

- The foresight phase sought to validate the findings from the scoping, horizon scanning and landscaping analysis, and to develop future scenarios covering each of the critical and emerging technologies for deployment identified, with a 2034-time horizon (end of the next MFF).
- The foresight exercise also sought to build from the gaps identified and related objectives to fill those gaps with the development of strategic roadmaps for investments, and to define the weight and dimensions of the model for their prioritisation.
- This roadmap will be further enriched by the second round of the Delphi and the second foresight workshop, testing the investment options and underlaying policy options against contextual factors, for the development of evidenced-based considerations for the successor(s) of the Digital Europe Programme.
- The assessment of the impact of the different options will be carried out through a cost-benefit and multi-criteria analysis, possibly enhanced by some modelling analysis with the support of the JRC (discussions ongoing).
- Such considerations also covers the specificities of the programme design to support the deployment of digital technologies, the EU added value of those investments, the need for continuity of support throughout the investment journey, and ultimately the EU internationalisation strategy tailored to specific digital technology fields.
- The output from the study will be validated through policy workshops with stakeholders and policy makers in July 2025.

The figure below presents a schematic overview of our overall approach for this study, and illustrates the flow of the analysis.

Figure 58 Analytical framework



Source: Technopolis Group (2025)

Methodological toolbox

The table below shows the mix of research methods for data collection and analysis that we propose for this study. We have adopted a mixed research approach for data collection & analysis, ensuring compliance with the Better Regulation Guidelines on integration and triangulation of the findings.

- We have relied on a **strong conceptual indicator framework** drawing from various data sources to analyse the adoption of advanced digital technologies by industry, and structured around capability assessment, market structure, composition and investments.
- We have implemented a far-reaching and **large-scale stakeholder consultation strategy** complemented by a dedicated communication campaign, to seize key changes in the technology deployment and the consolidation of digital ecosystems across application sectors, allowing to define, test and prioritise options at every step of the project.
- We have also adopted a strong **forward-looking approach**, to test and develop a vision, beyond 2028 and up to 2034, accounting for uncertainty and criticality of action.
- The assessment of the options will combine **muti-criteria analysis** to appraise the likely impact of the options, together with a **Cost-Benefits Analysis** (CBA).

Table 46 The study's methodological toolbox

	T1 Scoping		T2 Landscaping and comparative analysis		T3 Foresight	T4 Impact Assessment
	Critical technologies	Emerging technologies	European landscape	Global landscape	2034 horizon	Investment options
Primary data collection - stakeholder consultation						
Semi-structured interviews	✓	✓	✓	✓		
Market interviews	✓	✓	✓	✓	✓	
Stakeholder survey	✓	✓	✓			✓
Public sector survey on adoption/investments			✓	✓		✓
Market survey			✓	✓		✓
Delphi survey		✓	✓	✓	✓	✓
Foresight workshops					✓	✓
Policy event	✓	✓	✓	✓	✓	✓
Technology expert board	✓	✓	✓	✓	✓	✓
Secondary data collection - qualititative and quantiative data						
Desk research	✓	✓	✓	✓	✓	✓
RTO portfolio & SRIA analysis	✓	✓	✓	✓		
International benchmark & dependency analysis				✓		✓
Secondary data sources			✓	✓		✓
Portfolio&composition	✓	✓	✓			✓
Cost-benefit analysis/ MCA						✓

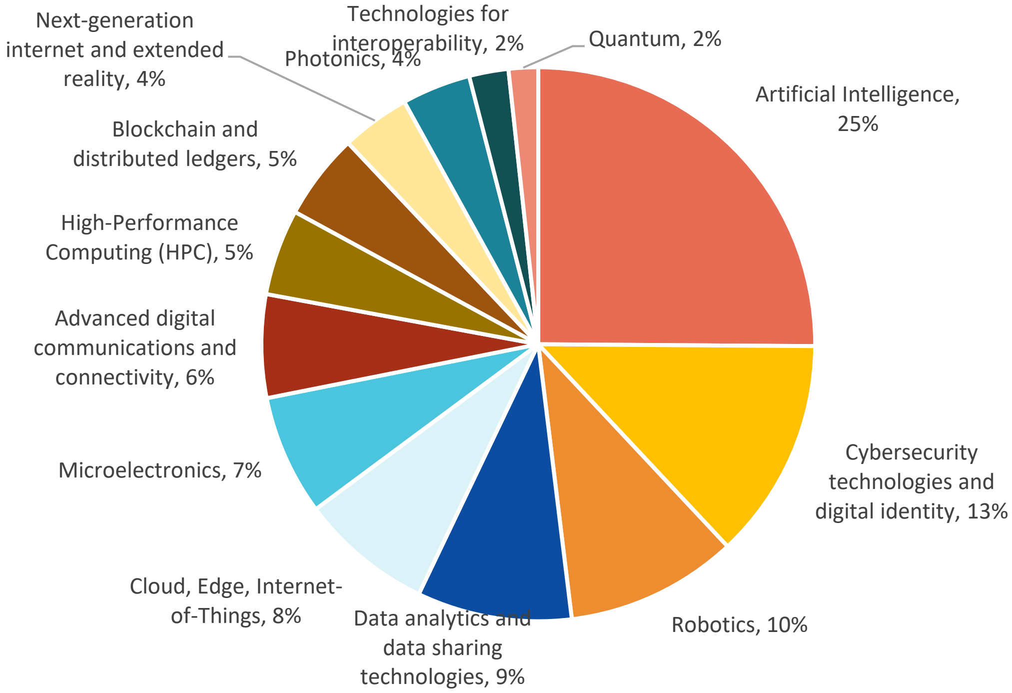
Source: Technopolis Group (2025), based on the Better Regulation Guidelines
Note: ✓ corresponds to the method coverage of the specific analytical dimension, three ticks corresponding to the most in-depth contribution of the methods to the specific analysis.

As a note, the study has also been able to leverage some of the evidence collected through the "**Study on the EU's strategic digital technologies for the next EU R&I programme**", which will expand the data sources and validation opportunities for this study, while ensuring alignment of stakeholder consultation tools to avoid overlaps and stakeholder fatigue.

Representativeness of data

The study relied on data from five surveys, notably two public sector surveys, a CATI and online market survey, and a stakeholder survey. The CATI survey followed a stratified random sampling strategy that resulted in a representative sample of firms per company size and sector.

Figure 59 Distribution of market survey sample across technology areas



The stakeholder consultation was open attracting 310 respondents from diverse backgrounds. The public sector survey on investments had a very low response rate, hence the results should be interpreted in the light of the respondents.

The data collection on startups and venture capital investment into digital technologies relied on Crunchbase that is one of the most comprehensive database of technology companies and start-ups and is widely used.

LinkedIn used for the skills analysis is the largest professional network platform with information such as profile summary, job title, job description and field of study. It represents the single most comprehensive source currently available for the construction of technology-specific skills related indicators. The representativeness of LinkedIn has been analysed in detail in the European Monitor of Industrial Ecosystems'[361] methodological report. More specifically:

LinkedIn is the largest professional network platform with rich information like profile summary, job title, job description and field of study, which can be used for the identification of skilled professionals in advanced technologies. **It represents the single most comprehensive source currently available for the construction of technology-specific skills related indicators**.

Compared to highly resource intensive alternatives such as surveys it represents the most cost-effective alternative considering not just the cost of running the analysis once but also the potential to run the analysis at regular intervals.

In order to take into account representativeness, the data have been corrected for the under or overrepresented groups in the population using post stratification techniques. The lack of representativeness for the population characteristics is expected and the objective, as in every statistically sound survey analysis, is to apply the right method to derive correct estimates of the population.

As also highlighted in the case of the EMI project, the considerations to be taken into account when using LinkedIn data include the following:

- Registering on LinkedIn is voluntary, which leads to self-selection bias. Users join based on perceived personal utility, which varies by factors such as country, sector,

[361] https://monitor-industrial-ecosystems.ec.europa.eu/about/monitoring-framework

and education level. This creates systematic differences across regions and industries, making the sample non-random and not representative of the active population.
- LinkedIn is a powerful but imperfect data source for tracking skills supply. While it enables flexible, large-scale monitoring that traditional sources cannot provide, access to raw data for full verification is not possible. Skill data is self-reported, cannot distinguish proficiency levels or academic versus industry expertise, and depends on user honesty, self-assessment, and profile completeness. However, sector-based filtering allows more targeted analysis of industry-specific skills, and similar limitations also apply to survey-based data.

Considerations to be taken into account when reading the representativeness analysis include:

- The LinkedIn database suffers from missing data points such as for instance the level of education. This does not compromise the indicators but rather the possibility to run a comprehensive representativeness analysis.
- Another limitation in performing a comprehensive representativeness analysis by comparing the LinkedIn database, with the data retrieved from Eurostat is that the two datasets have different origins and hence there are mismatches in the definition of some categories. For example, the educational attainment categories on LinkedIn (masters' degree; bachelor's degree; high school) are different from Eurostat (tertiary education; upper secondary and post-secondary non tertiary education; lower than primary, primary and lower secondary education). The same kind of mismatch exists for skills and sector. These differences affect the assessment of representativeness as the comparisons between the two datasets have to be made based on criteria that are not identical.

KK-01-26-087-EN-N

Publications Office
of the European Union

doi: 10.2759/0673677
ISBN 978-92-68-40079-1