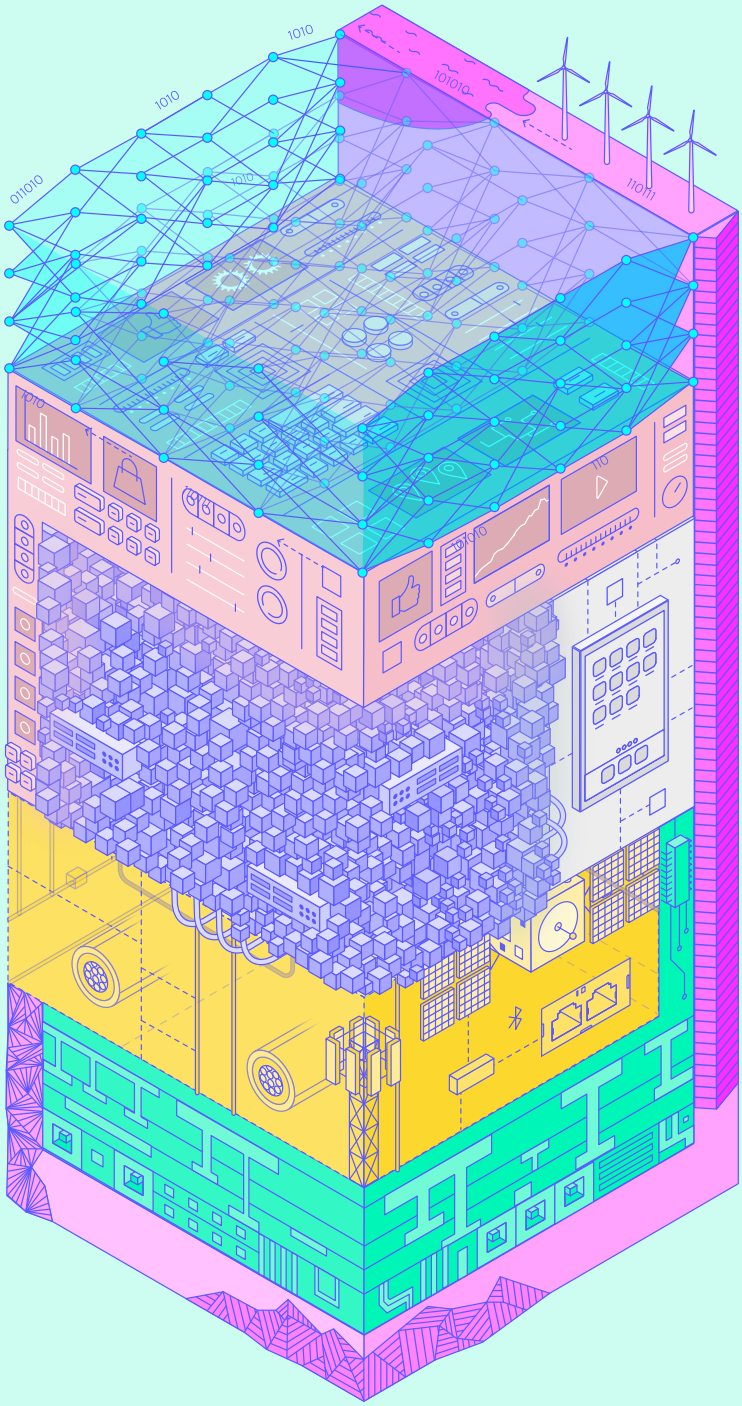
EuroStack – A European Alternative for Digital Sovereignty



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EuroStack – A European Alternative for Digital Sovereignty

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Preface

Europe stands at a crossroads in its history. The question is no longer whether technology will shape our future, but who will shape it and how. Today, a handful of powerful global actors dominate much of the digital narrative, while smaller voices – particularly those advocating for the public interest – often struggle to be heard or to exert meaningful influence. This imbalance highlights a broader reality: digitalization is no longer just one thematic silo among many; it has become the structural backbone of our societies.

Recent events have underscored how vulnerable our societies and economies become when ideological interests intersect with concentrated technological power. If Europe is to maintain its peace-promoting democratic principles, foster digital innovation that serves the common good, and achieve genuine sustainability, it must actively shape the digital arena rather than merely adapting to external trends. The time has come for Europeans to take decisive steps toward building an interconnected digital future on their own terms.

Against this backdrop, we have undertaken a comprehensive mapping of the EuroStack to lay the groundwork for future-oriented digital self-determination. We are honored to contribute to this effort as part of a coalition of supporting organizations – including Stiftung Mercator, the UCL Institute for Innovation and Public Purpose (UCL IIPP), and the Centre for European Policy Studies (CEPS) – that share our commitment to a forward-thinking, values-driven digital Europe. We also extend our sincere gratitude to the authorship collective, led by Francesca Bria, for their foundational work on this initiative.

The EuroStack vision presents a tangible pathway for Europe to reduce its technological dependence, enhance its strategic autonomy, and lead in values-driven innovation. By examining advanced technologies – from AI and quantum computing to cloud infrastructure – the initiative aims to foster a resilient digital ecosystem that embodies Europe's democratic principles, social equity commitments, and economic ambitions.

We hope this publication serves both as a roadmap and a call to action, providing stakeholders with strategies to reclaim European agency in the digital sphere. At the same time, it challenges us to unite – to bring diverse voices into the conversation, strengthen cross-sectoral connections, and invest meaningfully in European innovators.

Recognizing that complete self-sufficiency is neither feasible nor desirable, the EuroStack initiative calls instead for a shared effort to bolster strategic capabilities and cultivate beneficial international partnerships. It also seeks to demonstrate that digital sovereignty is not about isolation but about advancing a shared vision of the common good.

As you engage with the analysis and recommendations in the following pages, we invite you to consider how this mapping and its recommendations can help spark innovations that are both competitive and compassionate. Together, we can build a future in which digitalization serves not as a source of division but as a force for the common good.

Martin Hullin
Director Digitalization and the Common Good
Bertelsmann Stiftung

Quotes

Francesca Bria, Fellow Stiftung Mercator, Hon. Professor, UCL IIPP

"Europe's sovereignty demands a tech leap: Build EuroStack now. We're importing technologies that undermine our autonomy and values. EuroStack is our moonshot – the digital evolution of the euro and Single Market. Launch an EU Sovereign Tech Fund to scale homegrown chips, sovereign AI clouds, and open-source, federated systems. Mandate "Made-in-Europe" standards, leverage public funds and procurement, and forge partnerships to curb monopoly dominance. Without this, we surrender our economy to foreign powers, expose democracies to algorithmic manipulation, and betray our climate goals. EuroStack isn't optional – it's how Europe innovates in the public interest and leads on its own terms."

Carla Hustedt, Director Centre for Digital Society, Stiftung Mercator

"Europe needs its own digital ecosystem to safeguard its values and democracies. This can only be achieved from a position of economic independence and strength. With the EuroStack, there is now a coherent vision of how this can be accomplished – along with concrete approaches for implementation."

Prof. Mariana Mazzucato, Founding Director of the UCL IIPP

"The EuroStack report is a powerful call for Europe to move beyond incrementalism and embrace a mission-driven approach to digital sovereignty. This isn't about replicating existing models but about designing a values-driven framework that protects our environment, secures our data, and places public-interest innovation at the heart of economic transformation. Governments must forge symbiotic partnerships with the private sector to enable catalytic change. This means driving sustainable growth, closing Europe's innovation gap, and building independent public digital infrastructures that enhance European industrial competitiveness. But ambitious investments must come with bold conditionalities, ensuring that private collaboration aligns with Europe's sustainability, inclusivity, and industrial ambitions. The EuroStack is a strategic vision for Europe to lead in creating a fairer, greener, and more democratic digital economy."

Andrea Renda, Director of Research, CEPS

"European leaders are slowly realizing that our industrial future, as well as our democracy and social cohesion, increasingly depends on Europe's ability to rely on a trustworthy technology stack, ranging from compute infrastructure to digital identity, cloud, and data. This paper provides the most up-to-date view on what the EU should do to create this EuroStack, why it more urgent than ever, and why it should respect EU values and principles. Policymakers should not ignore such compelling evidence and this hands-on description of the steps toward true Europea technological sovereignty."

Executive summary

The EuroStack initiative presents a bold vision for Europe's digital future, aiming to establish the continent as a leader in digital sovereignty. This comprehensive strategy seeks to foster innovation, strengthen strategic autonomy, and build inclusive partnerships to overcome Europe's reliance on external technologies and position itself at the forefront of the global digital economy.

Currently, over 80% of Europe's digital infrastructure and technologies are imported, creating systemic vulnerabilities and hampering the region's capacity for innovation and self-reliance. The EuroStack initiative directly addresses these challenges by providing a comprehensive strategy to strengthen Europe's competitiveness, secure essential resources, and build a resilient and forward-looking digital ecosystem.

At the core of the EuroStack blueprint is a digitally sovereign Europe built on interconnected layers of advanced technologies, ranging from semiconductors and artificial intelligence (AI) to cloud computing and quantum systems. This approach prioritizes sustainability, inclusivity, and interoperability, ensuring Europe's digital future aligns with its democratic values, social equity goals, and economic aspirations. Crucially, the strategy recognizes that full self-sufficiency is neither feasible nor desirable in a globalized world. Instead, the EuroStack initiative promotes building strategic capabilities while maintaining beneficial international collaborations.

Artificial intelligence stands out as the cornerstone of the EuroStack vision, offering unparalleled opportunities to revolutionize Europe's digital ecosystem. AI's transformative potential extends across all sectors, from manufacturing and healthcare to public services and energy management. By investing in sovereign AI ecosystems, Europe can unlock efficiencies, create smarter public services, and promote indigenous innovation that aligns with European values of transparency, accountability, and privacy.

With 70% of foundational AI models developed in the United States, and China rapidly expanding its share, Europe must focus on fostering homegrown AI capabilities. AI is a strategic enabler that powers data-driven decision-making, optimizes industrial processes, and accelerates research and development. By creating sovereign AI platforms and federated data spaces, the EuroStack initiative aims to reduce dependencies on foreign providers, protect intellectual property, and position Europe as a leader in public interest AI.

Moreover, AI has the potential to significantly narrow the innovation gap between Europe and its global competitors. As highlighted in the Mario Draghi Report of 2024, Europe's slower productivity growth relative to the United States stems from underinvestment in cutting-edge technology and limited translation of Research & Development (R&D) into market successes. AI offers the means to reverse this trend, providing the tools needed to accelerate

innovation and bridge this gap. By integrating AI with Europe's industrial base, including small and medium-sized enterprises, the EuroStack initiative lowers technology adoption costs, enhances productivity, and generates valuable knowledge spillovers that drive economic growth.

With a proposed investment of €300 billion over the next decade, EuroStack aspires to deliver transformative economic, social, and environmental benefits. These include generating high-skilled jobs, reducing dependencies, and advancing critical sectors such as energy, manufacturing, and healthcare. The initiative also aims to position Europe as a leader in values-driven, citizen-focused innovation, shaping a digital future that prioritizes privacy, trust, and accountability.

The EuroStack model champions a more balanced power dynamic by enabling smaller firms to access advanced tools and technologies, creating a level playing field that fosters entrepreneurship and innovation. By encouraging knowledge-sharing and inclusivity, the initiative aims to transform Europe's digital economy into an ecosystem that creates long-term value rather than simply extracting it.

The EuroStack initiative is not just a policy framework; it is a call to action for a united Europe to take control of its digital destiny. By prioritizing strategic autonomy and integrating emerging technologies such as AI, quantum computing, and advanced cloud solutions, the EuroStack strategy ensures Europe is prepared to confront future challenges while capitalizing on emerging opportunities. This is Europe's moment to create a digital future that embodies its democratic ideals, economic aspirations, and environmental commitments, thereby ultimately strengthening its sovereignty and shaping its role in a multipolar world.

Introduction

Building the EuroStack initiative – a European alternative for digital sovereignty

Europe is at a crossroads in a world undergoing rapid and dramatic change. Technological innovation is accelerating, global supply chains are splintering, and economic dependencies are being weaponized in geopolitical rivalries.

The global digital technology ecosystem is fiercely competitive and profoundly techno-political. Digital technologies define geopolitical power, economic competitiveness, and scientific excellence. Within this dynamic environment, Europe faces significant technological dependencies and vulnerabilities. Addressing these challenges is critical to securing resilient supply chains, safeguarding energy systems, protecting critical infrastructures, and strengthening cybersecurity. Europe must respond not merely by addressing dependencies but by unifying its fragmented efforts under a cohesive and ambitious vision akin to the Common Market initiative of the past.[1]

In this report, we outline the EuroStack initiative as a key policy strategy for Europe. Coined by one of the authors of this report,[2] the term has since united a coalition of European stakeholders who convened at a Brussels event that was backed by a multiparty initiative in the European Parliament.[3]

The EuroStack initiative represents such a vision – more than a technological program, it serves as a political framework designed to ensure Europe's relevance and leadership in the global digital economy. Just as the Common Market galvanized Europe's economic integration, the EuroStack initiative seeks to provide a bold, unifying strategy. Grounded in Europe's core values of shared governance, subsidiarity and solidarity, the initiative seeks to modernize and reorient the continent's approach to digital sovereignty. It calls on policymakers to take bold action to realize this vision, address emerging threats and secure Europe's digital strategic autonomy.

This report examines Europe's strategic opportunities in an era of technological disruption, advocating for the development of a common digital stack as the cornerstone of Europe's competitiveness in a rapidly evolving global economy. This initiative aligns closely with the principles of the European Commission's Competitiveness Compass, offering a cohesive framework to unify existing initiatives, set clear standards and principles, and chart a path for future actions. By combining technological infrastructure with Europe's core political values and industrial capabilities, the common digital stack will

1 Enrico Letta, "Much More than a Market Report" (European Council, 10 April 2024), https://single-market-economy.ec.europa.eu/news/enrico-lettas-report-future-single-market-2024-04-10_en.

2 Francesca Bria, "Open, Sovereign, Independent AI: Europe's Greatest Challenge?", Medium (blog), 10 December 2023, https://medium.com/@francescabria/open-sovereign-independent-ai-europes-greatest-challenge-6c8a899041ec.

3 Francesca Bria, Cristina Caffarra, and Meredith Whittaker, "Toward European Digital Independence Brussels 24th September 14.30-18.30" (Brussels, 24 September 2024), https://digitalindependenceeu.wordpress.com/.

serve as a catalyst for enhancing economic resilience, bridging innovation gaps and ensuring global leadership in critical sectors.

The need for a common digital stack: reducing dependency and towards integration

The European Union's current position in the global technological landscape is marked by significant dependencies. Over 80% of Europe's digital technologies are imported.[4] These dependencies primarily involve the United States and China, as well as major tech companies based in these countries. These technologies are as follows:

- **Digital infrastructure:** Three U.S.-based companies – Amazon, Microsoft, and Google – dominate almost 70% of the European cloud computing (IaaS) market, while Europe's largest cloud provider holds a mere 2% share.[5]

- **R&D and patenting:** EU firms represent only 7% of global R&D spending in software and internet technologies, compared to 71% by U.S. firms and 15% by Chinese companies. In electronics, EU firms account for 12% of global R&D, compared to 40% for the United States, and 19% each for China, Japan and South Korea.[6, 7]

- **Critical raw materials:** Key resources such as lithium, cobalt, nickel, gallium, graphite, and tungsten are essential for batteries, semiconductors, aerospace, and other industries. These markets are highly concentrated, with China controlling about 90% of global rare earth refining capacity.

- **Microchips:** Europe consumes about 20% of the world's microchips but manufactures only 9%. The European Chips Act aims to double the EU's share of the advanced semiconductor market to 20% by 2030 to mitigate shortages and reduce dependencies on foreign suppliers.[8] However, achieving this goal faces significant challenges, as illustrated by the delay of Intel's €30 billion chip factory in Germany due to financial and market conditions.[9]

- **Artificial intelligence:** Since 2017, 70% of foundational AI models have been developed in the United States and 15% in China. However, China's share is growing rapidly, and both figures continue to rise.[10]

While these dependencies expose vulnerabilities, the challenge is compounded by fragmented and undercoordinated efforts in Europe's digital ecosystem. Unlike the economic coherence provided by the Common Market, Europe's growing R&D spending and innovation efforts are not aligned by an overarching vision that leverages synergies or amplifies impact.

This contributes to Europe's innovation gap,[11] which led to slower productivity growth relative to the United States, reflecting weaknesses in translating R&D into market success and lower levels of

4 Mario Draghi, "The Future of European Competitiveness – A Competitiveness Strategy for Europe", 9 September 2024, https://commission.europa.eu/topics/strengthening-european-competitiveness/eu-competitiveness-looking-ahead_en.

5 Synergy Research Group, "Cloud Market Gets Its Mojo Back; AI Helps Push Q4 Increase in Cloud Spending to New Highs", accessed 7 January 2025, https://www.srgresearch.com/articles/cloud-market-gets-its-mojo-back-q4-increase-in-cloud-spending-reaches-new-highs.

6 European Investment Bank, "Chapter 5, Progress on Digital Transformation", in Resilience and Renewal in Europe, Investment Report 2022/2023 (Luxemburg: European Investment Bank, 2023), 175–215.

7 European Commission. Joint Research Centre, The 2021 EU Industrial R&D Investment Scoreboard. (Luxemburg: Publications Office, 2022), https://data.europa.eu/doi/10.2760/559391.

8 European Commission, "A Chips Act for Europe", 8 February 2022, https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52022DC0045&qid=1664190455505.

9 Christopher Rauwald and al., "Intel's German Plant Delay Lands a Blow to EU's Chip Ambitions", Bloomberg.Com, 17 September 2024, https://www.bloomberg.com/news/articles/2024-09-17/germany-faces-fresh-setback-as-intel-halts-planned-chip-factory.

10 LEAM.AI, "Large AI Models for Germany – Feasibility Study 2023", accessed 11 January 2025, https://leam.ai/feasibility-study-leam-2023/.

11 Mario Draghi, "The Future of European Competitiveness – A Competitiveness Strategy for Europe".

investment. Corporate R&D investment remains concentrated in "mid-tech" industries, particularly automotive. Of the world's 50 leading technology companies, only four are European, and none of these were created in the past 50 years. The digital economy's rapid growth has shifted the global R&D landscape, with the EU lagging compared to the United States and China.[12]

This EU underinvestment is mirrored by the difficulties startups face in scaling within Europe. Between 2008 and 2021, nearly 30% of Europe's "unicorns" relocated their headquarters abroad, predominantly to the United States, highlighting structural barriers to retaining high-growth companies. Acquisitions by non-EU players are eroding Europe's digital platform presence. Non-EU entities account for 19% of global online platform acquisitions of EU companies, while EU residents acquire only 6% of companies outside the bloc.[13]

Europe is geopolitically and geo-economically highly exposed. COVID-19, the Ukraine war, the semiconductor shortages, and rising energy prices demonstrate dependencies on global supply chains. Disruptions severely impact industries like automotive manufacturing[14] and healthcare.[15]

Europe's vulnerabilities and critical dependencies in the digital sphere result in:

- The erosion of Europe's ability to compete, innovate, and act autonomously, domestic job losses, brain drain, underinvestment, and a diminished ability to achieve technological breakthroughs. This translates into a lack of competitiveness, which ultimately contributes to a broader decline in living standards.
- The imposition of unwanted rules of foreign countries, shaped by their national security requirements, affecting control of Europeans over sensitive information of citizens, companies, and governments.
- Intellectual property theft and espionage create critical vulnerabilities, including reduced resilience and the risk of prepositioning within critical infrastructures for potential future disruption.
- Market dominance with cases of abuse of market power, the need to spend efforts of regulators and competition authorities on keeping the EU Single Market functioning properly.
- An inability to protect democracy or worse, actions that undermine it.

12 European Commission (2022b). Science, research and innovation performance of the EU 2022: Building a sustainable future in uncertain times. Luxembourg: publications Office of the European Union.

13 Mario Draghi, "The Future of European Competitiveness – A Competitiveness Strategy for Europe".

14 Roberto A. De Santis et al., "Motor Vehicle Sector: Explaining the Drop in Output and the Rise in Prices", 10 November 2022, https://www.ecb.europa.eu/press/economic-bulletin/focus/2022/html/ecb.ebbox202207_02~5bde8eeff0.en.html.

15 OECD and European Commission, Health at a Glance: Europe 2024: State of Health in the EU Cycle, Health at a Glance: Europe (OECD, 2024), https://doi.org/10.1787/b3704e14-en.

The case for the EuroStack: From vulnerability and dependency to competitiveness and autonomy

Digital autonomy is no longer a luxury – it is the foundation of sovereignty. Europe must take decisive steps to reduce reliance on external providers for critical digital infrastructure, safeguarding its competitiveness, strategic autonomy, and democratic governance. The European Commission's Digital Compass outlines the Union's digital ambitions for 2030, while the Digital Decade Program provides a roadmap to achieve these goals. Together with the Competitiveness Compass, these frameworks aim to build a resilient digital ecosystem that aligns with Europe's values, secures technological leadership, and ensures long-term economic strength.[16]

The EuroStack initiative presents a bold and balanced vision for Europe's digital future. It redefines digital sovereignty not as an isolationist pursuit but as a foundation for deeper integration, reinforcing Europe's collective strength in the face of shared challenges. Just as the Common Market laid the foundation for economic interdependence and stability, the EuroStack initiative will enable Europe to modernize its economy and digital infrastructures while safeguarding democratic principles. The initiative is not merely about reducing external dependencies but about fostering interconnectedness and enhancing the competitiveness of the European economy. By integrating digital infrastructure into a cohesive framework, the EuroStack initiative ensures that the Single Market remains robust and adaptive to 21st-century challenges. Complete self-sufficiency is neither feasible nor desirable in an interconnected world, but by building the capabilities and control necessary to protect its interests and those of its member states, Europe can create a resilient digital ecosystem that still benefits from global exchanges.

Europe faces mounting risks stemming from external dependencies and internal fragmentation. Job losses, diminished value creation, and a weakening ability to shape its own destiny in a volatile geopolitical landscape underscore the existential nature of the challenge. The urgency to act is clear. The EuroStack initiative begins by leveraging existing strengths and policy instruments, while laying the groundwork for a long-term commitment that will take over a decade to fully materialize. It strikes a balance between immediate action and structural sustainability.

Achieving greater digital sovereignty through the EuroStack initiative is not just about asserting control – it is about boosting competitiveness and closing the innovation gap with other regions. By reducing reliance on imported technologies and integrating common tech solutions with Europe's industrial core, the initiative aims to lower adoption costs, streamline operations, and accelerate the spread of high-impact technologies. Much like the technical infrastructure that underpinned the creation of the euro, required a vast technical infrastructure, the EuroStack initiative requires a similarly comprehensive approach to digital systems. This approach will boost efficiency, expand Europe's capabilities, and foster homegrown innovation in the public interest.

The EuroStack initiative promotes broad participation to address power imbalances and foster genuine value creation. By enabling smaller firms to access advanced tools and fostering sharing of data and AI insights across sectors, the initiative benefits the entire economy. This more balanced power dynamic supports smarter production processes, more responsive public services, richer product offerings, and greater knowledge spillovers – key to addressing Europe's innovation gap with the United States and China. In short, the EuroStack initiative aims to transform a system skewed toward value extraction into a vibrant ecosystem built for creating value within Europe – ultimately strengthening its autonomy, resilience, and sustainable growth.

Strategic autonomy cannot be achieved in isolation. The resources, expertise, and networks required

16 European Commission (2022a). "Towards a green, digital and resilient economy: Our European Growth Model." COM(2022) 83 final.

to build EuroStack initiative exceed the capacity of any single region. Moreover, isolationism and protectionism are counterproductive to innovation, and sustainable and inclusive growth. Instead, the initiative champions openness, knowledge-sharing, and inclusivity, fostering alliances to co-develop and co-govern the technologies of the future. These partnerships should operate within framework of digital public goods while respecting Europe's sovereignty. They must also be rooted in shared values, including economic empowerment, social rights, and democratic principles.[17]

Given the significant imbalances and dependencies Europe faces, the EuroStack initiative adopts a "Europe-first" approach. As a matter of principle, this entails purchasing European solutions, with exceptions only when justified by a clear, objective assessment of the risks for strategic autonomy in the short and long run.

To realize this vision, Europe needs a joined-up industrial strategy[18] that integrates all relevant policy domains, including market access, standardization, research and development, public procurement, investment, trade, international cooperation, and both inbound and outbound investment control. Coordination and alignment must come with a mandate to drive synergy across the block. By learning from the strategies of global competitors such as Brazil, China, India and the United States, the EuroStack initiative seeks to demonstrate how comprehensive and coordinated industrial policies can drive progress and address Europe's unique challenges. At the same time, the initiative draws lessons from past failures and sets forth a modern, proactive industrial policy that avoids fragmentation, fosters strategic collaboration, and ensures long-term resilience and competitiveness in the global digital economy. Past industrial policies in Europe have often lacked the coherence and strategic focus needed to drive competitiveness, leading instead to inefficiencies and a failure to close the innovation gap, as highlighted by Mario Draghi in his competitiveness report.

Inclusivity, paired with speed and agile execution, is central to the EuroStack initiative's strategy. By uniting industry, member states, the tech sector, and civil society, it strengthens both national and EU sovereignty. A successful industrial strategy requires recognizing the shifts it will create, with new winners and losers across countries, regions, sectors, and individuals. To harmonize this transformation, Europe must incentivize today's leaders to embrace change while investing in lagging regions through cohesion funds, skills programs, and training initiatives. Engaging trade unions as partners is also essential to empower workers as drivers of change, ensuring a just and inclusive transition. This dual focus on economic competitiveness and social equity reinforces Europe's digital sovereignty while fostering shared progress. Even with a robust industrial strategy and strong partnerships, critical dependencies will remain. These can be weaponized in times of geopolitical tension, posing risks to Europe's stability and security. Technological disruptions further complicate the landscape. To mitigate these risks, the EuroStack initiative incorporates proactive monitoring, contingency planning, and the agility to adapt to unforeseen challenges. These measures also reinforce democratic accountability for the use of EU resources.

Ultimately, EuroStack is designed to strengthen Europe's competitiveness, security, and democracy. By addressing the needs of industry and investing in foundational public digital infrastructure, the strategy ensures that Europe is well-positioned to compete in global markets while safeguarding its citizens and democratic values.

17 This approach aligns with the European Pillar of Social Rights, which underscores the importance of social inclusion and fairness, See: European Commission, The European Pillar of Social Rights Action Plan (Luxemburg: Publications Office, 2021), https://data.europa.eu/doi/10.2767/111056.; as well as with the inclusive prosperity across the Union, as put forward in the Letta report, see: Enrico Letta, "Enrico Letta's Report on the Future of the Single Market – European Commission", 10 April 2024, https://single-market-economy.ec.europa.eu/news/enrico-lettas-report-future-single-market-2024-04-10_en.

18 Francesca Bria, "X. European Digital Independence: Building the EuroStack", AI Now Institute (blog), 15 October 2024, https://ainowinstitute.org/publication/x-european-digital-independence-building-the-eurostack.

EuroStack summarized: Investment and strategic impact

The EuroStack Initiative represents Europe's ambition to achieve digital strategic autonomy through a total investment of €300 billion over ten years.

This effort proposes the creation of a European Sovereign Tech Fund, which includes an initial €10 billion earmarked for the development of digital EuroStack demonstrators. These demonstrators – selected through an open competition known as the EuroStack Challenge – will serve as minimum viable products to showcase Europe's capacity to innovate and scale foundational digital technologies.

By consolidating and aligning ongoing efforts across public and private sectors, the EuroStack initiative underscores Europe's commitment to reducing dependencies, fostering industrial champions, and driving competitiveness in critical technologies such as AI, semiconductors, cloud infrastructure, and IoT. The EuroStack strategy supports:

- ***Economic resilience:*** Creating high-skilled jobs, reducing dependencies, and supporting critical industries like healthcare, manufacturing, and energy.
- ***Strategic leadership:*** Positioning Europe as a leader in the world in values-driven, citizen-centric digital innovation.
- ***Technological independence:*** Building a sustainable, interoperable digital ecosystem rooted in European values of privacy, transparency, and trust.

This is more than a policy framework – it is a call to action. It reflects Europe's commitment to shaping a digital future aligned with its democratic ideals, economic aspirations, and global responsibilities. Through unified and principled action, the EuroStack initiative positions Europe as a leader in the digital age, prepared to tackle challenges and seize opportunities on the global stage. The path forward is complex, but it is both possible and necessary.

Summary of main actions: A radical vision for Europe's digital competitiveness

The EuroStack initiative represents a bold and transformative strategy to secure Europe's digital sovereignty and competitiveness. By addressing the structural weaknesses that have long hindered Europe's digital economy, the initiative aims to leverage the continent's unique strengths to build a cohesive, scalable, and innovative digital ecosystem. It draws on Europe's established industrial strengths in key sectors such as manufacturing, biotechnology, and healthcare as a foundation for growth. Recognizing the increasing returns to scale in digital products and services – where dominance in unified markets like the United States and China has outpaced Europe – EuroStack proposes coordinated actions to make Europe a global leader in technology within the next 10 years.

Incremental reforms, however, are no longer sufficient. Europe's past policies have struggled to fully capitalize on the potential of the Single Market. For instance, the liberalization of national telecom markets did not create a unified European telecom market. Similarly, Europe's early leadership in mobile telephony did not translate into success in digitalization or EU-wide platform development due to fragmented governance and misaligned priorities. More recently, initiatives like Gaia-X, intended to achieve cloud sovereignty, have faced significant challenges. Issues such as competing national agendas, unnecessary red tape, lack of scalability, and lack of common vision have hindered progress. These failures echo earlier difficulties in coordinating microelectronics and fostering platform-based

firms, leaving Europe vulnerable to external dominance.

To address these structural shortcomings, the EuroStack initiative proposes a series of radical reforms:

- **Reimagining market harmonization:** Move beyond fragmented national efforts to create a truly unified European digital market with a common digital stack that integrates platforms, innovation, procurement, and investment.
- **Championing strategic coordination:** Establish governance frameworks that align member states, industries, and investors around long-term digital sovereignty. These frameworks would prioritize collective goals over short-term national interests.
- **Scaling through federation:** Adopt a federated model that balances regional autonomy with shared objectives. This approach would harness the efficiencies of global supply chains while maintaining European control and independence.

Hit the ground running

The EuroStack initiative is well-positioned to launch quickly by leveraging Europe's existing resources, which align closely with its overarching objectives. Europe benefits from an abundance of assets that, while often fragmented or lacking in scale, are both impressive and highly innovative.

These assets include diverse array of world-class European companies driving innovation across the technology stack. The initiative also builds on an extensive network of existing public, industrial and private-public partnerships, as well as ongoing projects. By consolidating and scaling these strengths, the EuroStack initiative aims to overcome fragmentation, maximize its impact, and accelerate Europe's progress toward achieving digital sovereignty.

Seizing opportunities through European digital sovereignty

Europe finds itself at a pivotal moment, with the potential to emerge as a global leader in the digital era by embracing the concept of digital sovereignty. The EuroStack initiative offers a comprehensive blueprint for building a resilient, competitive, and inclusive digital ecosystem that reflects European values and leverages the continent's unique strengths. Instead of focusing solely on risks, this analysis emphasizes the significant opportunities that come with achieving greater digital autonomy.

- ***Unlocking innovation and economic growth:*** By reducing reliance on imported technologies and fostering a thriving open-source community, the EuroStack initiative can spark innovation across Europe. Strategic investments in areas such as AI, cloud infrastructure, and quantum technologies will pave the way for new markets, high-quality jobs, and sustained economic growth. EuroStack is not merely about control; it is about enhancing Europe's competitiveness and bridging the innovation gap with other global regions.
- ***Strengthening European industry:*** The EuroStack initiative presents a unique opportunity to revitalize European industries, particularly in sectors like manufacturing, healthcare, and biotechnology. By integrating digital solutions with Europe's industrial core, the initiative will enable more efficient processes, secure supply chains, and innovative business models. The promotion of "Made in Europe" digital products and services will foster regional value creation and bolster Europe's position as a global manufacturing hub.

- ***Leading in ethical and sustainable technology:*** Europe has the chance to set a global benchmark for ethical and sustainable technological development. By prioritizing data sovereignty, transparency, and environmental sustainability, the EuroStack will establish a trustworthy digital ecosystem aligned with European values. Initiatives focusing on renewable energy, water efficiency, and responsible data governance will ensure that Europe's digital transformation is both cutting-edge and environmentally conscious.

- ***Empowering citizens and businesses:*** The development of secure, interoperable digital public infrastructure through the EuroStack will empower both citizens and businesses. Digital identity systems, secure payments and data platforms will create a more inclusive and efficient digital society. By promoting digital skills and fostering a culture of innovation, EuroStack will ensure that all Europeans can participate in and benefit from digital advancements.

- ***Shaping a digital foreign policy:*** Europe's approach – balancing strategic autonomy with international collaboration – positions it to lead in global partnerships for ethical, inclusive, and sustainable digital development. By fostering partnerships with like-minded countries and advocating for open-source technologies and equitable technology transfers, Europe can contribute to a global digital order that prioritizes public interest and resilience. The EuroStack offers a model for a decentralized and collaborative digital future.

- ***Leveraging open source and collaboration:*** The EuroStack champions an open-source innovation ecosystem. By building on Europe's established strengths in open-source software and cultivating a collaborative network of developers, researchers, and innovators, the initiative will accelerate innovation and ensure sustainability. Emphasis on open APIs, data sharing, and digital commons empowers European stakeholders while fostering collective growth.

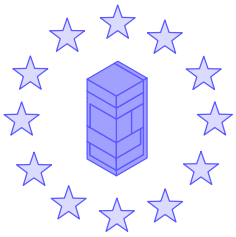
- ***Strategic investments in key technologies:*** The EuroStack initiative includes targeted investments in key technologies such as AI, cloud computing, quantum computing, and next-generation semiconductors. These investments, supported by public-private partnerships, will secure Europe's leadership in high-impact fields.

Core strategic actions

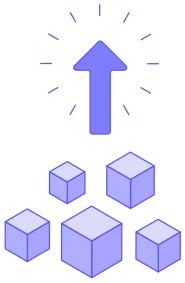
1. ***Develop a European common digital stack***
   Build interoperable, cyber-secure platforms for AI, cloud computing, eID, data access, and digital currencies such as the Digital Euro. Unlike the fragmented efforts of the past, this strategy prioritizes harmonized European platforms capable of competing with global leaders in scale and impact. Investments in infrastructure will include energy efficient public computing capacity (EuroHPCs) and next-generation chips to support AI development and adoption across key sectors.

2. ***Deploy high-impact digital services***
   Introduce minimum viable products (MVPs) as scalable digital solutions in strategic areas such as AI-driven biotech, smart manufacturing, robotics, mobility, and healthcare. These unified, pan-European deployments will demonstrate Europe's capacity for high-value innovation.

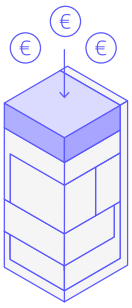
The EuroStack
Actions



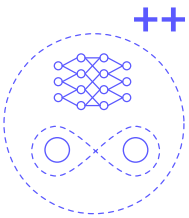
Develop a European common digital stack



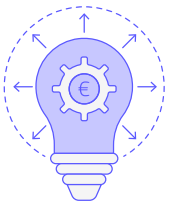
Deploy high-impact digital services through the EuroStack Challenge



Foster sovereign AI and federated data spaces



Lead in next-generation technologies



Scale innovation through "Europe first" procurement and strategic investments. Establish a European Sovereign Technology Fund

3. ***Foster sovereign AI and federated data spaces***
   Invest in sovereign AI clouds, platforms, and interoperable data ecosystems to drive innovation and adoption in industrial sectors while ensuring ethical oversight and control. These initiatives aim to overcome market fragmentation and enable greater scalability across Europe.

4. ***Lead in next-generation technologies***
   Strengthen Europe's capabilities in edge computing, quantum technologies, industrial AI, space technologies, and biotechnology. Strategic investments aligned with industrial priorities will secure leadership in cutting-edge fields and establish the foundation for next-generation digital infrastructure.

5. ***Scale innovation through strategic investments***
   Establish a European Sovereign Technology Fund to address investment gaps and prevent the foreign acquisition of critical firms such as ARM and DeepMind. This fund will create a robust financial ecosystem to sustain innovation and ensure Europe's long-term competitiveness.

The EuroStack initiative is more than a strategy for reducing dependencies; it is a forward-looking plan to build a thriving digital future for Europe. By capitalizing on opportunities, fostering collaboration, and staying true to European values, the EuroStack positions Europe as a global leader in the digital age. This approach will unlock new pathways for growth, innovation, and social progress, ensuring Europe's influence and resilience on the world stage.

Report structure

This report outlines the EuroStack initiative's vision and provides a comprehensive roadmap for advancing Europe's digital sovereignty. It is organized as follows:

Section 1 – The EuroStack initiative
The first section presents the vision and strategic objectives of the EuroStack initiative, emphasizing the importance of leveraging Europe's industrial strengths to create a common digital stack. It highlights the transformative potential of MVPs as scalable digital services, selected for their high impact in sectors such as advanced manufacturing, biotechnology, mobility, and healthcare. These sectors and their use cases serve as illustrative examples, focusing on services and products capable of driving joint European industrial missions. The initiative prioritizes fostering open-source innovation and agile development to accelerate collaboration and ensure efficient project execution. It also introduces a governance framework designed to facilitate effective implementation. This framework balances flexibility with alignment to Europe's values through a clearly defined execution model.

Section 2 – The political economy of digital sovereignty
The second section situates the EuroStack initiative within a broader geopolitical and macroeconomic context, framing the tech stack as a contested domain where technology, strategy, and power converge. It explores how Big Tech firms are reshaping the stack through vertical integration and dominance strategies, while governments compete to control technologies critical to economic and geopolitical influence. This analysis identifies Europe's vulnerabilities and bottlenecks in areas such as raw materials, semiconductors, networks, cloud computing, and AI. It underscores the interplay between value creation and value capture, presenting the development of the EuroStack as a strategic imperative. The initiative is framed as essential not only for integrating and strengthening the European Common Market but also for addressing global challenges and securing Europe's competitiveness, security, and technological sovereignty in a rapidly evolving world.

Section 3 – European digital industrial policy blueprint
The third section evaluates Europe's industrial policy, drawing lessons from past successes and failures to translate the EuroStack vision into actionable recommendations. It proposes a forward-looking digital industrial policy focused on coordinated investment, harmonized regulations, and public procurement that prioritizes European-made digital solutions. The blueprint emphasizes partnerships and robust governance frameworks, culminating in an agile implementation roadmap designed to position Europe as a global tech leader within the next decade. The EuroStack approach explicitly rejects the pitfalls of excessive bureaucracy in favor of an agile, innovative strategy. This pragmatic approach ensures efficiency, adaptability to geopolitical and technological shifts, and a focus on delivering tangible outcomes that bolster Europe's strategic autonomy and competitiveness.

Section 4 – References and annexes
The report concludes with references and two annexes. Annex A examines how major tech firms shape the digital stack to assert dominance and extract rents. Annex B maps ongoing EU policy actions and key stakeholders, aligning these efforts with the EuroStack initiative.

Section 1 – The EuroStack initiative

An infrastructural layered framework for digital sovereignty

Carlota Perez's techno-economic paradigms framework[19] highlights that each technological revolution progresses through phases, from early innovation to widespread deployment. In the current internet, communications and technology (ICT) revolution, we are in the deployment phase, where digital technologies are becoming integral to all aspects of society and industry. These drive a growing demand for robust infrastructure like broadband, cloud computing, and data centers. Emerging technologies further amplify this need, making digital infrastructure a cornerstone of economic, industrial, and societal transformation.

The EuroStack initiative organizes digital infrastructure into a cohesive system of interconnected layers, ranging from foundational technologies to advanced applications. It employs the stack model as a conceptual framework,[20] where each layer builds upon the capabilities of the one below it while dynamically interacting with all others. This design enables targeted actions, allowing policymakers and stakeholders to visualize and address specific areas of need more effectively.

Specialized "sub-stacks," such as those for cloud computing and AI, address specific needs but remain integral to the unified EuroStack system. The framework prioritizes interoperability, resilience, scalability, and adaptability to ensure seamless functionality across the system. These layers also underpin sectoral applications in biotechnology, advanced manufacturing, and public services, helping Europe remain competitive and self-reliant in the global digital landscape. Moreover, the EuroStack initiative includes cross-stack topics such as cybersecurity, emerging technologies, and competitive shifts that can reshape its structure and create new strategic autonomy opportunities.

The layers of the EuroStack are represented as follows:

1. **Resources:** This foundational layer includes critical materials like rare earth elements, energy sources, and skilled labor. These elements form the bedrock of all digital infrastructure.

2. **Chips:** This layer encompasses processors and memory technologies, GPUs, and emerging quantum communication systems, all essential for powering digital infrastructure and ensuring secure supply chains.

3. **Networks:** This layer encompasses both digital and physical connections, including cell towers, fiber-optic networks, and undersea cables that link Europe to the global digital ecosystem.

19 Carlota Perez, "Technological Revolutions and Techno-Economic Paradigms", Cambridge Journal of Economics 34, no. 1 (2010): 185–202.

20 Haroon Sheikh, "European Digital Sovereignty: A Layered Approach", Digital Society 1, no. 3 (18 November 2022): 25, https://doi.org/10.1007/s44206-022-00025-z.

4. **Connected devices & IoT:** This layer includes everything from smartphones and laptops to Internet of Things (IoT) devices that enable real-time information processing and data collection.

5. **Cloud infrastructure:** This layer comprises secure data storage and computational power, both of which are central to data sovereignty and autonomy.

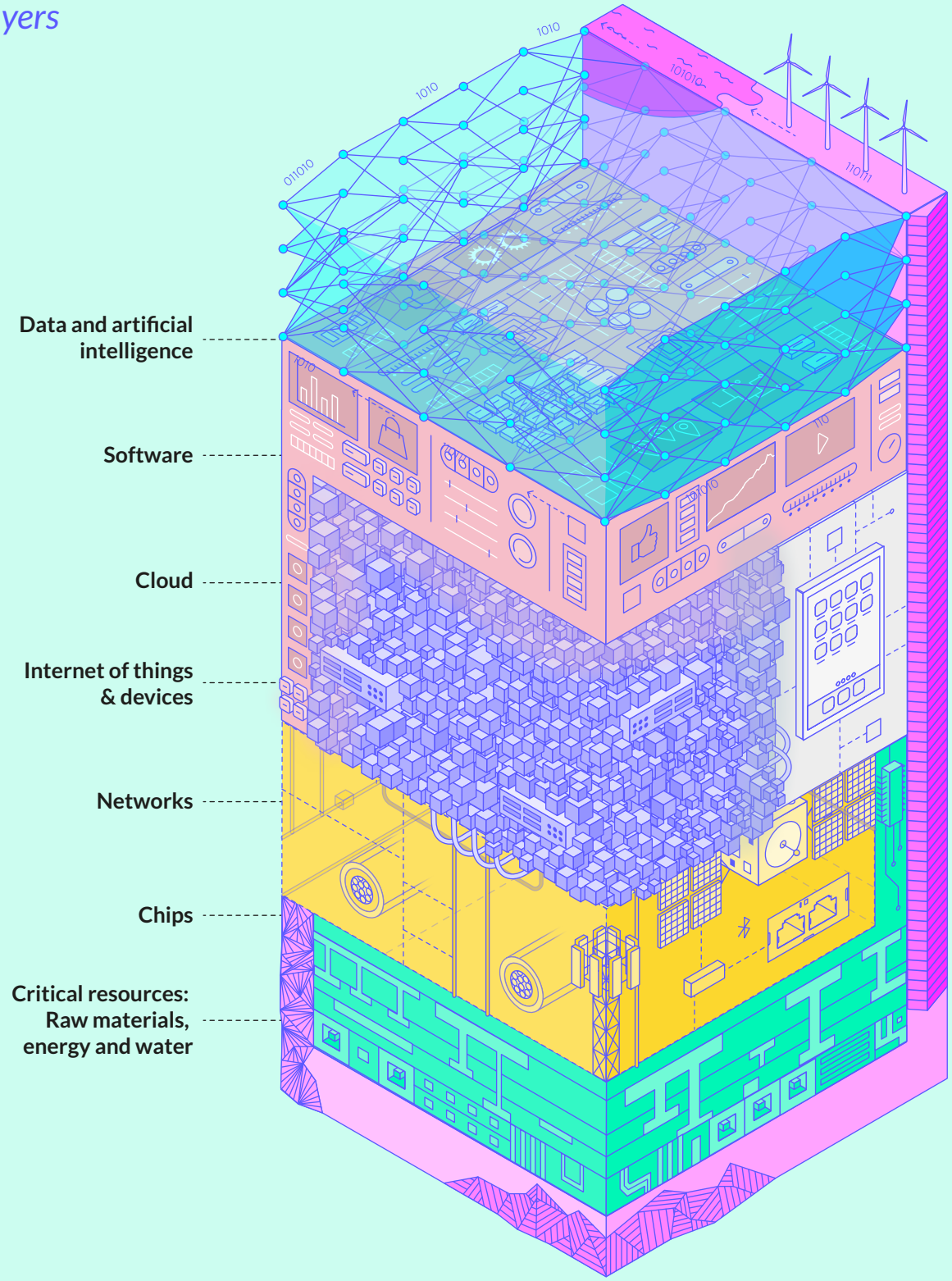
6. **Software platforms, applications, and algorithms:** This layer encompasses operating systems, applications, and cybersecurity frameworks that drive digital interactions.

7. **Data and artificial intelligence:** This layer processes data and generates insights, positioning Europe to build and control core AI capabilities for a competitive edge.

The EuroStack, illustrated here as a layered structure, should also be envisioned as a dynamic circular ecosystem. Each element functions as a node, highlighting the interdependencies and interconnected nature of digital technologies. This approach emphasizes the need for adaptability, allowing the model to evolve as new technologies emerge or priorities shift. It also visualizes the strengths of European capabilities in each area while identifying potential vulnerabilities or investment needs to strengthen the ecosystem further.

The current digital stack

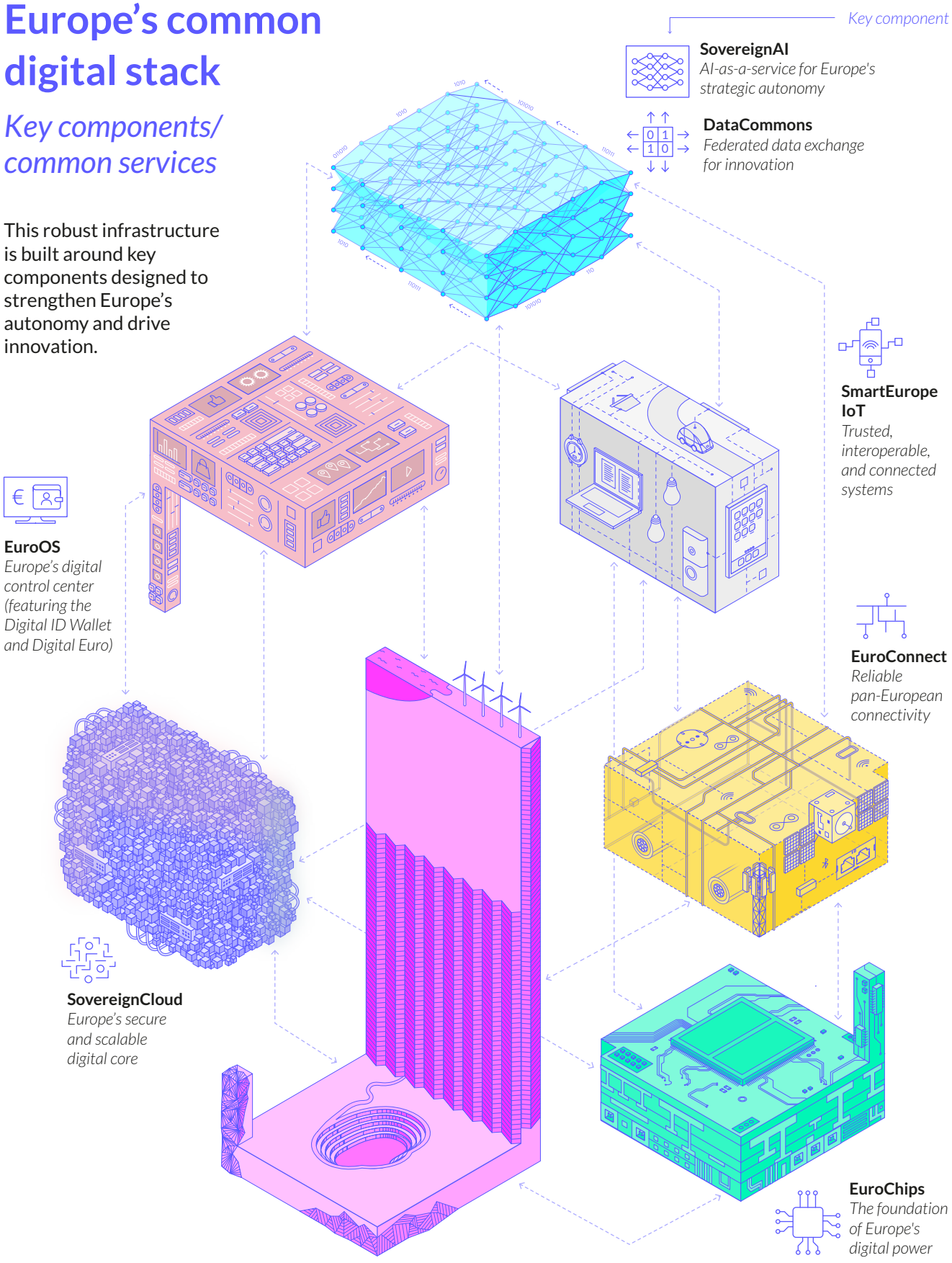
The layers



Europe's common digital stack

Key components/ common services

This robust infrastructure is built around key components designed to strengthen Europe's autonomy and drive innovation.



A vision tailored for Europe

The EuroStack initiative offers a bold and pragmatic vision for Europe's digital future, grounded in its industrial strengths, innovative capabilities, and unwavering commitment to democratic values. In a world marked by increasing geopolitical fragmentation, the initiative champions a federated and decentralized approach. This model reflects Europe's diversity while also ensuring resilience by fostering collaboration and aligning efforts across the Single Market. Unlike the centralized dominance of U.S. Big Tech or China's state-directed strategies, the EuroStack initiative leverages Europe's unique position within global supply chains. By embracing federation, Europe can maintain the benefits of international cooperation and interconnected markets while building the autonomy needed to safeguard its strategic interests. This approach balances regional autonomy with shared objectives, enabling Europe to navigate a multipolar world while driving innovation and sustaining its competitive edge.

Europe has solid assets to build upon. Industry leaders like ASML and SAP exemplify industrial and technological excellence, while innovative firms like ARM and DeepMind showcase Europe's potential for ground-breaking advancements – even though their acquisition by foreign investors underscore the need for greater attention to strategic autonomy. Advanced research centers and industries with strengths in advanced manufacturing, networking, robotics, chips manufacturing, and biotech provide a solid foundation for Europe to reclaim leadership in science and technology.

The EuroStack initiative is designed to leverage these strengths to reduce reliance on foreign technologies, nurture homegrown innovation, and revitalize Europe's industrial ecosystem. By focusing on interoperability, security, and sustainability, it aligns technological progress with societal needs while fostering inclusive growth and global competitiveness.

This vision is both actionable and grounded in clear principles. By integrating initiatives such as EuroHPC, IPCEIs, and the Quantum Flagship into a cohesive framework, the EuroStack streamlines innovation and accelerates the development of scalable platforms. The initiative emphasizes open-source technologies and cross-border collaboration among member states, ensuring that Europe's technological backbone reflects its values of transparency, accountability, and inclusivity.

The EuroStack initiative represents a distinctly European approach to achieving digital sovereignty. It provides the structure and governance needed to unify industry, policymakers, and investors, driving the development of critical technologies and reducing market fragmentation.

By addressing vulnerabilities across the tech stack and building on its industrial capabilities, the EuroStack positions Europe to compete effectively on the global stage. This initiative is not about overregulation but about empowering Europe's industrial top performers and fostering innovation. It aims to ensure that Europe remains at the forefront of a rapidly evolving global economy while upholding its commitment to democracy, sustainability, and shared prosperity.

The EuroStack initiative is built on the following six pillars:

1. **A vision tailored for Europe:** The EuroStack initiative embodies a bold yet achievable vision to enhance the EU's digital strategic autonomy. This vision leverages Europe's unique strengths – its diversity, democratic governance, regulatory leadership, and focus on industrial innovation and competitiveness. It is grounded in clear principles that align with Europe's long-term priorities and ensure its feasibility.

2. **A joined-up, modern industrial policy:** Investment, market regulation, R&D, standardization, trade and competition policies,

and international partnerships are all designed to work in harmony, consistently reinforcing one another to drive progress and innovation.

3. **The EuroStack digital infrastructure:** Serving as the backbone of Europe's digital services, hardware, and software, this infrastructure connects citizens, businesses, and governments through secure and interoperable systems. By integrating critical components such as networks, chips, cloud, IoT, data platforms, and AI, it ensures the viability of European innovation while democratizing access to advanced computing. Built with an emphasis on sustainability, resilience, and sovereignty, this infrastructure is designed to address Europe's immediate and long-term digital needs.

4. **Minimum viable products:** The EuroStack initiative introduces a set of scalable, interoperable digital services and applications designed for success within the Single Market. These MVPs act as operational trailblazers, meeting the immediate needs of citizens and businesses while showcasing the feasibility and value of Europe's digital sovereignty strategy.

5. **A growing open-source community:** At the heart of the EuroStack initiative lies a dynamic open ecosystem that brings together developers, researchers, SMEs, industry players, and innovators across software, hardware, and AI. This community collaborates with member states, European institutions, and private investors to build the EuroStack from the ground up, ensuring transparency, adaptability, and continuous innovation.

6. **A sustainable governance model:** To ensure lasting impact, the EuroStack initiative will adopt an accountable and independent governance framework. This framework will bring together public and private stakeholders to harmonize policies, monitor progress, and secure investments, fostering the initiative's long-term sustainability and growth.

Principles of the EuroStack

The EuroStack is grounded in seven guiding principles:

1. **Sovereignty and security:** Guaranteeing that Europe's critical digital infrastructure remains under European jurisdiction, protected by robust security-by-design and privacy-by-design frameworks.

2. **De-proprietarization and interoperability:** Promoting integration across an open-source, federated tech stack, while reducing dependence on proprietary solutions from major tech corporations.

3. **Sustainability:** Building energy-efficient and resource-resilient systems that align with Europe's environmental and climate goals.

4. **Data as a common good:** Treating data as a shared resource to unlock innovation while safeguarding societal interests and fundamental rights.

5. **Decentralized sovereign infrastructure:** Combining edge computing and centralized systems to improve efficiency and data sovereignty.

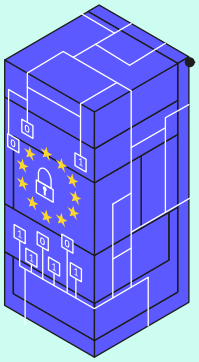
6. **Inclusive governance:** Establishing harmonized regulations and accountability mechanisms that balance short-term resilience with long-term autonomy.

7. **Strong democracy:** Advancing digital technologies that not only avoid harm but actively support and strengthen democratic societies .

These principles ensure that the EuroStack operates ethically, remains resilient, and adapts effectively, delivering lasting value to stakeholders.

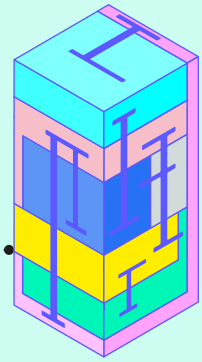
The EuroStack

Core principles



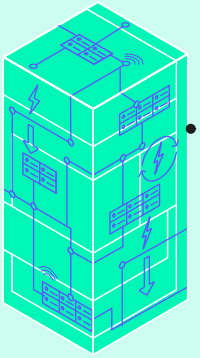
Sovereignty and security

Guaranteeing that Europe's critical digital infrastructure is under European jurisdiction, and is protected by robust security-by-design and privacy-by-design.



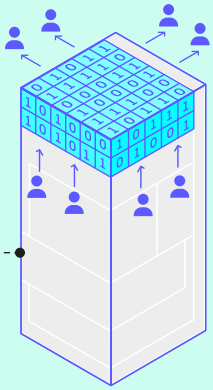
De-proprietarization and interoperability

Promoting integration across an open-source, federated tech stack, while reducing reliance on Big Tech proprietary solutions.



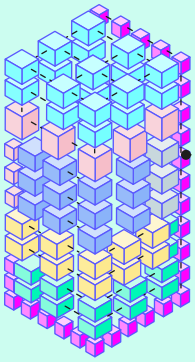
Sustainability

Building energy-efficient and resource-resilient systems to meet Europe's environmental and climate objectives.



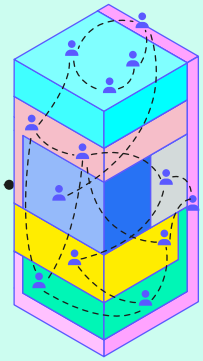
Data as common good

Treating data as a shared resource to unlock innovation while safeguarding societal interests and fundamental rights.



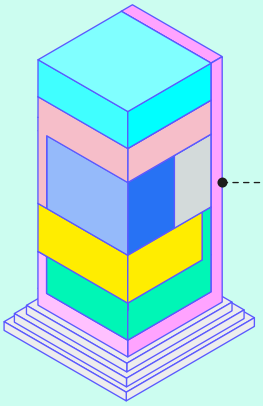
Decentralized sovereign infrastructure

Combining edge computing and centralized systems for improved efficiency and data sovereignty.



Inclusive governance

Ensuring harmonized regulations, accountability, and a balance between short-term resilience and long-term autonomy.



Strong democracy

Digital technologies that do no harm and fundamentally strengthen democratic societies.

Europe's common digital stack

At the heart of the EuroStack initiative lies its digital infrastructure, a foundational backbone that integrates Europe's capabilities across semiconductors, networks, cloud computing, IoT, data platforms, AI, and digital identity. Designed to secure Europe's digital sovereignty, this infrastructure ensures a resilient, interoperable, and scalable ecosystem that supports both public and private services, all while adhering to EU regulatory and ethical standards.

This robust infrastructure is built around key components, each designed to enhance Europe's autonomy and drive innovation:

1. EuroChips: The foundation of Europe's digital power

Semiconductors form the cornerstone of Europe's digital infrastructure. Through the European Chips Act, significant investments are being made in cutting-edge fabrication facilities and next-generation chip designs, with a focus on energy-efficient, low-power semiconductors. These efforts are bolstered by the adoption of RISC-V, an open-standard architecture that reduces dependency on proprietary technologies, fosters innovation, and strengthens Europe's technological independence. To enhance resilience, the EuroStack initiative supports expanded RISC-V development, the creation of a robust software ecosystem around it, and the establishment of secure, sovereign supply chains. These measures are essential to ensuring access to critical components, safeguarding uninterrupted production, and positioning Europe as a leader in the global semiconductor ecosystem.

2. EuroConnect: Reliable pan-European connectivity

The EuroStack's network infrastructure is designed to deliver secure, seamless communication across borders, enabling real-time data exchange essential for Europe's digital economy. The initiative promotes the development of standalone 5G networks and anticipates the transition to 6G technologies, ensuring Europe remains competitive on the global stage. Decentralized and localized edge operations reduce latency, improve resilience, and optimize performance, particularly for critical sectors such as healthcare, manufacturing, and smart cities. By prioritizing energy-efficient network technologies, EuroStack aligns with Europe's sustainability goals while minimizing environmental impact. To ensure resilience, the infrastructure incorporates redundancy, robust cybersecurity measures, and preparation for quantum technologies. Future-oriented initiatives such as adopting the Scalability, Control, and Isolation on Next-generation Networks (SCION) architecture (which enhances scalability, control, and data isolation) and strengthening the resilience of undersea cables and satellite connectivity will further strengthen Europe's digital autonomy.

3. SovereignCloud: Europe's secure and scalable digital core

Leveraging initiatives like 8ra and the Important Projects of Common European Interest (IPCEI)-CIS, the EuroStack advances decentralized cloud and edge infrastructures to reduce reliance on foreign providers, ensuring sovereignty and operational flexibility. The disruption in the AI cloud market presents a critical opportunity for Europe to lead by developing sovereign AI cloud infrastructure, mid-sized data centers, and AI Factories to support advanced AI development and deployment. By integrating public high-performance computing (HPC) centers and optimizing them for AI applications, EuroStack aims to establish a scalable, unified cloud infrastructure fully under European jurisdiction. This infrastructure will cater to sectors such as healthcare, energy management, and manufacturing, offering reconfigurable and tailored cloud services. A strong emphasis on sustainability and energy efficiency ensures alignment with Europe's climate goals, while redundant systems provide resilience and robust performance under high demand.

4. SmartEurope IoT: Trusted, interoperable, and connected systems

The EuroStack IoT platform enables the large-scale deployment of certified devices and services, driving innovation across smart cities, industrial automation, renewable energy management, advanced manufacturing, and robotics (e.g., Industry 5.0). Designed to comply with EU regulations like the Cyber Resilience Act and NIS-2 Directive, it ensures the highest standards of privacy and security. Built on EU-developed specifications like FIWARE and the work in the IPCEI-CIS, the platform fosters interoperability, allowing the seamless integration of IoT solutions across sectors. Scalable and adaptable, the platform supports diverse applications while maintaining alignment with Europe's regulatory and sustainability principles.

5. DataCommons: Federated data exchange for innovation

Industry data exchange: Accelerating industrial innovation

For industrial sectors, platforms such as Manufacturing-X and Catena-X create secure ecosystems for sharing industry-specific data, fostering collaboration, and driving innovation. These platforms enable manufacturers and supply chain partners to share data efficiently while maintaining data sovereignty and ensuring compliance with European regulations. They prioritize interoperability, allowing seamless integration of data across businesses and sectors. By fostering trust and transparency, these platforms enhance Europe's competitive edge in advanced manufacturing and industrial ecosystems.

Public interest data as a public good

Public interest data platforms treat data as a collective resource managed for societal benefit. Drawing inspiration from Finland's Suomi.fi and Estonia's X-Road, these platforms enable secure and ethical cross-border data sharing among public and private entities. They focus on critical public interest use cases, such as healthcare, urban planning, and environmental monitoring, while prioritizing data sovereignty and compliance with privacy regulations. By treating data as a public good, these platforms uphold European values, facilitating transparent, ethical exchanges that prioritize citizen rights and promote societal well-being.

Both frameworks emphasize interoperability, enabling data to flow seamlessly within and across sectors, while safeguarding trust, security, and regulatory compliance. Together, they form the backbone of Europe's data-driven economy, balancing innovation with ethical stewardship to harness data as both a strategic asset and a public good.

6. EuroOS: Europe's digital control center (featuring the Digital ID Wallet and Digital Euro)

Software forms the operational core of digital infrastructure, encompassing operating systems, application platforms, and algorithmic frameworks. It powers critical functions such as identity management, electronic payments, transactions, and document delivery, forming the foundation of digital public infrastructures. In this domain, U.S. companies dominate foundational tools, with Microsoft, Apple, and Google controlling over 90% of the European market for operating systems across desktops, mobile devices, and embedded systems. While Europe boasts global leaders in enterprise software, its presence in algorithmic frameworks, vital for innovation and developer ecosystems, remains limited and often reliant on U.S.-based platforms. Programs like the Next Generation Internet (NGI) initiative have developed alternative software solutions in Europe, but their scale has not yet reached the critical mass needed to compete globally.

The Sovereign Digital Identity Wallet provides secure, privacy-first authentication for citizens and businesses, ensuring seamless access to both public and private services across Europe. By overcoming the limitations seen in models like India Stack, which

rely on centralized biometric IDs and foreign cloud infrastructure, the EuroStack offers a federated, privacy-preserving platform. With a focus on privacy-by-design, cross-border interoperability, and user empowerment, the wallet ensures that citizens control their data, sharing only what is necessary while maintaining full compliance with EU privacy standards. As the gateway to Europe's digital infrastructure, the wallet enables seamless access while safeguarding privacy and sovereignty. Governments must ensure voluntary participation, protect against coercive enrollment and provide opt-out options to prevent service denial for non-participants. Clear procedures for withdrawing consent, deleting data, and conducting regular audits can ensure accountability.

The Digital Euro, to be issued by the European Central Bank, anchors trust and stability in Europe's monetary system as a central bank-backed digital currency. It offers universal access, ensuring all citizens and businesses, including those underserved by traditional banking, can fully participate in the digital economy. Fee-free transactions foster financial inclusion, reduce costs, and promote economic equity. With General Data Protection Regulation (GDPR) compliance at its core, the Digital Euro ensures secure transaction data processing exclusively within European jurisdiction, facilitating secure cross-border transactions while seamlessly integrating with public and private digital systems. This strengthens Europe's financial sovereignty, supports innovation, and fosters sustainable economic growth across the EU.

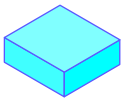
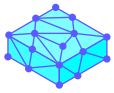
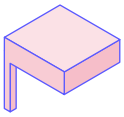
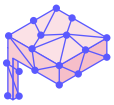
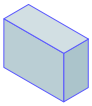
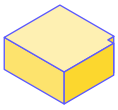
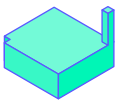
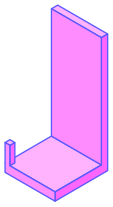
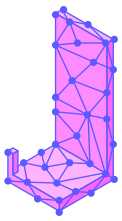
7. SovereignAI: AI-as-a-service for Europe's strategic autonomy

The EuroStack initiative's sovereign AI solutions aim to power critical sectors such as mobility, healthcare, education, and climate monitoring across Europe. By combining the scalability of large AI models with the precision of bespoke solutions, Europe is leveraging its growing ecosystem of AI labs, companies, and public HPC centers. Initiatives like AI Factories, OpenGPT-X, and LEAM-Large European AI Models utilize Europe's public compute infrastructure to develop large, multilingual AI models that reflect European values. Localized, smaller-scale AI models complement these efforts, offering tailored solutions for niche sectors while addressing regional and sector-specific needs. By embracing composite learning, a hybrid approach combining decentralized, distributed, and federated learning, Europe is building privacy-preserving, accountable AI systems that align with public interest goals, driving innovation while ensuring data sovereignty and ethical governance. A sound approach for Europe's AI development involves investing in specialized large-scale models that address its unique linguistic and cultural diversity, as well as domain-specific needs. Where feasible, these models should be made open source to foster transparency and collaboration. At the same time, agile application development is essential, as it leverages a mix of European-developed technologies and globally available models to accelerate deployment. Strategic funding and partnerships between government, industry, and academia will be crucial to sharing the costs and benefits of foundational AI investments, leading to robust, innovative, and competitive outcomes.

The EuroStack initiative represents Europe's commitment to building a secure, resilient, and sovereign digital ecosystem. Its goal is to establish European alternatives across the technology stack, building on Europe's core assets and industrial capabilities. Achieving this requires the formation of a coalition of European tech leaders to spearhead innovation and reduce dependency on foreign technologies. A critical step involves mapping Europe's existing assets in a dynamic, evolving joint catalogue that links and aligns industrial policy initiatives. By integrating these efforts and scaling existing alternatives, the EuroStack initiative can strengthen Europe's industrial competitiveness, foster innovation, and uphold digital rights, sustainability, and ethical governance. Positioned as a global alternative, the EuroStack initiative offers a uniquely European approach to thriving in the global digital economy.

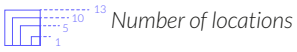
The EuroStack

Key companies, alliances, and networks

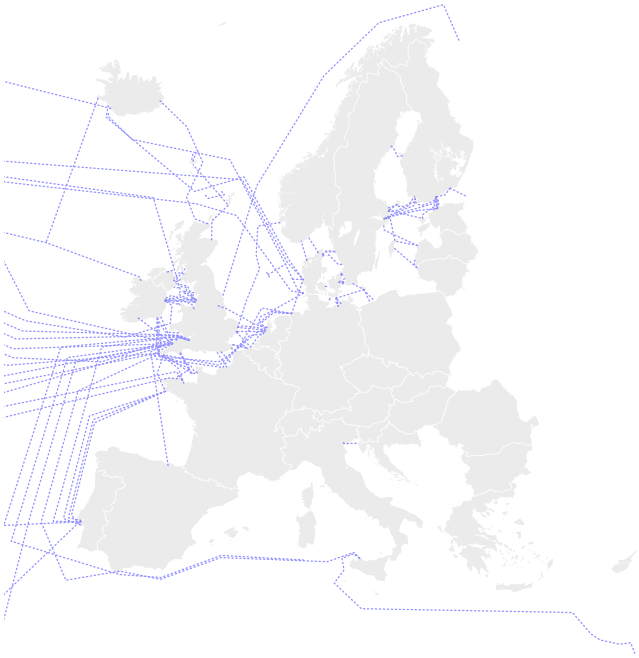
	KEY COMPANIES	ALLIANCES AND NETWORKS
Data and artificial intelligence 	• Mistral (France) • Aleph Alpha (Germany) • Siemens (Germany) • iGenius (Italy) • UiPath (Romania) • DeepL (Germany) • Celonis (Germany)	 • European AI Alliance • AI4EU Platform • Big Data Value Association (BDVA)
Software 	• SAP (Germany) • Nextcloud (Germany) • LibreOffice (Germany) • Dassault Systèmes (France) • Thales (France) • Bitdefender (Romania)	 • OpenForum Europe • European Software Strategy Alliance (ESSA) • Secure Identity Alliance
Internet of things & devices 	• Siemens (Germany) • Schneider Electric (France) • Bosch (Germany) • Philips (Netherlands) • Atos (France)	 • IoT European Platforms Initiative (IoT-EPI)
Cloud 	• OVHcloud (France) • Scaleway (France) • Deutsche Telekom (Germany) • Schwarz (Germany)	 • European Alliance for Industrial Data, Edge, and Cloud
Networks 	• Nokia (Finland) • Ericsson (Sweden) • Alcatel Submarine Networks (France) • Orange (France) • Airbus Defence and Space (Germany/France	 • 5G Infrastructure Public Private Partnership (5G PPP) • Smart Networks and Services Joint Undertaking for 5G and 6G
Chips 	• ASML (Netherlands) • STMicroelectronics (France/Italy) • Infineon Technologies (Germany) • NXP Semiconductors (Netherlands) Key R&D innovators: • Fraunhofer Society (Germany) . • IMEC (Belgium)	 • Important Projects of Common European Interest (IPCEI) on Microelectronics • Silicon Saxony • European Semiconductor Industry Association (ESIA) • Industrial Alliance on Processors and Semiconductor Technologies
Raw materials, energy, and water 	• Umicore (Belgium) • Boliden (Sweden)	 • European Raw Materials Alliance (ERMA)

The EuroStack
Geographic mapping

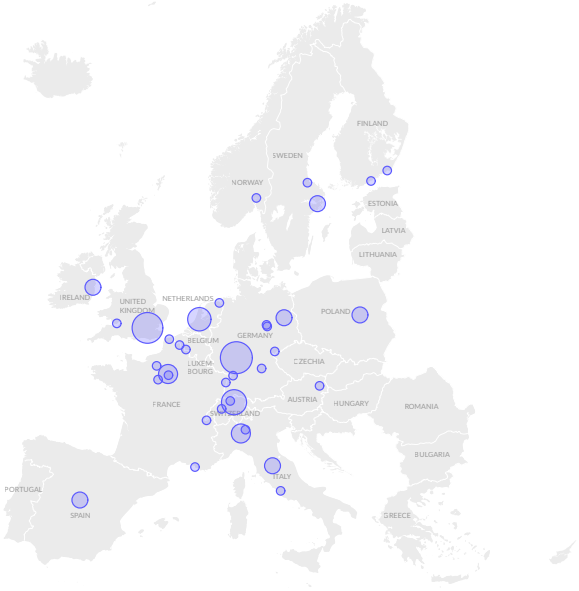
Legend



Undersea cables

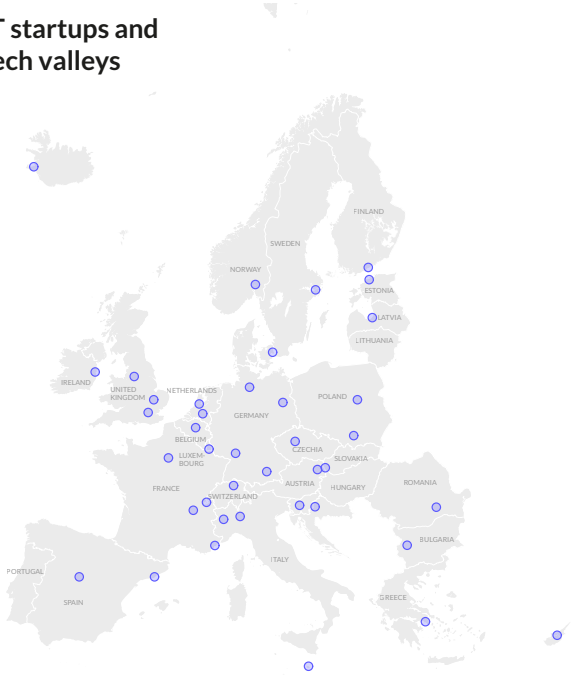


Data centers for cloud services

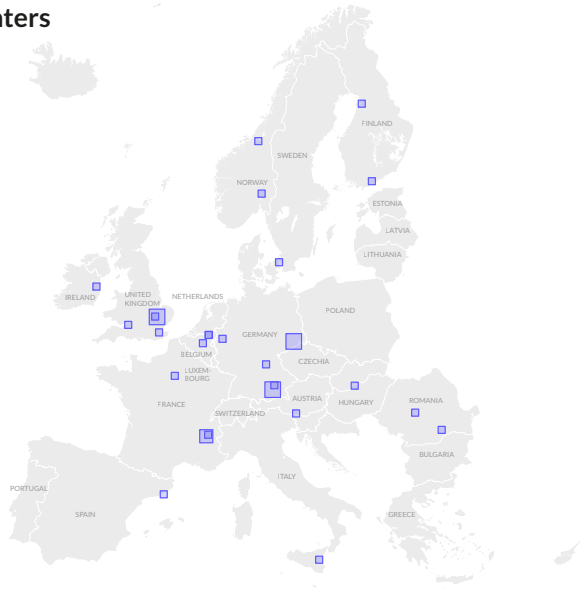


High performance computing (HPC) facilities

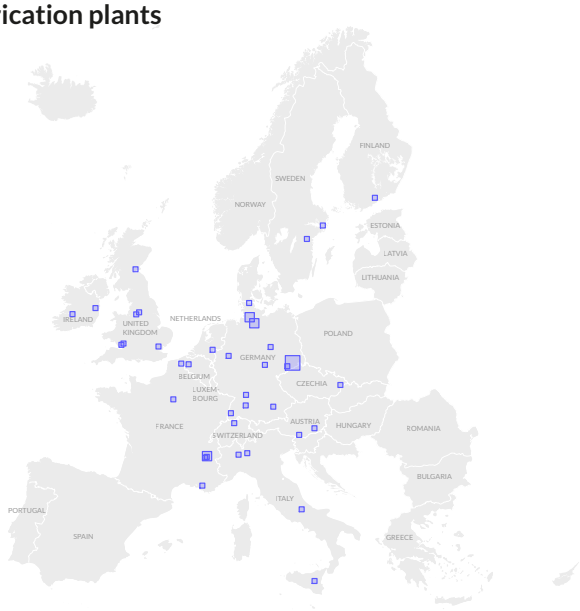
IT startups and tech valleys



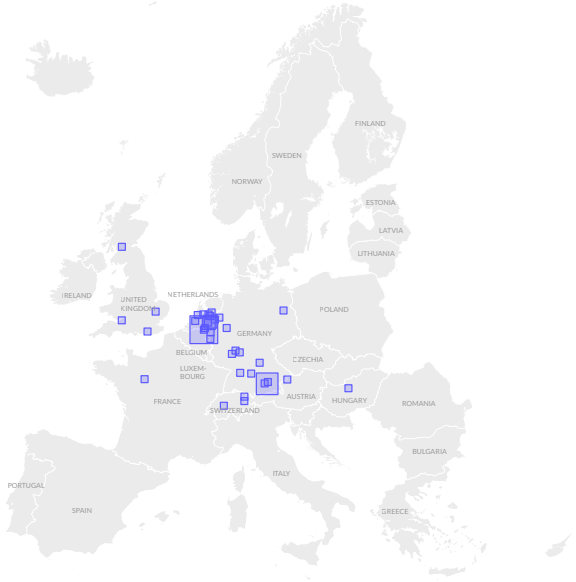
Semiconductor design centers



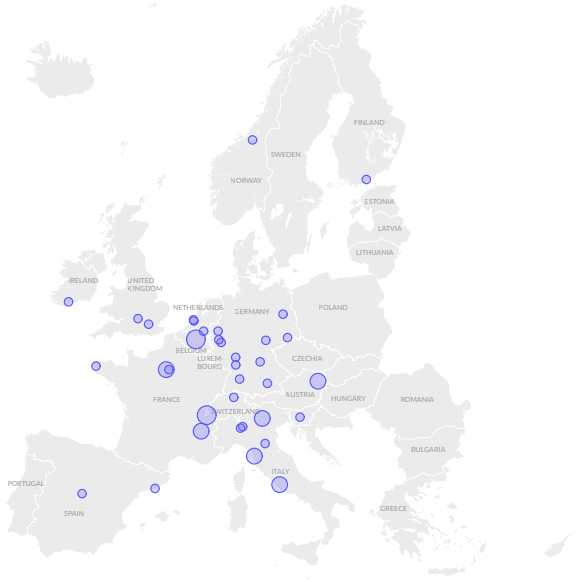
Semiconductor fabrication plants



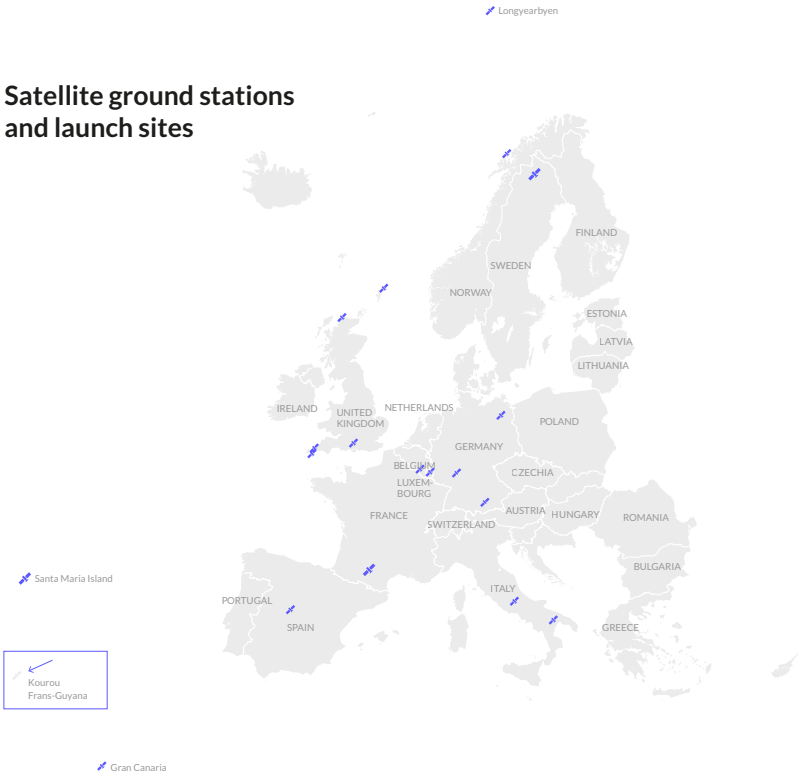
Semiconductor equipment manufacturers



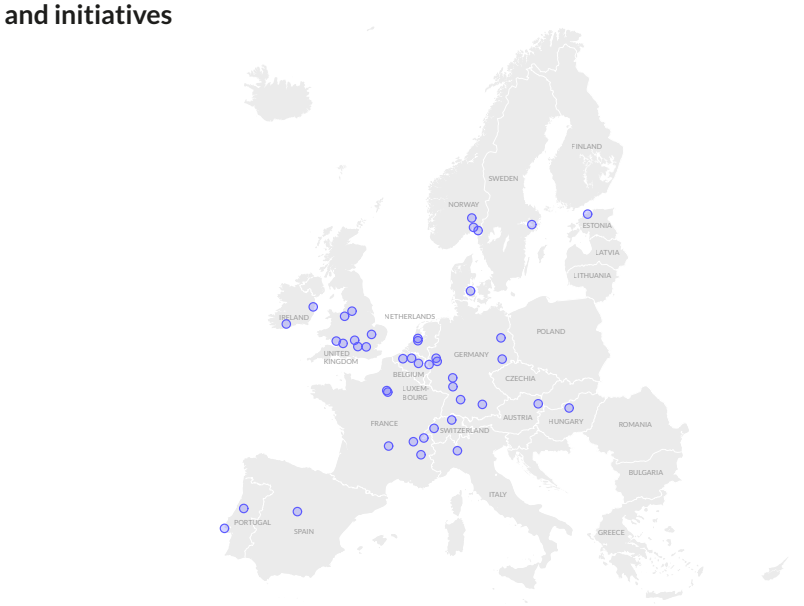
Advanced research centers and digital innovation hubs



Satellite ground stations and launch sites



Key AI companies and initiatives



Source: Submarine Cable Map, Various

The EuroStack Challenge: MVPs as highly scalable digital services

The EuroStack initiative introduces a measure – the EuroStack Challenge – to identify MVPs – sovereign, interoperable, and cross-border trailblazers of digital services that showcase the scalability, flexibility, market potential, and societal value of Europe's Digital Infrastructure Stack. These MVPs align with Europe's principles of openness, privacy, and sovereignty, proving the EuroStack's capacity to support transformative services in mobility, healthcare, manufacturing, and biotech.

To foster innovation and accelerate adoption, the EuroStack initiative will provide developers with open APIs, open reference implementations, and open-source development environments for building and deploying applications, customized AI models, and services. These resources will ensure an inclusive developer experience, enabling startups, researchers, and enterprises to harness the full capabilities of the EuroStack infrastructure without facing entry barriers.

The EuroStack Challenge will further accelerate innovation by inviting Europe's brightest developers, researchers, and entrepreneurs to create new services leveraging these tools. This initiative is designed to unlock Europe's talent pool, foster collaboration, and validate the infrastructure's ability to solve real-world challenges across key industrial sectors while expanding its ecosystem of open-source solutions.

By providing interoperable, privacy-first platforms and tools to enable rapid innovation, the EuroStack initiative creates the foundation for a resilient, unified European digital ecosystem. It empowers developers to contribute to Europe's digital future while securing long-term digital sovereignty, ensuring services that meet the needs of both citizens and businesses.

Comprehensive pilot testing will be conducted across diverse geographic and demographic contexts to ensure system robustness. This will include stress testing under various operational conditions and integration with existing infrastructure. Clear success criteria, combining quantitative metrics and qualitative user experience assessments, will be clearly defined prior to launch and regularly updated based on user feedback and technological advancements. A robust feedback mechanism will collect input from users, technical evaluations, and stakeholder consultations, ensuring a transparent and structured process for implementing improvements and reporting updates throughout the pilot phase.

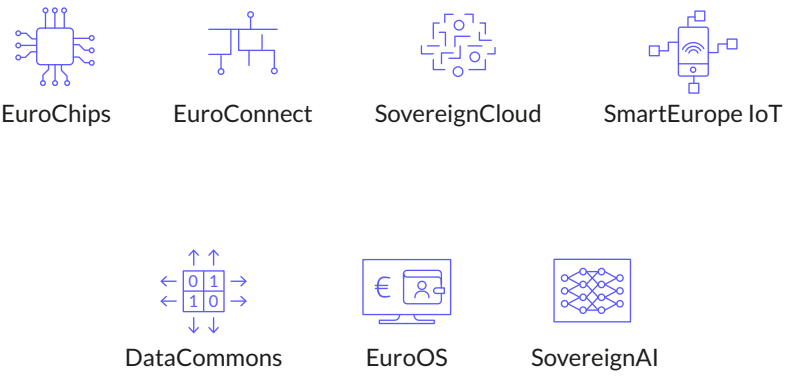
The EuroStack Industrial Challenge

Minimum viable products (MVPs) as highly scalable digital services

What are MVPs?

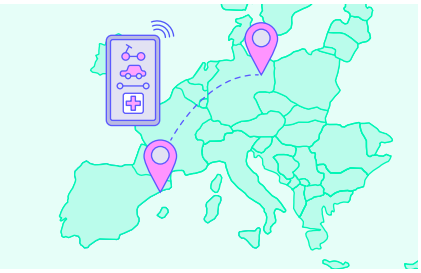
A set of highly scalable, interoperable pan-European, digital services, products, and apps designed to succeed in the Single Market. MVPs are operational trailblazers and will meet the immediate needs of citizens and businesses while demonstrating the feasibility and value of Europe's digital sovereignty strategy. **MVPs use the key components of the EuroStack**.

Key components

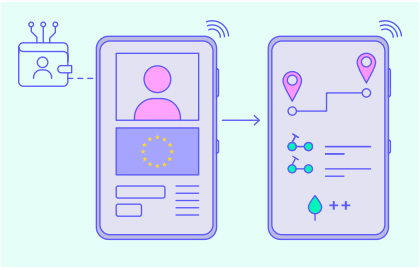


Citizen-centric public services (Mobility and healthcare)

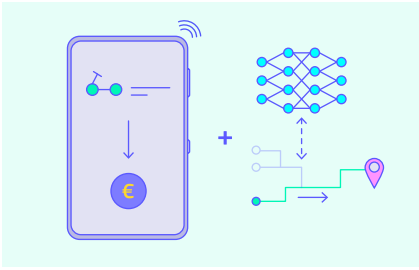
MVP example 1



Clara, a Barcelona resident, travels to Berlin for a music festival, seamlessly accessing **EuroStack-enabled mobility and healthcare services**.

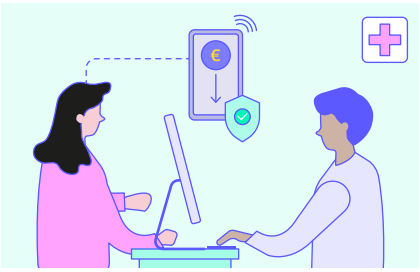


Using her **Sovereign Digital Identity Wallet**, Clara logs into a Berlin mobility app that securely verifies her identity. She receives personalized discounts for eco-friendly transport options, such as e-scooters.



She completes instant, fee-free payments via **Digital Euro. Federated AI** provides her with real-time updates on low-carbon travel routes.

Later, Clara visits a pharmacy for an emergency prescription. The pharmacist securely accesses her medical history through the **Federated Data Exchange**, ensuring GDPR compliance and safeguarding her privacy.



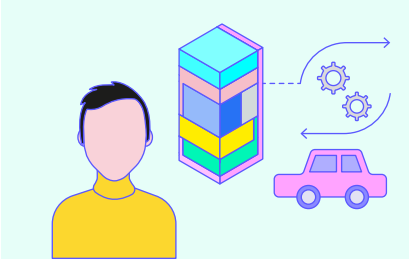
Clara pays securely with **Digital Euro**, and the transaction is automatically registered with her home healthcare insurance.

What does this MVP illustrate?

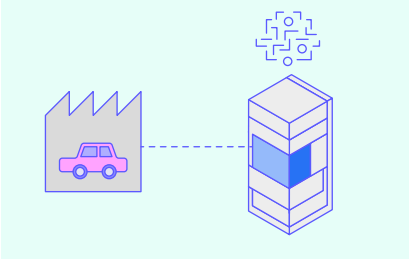
*This MVP illustrates how EuroStack creates **interoperable, privacy-first solutions** that improve citizen experiences, reduce administrative burdens, and promote sustainability and cross-border collaboration in mobility and healthcare.*

Advanced manufacturing – transforming supply chains

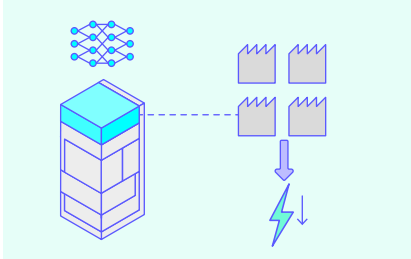
MVP example 2



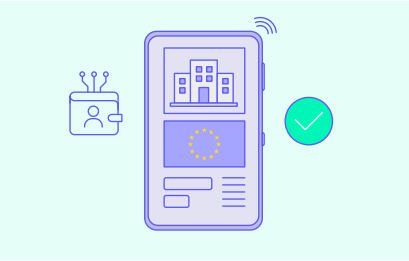
Markus, an automotive manufacturer in Munich, optimizes production with a Dutch supplier using EuroStack-enabled tools.



Markus's factory connects to the **EuroStack decentralized cloud**, enabling secure, real-time local processing of production data.

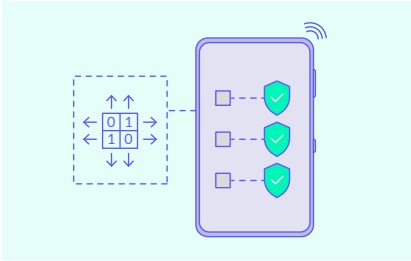


Federated AI analyzes data across EU factories, providing actionable insights to minimize waste and energy consumption in alignment with the EU Green Deal.



Supplier credentials are verified through the **Sovereign Digital Identity Wallet**, streamlining contract approvals and ensuring compliance.

Payments are processed instantly via **Digital Euro**, eliminating delays and transaction fees.



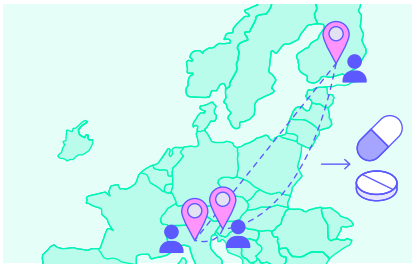
Material quality updates and delivery schedules are shared securely through the Federated Data Exchange, enabling predictive maintenance, and preventing disruptions. Markus's operations set a new standard for productivity growth in the sector.

What does this MVP illustrate?

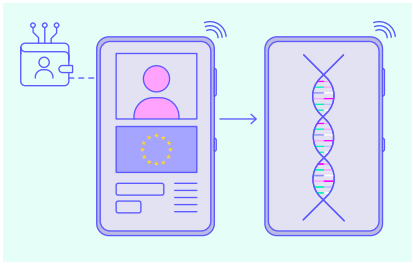
This MVP highlights EuroStack's potential to enhance efficiency, sustainability, and resilience in Europe's manufacturing sector.

Cross-border genomic innovation for precision medicine

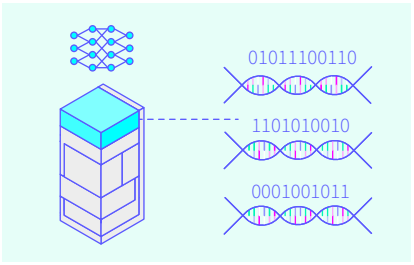
MVP example 3



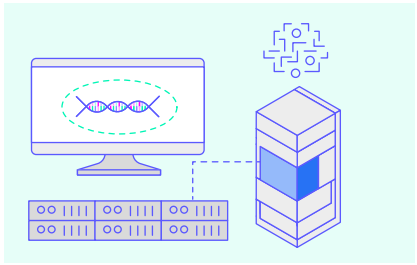
Maria, a biotech product manager in Ljubljana, collaborates with teams in Bologna and Finland to develop a precision medicine drug.



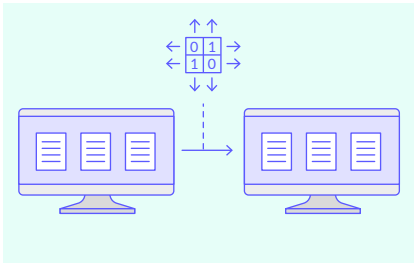
Using her **Sovereign Digital Identity Wallet**, Maria securely accesses sensitive genomic datasets stored in EU data infrastructures.



Federated AI analyzes distributed data without transferring raw information, identifying genetic markers while maintaining privacy.



Simulations are performed on Bologna's *Leonardo* and Finland's *LUMI* supercomputers via the **EuroStack decentralized cloud,** ensuring compliance and security.



Anonymized findings are shared through the **Federated Data Exchange**, allowing a healthcare provider in Denmark to ethically pilot the drug across borders. Maria's Ljubljana company consistently beats international competition in lab-to-market time.

What does this MVP illustrate?

This MVP demonstrates EuroStack's role in accelerating innovation in precision medicine, enabling secure collaboration while safeguarding patient privacy.

A growing innovation ecosystem

The EuroStack initiative is more than just infrastructure – it is Europe's platform for talent, innovation, and collaboration. Designed to address Europe's critical talent gap, it empowers the continent's brightest minds to develop transformative digital solutions. At its core is a dynamic, expanding ecosystem of open-source developers, hardware designers, AI specialists, entrepreneurs, and researchers, working in tandem across the public and private sectors.

This ecosystem aims to create an environment where talent can thrive. Innovators are encouraged to create open-source software, hardware solutions, and sovereign AI models, strengthening Europe's leadership in ethical and accountable digital development. By connecting research centers, SMEs, large industries, and member states, the EuroStack initiative fosters a culture of innovation and collaboration that anchors Europe in the global technology landscape.

Guided by principles of transparency, adaptability, and community ownership, this ecosystem promotes long-term sustainability and impact. By mobilizing talent and aligning diverse stakeholders, the EuroStack initiative ensures Europe builds an innovation-driven future rooted in its democratic values and economic ambitions.

A governance framework to deliver the EuroStack initiative

The EuroStack initiative is built on a governance model that combines agility with shared accountability, ensuring the effective coordination and scaling of Europe's digital infrastructure in an era of rapid technological change. This model is rooted in the principles of digital commons – collectively managed resources designed to serve the public good – and draws inspiration from successful industry-led and publicly backed initiatives. These include dynamic frameworks and instruments such as the 8ra model, the most effective Important Projects of Common European Interest (IPCEIs), and the European Digital Infrastructure Consortium (EDIC), which could be fast-tracked and scaled to accelerate implementation.

The evolution of the EU project management toolbox is essential, requiring the elimination of overly bureaucratic processes. It should transition toward a renewed product management approach that emphasizes short-cycle investment schemes, lean start-up methodologies, and the development of digital commons. This shift will enable more agile, efficient, and innovation-driven management of projects, better aligned with the rapid pace of technological change and the needs of Europe's digital sovereignty goals. The model envisioned here focuses on identifying and scaling key, high-impact use cases (what we refer to as MVPs) that drive value across the digital ecosystem. This approach marks a significant departure from traditional governance models. Rather than operating as a bureaucratic oversight body, the EuroStack governance structure is designed to act as an engine of disruption, accelerating Europe's progress toward digital sovereignty. It relies on collaborative governance and open innovation to ensure that Europe's digital infrastructure is not only globally competitive but also aligned with the values and needs of its citizens.

The successful implementation and sustainability of the EuroStack initiative require a robust and adaptive governance framework that ensures safety, security, and alignment with European values. This framework must balance strategic oversight, operational efficiency, and ethical considerations, while remaining flexible enough to accommodate emerging technologies.

Strategic oversight and leadership

The EuroStack Steering Committee, comprising representatives from EU institutions, member states, industry leaders, academia and civil society, guide the initiative's strategic direction, approve major policies, and make critical decisions. Meeting

quarterly, this committee will ensure that the initiative remains aligned with Europe's values of inclusivity, transparency, and sovereignty, while fostering equitable access to innovation and resisting monopolization.

A Chief EuroStack Officer (CEO), appointed by the Steering Committee, will oversee day-to-day operations and ensure alignment with the initiative's strategic goals. Supporting the CEO, a EuroStack Advisory Board of independent experts will provide guidance on technical, ethical, and policy matters.

Operational coordination and implementation

A EuroStack Program Office will be responsible for overseeing the initiative's implementation, coordinating stakeholders, and preparing progress reports for the Steering Committee. To maintain a results-driven focus, the Program Office will track systemic change using Key Performance Indicators (KPIs) such as adoption rates for cross-border digital services, energy efficiency improvements, and the development of scalable interoperable systems. Layer-specific Working Groups will focus on components of the EuroStack initiative, bringing together experts to develop detailed implementation plans and technical standards. A strategic emphasis will be placed on empowering startups, scaleups, and unconventional innovators through open innovation frameworks and funding mechanisms. This approach directly addresses concerns about disproportionately favoring entrenched incumbents.

Agility and rapid response

The governance framework incorporates agile governance principles to adapt quickly to emerging technologies, including AI, quantum computing, and cybersecurity. Transparent technical audits and security assessments should follow standardized methodologies, with independent third-party verification and risk-based frameworks to ensure accountability and timely remediation. To prevent mission and function creep, systems must have explicit scope limitations, regular reviews to align usage with original mandates, and strict protocols for managing any expansion of capabilities or data use.

A Rapid Response Team will address urgent security or operational challenges, while a Policy Adaptation Mechanism will ensure that policies and standards evolve to reflect new developments and lessons learned.

Transparency, accountability, and collaboration

Accountability will be ensured through radical transparency, with publicly available progress reports tracking KPIs such as innovation milestones and cost reductions. An annual EuroStack Conference will present achievements and gather feedback from stakeholders, while a Stakeholder Engagement Platform will foster ongoing dialogue with industry, civil society, and the public.

Leadership within the EuroStack governance model will be decentralized and collaborative, reflecting Europe's diversity and shared commitment to sovereignty and inclusivity. Member states, public institutions, industry leaders, and innovators will co-create and govern the initiative to ensure collective ownership of its success.

Global partnerships and knowledge-sharing

Recognizing the global nature of digital technologies, a Global Partnerships Office will manage relationships with international partners, ensuring alignment with global standards while upholding European values. A Technology Transfer and Knowledge-Sharing Unit will facilitate responsible sharing of EuroStack innovations and promote the adoption of European standards internationally.

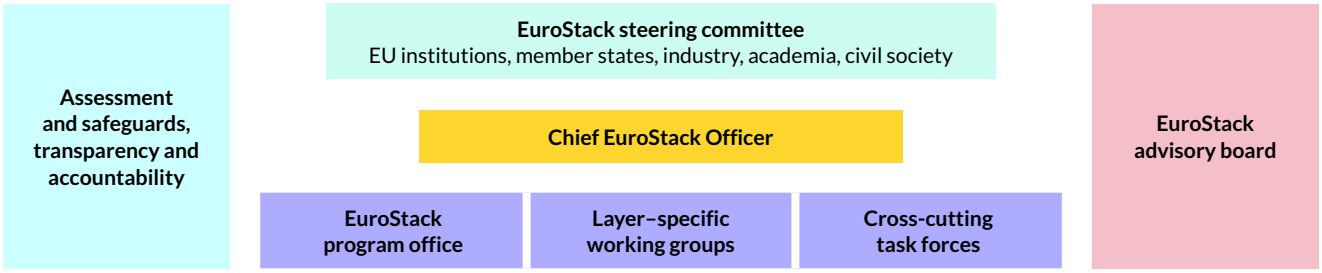
Ensuring long-term success

This governance framework integrates strategic oversight, operational efficiency, and robust safeguards while prioritizing outcomes and accountability. The EuroStack execution strategy should incorporate sophisticated success metrics

beyond adoption rates, focusing on service quality through benchmarks for latency, uptime, and response times. These metrics should be complemented by user satisfaction surveys and real-time monitoring. To ensure inclusivity, metrics should track adoption across demographics like the elderly, disabled, and rural populations, alongside improvements in digital literacy and support for underserved communities. Privacy and security metrics should measure incidents of data breaches, transparency reporting, the effectiveness of consent management systems, results of penetration testing, and incident response times. Economic impact measures should assess job creation, innovation capacity, ecosystem growth, local technology development, and the expansion of European digital service providers.

By emphasizing agility, transparency, and collaboration, the EuroStack initiative positions Europe to lead in digital sovereignty and innovation, ensuring it remains aligned with its values and long-term objectives in a rapidly evolving digital landscape.

EuroStack governance framework



Section 2 – The political economy of digital sovereignty: unpacking power in the stack

Strategies of value capture in the digital economy

Digital strategic autonomy, or "digital sovereignty," is a cornerstone of Europe's strategic vision for its future. Digital strategic autonomy consists of the capabilities, capacities, and control in the digital domain that are necessary to safeguard sovereignty.[21] Digital infrastructures – data centers, cloud platforms, semiconductors, software ecosystems, and AI – have reshaped global industries. The current economic landscape sees a concentration of power in the hands of a few dominant players that are not European – particularly in cloud infrastructure, semiconductors, and AI platforms. This power imbalance hampers Europe's ability to innovate, compete, and maintain control in the digital economy, as well as in its broader societal and democratic structures.

Reclaiming digital sovereignty requires Europe to address structural dependencies, tackle systemic bottlenecks and other control points, and leverage its regulatory and industrial strengths to build a resilient and competitive digital ecosystem. Bottlenecks – essential inputs with limited supply – expose vulnerabilities across the digital stack and are often exploited in geopolitics and geo-economics.

Market concentration and structural dependencies on technology giants extend beyond individual layers of the digital stack. Typically, dominant companies seek to extend their business across the stack through vertical integration, data monopolization, and control of key markets from digital advertising to semiconductor manufacturing and AI computing.[22] These strategies amplify the risks of market power abuse, the imposition of foreign regulatory norms, diminished accountability to safeguard democracy, reduced domestic job opportunities, and the exodus of top talent.

At the foundation of the digital stack, China exerts near-total control over the refining of certain rare earth elements (REEs), which are essential for manufacturing electronics, magnets, and other high-tech components. China accounts for approximately 90% of global REE refining capacity,[23] a dominance maintained through deliberate state policies and tightly integrated supply chains. Further up the stack, Taiwan Semiconductor Manufacturing Company (TSMC) dominates advanced chip production, controlling over 90% of the global market for cutting-edge semiconductors.[24]

By contrast, Europe produces less than 10% of the world's semiconductors and relies heavily on TSMC

21 Paul Timmers, "How Europe Aims to Achieve Strategic Autonomy for Semiconductors", Brookings Tech Stream, 9 August 2022, https://www.brookings.edu/techstream/how-europe-aims-to-achieve-strategic-autonomy-for-semiconductors/.

22 Fausto Gernone, "Moore's Death and the Rebirth of Vertical Monopolies", UCL IIPP (blog), 27 April 2023, https://medium.com/iipp-blog/moores-death-and-the-rebirth-of-vertical-monopolies-befa9ce5b892.

23 IEA, "Energy Technology Perspectives 2023 – Analysis", IEA, 12 January 2023, https://www.iea.org/reports/energy-technology-perspectives-2023.

24 The Economist, "Taiwan's Dominance of the Chip Industry Makes It More Important", 6 March 2023, https://www.economist.com/special-report/2023/03/06/taiwans-dominance-of-the-chip-industry-makes-it-more-important.

and South Korea's Samsung for advanced chips.[25] This dependency creates a significant strategic vulnerability, especially in the face of geopolitical tensions, particularly amid geopolitical tensions – such as those between China and Taiwan – or during disruptions to global supply chains, as seen during the COVID-19 pandemic. These supply chain shocks severely impacted industries like automotive, consumer electronics, and telecommunications. However, one key strength Europe possesses is its dominance in the machines that make chips, with ASML leading the global market in advanced lithography equipment essential for semiconductor manufacturing, giving Europe a critical foothold in the semiconductor value chain.

Many global tech companies have perfected the concept of "ecosystem power," integrating several products seamlessly into cohesive offerings, including cloud infrastructure, hardware, software, and user interfaces.[26] Central to this dominance is their "platform play,"[27] a strategy that leverages programmability, software, APIs, and infrastructure services to create powerful ecosystems. This model allows a small, highly specialized (and often expensive) team of experts to build and maintain a platform, enabling vast networks of developers and tech workers to create applications for end users. By leveraging dominance in one layer of the digital stack, these companies extend their dominance to others, dictating their terms for downstream applications, extracting rents through fees or commissions, and capturing valuable data streams. This entrenches market power, raises barriers to entry, and fosters dependency, reshaping competition across the digital stack.[28]

These companies, typically based in the United States, also benefit from robust venture capital ecosystems and public markets that reward innovation and scale. NVIDIA, with its market capitalization of approximately $3 trillion in 2025, exemplifies this advantage. The company has aggressively reinvested in research, development, and strategic acquisitions to consolidate its leadership in AI and Graphics Processing Units (GPU) technologies. Sovereign wealth funds, such as Saudi Arabia's Public Investment Fund (PIF), have further reshaped the AI and semiconductor landscapes by backing transformative initiatives like SoftBank's Vision Fund, which channels vast resources into AI and semiconductor startups. MGX, an Emirati investment firm specializingin AI, has also emerged as a key player in AI and data centers ventures, entering partnerships with Big Tech companies such as Microsoft, and financial giants such as BlackRock and SoftBank.[29] These financial networks enable dominant firms to acquire promising startups, further consolidating their power.

A similar pattern is evident in China. Both China[30] and, more recently, the United States[31] have introduced large industrial policy programs, investing hundreds of billions of dollars in the digital sector. These programs designate a broad range of digital technologies as strategic for economic and national security, mandating national control over critical technologies.[32] Global technology giants – including U.S. heavyweights such as Amazon,

25 European Commission, "A Chips Act for Europe".

26 Cristina Caffarra, Annabelle Gawer, and Michael Jacobides, "Mapping Antitrust onto Digital Ecosystems", CPI Antitrust Chronicle, 25 October 2024.

27 Annabelle Gawer, "Digital Platforms and Ecosystems: Remarks on the Dominant Organizational Forms of the Digital Age", Innovation 24, no. 1 (2 January 2022): 110–24, https://doi.org/10.1080/14479338.2021.1965888.

28 Vili Lehdonvirta, Cloud Empires: How Digital Platforms Are Overtaking the State and How We Can Regain Control (Cambridge, Massachusetts London, England: The MIT Press, 2022).

29 See: Hart, J. P. and C. (2024, September 17). BlackRock, Microsoft Partner on Massive New AI Infrastructure Fund. WSJ. https://www.wsj.com/tech/ai/blackrock-global-infrastructure-partners-microsoft-mgx-launch-ai-partnership-1d00e09f and "Announcing The Stargate Project", accessed 29 January 2025, https://openai.com/index/announcing-the-stargate-project/.

30 García-Herrero, A. and R. Schindowski (2024) "Unpacking China's industrial policy and its implications for Europe", Working Paper 11/2024, Bruegel

31 Aurelia Glass and Karla Walter, "How Biden's American-Style Industrial Policy Will Create Quality Jobs", Center for American Progress (blog), 27 October 2022, https://www.americanprogress.org/article/how-bidens-american-style-industrial-policy-will-create-quality-jobs/.

32 Alessandro Gili and Davide Tentori, "The Comeback of Industrial Policy. The Next Geopolitical Great Game" (ISPI, n.d.), accessed 11 January 2025.

Microsoft, Google, Apple, Meta, NVIDIA, Tesla/SpaceX, and Musk's associated ventures, as well as Chinese powerhouses like Huawei,[33] Alibaba, Tencent, and ByteDance – actively pursue integrated ecosystems that span critical infrastructure, platforms, and services.[34] Rather than simply offering discrete products, they embed their services deeply into essential layers of the digital economy – from cloud computing and data centers to software, operating systems, chips, AI models, mobile platforms, fulfillment logistics, advertising networks, and social media communities.

By controlling "stacks" of interdependent technologies, these companies generate powerful lock-in effects. Firms like Amazon, Microsoft, and Google integrate cloud, AI, and productivity tools, ensuring steady revenue streams while discouraging customers from switching due to high migration costs and complexity. Apple's similarly closed ecosystem tightly couples hardware, software, and its App Store, generating high user loyalty while capturing revenue from third-party developers. Meanwhile, Meta's social and virtual reality (VR) platforms rely on user data and open-source AI frameworks to encourage developers to build within its orbit, and NVIDIA's hardware-software alignment in GPUs fosters a similar kind of dependency.

Tesla has revolutionized electric vehicles by creating an advanced software ecosystem and AI-powered autopilot, while SpaceX leads global satellite communications through Starlink, now operating over 60% of active satellites.[35] Meanwhile, Musk's broader ventures also play into this strategy: xAI enhances Tesla's autonomous driving capabilities and explores broader AI applications, leveraging data from X, which he aims to transform into a unified hub for communication, payments, and AI services.

In China, well-funded government policies, including government-backed venture capital,[36] support firms like Huawei, Alibaba, Tencent, and ByteDance to replicate and refine strategies of infrastructural dominance. By leveraging their market power in specific domains – such as telecommunications, e-commerce, social networks, or video-sharing – these firms expand into critical layers like cloud computing, AI, and other foundational technologies.

Taken together, this model of infrastructural integration amplifies the power and resilience of a few dominant players, undermining domestic competitiveness, complicating regulatory oversight, and shaping information and commerce landscapes in ways that raise serious concerns about fairness, consumer choice, and democratic governance. Furthermore, in both China and the United States, demand from defense and security sectors significantly drives technological advancement. In contrast, the EU's decentralized defense policies and fragmented markets leave it without a comparable mechanism to support its industrial strategies.

Dominance is often fueled through data monopolization. Consumer-facing platforms collect vast amounts of data, which feed AI models. User data is commodified to predict and influence behavior.[37] Acting both as an input and as an output for many digital products, data creates feedback loops that entrench the dominance of existing players. For instance, Google's extensive data collection not only helps the company build better products, but it fuels advertising algorithms that dominate the digital advertising market, capturing

33 Xiaoying Dong, Mengling Yan, and Yanni Hu, Huawei: From Catching Up To Leading (Singapore: Springer Nature, 2023), https://doi.org/10.1007/978-981-19-4078-1.

34 Michael G. Jacobides, "How to Compete When Industries Digitize and Collide: An Ecosystem Development Framework", California Management Review 64, no. 3 (May 2022): 99–123, https://doi.org/10.1177/00081256221083352.

35 Debra Werner, "Want to Challenge Starlink in the Satcom Market?", SpaceNews, 16 September 2024, https://spacenews.com/want-to-challenge-starlink-in-the-satcom-market/.

36 Martin Beraja et al., "Government as Venture Capitalists in AI" (Cambridge, MA: National Bureau of Economic Research, July 2024), https://doi.org/10.3386/w32701.

37 This practice is called "surveillance capitalism" by Shoshana Zuboff, "The Age of Surveillance Capitalism: The Fight for a Human Future at the New Frontier of Power", Yale Law Journal 129, no. 5 (2020): 1460–1515, https://doi.org/10.26522/brocked.v29i2.849.

approximately 39% of global digital ad revenues in 2023. Meta holds an additional 18%.[38] These advertising revenues reinforce the financial strength of these companies, which in turn finances their expansion into digital ecosystems.

This consolidation has profound societal consequences. In their quest to increase their data harvest, platforms often amplify polarizing content to maximize engagement, creating fertile ground for fake news, conspiracy theories, and extremist ideologies. Algorithmic prioritization of sensational content exacerbates social divisions, undermines democratic discourse, and supports the rise of populism, which exploits these dynamics to spread misinformation and erode institutional trust.[39] Regulatory measures aimed at countering these effects include enforcing algorithmic transparency, limiting data monopolies, regulating targeted advertising, and curbing addictive design practices.[40]

If Europe fails to create the EuroStack and establish digital sovereignty, the global digital economy and its value capture mechanisms are likely to become even more concentrated and dominated by non-European players. Over the next decade, the consequences of inaction would be severe. Without the EuroStack initiative, Europe risks becoming a "digital colony," where critical technologies, data, and digital services are almost entirely controlled by external powers. In this scenario, transformative technologies such as IoT and edge computing would be dominated by non-European ecosystems, reducing Europe to a passive consumer rather than an innovator. The lack of European alternatives in cloud services and AI platforms would severely limit the ability of EU companies to compete globally in data-driven industries. This digital dependency will have profound implications for Europe's economic sovereignty, potentially constraining policy choices and leaving the continent vulnerable to economic coercion through control of vital digital infrastructure.

The absence of a robust European digital ecosystem will likely result in significant economic losses, including the erosion of high-skilled jobs and diminished value creation within the EU. The data generated by European citizens and businesses will increasingly be processed and monetized outside Europe, leading to a massive transfer of wealth and strategic assets to foreign entities. This scenario not only threatens Europe's economic prosperity but also its ability to uphold its values of privacy, transparency, and democratic governance in the digital realm.

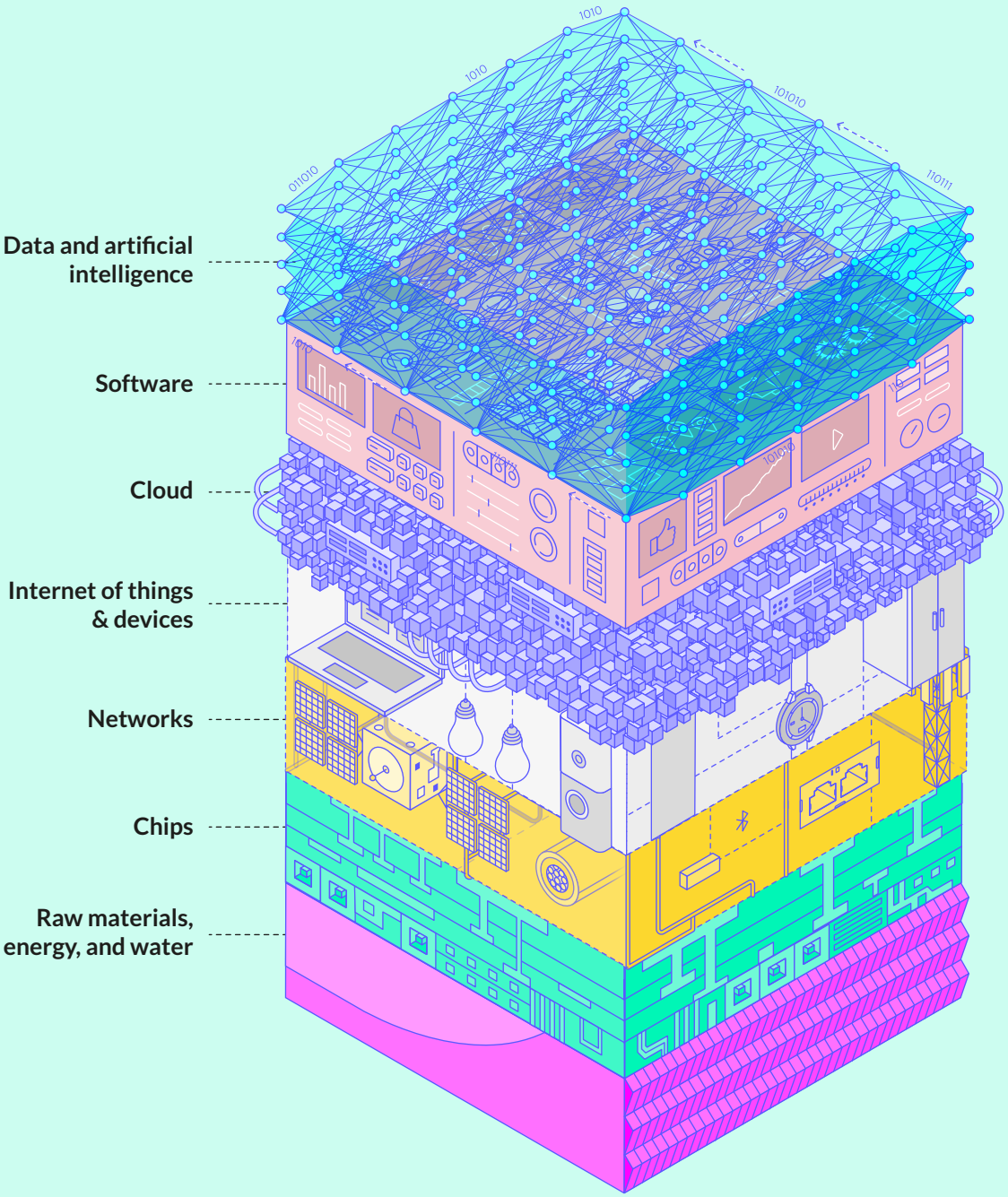
38 Statista, "Digital Ad Revenue Share by Company 2023", 3 December 2024, https://www.statista.com/statistics/290629/digital-ad-revenue-share-of-major-ad-selling-companies-worldwide/.

39 Steven Livingston, "The Rise of Right-Wing Populism: Diagnosing the Disinformation Age", Media@LSE (blog), 8 November 2023, https://blogs.lse.ac.uk/medialse/2023/11/08/the-rise-of-right-wing-populism-diagnosing-the-disinformation-age/.

40 European Parliament, "Addictive Design of Online Services and Consumer Protection in the EU Single Market – Tuesday, 12 December 2023", 12 December 2023, https://www.europarl.europa.eu/doceo/document/TA-9-2023-0459_EN.html.

The political economy of digital sovereignty

Exploring the tech stack



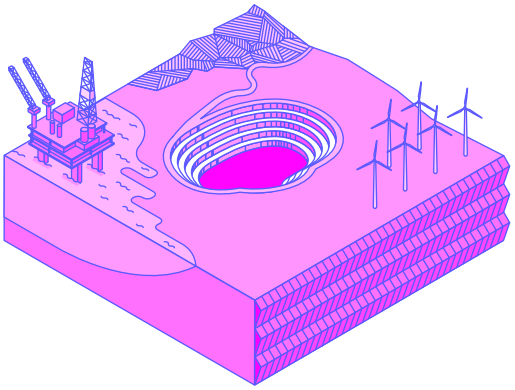
The separate layers explained

Raw materials, energy and water

The hidden backbone of technology

This foundational layer comprises essential resources – such as rare earth elements, energy sources, and skilled labor – that form the backbone of all digital infrastructure.

Key segments:
All layers

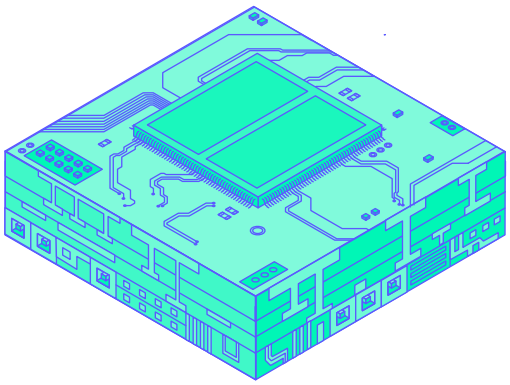


Chips

The brain of the stack

Processors and memory technologies, essential for powering digital infrastructure and ensuring secure supply chains, GPUs, and emerging quantum technology.

Key segments:
Foundry, design, equiament

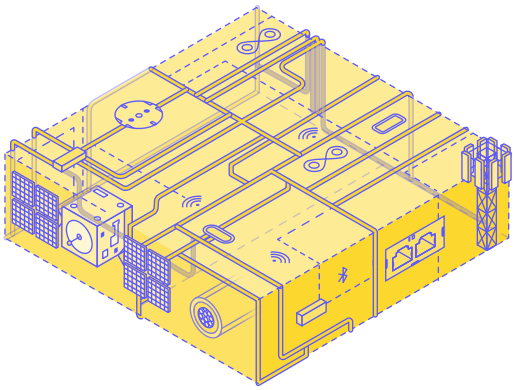


Networks

The lifelines of connectivity

This layer is comprised of physical and digital infrastructures – such as cell towers, fiber-optic networks, undersea cables, and the public core of the internet – that connect Europe to the global digital ecosystem.

Key segments:
TMC equiament, mobile networks, satellites, submarine communication cables

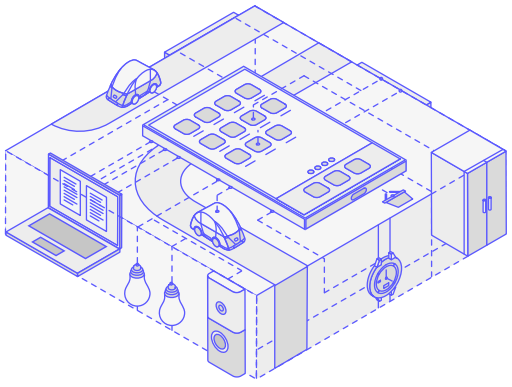


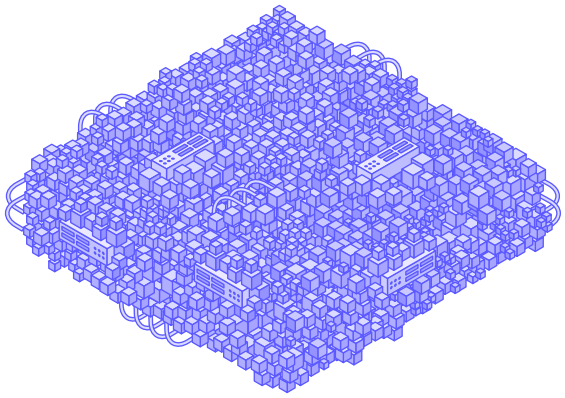
Internet of things & devices

The connective tissue of the digital ecosystem

From smartphones and laptops to IoT devices, this layer enables real-time information processing and data collection.

Key segments:
amartaaones, laatoas, smart aome devices, wearables, industrial & automotive IoT



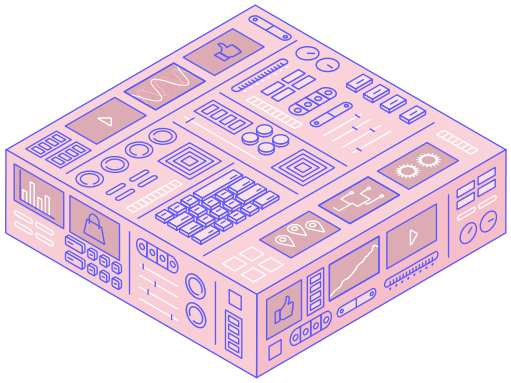


Cloud

The operational core of the digital economy

This layer includes secure data storage and computational power, with distributed computing infrastructures that are essential for ensuring data sovereignty and autonomy.

Key segments:
Data centers, cloud services

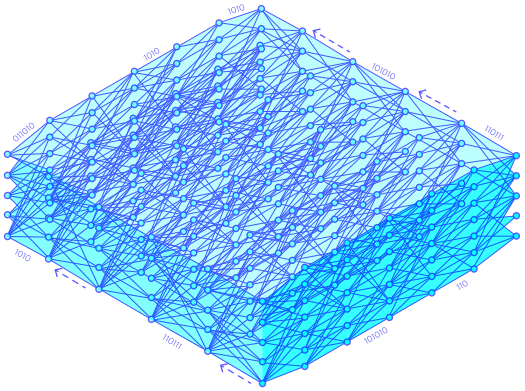


Software

The command center of platforms and applications

This layer includes operating systems, applications, authentication and cybersecurity frameworks that drive digital interactions.

Key segments:
OS, online platforms, programs



Data and artificial intelligence

Catalysts for innovation and strategic autonomy

This layer includes secure data storage and computational power, along with distributed computing infrastructures that are central to maintaining data sovereignty and autonomy.

Key segments:
AI, data

The evolving dynamics of the tech stack

The current stack – the computational framework that forms the backbone of the global digital supply chain – is not a fixed, static structure. Instead, it represents a dynamic and contested space where technology, strategic interests, and power intersect. Major tech companies are reshaping the stack through vertical integration, merging hardware, software, and cloud infrastructure into unified ecosystems. At the same time, governments worldwide are competing to control the technologies that underpin economic power and geopolitical influence. Today, the stack is a living, evolving system, with every layer – hardware, cloud computing, AI, edge computing, and quantum technologies – being continuously transformed by relentless innovation and strategic ambitions of both governments and large companies.

Vertical integration is particularly evident in the AI sector, though it is not confined to it. The surge in generative AI has driven demand for Nvidia's advanced GPUs, particularly the H100, catapulting the company to a trillion-dollar valuation. This surge in demand has also prompted companies like Microsoft, Meta, OpenAI, Amazon, and Google to develop custom AI processors, signaling a shift away from dependence on external suppliers. For example, Google's Axion chip and Amazon's Trainium3 are enabling these firms to improve performance, reduce costs, and maintain control over AI workloads.[41] As AI applications proliferate across industries, AI-specific chips are expected to account for a growing share of global semiconductors revenue.

Infrastructure is also evolving rapidly to support the AI boom. Microsoft, in partnership with asset managers like BlackRock, is building AI-dedicated data centers powered by renewable energy and exploring the use of micro-nuclear reactors to meet the growing energy demands of advanced AI systems. Amazon is experimenting with on-site energy generation to reduce dependency on external grids. Musk's xAI, powered by its Colossus data center with 100,000 NVIDIA GPUs, has taken aggressive steps to scale its infrastructure, doubling chip capacity and straining Nvidia's supply chain.[42] These moves highlight how innovation in infrastructure is not just about enhancing efficiency but also about integrating environmental sustainability into business strategies while consolidating market power. The stack is currently dominated by centralization, as illustrated by OpenAI and Microsoft's collaboration on custom AI supercomputers, which further consolidates chip design and manufacturing under a few global players. Without decisive action to enhance its own capabilities, this centralization risks deepening Europe's dependency on non-European systems, particularly in critical sectors like AI and cloud infrastructure.

The evolution of the tech stack is as much a geopolitical phenomenon as it is a technological one. Countries across the globe are prioritizing control over critical technologies to secure economic competitiveness and national security. The U.S.-China rivalry for technological dominance has emerged as one of the defining contests of the 21st century, reshaping global supply chains and international alliances.

The United States has escalated its efforts to curb China's advances in semiconductors, AI, and quantum computing. In October 2022, the Biden administration imposed severe export controls to block Chinese firms from accessing advanced chips and manufacturing tools like the extreme ultraviolet (EUV) lithography machines made by Dutch firm ASML. These measures are part of a broader U.S. strategy to limit China's technological rise, pressuring allies such as the Netherlands and Japan to restrict key exports.

41 Gernone, "Moore's Death and the Rebirth of Vertical Monopolies".

42 Stephen Morris and Tabby Kinder, "Elon Musk Plans to Expand Colossus AI Supercomputer Tenfold – FT", Financial Times, 4 December 2024, sec. xAI, https://www.ft.com/content/9c0516cf-dd12-4665-aa22-712de854fe2f.

The United States has also targeted Huawei, a global leader in 5G, citing national security concerns. These actions have significantly disrupted Huawei's supply chain. At the same time, Washington is investing heavily in AI and quantum technologies through initiatives like the CHIPS and Science Act, which allocates billions to strengthen domestic semiconductor production and R&D.

China is countering with a two-pronged strategy: ramping up domestic production and leveraging its dominance in critical raw materials. Beijing has committed over €140 billion under its Made in China 2025 plan to achieve self-sufficiency in advanced technologies. Despite restrictions, China's Semiconductor Manufacturing International Corporation has developed 7-nanometer chips, showcasing resilience, though it still faces significant technical limitations. Additionally, China has restricted exports of rare earth elements like gallium and germanium – essential for semiconductors and other advanced technologies – using these resources as leverage in the global supply chain.

Europe finds itself in a pivotal but precarious position within this geopolitical rivalry. ASML, the world's only producer of EUV lithography machines, is under pressure from the United States to limit sales to China, despite its economic interests – 14% of ASML's 2022 revenue came from China.[43] Meanwhile, the European Union is advancing its digital sovereignty with the €43 billion European Chips Act, aiming to double its share of global production of cutting-edge and sustainable semiconductors by 2030. Complementary initiatives like EuroStack underscore Europe's commitment to building a secure, independent digital infrastructure aligned with democratic values.

However, challenges remain. The semiconductor supply chain is highly complex, involving numerous countries and intricate processes, which complicates the enforcement of export controls. Additionally, Europe's economic dependencies on China further make full decoupling difficult. As the United States seeks to maintain dominance and China accelerates its self-sufficiency goals, Europe has the opportunity to assert its leadership by investing in innovation, protecting strategic industries, and charting a path toward autonomous yet interconnected digital sovereignty.

The stakes are clear: this tech rivalry will shape the future of digital capitalism, influencing global power dynamics for decades to come. However, escalating trade wars fueled by these technological tensions threaten to deepen economic fragmentation, disrupt supply chains, and undermine the collaborative frameworks needed to address global challenges. This, in turn, casts uncertainty over the path to stability and innovation, leaving all parties at risk.

Key paradigm shifts are transforming the technological landscape, including decentralization through edge cloud computing, advancements in quantum technologies, and the deep integration of the physical and digital realms. Decentralization is emerging as a countertrend to traditional centralized paradigms. The rise of edge cloud computing and next-generation networks is reshaping how data is processed and managed. Europe, leveraging its strengths in industrial IoT, federated cloud systems, and data sovereignty-oriented regulatory frameworks, is well-positioned to take the lead in this space.

Initiatives such as the Important Projects of Common European Interest in Cloud Infrastructure and Services (IPCEI-CIS) are paving the way for decentralized, federated infrastructures capable of processing data closer to its source. This approach enhances resilience, reduces latency, and bolsters security. Edge computing has moved beyond theoretical discussions and is now being actively deployed in sectors such as autonomous driving, smart factories, and healthcare, placing Europe at the forefront of these transformative technologies. However, blockchain technology, which underpins

43 Adam Levine, "The U.S. Has 2 Choices on China Chip Policy. Neither Are Good for Stocks.", barrons, accessed 13 January 2025, https://www.barrons.com/articles/chip-stocks-us-china-trade-policy-78acc6e4.

much of the current decentralization movement and the so-called web 3.0 paradigm, remains dominated by U.S. players. Europe has yet to reclaim its footing in this critical domain, presenting a challenge to its broader decentralization ambitions.

The cutting edge of the stack's transformation lies in quantum, photonics, and neuromorphic technologies which promise to disrupt traditional computing and communication paradigms. Quantum processors, such as IBM's 127-qubit Eagle and Pascal's 100-qubit quantum computer,[44] may be advancing encryption and simulation capabilities. Meanwhile, European hubs in Germany and the Netherlands are leading innovations in photonics, which uses light for data processing and transmission. Photonics offers significant advantages in speed and energy efficiency over traditional semiconductors, positioning Europe as a frontrunner in sustainable technology innovation.

The profound convergence of the physical and digital worlds is also driving the development of integrated ecosystems that combine AI, IoT, robotics, and AR/VR technologies. Examples include Amazon's warehouse robotics, Apple's Vision Pro AR headset, and Bosch's industrial IoT systems. These innovations blur the boundaries between real and virtual environments. Major players such as Meta (AR/VR) and NVIDIA (robotics) are investing heavily in this paradigm shift.[45] Europe's established strengths in areas like industrial IoT and robotics offers opportunities to lead in this domain, though competition from China and the United States remains intense.

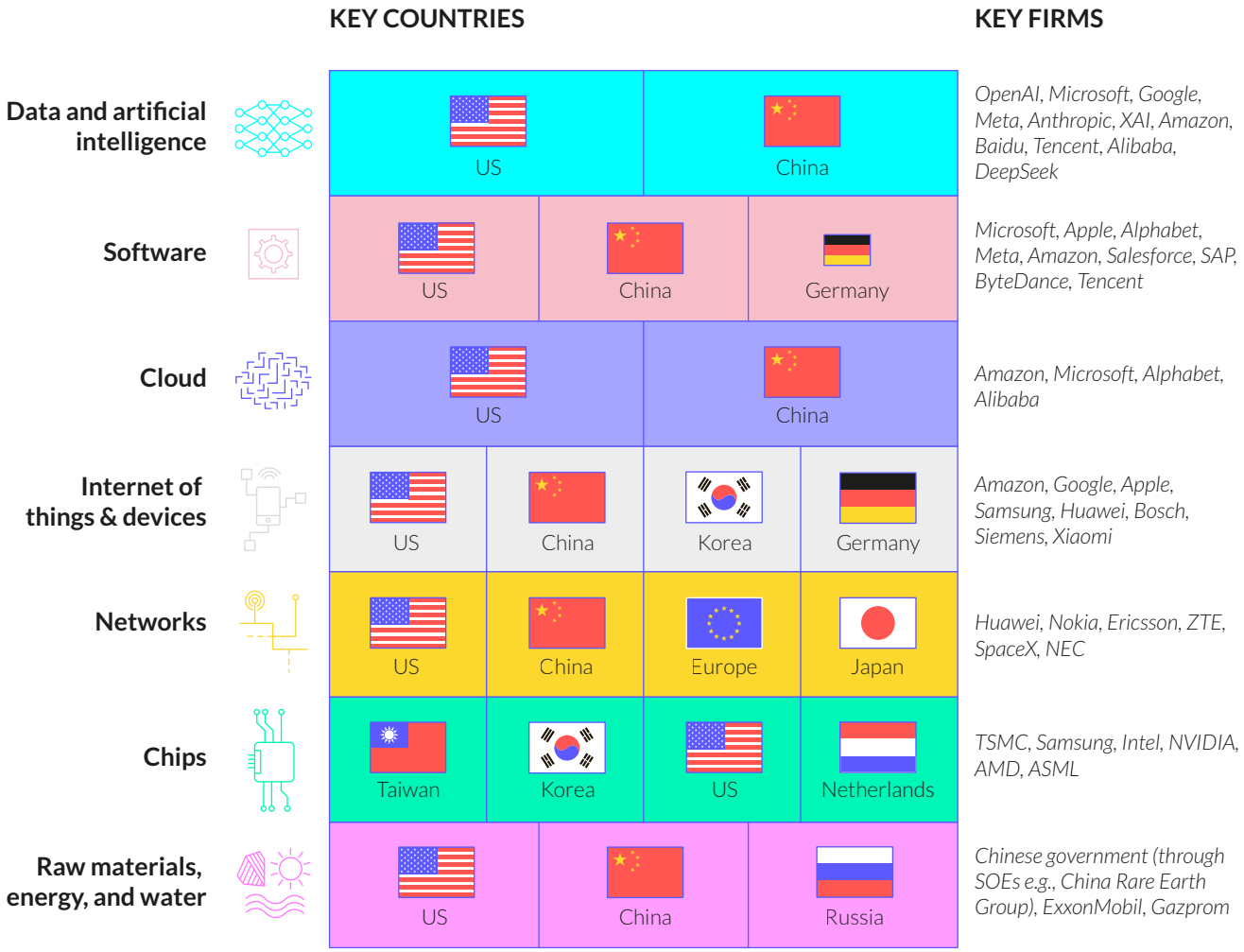
The stack has become a battleground for economic power and digital sovereignty. Big Tech firms are consolidating control through bespoke innovation and vertical integration, while Europe's initiatives focus on decentralization, resilience, and sustainability. The future stack will evolve as a dynamic interplay of centralized and decentralized systems, shaped by technological breakthroughs and geopolitical priorities. For Europe, this transformation presents both challenges and opportunities. The growing centralization of AI and cloud infrastructure by non-European players highlights vulnerabilities in Europe's digital sovereignty. Defining the future stack is not just about technology – it is about shaping the systems that will define economic, societal, and political power for decades to come.

44 insideHPC, "Pasqal 100-Qubit Quantum Computer Shipped to Jülich Supercomputing Centre", High-Performance Computing News Analysis (blog), 2 December 2024, https://insidehpc.com/2024/12/pasqal-100-qubit-quantum-computer-shipped-to-julich-supercomputing-centre/.

45 Michael Acton and Cristina Criddle, "Nvidia Bets on Robotics to Drive Future Growth", Financial Times, 29 December 2024.

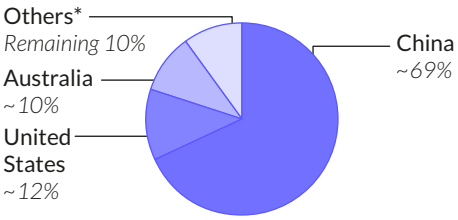
The geopolitical dimension

Key countries and leading firms in each stack layer



FACTS

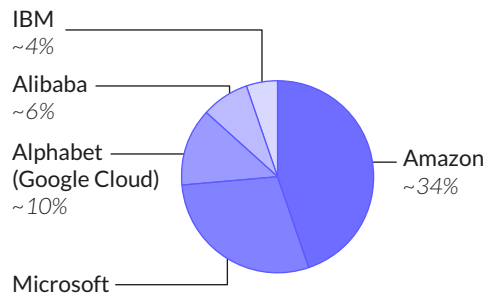
Global rare earth elements market
Market share by percentage



*Including Russia and Myanmar

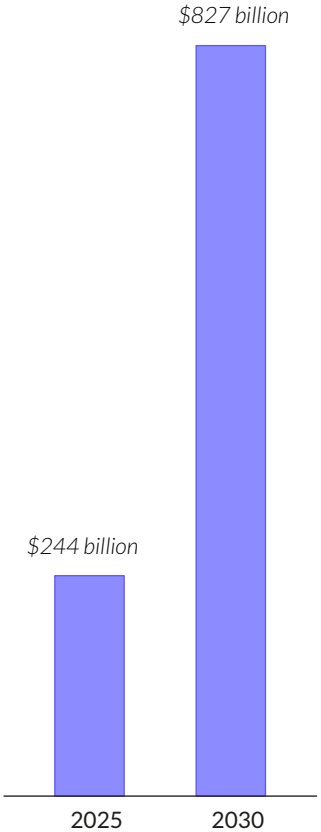
Source: U.S. Geological Survey

Cloud infrastructure market,
Market share by percentage



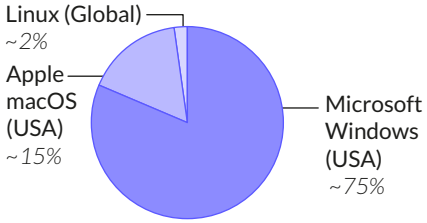
Source: Synergy Research Group

The global AI market
Estimated value
(in billion U.S. dollars)

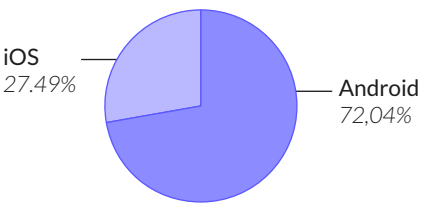


Source: Statista

OS desktop market
Market share by percentage



Global mobile operating system
Market share by percentage



Source: StatCounter

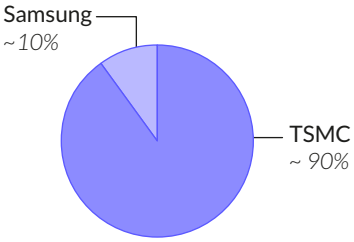
Emerging trends

Quantum communication networks are being developed, with **China leading** in satellite-based quantum communications.

RAN technology

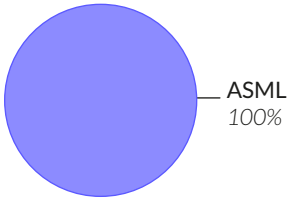
Open RAN technology providers are **gaining traction**, including Rakuten Symphony, Parallel Wireless, and Ericsson.

Advanced nodes manufacturing market
Market share by percentage



Source: Counterpoint Research

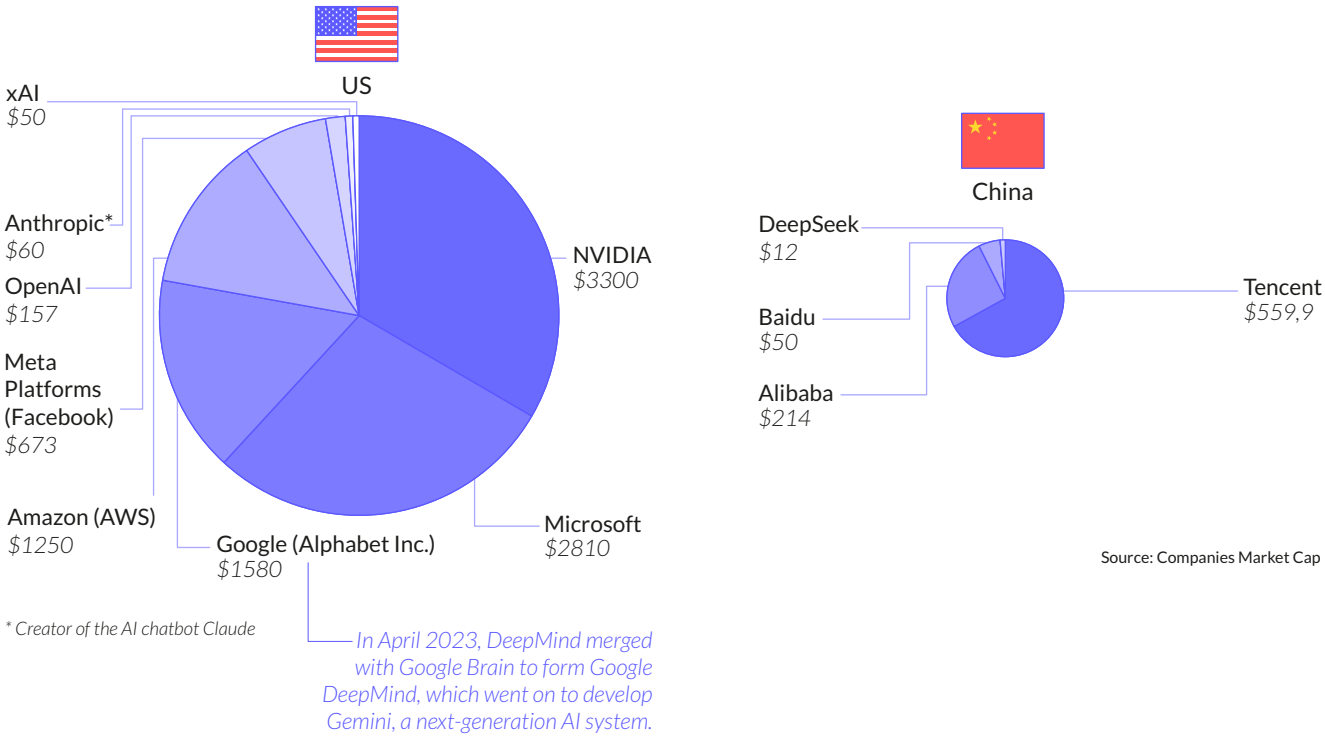
EUV lithography equipment market
Market share by percentage



Source: Semiconductor Industry Association

FACTS

Key AI companies by market capitalization and valuations, 2024
(in billion U.S. dollars)

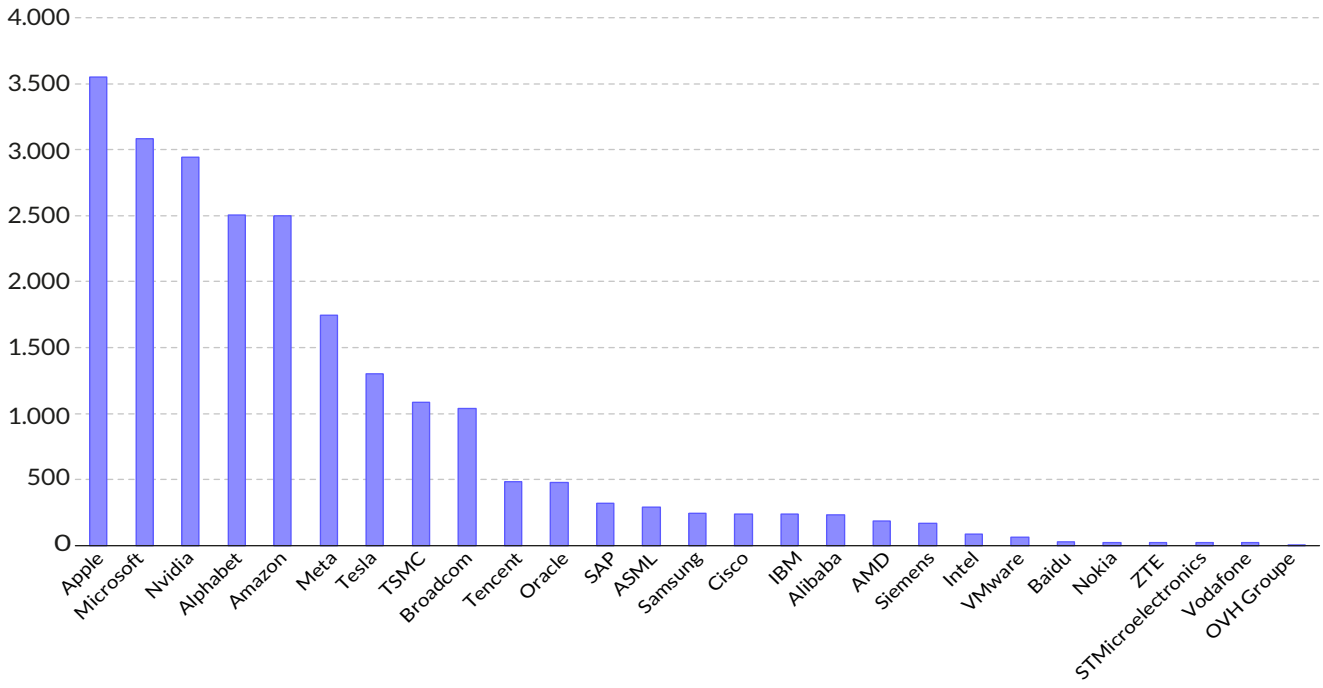


Source: Companies Market Cap

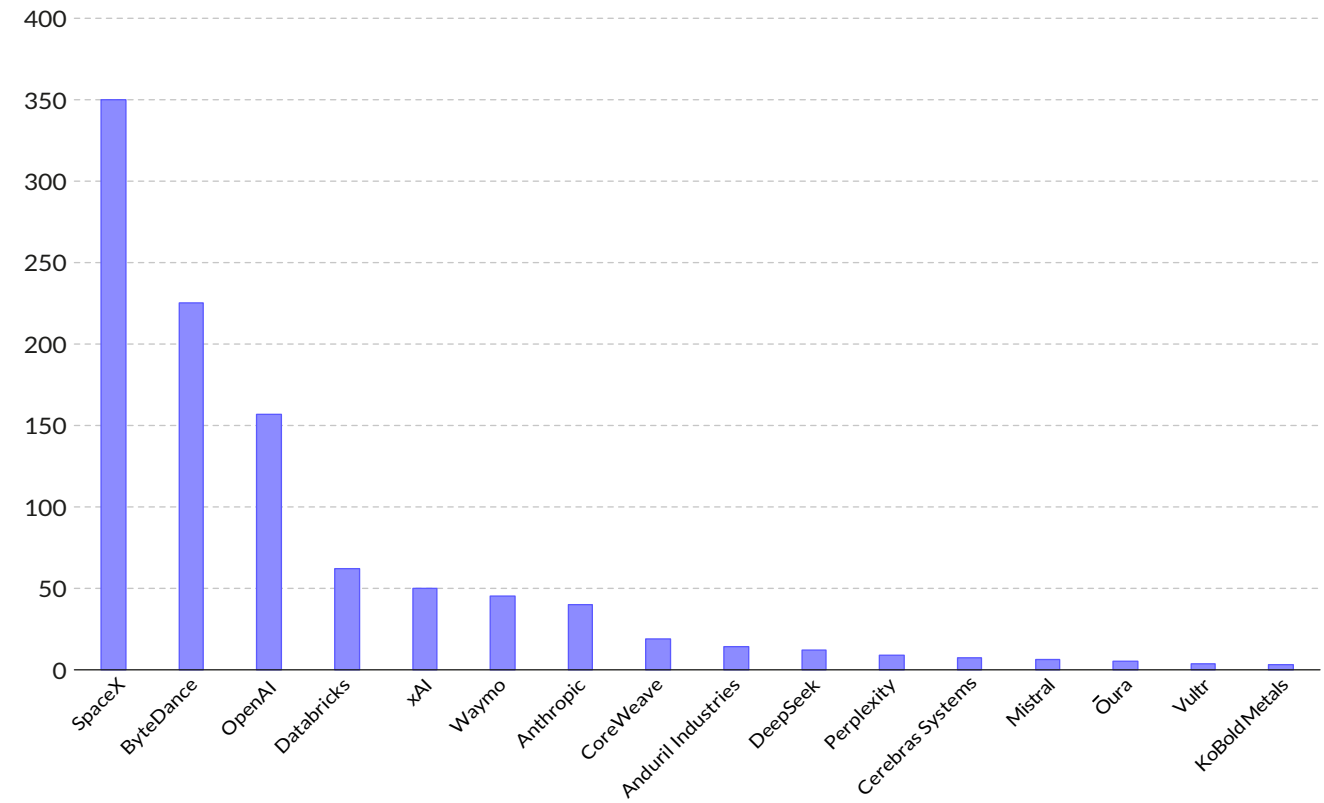
* Creator of the AI chatbot Claude

In April 2023, DeepMind merged with Google Brain to form Google DeepMind, which went on to develop Gemini, a next-generation AI system.

Market capitalization of key public companies in the digital sector, February 2025
in billion U.S. dollars



Market valuation of key private companies in the digital sector, 2024
in billion U.S. dollars



Source: Statista, Nasdaq, Wall Street Journal, Foundation Capital, Crunchbase, The Guardian, NY Times, Financial Times, TechCrunch, CNBC

Raw materials, energy and water: The hidden backbone of technology

The digital stack fundamentally depends on critical raw materials such as REEs, lithium, and cobalt. These materials are essential for manufacturing the key components of modern digital infrastructure, including semiconductors, batteries, displays, and high-performance magnets. However, their supply chains are largely controlled by foreign actors, particularly China. China dominates REE refining, accounting for over 90% of global capacity.[46] This dominance, achieved through state-backed policies and strategic acquisitions, extends to key battery materials like lithium and cobalt, where China's influence is reinforced by its investments in the Democratic Republic of Congo (DRC). Companies like China Northern Rare Earth Group and China Minmetals Corporation lead the sector, giving China unparalleled leverage, including the power to impose export restrictions during geopolitical disputes.

Europe remains heavily reliant on imports of critical raw materials. Over 68% of its cobalt and 78% of its lithium are imported, leaving the continent vulnerable to geopolitical risks and supply chain disruptions.[47] While countries like Sweden and Portugal, as well as Serbia – geographically close but outside the EU – possess promising reserves, large-scale extraction has yet to materialize. Notably, Serbia holds an estimated 1.2 million tons of lithium, representing a potential opportunity for reducing Europe's reliance on imports if sustainable extraction practices are developed and implemented. Europe's vulnerability is further exacerbated by its limited refining capacity. Addressing resource dependency requires not only greater access to raw materials but also technological innovation. For instance, germanium – one of the resources China has restricted for export – can be derived from zinc, as demonstrated by Europe's Nyrstar. An industrial policy is needed to further stimulate such technological innovation in resources.

The European Union has launched ambitious initiatives to reduce these dependencies. The Critical Raw Materials Act aims to secure 15% of Europe's raw material needs through recycling and ensure 10% of critical materials are sourced domestically by 2030.[48] Initiatives like the European Raw Materials Alliance (ERMA) are fostering partnerships with resource-rich regions such as Australia and Latin America while promoting investment in advanced recycling technologies. Recycling innovations offer a promising path forward. Companies like Germany's Aurubis and Belgium's Umicore, leaders in electronic waste recycling, and Norway's Hydrovolt, which specializes in battery recycling, demonstrate the potential of circular economies to reclaim valuable materials. However, scaling these efforts remains a challenge, requiring substantial investments and alignment with sustainability goals.

The digital economy's reliance on energy is also intensifying, growing energy demands add another layer of complexity, particularly with the rapid proliferation of AI models, whose training requires enormous computational resources. According to the International Energy Agency, data centers account for 2–4% of global electricity consumption, with localized impacts even higher.[49] For example, in Ireland, data centers consume over 20% of the country's electricity. These figures are likely to increase, as U.S. tech giants are investing heavily in Europe's data economy.[50] While these investments create opportunities, they also pose challenges, as many projects explore energy-intensive solutions, including nuclear power, which clash with Europe's

46 IEA, "Critical Minerals Market Review 2023 – Analysis", IEA, 11 July 2023, https://www.iea.org/reports/critical-minerals-market-review-2023.

47 Samuel Carrara et al., "Supply Chain Analysis and Material Demand Forecast in Strategic Technologies and Sectors in the EU – A Foresight Study", 16 March 2023, https://doi.org/10.2760/386650.

48 Council of the European Union, "Critical Raw Materials Act", Consilium, 18 March 2024, https://www.consilium.europa.eu/en/press/press-releases/2024/03/18/strategic-autonomy-council-gives-its-final-approval-on-the-critical-raw-materials-act/.

49 IEA, "What the Data Centre and AI Boom Could Mean for the Energy Sector – Analysis", IEA, 18 October 2024, https://www.iea.org/commentaries/what-the-data-centre-and-ai-boom-could-mean-for-the-energy-sector.

50 United Nations Conference on Trade and Development, "Digital Economy Report 2024", 2024, https://unctad.org/system/files/official-document/der2024_en.pdf.

renewable energy priorities. The widespread use of renewable energy certificates by major providers often masks the true environmental cost, underscoring the need for stricter transparency and oversight.

Europe's energy landscape is evolving. Renewable sources like wind, solar, and hydropower are expanding, with leaders such as Sweden and Finland attracting energy-intensive industries due to their clean energy production. However, countries like Germany and Poland face challenges in balancing their reliance on coal and natural gas with the integration of renewables. The 2022 energy crisis, triggered by Russian supply disruptions, accelerated Europe's transition to renewables but also exposed its energy vulnerabilities. Rising energy prices increased operational costs for businesses, potentially dampening investment in the region. To address these challenges, Europe must prioritize energy-efficient, renewables-based solutions for AI-centric infrastructure. Innovations like Finland's LUMI supercomputer, powered entirely by hydropower from Vattenfall, provide a model for sustainable high-performance computing. Transparent emissions reporting and stricter oversight of renewable energy certificates are critical to ensuring alignment with Europe's carbon neutrality goals.

The security and resilience of the electricity grids are essential prerequisites for digital sovereignty and strategic autonomy. However, the security of ICT systems and supervisory control and data acquisition components, which are critical for managing power grids, has received relatively little attention in this context. These components must undergo comprehensive 360° risk assessments to address vulnerabilities. Such assessments typically focus on the following risk categories:

- **Geopolitical:** Disruptions in supply chains, competitive distortions as tools of hybrid warfare, anticipated trade restrictions, impacts on economic security, and related threats.
- **Strategic:** Dependence on foreign economies and technologies, loss of sovereignty, reduced market diversity, and external influence on standards.
- **Technical:** Data manipulation, targeted infiltrations (e.g., "backdoors"), and concealed "kill switches" that could compromise grid integrity.

Water is another critical resource, especially for cooling HPC systems. In 2023, Google's hyperscale data centers consumed an average of 2.1 million liters of water daily for cooling purposes.[51] This demand poses significant long-term risks, particularly as more than half of the global population is projected to live in water-stressed regions by 2050, including drought-prone areas such as Southern Europe. While advances in water recycling and desalination technologies hold promise, their adoption across Europe remains inconsistent. Strengthening these systems is vital to mitigate the environmental impact of expanding digital infrastructure.

Europe's digital sovereignty hinges on scaling its mining, refining, and recycling capabilities, all while adhering to sustainability goals. Partnerships with resource-rich regions and investments in advanced recycling technologies can reduce reliance on imports. Equally important is the integration of renewable energy sources and efficient water systems into AI and data center operations, which is essential for meeting climate targets and maintaining global competitiveness.

Chips: The brain of the stack

The forces shaping semiconductor dominance

Semiconductors form the backbone of the digital age, encompassing components ranging from basic resistors and sensors to memory chips and microprocessors. While early microprocessors were designed for general-purpose computing, they have

51 Mary Zhang, "Data Center Water Usage: A Comprehensive Guide", Dgtl Infra, 17 January 2024, https://dgtlinfra.com/data-center-water-usage/.

since evolved into specialized processors engineered for applications like AI, HPC, and machine learning (ML). Today's chips span a broad spectrum, from general-purpose central processing units used in PCs and servers to specialized GPUs and task-specific processors, such as Tensor Processing Units (TPUs), optimized for AI and HPC workloads. With increasing demands for efficiency, scalability, and energy optimization in cloud environments, the global microprocessor market has become a critical enabler of technological innovation. The global semiconductor market is estimated to grow from over €600 billion in 2024 to over €1 trillion by 2030.[52]

The semiconductor industry is shaped by powerful economic forces that concentrate control among a handful of dominant players, while relying on highly intricate and globalized supply chains.[53] The manufacturing stage of semiconductors is characterized by significant economies of scale that require billions of euros in investment and a massive concentration of tacit knowledge and talent, all of which creates formidable barriers for new entrants. Asian foundries, particularly those in Taiwan and South Korea, dominate advanced chip manufacturing, producing chips at cutting-edge process nodes like 5nm and 3nm. TSMC alone commands over 50% of the global semiconductor market and 90% of advanced chip production. Companies like TSMC and Samsung leverage their scale to reduce per-unit costs, ensuring efficiency while reinforcing their market dominance. The industry's rapid technological progress continues to be driven by "Moore's law," which remains a foundational principle of advancement.

Another critical factor is the network effect in chip design, where established architectures like x86 (used by Intel and AMD) and ARM gain dominance through widespread adoption and robust developer ecosystems. ARM's architecture, owned by Japan's SoftBank, underpins many custom chip designs, including Amazon Web Services (AWS's) Graviton and Google's TPUs. These network effects not only spur innovation but also lock developers into specific ecosystems, further consolidating market control.

Co-specialization plays an important role in the chips industry. Intel's integrated design-manufacturing exemplifies the traditional model based on the co-specialization between design and production, allowing seamless optimization of chip performance and cost efficiency. More recently, new business models harness the specialization between chip design and end use.[54] NVIDIA, for example, controls over 80% of the chips specialized for AI – so-called GPUs – and provides a programming platform tightly coupled with its chips, enhancing performance while fostering ecosystem dependence. The company generated €26.3 billion in data center revenue in the second quarter of the 2024 calendar year.[55] Similarly, cloud providers like AWS, Google Cloud, and Microsoft Azure increasingly integrate chip design and cloud-specific applications, creating proprietary processors tailored to their platforms. Innovations like AWS's Graviton processors, Google's TPUs, and NVIDIA's proprietary GPU architectures exemplify this trend, optimizing performance and energy efficiency while locking customers into their ecosystems. NVIDIA CUDA further illustrates this model by providing a programming platform tightly coupled with NVIDIA's GPUs, enhancing performance while fostering ecosystem dependence.

These economic dynamics often create tension within the industry, influencing its trajectory. Specialization fosters the development of narrow-purpose chips tailored to specific applications, but this clashes with the benefits of standardization, which supports network effects by enabling broad applicability across platforms. Similarly, the tailored processes required for specialized designs

52 PwC, "State of the Semiconductor Industry", PwC, 28 November 2024, https://www.pwc.com/gx/en/industries/technology/state-of-the-semicon-industry.html.

53 Miller, C. (2022). Chip War: The Fight for the World's Most Critical Technology. Scribner.

54 Gernone, "Moore's Death and the Rebirth of Vertical Monopolies".

55 Statista, "Data Center/AI Chip Revenue of Nvidia, AMD, and Intel 2024", 29 August 2024, https://www.statista.com/statistics/1425087/data-center-segment-revenue-nvidia-amd-intel/.

conflict with the economies of scale that favor the high-volume production of standardized chips. These competing forces underscore the inherent complexity of the semiconductor industry.[56]

Europe's path to semiconductor resilience

Europe plays a relatively modest role in the semiconductor industry, accounting for just 10% of global production and possessing limited capacity for advanced chip manufacturing. The continent relies heavily on foreign suppliers for leading-edge chips.[57] As noted earlier, this reliance exposes the region to geopolitical risks.

However, Europe is not without strategic assets. The region holds approximately 25% of the global market for semiconductor equipment, with key players such as ASML, Bosch, and STMicroelectronics driving the industry forward.[58] The Netherlands-based ASML, a global leader in the production of semiconductor equipment, holds a critical position in the semiconductor ecosystem. ASML's extreme ultraviolet (EUV) lithography technology is indispensable for manufacturing advanced chips, a monopoly that gives giving Europe leverage in the global value chain. Nevertheless, ASML's dominance is constrained by U.S. export controls, imposed for national security and potentially economic reasons.[59] Moreover, Europe lacks the downstream production capacity to capitalize on this advantage, particularly in areas like HPC and AI-specific chips.

To address these vulnerabilities, Europe has taken decisive action. The European Chips Act, with its €43 billion investment plan, aims to double Europe's share of global advanced semiconductor production to 20% by 2030 and leverage strengths in specialized equipment and areas like automotive and industrial electronics. This initiative aligns with global trends: the U.S. CHIPS Act allocates €51 billion to domestic semiconductor production, while China is investing €140 billion over five years to achieve greater self-sufficiency in the sector. Nevertheless, Europe's contribution to the semiconductor industry remains uneven. While companies like STMicroelectronics, NXP Semiconductors, and Infineon excel in automotive and industrial electronics, they have limited presence in sectors driving the next wave of digital innovation. Furthermore, despite significant investments, Europe's semiconductor industry faces challenges in securing subsidies, diversifying production, and attracting talent. These obstacles are exemplified by the delays and uncertainties surrounding Intel's planned factory in Magdeburg.[60]

Initiatives like SiPearl's Rhea processor and the Barcelona Supercomputing Center's investment in open-source RISC-V architecture signal a shift in Europe's approach to reducing its dependence on proprietary technologies like ARM. RISC-V's flexibility and free licensing can enable Europe to develop tailored software ecosystems for AI, advanced manufacturing, and high-performance computing, fostering innovation while reducing reliance on foreign intellectual property. The RISC-V is projected to grow at a compound annual growth rate (CAGR) of 33.1%, reaching €2.6 billion by 2027.[61] Another promising area is photonic chips, which use light to achieve faster processing speeds and lower energy consumption. The Spanish Institute of Photonic Sciences (ICFO), in collaboration with institutions

56 W. Edward Steinmueller, "The Economics of Flexible Integrated Circuit Manufacturing Technology", Review of Industrial Organization 7, no. 3/4 (1992): 327–49.

57 European Commission, "European Chips Act: Staff Working Document | Shaping Europe's Digital Future", 12 May 2022, https://digital-strategy.ec.europa.eu/en/library/european-chips-act-staff-working-document.

58 Credence Research, "Semiconductor Equipment Market Size, Growth and Forecast 2032", 7 October 2024, https://www.credenceresearch.com/report/semiconductor-equipment-market.

59 Reuters, "ASML CEO Says US Desire to Restrict Exports to China 'Economically Motivated'", Reuters, 4 September 2024, sec. Technology, https://www.reuters.com/technology/asml-ceo-says-us-motivation-restricting-equipment-exports-china-is-economically-2024-09-04/.

60 Politico, "The EU's Chips Plan Implodes as Intel Pauses Investments", POLITICO, 17 September 2024, https://www.politico.eu/article/intel-germany-chips-plant-competitiveness-eu-ambition/.

61 BCC Publishing, "RISC-V Technology Market Size, Share & Growth Analysis Report", 1 December 2022, https://www.bccresearch.com/market-research/semiconductor-manufacturing/global-risc-v-technology-market.html.

from Ireland, the Netherlands, Finland, Belgium, Portugal, Poland, Austria, Italy, and France, is leading a €380 million project to advance this technology. These efforts showcase Europe's ability to lead in next-generation semiconductor technologies.

Networks: The lifelines of connectivity

Networks serve as the backbone of Europe's digital infrastructure, connecting devices, services, and systems across telecommunications and cloud environments. The public core of the internet, including the domain name management system (DNS) and Internet Exchange Points (IPX), is located in this layer. The rise of 5G and the shift toward standalone 5G networks – which integrate 5G radio and core systems – along with the increasing role of private networks supported by satellite systems and undersea cables, are driving a significant transformation. These networks enable low-latency, high-speed, and redundant connections that are critical for cloud platforms as well as for emerging technologies such as autonomous vehicles, industrial automation, and smart cities. Virtualization is now a defining feature of these networks, as they increasingly rely on cloud services, blurring the traditional distinctions between traditional telecommunications providers and cloud providers.

The concept of network sovereignty – or strategic autonomy in the network layer – has emerged as a pressing priority for Europe, influencing its competitiveness, security, and resilience. This issue is particularly evident in areas such as network equipment, undersea cables, and satellite systems, but may also become more prominent in DNS. Globally, the communications equipment market is dominated by a handful of players, including Huawei, Ericsson, and Nokia, followed by ZTE, Cisco, Ciena and Samsung.[62] European manufacturers, particularly Ericsson and Nokia, excel in technological innovation, such as 6G research and pre-standardization. However, these firms face intense competition from Chinese vendors, whose state-backed support enables aggressive pricing strategies and rapid global market penetration. Europe's fragmented telecom market, with hundreds of mobile operators compared to the much more concentrated markets in the United States and China, further complicates its ability to compete.[63] Market fragmentation, including inconsistent security requirements across member states, limits economies of scale and reduces investment efficiency, constraining the sector's capacity for innovation and the deployment of advanced networks.[64]

The telecom ecosystem is shaped by the interplay of equipment manufacturers, telecom operators (telcos), cloud providers, and value-added service providers such as entertainment and e-commerce platforms. European telcos, including Deutsche Telekom, Telefónica, and Vodafone, maintain large global footprints, particularly in the United States and Latin America. Despite this, European telcos face significant financial constraints. Average revenue per user in Europe is far lower than in other regions, which limits the resources available for investing in advanced networks. These financial constraints contribute to delays in the rollout and adoption of 5G, leaving Europe trailing behind the United States and China in this critical area.

Dominant foreign cloud and platform providers are playing an increasingly influential role in the network layer, providing virtualized services critical for 5G while increasingly competing with telcos. Their proprietary virtualized network solutions enable them to control critical parts of the network layer. Additionally, several platform providers, such as Alphabet and Meta, have become significant players in the telecom backbone, investing heavily in undersea cables and low-Earth orbit satellite

62 2023 data as reported in Mario Draghi, "The Future of European Competitiveness – A Competitiveness Strategy for Europe".

63 Mario Draghi, 69.

64 ETNO, "ETNO – Future of Electronic Communications Networks in Europe – Fact-Pack" (ETNO, September 2023), https://etno.eu/library/reports/116-future-of-electronic-communications-networks-in-europe.html.

networks. Companies like SpaceX and its Starlink service dominate satellite communications, raising further concerns about critical dependencies In the undersea cable business, limited and highly concentrated repair capacity represents an additional vulnerability. The EU has initiated coordinated measures to enhance the protection of undersea cables,[65] while the European Space Agency is working to develop satellite launch capacities.[66] However, it remains unclear whether these efforts will achieve the strategic autonomy that Europe aspires to in the network domain.

The EU must remain vigilant in safeguarding its strategic autonomy in the evolution of the public core of the internet, including critical elements like DNS management, undersea cables, and satellite networks. Discussions on proposals such as new intellectual property (IP) frameworks at the International Telecommunication Union (ITU) underscore the risks of influence from major powers, which could undermine European interests. Emerging technologies like AI and blockchain are set to transform domain name management, potentially shifting the balance of control. To protect its digital sovereignty, the EU must actively engage in these developments, ensuring its values and priorities remain central to shaping the global digital landscape.

Security concerns add another dimension to the set of challenges facing Europe's network layer. The reliance on Chinese equipment has prompted the European Commission to issue a 5G Security Recommendation,[67] prompting several operators to remove Huawei and ZTE equipment from their networks. However, adoption of these measures has been uneven. Large telcos such as Deutsche Telekom and Telefónica have been slower to replace Chinese components.

Ensuring digital sovereignty in 6G will require a comprehensive network security architecture capable of isolating security concerns (e.g., for core-of-government information) while learning lessons from the 5G security challenges. Such an approach must also adapt to emerging business models and regulatory frameworks.[68] This principle extends to potential new internet designs such as SCION.[69]

The security risks extend beyond 5G hardware to include undersea cables and – increasingly – satellite connections and AI-driven network management. These risks are not limited to cyber threats but also encompass physical sabotage – such as cutting undersea communications cables in the Baltic Sea, arson attacks on 5G base stations, hybrid warfare, and geopolitical disruption. Climate-related risks such as the 2024 Boris flooding, which disrupted electricity and telecom networks, further exacerbate these vulnerabilities, given the high interdependence of these systems. Addressing these evolving threats will require the integration of cybersecurity and defense policies into telecom strategies, along with cross-sectoral cooperation to enhance resilience.[70] The rise of Open Radio Access Network (OpenRAN) technologies offers a potential pathway for Europe to reduce dependencies and strengthen its position. OpenRAN decouples hardware and software in the access (radio) network, allowing telcos to source components from multiple vendors and fostering competition. Countries such as Canada have successfully replaced Chinese equipment with OpenRAN solutions, highlighting its potential as a secure and cost-effective alternative. For Europe,

65 European Commission, "Commission Recommendation on the Security and Resilience of Submarine Cable Infrastructures | Shaping Europe's Digital Future", 21 February 2024, https://digital-strategy.ec.europa.eu/en/library/recommendation-security-and-resilience-submarine-cable-infrastructures.

66 Ariane 6 overview. (n.d.). Esa.Int. Retrieved 3 February 2025, from https://www.esa.int/Enabling_Support/Space_Transportation/Launch_vehicles/Ariane_6_overview.

67 European Commission, "COMMISSION RECOMMENDATION (EU) 2019/ 534 – of 26 March 2019 – Cybersecurity of 5G Networks", Official Journal L, no. 88/42 (26 March 2019): 6.

68 Paul Timmers, "There Will Be No Global 6G Unless We Resolve Sovereignty Concerns in 5G Governance', Nature Electronics 2020 3:1 3, no. 1 (24 January 2020): 10–12, https://doi.org/10.1038/s41928-020-0366-3.

69 For more information, see SCION's website: https://www.scion.org.

70 Richard Feasey et al., "Ideas for the Future of European Telecommunications Regulations | CERRE" (CERRE, 12 September 2024); Georg Serentschy, "Digital Networks Resilience and Security, Policy Implications and Mitigation Measures – Summary", 13 January 2024.

OpenRAN presents an opportunity to promote domestic innovation and diversify supply chains.

Europe's strengths in 5G and 6G research and development, as well as pre-standardization, provide a solid foundation for future competitiveness if adoption is accelerated. Supported by leading academic institutions and research organizations, European manufacturers are well-positioned to shape the next generation of network technologies. Initiatives like the announced Digital Networks Act (DNA) may address market fragmentation, enhance security, and facilitate telco consolidation, fostering a more competitive telecom sector while safeguarding consumer interests. Revising competition policies to prioritize public interests such as security and sustainability could further bolster the industry.[71]

Finally, integrating advanced technologies into telecom infrastructure is essential for Europe's resilience. Quantum cryptography, including quantum key distribution (QKD) and post-quantum cryptography (PQC), will be critical for securing next-generation networks against emerging cyber threats. Additionally, the telecom sector's heavy reliance on electricity highlights the need for closer integration of energy and network strategies to ensure both resilience and sustainability, as previously discussed. Europe has an opportunity to redefine its telecom sector. Through strategic investments in 6G, OpenRAN, and quantum technologies, alongside policies that foster innovation, adoption, and consolidation, Europe can build a robust and secure network layer that safeguards its digital sovereignty while driving competitiveness and economic growth.

71 Feasey et al., "Ideas for the Future of European Telecommunications Regulations | CERRE".

IoT: The connective tissue of the digital ecosystem

The internet of things bridges the physical and digital worlds by embedding sensors, processors, and connectivity into objects, enabling real-time data exchange and automation across a broad range of sectors. Connected devices consist of self-contained equipment connected to digital communication networks, including heart monitors, other medtech devices, and mobile phones. This discussion excludes more complex equipment such as connected e-vehicles. The number of IoT devices is forecast to grow from 18 billion in 2024 to 39 billion by 2033.[72] IoT-generated data is projected to generate over 79.4 zettabytes of data annually by 2025.[73] IoT global markets are projected to reach €1.3 trillion in value by 2030.[74] High-growth areas include healthcare (projected to contribute €60 billion in IoT-driven growth by 2030) and industrial manufacturing, where IoT plays a critical role.

The transformative potential of IoT spans key industrial sectors such as manufacturing (e.g., smart factories), agri-food, smart energy, mobility, healthcare and environmental management. For instance, IoT enhances grid efficiency by enabling real-time data analysis and decision-making.[75] IoT technical systems often rely on orchestration software, which facilitates the identification, authentication, and connection of IoT devices while aggregating the data they generate, typically within a cloud-based service.

72 Transforma, "Current IoT Forecast Highlights – Transforma Insights", 9 December 2024, https://transformainsights.com/research/forecast/highlights.

73 Statista, "IoT Devices Installed Base Worldwide 2015–2025", 27 November 2016, https://www.statista.com/statistics/471264/iot-number-of-connected-devices-worldwide/.

74 Transforma Insights, "Global IoT Market to Grow to $1.5trn Annual Revenue by 2030 | IoT Now News & Reports", IoT Now News – How to Run an IoT Enabled Business (blog), 20 May 2020, https://www.iot-now.com/2020/05/20/102937-global-iot-market-to-grow-to-1-5trn-annual-revenue-by-2030/.

75 Sunkari Pradeep et al., "Analysis and Functioning of Smart Grid for Enhancing Energy Efficiency Using OptimizationTechniques with IoT", in 2023 IEEE 5th International Conference on Cybernetics, Cognition and Machine Learning Applications (ICCCMLA), 2023, 316–21, https://doi.org/10.1109/ICCCMLA58983.2023.10346767.

Smart factories (Industry 4.0) that integrate IoT, AI/ML and 5G, are poised to enhance productivity and efficiency. By fostering AI-driven industrial innovation, Europe can strengthen its manufacturing base while promoting ethical and trustworthy AI applications. While Industry 4.0 focuses on automation, interconnectivity, and data exchange in manufacturing technologies, Industry 5.0 represents the next evolutionary step in industrial development (see Box 1: Advanced manufacturing and robotics). Industry 5.0 emphasizes collaboration between humans and machines, aiming to combine the speed and precision of automation with human creativity, critical thinking, and problem-solving skills.

Companies like Bosch and Siemens are at the forefront of deploying industrial IoT for industrial efficiency, scalability and trustworthiness. Their initiatives demonstrate how integrating IoT with AI and data analytics can lead to significant improvements in operational performance, resource management, and energy consumption. Overall, Germany's industrial IoT (IIoT) market is projected to grow at an annual rate of 10.54% from 2024 to 2029, reaching €12.5 billion by 2029.[76] Germany's industrial IoT capabilities are bolstered by robust market growth, active academic research, and strong public-private partnerships. The strategy of Bosch and Siemens reflects a commitment to fostering open ecosystems and trustworthiness (e.g., in the Charter of Trust) that support widespread adoption of IoT technologies across various industries.

Europe, home to two of the world's top three telecom vendors, has a strong foundation in 5G and 6G, enabling IoT adoption at greater scale and with increased reconfigurability.

The EU's Next Generation Internet of Things initiative highlights IoT's transformational role in the digitalization of the economy, society, and environment.[77] As connected devices proliferate, IoT integrates data, computing, and connectivity, enabling intelligent systems that collect, process, and act on information in real time. Trusted IoT and edge computing platforms, along with effective orchestration mechanisms, are widely recognized as essential for this next phase of digitalization. The European Commission, through Horizon Europe, is funding research and innovation to advance joint digital technology initiatives, AI and robotics partnerships, and programs such as sector-specific data spaces and cloud-edge federations. The Digitizing European Industry initiative prioritizes ecosystem development, interoperability, technology integration, and standardization.[78] Large-scale pilots and Technology and Experimentation Facilities target key sectors including agriculture, energy, manufacturing, mobility, healthcare, and smart communities, advancing Europe's IoT innovation.

Open-source initiatives, such as RIOT OS[79] for low-power IoT devices and the EEBus Initiative[80] for smart home and energy communication, exemplify efforts to foster collaboration, reduce reliance on proprietary platforms, and build a resilient IoT ecosystem. Meshtastic[81] is an open-source, community-driven project using inexpensive LoRa radios to create long-range, off-grid communication platforms in areas without reliable infrastructure. Arduino another leading open-source initiative, offers microcontroller boards widely used in IoT projects to connect sensors, actuators, and other components. Companies like Lithuania/Poland-based Cogniteq commercialize these technologies

76 Statista, "Industrial IoT – Germany | Statista Market Forecast", June 2024, https://www.statista.com/outlook/tmo/internet-of-things/industrial-iot/germany.

77 European Commission, "The next Generation Internet of Things | Shaping Europe's Digital Future", 29 November 2024, https://digital-strategy.ec.europa.eu/en/policies/next-generation-internet-things.

78 European Commission, "The Digitising European Industry Initiative in a Nutshell | Shaping Europe's Digital Future", 16 March 2018, https://digital-strategy.ec.europa.eu/en/library/digitising-european-industry-initiative-nutshell.

79 "RIOT – The Friendly Operating System for the Internet of Things", accessed 11 January 2025, https://www.riot-os.org/.

80 "Eebus – Homepage", EEBus – Empowering the digitalisation of Energy transition, accessed 11 January 2025, https://www.eebus.org/.

81 "Meshtastic – Introduction", accessed 11 January 2025, https://meshtastic.org/docs/introduction/.

to expand their application in IoT ecosystems.[82] FIWARE defines open standards for IoT, data management, and Big Data, enabling businesses to build scalable, interoperable, and sustainable solutions free from vendor lock-in.[83] Libelium, a standout European IoT company focuses on applying IoT solutions to enhance productivity and reduce costs while minimizing environmental impact.[84]

Challenges for Europe in IoT and connected devices.

Tightly integrated IoT ecosystems: While being strong in industrial IoT, Europe faces significant challenges in consumer IoT and connected devices, where global tech giants like Apple, Google, Huawei, and Samsung dominate and Chinese companies increasingly enter medtech. These companies often leverage vertically integrated ecosystems that combine hardware, software, and cloud services, allowing them to set de facto global standards and capture significant market value. Smartphone operating systems are increasingly the backbone of their IoT strategies.

Cybersecurity has become a critical issue as IoT and connected devices massively expand what is called the cyber-attack surface. The EU's Cybersecurity Resilience Act will be pivotal in shaping IoT's security regulatory environment. This is expected to drive demand for integrated hardware and software security, and data minimization (see also the data layer).

Data governance, privacy and ethical use all pose challenges in the IoT and connected devices landscape. Especially in the consumer world, massive amounts of data are collected by the vendors that pursue integrated digital ecosystems (for more context, see the data layer). Despite the robust personal data protection framework provided by GDPR, severe privacy infringements continue to occur. With IoT becoming more pervasive in homes, there is a growing need for stronger assurances, such as voluntary certification and trust-labeling mechanisms. This challenge could also present an opportunity for competitive differentiation, particularly if EU vendors are supported in applying data protection laws and ethical standards efficiently.

Standards: Standardization is closely tied to the challenges discussed above. Europe faces strong competition from Chinese companies in international standardization, particularly through initiatives like the oneM2M industry collaboration.[85] The EU currently holds a limited share of leadership roles in IoT standardization. Despite initiatives like Alliance for AI, IoT and Edge Continuum Innovation (AIOTI) and StandICT.eu, Europe's influence in global IoT standards remains constrained, emphasizing the need for further engagement.[86] Unless Europe adopts a more proactive stance on technical interoperability and responsible international IoT governance – addressing critical issues like security and privacy – it risks encountering challenges akin to the 5G security debacle, including potential import bans and fragmented markets.[87]

82 "Building IoT Ecosystems with Open-Source Tools | Cogniteq", 20 August 2024, https://www.cogniteq.com/blog/building-iot-ecosystems-open-source-tools.

83 European Commission, "FIWARE – a European Success Story | Shaping Europe's Digital Future", 30 March 2017, https://digital-strategy.ec.europa.eu/en/news/fiware-european-success-story.

84 Susana Asin, "We were pioneers in providing IoT services", Go Aragón (blog), 28 September 2022, https://www.goaragon.eu/alicia-asin-ceo-of-libelium-iot-we-were-pioneers-in-providing-iot-services/.

85 "oneM2M Sets Standards For The Internet Of Things & M2M", accessed 11 January 2025, https://www.onem2m.org/.

86 https://standict.eu/news/iot-standards-landscape-report?utm_source=chatgpt.com

87 The White House, "FACT SHEET: Protecting America from Connected Vehicle Technology from Countries of Concern", The White House, 23 September 2024, https://www.whitehouse.gov/briefing-room/statements-releases/2024/09/23/fact-sheet-protecting-america-from-connected-vehicle-technology-from-countries-of-concern/.

Box 1 – **Advanced manufacturing and robotics: resilience and strategic autonomy**

Advanced manufacturing and robotics are integral to Europe's competitive advantage, driving key industries such as automotive, aerospace, and industrial machinery. Europe's leadership in precision engineering – exemplified by Germany's automotive sector and its complex industrial products – reinforces its potential as a global manufacturing hub. Recent disruptions in global supply chains have underscored the critical importance of maintaining a robust manufacturing base to ensure resilience and strategic autonomy. In the realm of advanced manufacturing and robotics, Industry 5.0 promises to revolutionize production by enabling seamless human-robot collaboration. Cobots, or collaborative robots, will work alongside humans to integrate creativity and problem-solving with the precision and efficiency of machines. Robotics systems are set to become increasingly intelligent and adaptive, harnessing advanced AI, machine learning, edge computing, and 5G networks to enable real-time decision-making and autonomous operations. This technological progress will support highly flexible and customizable production lines, facilitating mass customization without compromising efficiency. Industry 5.0 robotics will also focus on optimizing energy use, reducing waste, and incorporating innovations like bionic design and soft robotics, which allow for the safe and efficient handling of delicate objects. Augmented reality will further enhance human-robot interaction, offering intuitive visualization and control over processes.

This sector also includes specialized materials, such as advanced composites and alloys, supplied by leading European firms like BASF and ArcelorMittal. However, the reliance on global sources for raw materials exposes the sector to geopolitical risks. The integration of industrial IoT, which links sensors and machines to digital systems, enables the creation of responsive and intelligent manufacturing ecosystems. European companies such as Siemens are at the forefront of developing digital twins and industrial metaverses, transforming factory processes through virtual planning and resource management.

Robotics and factory automation represent additional areas of European strength. Swiss ABB Robotics is a global leader but faces intense competition from Japanese firms such as Fanuc and Yaskawa Electric. While the integration of AI-driven software for process automation remains an emerging field, companies like Romanian UiPath demonstrate Europe's potential. Nonetheless, the sector's reliance on U.S.-based cloud providers for real-time analytics and automation poses a strategic vulnerability.

Cloud infrastructure: The operational core of the digital economy

Cloud infrastructure has evolved far beyond its initial role as a tool for data storage or application hosting; it has become the critical backbone of the digital economy. Functioning as the "power grid" of this new economy, it provides a foundational production environment that transforms industries, public services, and operational models into tightly integrated ecosystems.[88] This shift has cemented the dominance of a few global tech giants, granting them extraordinary influence over critical digital infrastructure. The Draghi Report (September 2024) underscores the essential role of cloud infrastructure in safeguarding Europe's competitiveness and

88 BEREC, "Draft BEREC Report on Cloud and Edge Computing Services", 12 March 2024, https://www.berec.europa.eu/en/document-categories/berec/reports/draft-berec-report-on-cloud-and-edge-computing-services.

strategic autonomy. The report frames cloud not merely as a component of a digital strategy but as a holistic enabler of the broader economy. It highlights the region's shortcomings in cloud technology provisioning and adoption, which have deepened its reliance on foreign providers and weakened its data sovereignty. To address this, the report advocates for a unified strategy through a proposed New EU Cloud and AI Development Act. This initiative emphasizes high-performance computing, AI, and quantum technologies, alongside harmonized standards and procurement processes. [89]

Recent data highlights the growing reliance on cloud services. In 2023, European spending on public cloud services was projected to reach €139 billion, with forecasts suggesting growth to €285 billion by 2027.[90] Thirty percent of companies now store 41–60% of their data in the cloud, while 22% rely on the cloud for more than 60% of their data storage.[91] Despite the adoption of multi-cloud strategies to mitigate risks, these efforts have not significantly disrupted the dominance of leading cloud providers. AWS, Microsoft Azure, and Google Cloud collectively control nearly 70% of the global Infrastructure-as-a-Service (IaaS) market, with AWS holding 31%, Azure 24%, and Google Cloud 11% as of Q4 2024.[92] In contrast, European cloud service providers (CSPs) have experienced a steady decline in market share, dropping from 26% in 2017 to just 10% today – a trend expected to reach a point of no return within three to five years, around 2030.

As of 2021, EU cloud providers held less than 16% of the market, with Deutsche Telekom – the largest – capturing only 2%.[93] Most European providers concentrate on basic IaaS offerings and often rely on reselling platform-as-a-service (PaaS) solutions from dominant U.S. providers like Amazon, Microsoft, and Google, limiting their competitiveness. Non-EU providers such as IBM, Oracle, and Alibaba Cloud also hold portions of the market but lack the scale to challenge the U.S. giants. European firms like OVHcloud, IONOS, and Aruba Cloud face significant challenges in competing due to constraints in resource capacity, portfolio breadth, and innovation speed.

In response, some European providers have begun challenging unfair market practices. For instance, in July 2024, the Cloud Infrastructure Services Providers in Europe (CISPE) and Microsoft resolved a dispute over licensing practices, with Microsoft committing to enhance Azure Stack hyperconverged infrastructure (HCI) – the hybrid, multi-tenant version of the public Azure cloud stack – for European providers as part of the settlement. While this agreement aims to level the playing field in the European cloud market, major providers like Google and AWS were not included, and new complaints continue to raise concerns about persistent inequities. If Microsoft fails to meet its commitments within nine months, CISPE reserves the right to refile its case.[94] However, without proactive measures and a comprehensive industrial plan to protect, strengthen, and expand the size, capacity, and competitiveness of individual European providers, they are unlikely to be seen as viable alternatives by end users.

In the software-as-a-service (SaaS) market, businesses are increasingly relying on tailored applications. Recent data reveals that organizations used an average of 130 SaaS applications as of 2022, reflecting the growing specialization of tools designed to boost productivity and efficiency. Some

89 Mario Draghi, "The Future of European Competitiveness – A Competitiveness Strategy for Europe".

90 https://www.idc.com/getdoc.jsp?containerId=prEUR151144823&utm_source=chatgpt.com

91 IDC, "Worldwide Quarterly Enterprise Infrastructure Tracker: Buyer and Cloud Deployment", IDC: The premier global market intelligence company, 2024, https://www.idc.com/getdoc.jsp?containerId=IDC_P31615.

92 Synergy Research Group, "Cloud Market Gets Its Mojo Back; AI Helps Push Q4 Increase in Cloud Spending to New Highs".

93 Digitalisation World, "European Cloud Providers Double in Size but Lose Market Share", Digitalisation World, 28 September 2021, https://digitalisationworld.com/news/62320/european-cloud-providers-double-in-size-but-lose-market-share.

94 Ben Maynard, "CISPE and Microsoft Agree Settlement in Fair Software Licensing Case", accessed 11 January 2025, https://cispe.cloud/cispe-and-microsoft-agree-settlement-in-fair-software-licensing-case/.

companies now depend on over 100 applications to address diverse operational needs. Despite its fragmented nature, the SaaS market remains deeply integrated into the ecosystems of dominant IaaS providers, further reinforcing their control over the digital stack. To counteract this dependency, the open-source software ecosystem (explored in the next chapter) presents a strategic alternative to Big Tech's proprietary solutions. However, substantial private investment is required to support re-engineering programs – an undertaking complicated by the uncertainty surrounding their business benefits.

The dual influence of cloud providers

Leading cloud providers dominate the digital economy by integrating physical infrastructure with advanced software platforms, creating tightly interconnected ecosystems. This integration streamlines processes for software development teams by offering seamless hardware/software compatibility and powerful CI/CD (Continuous Integration/Continuous Deployment) tools. Computational infrastructures – comprising the cloud and end devices – function not as products but as production environments for digital services.[95] At the same time, business decision-makers are incentivized to choose these global platforms for their reliability and widespread adoption, often overlooking smaller local providers perceived as less scalable or reliable. Whether organizations avoid big cloud providers due to trust concerns, bypass smaller providers for scalability reasons, adopt off-the-shelf solutions, or re-engineer applications for cloud migration, the influence and control of Big Tech in the market remain substantial.

At the physical and computational layer, providers like AWS and Google offer the raw computational power for high-demand workloads, including AI. Leading cloud providers do not rely on standard commercial computing technologies (e.g., computer servers, storage servers, or network routers). Instead, they design custom hardware to optimize costs and performance while reducing dependencies on third-party suppliers. The rapid growth of AI technology has, however, created significant dependencies even for Big Tech, particularly on single-source chip suppliers like NVIDIA, due to a lack of viable alternatives. This reliance has spurred a new industrial strategy, focusing on the development of proprietary technologies encompassing both software stacks and chips to protect margins and retain customer loyalty.

Building on the foundational computing infrastructure, the software and platform layer transforms how ordinary businesses operate daily. These platforms are one-stop-shop solutions offering application development tools, integrated marketplaces, and advanced machine learning capabilities. For example, services like Google's TensorFlow and AWS's SageMaker provide not just the underlying computing power, but also pre-configured development environments, specialized software libraries, and automated workflows. As a result, businesses increasingly rely on cloud providers to create and deploy applications for tasks ranging from sales forecasting to customer service chatbots, embedding their most essential operations directly into the provider's ecosystem. This deep integration leads to significant dependency, as migrating away from these platforms would require not only transferring data but also rebuilding the core architecture of applications. Additionally, customers are reliant on the willingness of platform providers to maintain "baseline security-by-default," further entrenching this dependence.[96]

This model of end-to-end integration across the technology stack, from software applications (SaaS) to software frameworks (PaaS), down to IaaS, has reinforced Big Tech's market positioning and amplified its influence across industries. These include healthcare, finance, manufacturing, and

95 Agathe Balayn and Seda Gürses, "Misguided: AI Regulation Needs a Shift in Focus," Internet Policy Review 13, no. 3, September 30, 2024, https://policyreview.info/articles/news/misguided-ai-regulation-needs-shift/1796

96 See: "Security By Default – Homepage", accessed 12 January 2025, https://securitybydefault.org/.

automotive, where the exponentially increasing volume of data has created a pressing need for more integrated, auto-scalable, and cloud-native platforms to support predictive analytics, diagnostics, and operational optimization. Notable examples include Volkswagen's partnership with Microsoft to streamline production data and Renault's collaboration with Google Cloud to develop Software-Defined Vehicles. These alliances underscore the growing reliance on centralized cloud providers.

Partnerships between major telecom providers and Big Tech cloud platforms have driven the market's evolution. Rising operational costs and increasing competition have led telecoms to focus on cloud-based value-added services, forming strategic alliances to avoid costly proprietary infrastructure investments. Examples include Deutsche Telekom and Google, Telecom Italia and Google, and Orange and Microsoft with Bleu. These partnerships have deeply tied European businesses to Big Tech platforms, making it challenging to untangle dependencies due to significant business and technical barriers.

The physical infrastructure of the cloud

The rapid expansion of cloud computing and AI technologies highlights the critical role of physical infrastructure in shaping Europe's digital future. Data centers, HPC clusters, and their energy and cooling systems, long-distance and undersea cables and soon even satellite systems (Starlink of Musk's SpaceX, Kuiper of Amazon) enable these advancements but also expose Europe to critical dependencies, sustainability challenges, and geopolitical risks.

Global investment in data centers has surged, with private U.S. spending increasing from €1.8 billion in 2014 to €17.8 billion in 2023. The United States now hosts one-third of the world's data centers. Within Europe, HPC clusters such as those under the EuroHPC Joint Undertaking aim to provide sustainable and sovereign alternatives.[97]

For example, Finland's LUMI supercomputer, powered by hydropower from Sweden's Vattenfall, demonstrates the potential for green computing. Expanding EuroHPC into a public alternative for computing power could enhance European autonomy, drive innovation, and align with climate goals. However, the significant power demands of AI computing, the rapid obsolescence of AI technologies, and the private sector's dominance in developing foundational models and inference networks underscore the need for sustainable, long-term investment strategies supported by appropriate governance models. The HPC market will reach approximately €85.56 billion by 2030, with a CAGR of 7.5% from 2023 to 2030.[98] The performance of the world's fastest supercomputers has grown by a factor of 626 since 2010, with compute requirements increasing at an even faster pace.[99] Europe's success in this field is evident, with three of the world's top 10 supercomputers – a remarkable leap from having none in 2016.[100]

The concentration of data centers in a few countries,[101] coupled with competition to attract infrastructure, often results in tax breaks, weakened privacy or environmental standards, and a lack of inclusive growth.[102] This dynamic creates a "race to the bottom," undermining job creation, trade, and long-term economic growth.[103]

97 "EuroHPC JU – Homepage", 19 December 2024, https://eurohpc-ju.europa.eu/index_en.

98 Grand View Research, "High Performance Computing Market Worth $87.31 Billion By 2030", accessed 11 January 2025, https://www.grandviewresearch.com/press-release/global-high-performance-computing-hpc-market.

99 Jaime Sevilla et al., "Compute Trends Across Three Eras of Machine Learning", 2022, https://doi.org/10.48550/ARXIV.2202.05924.

100 TOP500, "November 2024 | TOP500", 64th edition of the TOP500, November 2024, https://top500.org/lists/top500/2024/11/.

101 Jukka Ruohonen, Geospatial Insights on the EuroHPC Supercomputing Ecosystem, 2024, https://doi.org/10.31219/osf.io/z94f2.

102 Enrico Letta, "Enrico Letta's Report on the Future of the Single Market – European Commission".

103 I. Papadakis and M. Savona, "The Uneven Geography of Digital Infrastructure: Does It Matter?", November 2024, https://leap.luiss.it/publication-research/publications/i-papadakis-m-savona-the-uneven-geography-of-digital-infrastructure-does-it-matter/.

Sustainability is a pressing concern. Data centers, driven by IoT data growth and AI applications, face mounting environmental pressures, with cooling systems accounting for up to 40% of energy consumption in some facilities. From 2015 to 2020, data center energy use in Europe rose by 10%, and by 2022, these facilities consumed 2.7% of Europe's electricity,[104] including almost 20% of Ireland's national consumption.[105] Google's hyperscale data centers used an average of 2.1 million liters of water daily in 2023 for cooling.[106] The widespread use of renewable energy certificates often obscures true environmental costs, highlighting the need for stricter transparency standards. The rapid expansion of data centers in Europe has also prompted calls for micro-nuclear plants (i.e., small modular reactors or SMRs) to meet future AI computing demands. However, these advancements also intersect with Europe's ongoing taxonomy debate, which seeks to define the environmental sustainability of emerging technologies and energy sources. The inclusion of nuclear energy and quantum computing under „green" or „sustainable" classifications has sparked contention among policymakers, reflecting broader concerns about balancing innovation with ecological and social objectives.[107] Green computing standards, emphasizing renewable energy, efficient cooling, and reduced water use, are essential to align data center growth with carbon neutrality targets.

Although still years away from widespread adoption, quantum computing holds the potential to address power demands in data centers by enabling highly efficient algorithms for specific classes of problems. These efficiency gains stem from algorithmic advancements, reduced hardware needs, and the use of enhanced machine learning and AI technologies.

European challenges and opportunities in cloud and edge infrastructure

European cloud service providers are making significant investments in infrastructure and services that emphasize data sovereignty and compliance with EU regulatory standards. By aligning their offerings with European data protection regulations, such as GDPR, and operating entirely within European territory, these providers ensure their services remain insulated from non-European jurisdictions, including the implications of legislation like the U.S. CLOUD Act.

France's OVHcloud positions itself as a secure alternative to non-European providers by emphasizing GDPR compliance and interoperability. Outscale, in partnership with Docaposte and Dassault, launched NumSpot as a sovereign cloud focused on public administration and defense services. Scaleway has shifted its business model from traditional data centers to exclusively public cloud services, pursuing growth through acquisitions.

In Italy, Aruba Cloud combines retail and enterprise cloud offerings with leading trust services (e.g., digital identity) and proprietary European data centers powered by renewable energy. Germany's IONOS, the largest European CSP with over €6 billion in revenue, plans to expand across Europe. StackIT, a subsidiary of Germany's Schwarz Group, has followed Amazon's AWS model by opening its IT infrastructure as a cloud platform, with the goal of becoming the largest EU CSP. Hetzner focuses on cost-effective bare-metal servers, while Leaseweb, based in the Netherlands, offers a diverse portfolio similar to that of IONOS and Aruba.

Most European CSPs operate on a relatively small scale. Only a few, such as IONOS and OVHcloud have a market capitalization exceeding €1 billion. Others,

104 Directorate-General for Energy, "Commission Adopts EU-Wide Scheme for Rating Sustainability of Data Centres – European Commission", accessed 12 January 2025, https://energy.ec.europa.eu/news/commission-adopts-eu-wide-scheme-rating-sustainability-data-centres-2024-03-15_en.

105 European Commission. Joint Research Centre., Energy Consumption in Data Centres and Broadband Communication Networks in the EU. (LU: Publications Office, 2024), https://data.europa.eu/doi/10.2760/706491.

106 Zhang, "Data Center Water Usage".

107 Martina Pilloni, "The Nuclear Debate and Energy Taxonomy in the European Union | Heinrich-Böll-Stiftung | Tel Aviv – Israel", 22 March 2022, https://il.boell.org/en/2023/03/30/nuclear-debate-and-energy-taxonomy-european-union, https://il.boell.org/en/2023/03/30/nuclear-debate-and-energy-taxonomy-european-union.

like Aruba and Leaseweb, generate revenues in the range of €3–5 million. While Scaleway and a handful of other providers surpass €100 million in revenue, the majority remain below €50 million, with many generating less than €20 million. This fragmented industry is further overshadowed by large European telecom providers offering cloud services based on U.S. hyperscalers like Microsoft Azure, Google Cloud, or Amazon AWS.

Deutsche Telekom and TIM have deepened partnerships with U.S. tech giants like Microsoft and Google to develop cloud and edge solutions. At the same time, proprietary tech vendors like the U.S.-based VMware (now part of Broadcom) have doubled their efforts in Europe to present themselves as providers of "sovereign cloud" solutions, similar to some of the hyperscalers. The European cloud market has also become a focal point for substantial investments by global technology giants, highlighting both opportunities and challenges for the region's digital sovereignty.

In Germany, AWS announced a €17.8 billion investment through 2040, including €7.8 billion for its European "sovereign cloud" in Brandenburg. In France, Microsoft committed €4 billion to expand AI capabilities, including advanced cloud infrastructure and GPU deployment. Meanwhile, in Spain, Oracle plans to invest $1 billion in AI and cloud computing, while AWS has committed €15.7 billion to data centers in Aragon over the next decade. A clearer definition of "sovereign cloud" is needed to counter the trend toward "sovereign-washing."

While these collaborations address immediate market needs, they increase reliance on foreign providers subject to U.S. legislation, such as the CLOUD Act. This law allows U.S. authorities to access data stored by American companies, regardless of its physical location, raising significant concerns about data sovereignty and security in Europe. These dependencies, along with compliance and regulatory challenges[108] expose critical infrastructure to external legal jurisdictions and undermine Europe's strategic autonomy, particularly in sensitive sectors such as government, aerospace, and defense.

The market control of cloud providers is partially addressed by the Digital Markets Act (DMA). The DMA is intended to ensure fair competition and reduce gatekeeper dominance. Under its provisions, companies identified as gatekeepers must adhere to specific obligations and limitations, such as ensuring fair access to their platforms, preventing self-preferencing, and promoting interoperability between different services. While it is too early to fully assess the effectiveness of this regulatory framework, it alone is unlikely to close the competitiveness gap faced by vertically disintegrated European cloud providers.

To address these structural weaknesses, Europe has launched several ambitious policy initiatives.[109] Gaia-X, initiated by Germany and France in 2019, was presented as a key component of Europe's strategy to reduce dependence on global hyperscalers and regain digital sovereignty. Designed as a federated cloud infrastructure built on shared European standards, Gaia-X has focused on addressing market fragmentation by fostering interoperability and trust. While it has succeeded in raising considerable awareness, establishing a collaborative framework, and launching several pilot projects, its reliance on non-European hyperscalers by many participants has caused confusion about its role in achieving digital sovereignty. Additionally, its broad scope, its tendency to overlook the cloud infrastructure layer, and its slow progress have raised concerns about its ability to deliver tangible results.[110] However, other initiatives

108 Dhruv Seth, Madhavi Najana, and Piyush Ranjan, "Compliance and Regulatory Challenges in Cloud Computing: A Sector-Wise Analysis", International Journal of Global Innovations and Solutions (IJGIS), 1 June 2024, https://doi.org/10.21428/e90189c8.68b5dea5.

109 European Commission, "Cloud Computing | Shaping Europe's Digital Future", 2022, https://digital-strategy.ec.europa.eu/en/policies/cloud-computing.

110 Francesco Bonfiglio, XI. Why Europe's Cloud Ambitions Have Failed, 15 October 2024, https://ainowinstitute.org/publication/xi-why-europes-cloud-ambitions-have-failed.

such as 8ra[111] and the IPCEI-CIS have the potential to build on Gaia-X's achievements with a clearer focus on EU strategic autonomy.

The new Important Project of Common European Interest on Next-Generation Cloud Infrastructure and Services (IPCEI-CIS), approved in 2023 with €3 billion in funding (half of which comes from private co-investments), has taken a different approach. Focused on open-source innovation, it aims to create the first interoperable, openly accessible cloud-edge computing continuum in Europe. Backed by over 100 companies and research institutions across 12 EU member states, the initiative provides €1.2 billion in state aid and is expected to leverage an additional €1.4 billion in private investments. The goal is to develop a decentralized, vendor-neutral platform that integrates data centers, public clouds, and edge computing, emphasizing multi-cloud interoperability, application portability, and low-latency solutions for critical sectors like energy, mobility, manufacturing, and tourism. The IPCEI-CIS initiative currently focuses on software and services but has yet to expand into hardware or infrastructure investments, leaving room for growth in the development of a federated and decentralized European cloud-edge infrastructure, an opportunity that initiatives like 8ra.com might effectively address.

Recognizing these gaps, the European Commission is planning new waves of IPCEIs to address infrastructure development and establish a commercial offering. However, the average timeline for such projects – three to five years from inception to delivery – risks delaying tangible results until 2030, by which time EU CSPs may have lost significant market share. To address scalability challenges, these new IPCEIs will support the development of a large-scale federated edge computing infrastructure and distributed AI services.[112] These efforts aim to amplify the impact of "made in Europe" edge cloud technologies developed under IPCEI-CIS, driving innovation and competitiveness across the EU.

The initiative's decentralized software infrastructure will reduce technological dependencies and lock-in effects while fostering innovative, data-driven business models in areas like artificial intelligence and industrial internet of things. By leveraging decentralization and federation, Europe can transform its heterogeneity into a strategic advantage, interconnecting European cloud providers into a diverse but scalable computing continuum. This approach promotes the emergence of "proximity cloud" service providers across the EU with strong local roots and a sense of social responsibility.

Software: The command center of platforms and applications

The software layer is central to digital infrastructure, encompassing operating systems, application platforms, and algorithmic frameworks. It orchestrates the execution of applications and services that use the functions and facilities of these systems, platforms, and frameworks. This includes common building-block functions such as identity and access management, electronic payments, transactions, and document delivery. In essence, software "runs the world." Yet, Europe lacks a comprehensive industrial strategy for software. U.S. companies dominate the foundational tools underpinning modern economies and societies, leaving Europe's digital sovereignty heavily contested.

Operating systems for desktops, mobile devices, and embedded systems are monopolized by three U.S. companies – Microsoft, Apple, and Google – which collectively over 90% of the European market. Microsoft Windows powers more than 70%

111 See: "8ra – Homepage", 8ra, accessed 11 January 2025, https://www.8ra.com/.

112 Joint European Forum for IPCEIs, "Opinion of the Joint European Forum for Important Projects of Common European Interest", 27 November 2024, https://competition-policy.ec.europa.eu/document/download/3d01ea9f-2c29-4f83-a66f-44f2e345c015_en?filename=JEF-IPCEI_Opinion%20of%20the%20high-level%20meeting_27%20November%202024.pdf.

of desktops,[113] Google's Android commands 72% of Europe's mobile market, and Apple's iOS dominates high-value segments.[114] Although open-source Linux has a global impact in servers, cloud environments, and the internet's core infrastructure, its adoption in consumer-facing systems remains limited. Efforts to develop Linux-based national operating systems have struggled to achieve scale, yet Linux's flexibility, security, and alignment with European values make it a critical asset for enhancing digital strategic autonomy.

Application platforms present a mixed picture. Europe is home to global leaders like SAP and Dassault Systèmes in enterprise software and industrial tools, with SAP leading the global Enterprise Resource Planning software market, holding a 6.2% share in 2023.[115] However, even these platforms depend on foreign-controlled operating systems and middleware, limiting their potential to function as fully sovereign alternatives. Moreover, in many key applications – such as office productivity, messaging, collaboration – the dominance of U.S. companies is uncontested. However, open-source platforms developed by the private sector (Nextcloud) or through a public-private partnership (openDesk, La Suite Numérique) represent a good model to build European alternatives.

Similarly, Europe's track record in developing and adopting common services is uneven. Secure eID and secure authentication methods for accessing government services digitally have been successful in countries like Estonia and Belgium, but their adoption in Germany remains limited. Nonetheless, the EU's long-term investments across the internal market, such as the EU Connecting Europe Facility (CEF) funding, demonstrate that common services can evolve into scalable digital infrastructures. Notable examples include e-invoicing based on the Pan-European Public Procurement OnLine (PEPPOL) system – now becoming mandatory in an increasing number of EU countries – as well as services for business reporting, document delivery, and translation. These services, along with e-signatures and timestamping, benefit from EU-wide legal recognition under regulations like the eIDAS2 Regulation.[116]

Despite their open-source nature, algorithmic frameworks such as TensorFlow and PyTorch, remain tethered to U.S.-based ecosystems. These frameworks shape developer communities, align innovation with proprietary platforms like Google Cloud or Meta's AI infrastructure, and reinforce dependencies on foreign systems.[117] The structural integration of operating systems, application platforms, and algorithmic frameworks creates high switching costs, further entrenching dependency and lock-in. Consequently, much of the value generated by these systems flows out of Europe, diminishing its influence over global standards and eroding tax revenues that could otherwise fuel local innovation.

Applications represent what end users interact with in their daily use of mobile phones, laptops, or professional equipment. They cover a huge range of use cases, from personal navigation to inventory management, from health monitoring to traffic control systems. Europe is home to several prominent companies, such as Spotify and SAP, yet their market capitalization is generally lower than that of foreign competitors. Over the years, entrepreneurial EU application startups have often achieved global expansion. However, this capitalization is frequently provided by foreign investors and larger international companies.

113 StatCounter, "Desktop Operating System Market Share Europe", November 2024, https://gs.statcounter.com/os-market-share/desktop/europe?utm_source=chatgpt.com.

114 Statista, "Mobile OS Market Share Europe 2010-2023", 7 March 2024, https://www.statista.com/statistics/639928/market-share-mobile-operating-systems-eu/?utm_source=chatgpt.com.

115 Albert Pang, Misho Markovski, and Ristik Marija, "Top 10 ERP Software Vendors, Market Size and Market Forecast 2023-2028", Apps Run the World, 10 June 2024, https://www.appsruntheworld.com/top-10-erp-software-vendors-and-market-forecast/.

116 European Commission, "eGovernment and Digital Public Services | Shaping Europe's Digital Future", 28 November 2024, https://digital-strategy.ec.europa.eu/en/policies/egovernment.

117 Amba Kak, Sarah Myers West, Meredith Whittaker, "Make No Mistake – AI Is Owned by Big Tech", MIT Technology Review, 5 December 2023, https://www.technologyreview.com/2023/12/05/1084393/make-no-mistake-ai-is-owned-by-big-tech/.

Europe's role in software

Beneath the surface of external dominance lies an "invisible" European strength: a long-standing presence in open-source software (OSS) and open standards that form the backbone of critical digital infrastructures. From Linux and Python to core internet protocols, Europe has made significant contributions to open source initiatives. European companies like SAP have long been global leaders in business systems, and Europe also shows promise in AI software, embedded security, and cybersecurity forensics – though on a smaller scale compared to the United States or China.

Open-source software, which constitutes 70-90% of modern codebases, serves as a cornerstone of software development and offers a promising pathway to strengthening Europe's digital sovereignty.[118] OSS enables decentralized, interoperable online services that can serve as alternatives to today's centralized and surveillance-based platforms. Beyond its technical advantages, OSS aligns with Europe's vision of transparency, collaboration, and interoperability. Public investments in OSS have yielded impressive returns: A 2021 European Commission study found that €1 billion invested in OSS could generate up to €95 billion in economic impact.[119] Thus, OSS is not only a technological enabler but also a strategic economic driver, capable of fostering innovation, reducing dependencies, and strengthening Europe's global competitiveness. By leveraging and investing in OSS, Europe can accelerate its digital sovereignty agenda while cultivating an open and sustainable technological landscape.[120]

However, the sustainability and governance of Europe's OSS ecosystem need bolstering. Funding remains fragmented, and reliance on non-European platforms like GitHub compromises sovereignty. Public procurement often favors proprietary solutions over open-source alternatives, while Big Tech companies strategically exploit OSS to entrench their dominance.[121] These companies acquire platforms such as GitHub, integrate proprietary code into open environments (e.g., Android or Chromium), and profit from community-driven innovations without adequately contributing in return. The European Commission's Open-Source Software Strategy has laid the groundwork for addressing these challenges, advocating for equal treatment of OSS in procurement and promoting a level playing field. Additionally, efforts such as the Open-Source Observatory (OSOR) and the Interoperable Europe Act underscore Europe's dedication to open-source integration.

The success of these initiatives depends on sustained investment, effective governance, and alignment with market realities to counteract the dominance of proprietary solutions. Power dynamics within open-source settings are often obscured, with some actors disproportionately reaping the benefits. For instance, Microsoft, once a vocal opponent of open-source,[122] has dramatically shifted its stance over the years, culminating in its acquisition of open-source platform GitHub.

Big Tech companies increasingly take advantage of open-source communities by sharing portions of their code while keeping their core business proprietary. This approach allows them to benefit from cost-effective, high-quality feedback and improvements, leveraging the community's

118 Jameson Perlow, "A Summary of Census II: Open Source Software Application Libraries the World Depends On", Linux Foundation, 7 March 2022, https://www.linuxfoundation.org/blog/blog/a-summary-of-census-ii-open-source-software-application-libraries-the-world-depends-on.

119 OpenForum Europe and Fraunhofer ISI, "Open Source Study", OpenForum Europe, 2021, https://openforumeurope.org/open-source-impact-study/.

120 Content and Technology European Commission: Directorate-General for Communications Networks et al., The Impact of Open Source Software and Hardware on Technological Independence, Competitiveness and Innovation in the EU Economy – Final Study Report (Publications Office, 2021), https://doi.org/10.2759/430161.

121 Alice Pannier, "How Big Tech Is Shaping the Global Open Source Ecosystem | SovereignEdge.EU", SovereignEdge (blog), 22 May 2023, https://sovereignedge.eu/blog/how-big-tech-is-shaping-the-global-open-source-ecosystem/.

122 Then Microsoft CEO Steve Balmer famously declared that "Linux is a cancer that attaches itself in an intellectual property sense to everything it touches." See: Thomas C. Greene, "Ballmer: 'Linux Is a Cancer'", The Register, 2 June 2001, https://www.theregister.com/2001/06/02/ballmer_linux_is_a_cancer/.

collaborative efforts for their gain. For example, Google's management of Android and Chromium, which integrates proprietary components and features into an open environment, helps the company entrench its dominance in key markets while shaping browser development and web standards.[123] Amazon's forking of Elasticsearch enabled it to avoid contributing to the original project while profiting from its functionality, raising concerns about the sustainability of open-source initiatives. Oracle's contentious stewardship of Java – particularly its legal disputes over Java APIs in Android – illustrates the conflicts that arise when proprietary interests intersect with widely adopted open-source technologies. This trend is also evident in the emergence of so-called open AI models, where foundational research and tools are released as open source, yet the resulting implementations are frequently embedded into proprietary platforms, reinforcing control by dominant players.[124]

These practices underscore the need for policies that protect the integrity and accessibility of the digital commons, ensuring open-source principles are not diluted by corporate interests. To counter this trend, Europe must build robust, independent open-source ecosystems that prioritize decentralization, interoperability, and alignment with its regulatory and ethical standards.

Successful examples already exist. Europeana institutionalizes data sharing in cultural heritage, and the European Open Science Cloud provides a trusted, sovereign framework for open science. Initiatives like Decidim thrive not only because they are open source but also because they are supported by long-term institutional backing, ensuring sustained growth.[125] Future opportunities include investing in Linux-based systems for public administration, leveraging open-source solutions in key sectors like healthcare and smart cities, and championing federated AI models. Decentralized networks based on open protocols can offer privacy-first, transparent alternatives in messaging and social media, while regulatory tools such as the Digital Markets Act, Digital Services Act, Media Freedom Act, and the Interoperable Europe Act help ensure that competition and innovation can flourish within a trusted, pluralistic digital ecosystem. Initiatives such as the EDIC offer a pathway for building open-source solutions in areas of public interest, from access to public services to key intermediation technologies.

Aligning digital commons with industrial strategies and leveraging public institutions as strategic supporters and early adopters can consolidate these gains. Europe has the opportunity to scale funding for OSS-based AI projects, digital infrastructure consortia, and common services for eID and e-invoicing. However, Europe's public institutions currently lack the capabilities to fully understand and address critical dependencies within the digital stack. Institutions like the proposed Sovereign Tech Agency and initiatives such as FOSSEPS and bug bounty programs represent important steps forward. The German Sovereign Tech Agency[126] is a promising model for funding the maintenance of digital commons while strategically driving their development. Nonetheless, the related Sovereign Tech Fund highlights the challenge of limited resources, with a total allocation of only €11.5 million for 2023. This modest budget underscores the need for more substantial financial commitments to ensure the sustainability and impact of open-source software. In the 2024 German Federal budget, €17 million was allocated to the Sovereign Tech Fund. To reduce reliance on external partners and safeguard Europe's technological independence, public

123 David McCabe and Nico Grant, "What's Next for Google's Search Monopoly", The New York Times, 21 December 2024, sec. Technology, https://www.nytimes.com/2024/12/20/technology/google-antitrust-case-chrome.html.

124 David Gray Widder, Meredith Whittaker, and Sarah Myers West, "Why 'Open' AI Systems Are Actually Closed, and Why This Matters", Nature 635, no. 8040 (November 2024): 827–33, https://doi.org/10.1038/s41586-024-08141-1.

125 See: "Decidim, Free Open-Source Democracy – Homepage", n.d., https://decidim.org/.

126 See: "Sovereign Tech Agency – Home", 6 December 2024, https://www.sovereign.tech/.

institutions must ensure long-term support and governance for open-source ecosystems.

In contrast, the French Ministry of Public Transformation and Civil Service has launched an ambitious free Software and Digital Commons action plan, spearheaded by the newly established Free Software Unit within the Interministerial Directorate for Digital Affairs (DINUM). This initiative aims to promote the adoption of free software and digital commons across public administration, encourage the release and publication of source codes, and enhance the state's appeal as a digital employer by recognizing public contributions to open-source projects.

Using agile methodologies, the French government is developing collaborative products such as La Suite and Albert AI. Currently, La Suite is actively utilized by approximately 300,000 public servants on a daily basis. The ambitious goal is to scale these solutions to serve millions while fostering the reuse of their modular building blocks – each representing an active open-source community – within the private sector as well. This initiative exemplifies the critical role of public administrations as orchestrators of open-source ecosystems,[127] and early adopters of digital commons,[128] creating a robust foundation for innovation and collaboration in both the public and private sectors. This approach, in which governments act as lead users for public innovation, demonstrates that success is not solely dependent on investment but also on adopting a product-driven methodology. Agile methodologies enable the capture of new users and use cases, emphasizing the importance of channeling resources through digital commons communities and public incubators to foster innovation and scalability. However, caution is required when referencing "digital assets." These assets must represent active communities with strong user bases – such as Matrix or Firefox – or risk becoming irrelevant without the foundational support of vibrant ecosystems. Building and sustaining these communities is essential for ensuring meaningful impact and long-term success.

Smart public procurement and sustained investment are key to ensuring that Europe's software ecosystem becomes a foundation of its digital sovereignty, transforming open source and digital commons into lasting strategic assets that underpin Europe's influence, resilience, and global competitiveness.

127 "Action Plan for Free Software and Digital Commons", Direction interministérielle du numérique, accessed 12 January 2025, https://code.gouv.fr/en/action-plan-for-free-software-and-digital-commons/.

128 See: "Mission Société Numérique – Homepage", accessed 12 January 2025, https://societenumerique.gouv.fr.

Box 2 – **Digital Public Infrastructure, a foundation for citizen-centric digital services**

Digital Public Infrastructure (DPI) is vital to modern governance, connecting citizens to public institutions through digital identity systems, secure payments, and interoperable data platforms. These systems drive inclusivity, accessibility, and efficiency while reflecting Europe's regulatory values. However, to fully unlock DPI's potential, Europe must reduce dependencies and ensure privacy, transparency, and interoperability.

At the core of Digital Public Infrastructure (DPI) are digital identity systems, exemplified by the European Digital Identity Wallet (EUDI Wallet). While national models like Estonia's e-ID, Germany's Online-Ausweisfunktion, FranceConnect, Denmark's MitID, Italy's SPID, and Finland's Suomi.fi have streamlined access to services, they remain nationally isolated and based on legacy architectures. The EUDI Wallet, established under the eIDAS 2.0 Regulation which entered into force in May 2024, aims to provide EU citizens with secure and interoperable digital identities. Member states are actively developing wallets through initiatives like Germany's Funke Competition, while the European Commission's common EU Toolbox ensures uniform implementation standards. By 2027, all EU member states must issue or certify at least one EUDI Wallet, with pilot projects currently testing functionality and user acceptance. Positioned to become a cornerstone of Europe's digital identity framework, the EUDI Wallet has also sparked discussions about aligning with Europe's digital sovereignty goals. Concerns include potential reliance on proprietary systems and the importance of robust security and privacy safeguards. Addressing these issues through privacy-first standards will be critical to its long-term success as a secure and trusted solution for EU citizens.

Secure payments are a key pillar, with Italy's PagoPA enabling seamless citizen-administration transactions. The proposed Digital Euro, led by the European Central Bank, has the potential to unify digital payment systems within a secure, interoperable framework, especially when integrated with solutions like the EUDIW.

Data platforms ensure secure, interoperable ecosystems. Examples like Estonia's X-Road, Finland's Suomi.fi Data Exchange Layer, and Spain's SARA enhance public service delivery. France's API Platform and Germany's GovData portal promote open data sharing, improving transparency and collaboration. Platforms such as AuroraAI in Finland and Decidim Barcelona highlight Europe's leadership in citizen-centric innovation.

Despite these successes, Europe's DPI remains heavily reliant on foreign cloud infrastructure. Critical DPI components – such as digital identities, payments, and data exchanges – must be based on EuroStack digital infrastructure ensuring alignment with EU regulations.

To accelerate adoption, DPI must demonstrate clear benefits to citizens. For example, the COVID-19 pandemic showed how digital contact tracing apps, linked to national digital IDs, enabled cross-border interoperability and increased trust in digital services. Integrating DPI into everyday interactions – such as healthcare, tax systems, and public administration – will further drive uptake.

The digital transformation of public administration is a critical priority for European governments seeking to enhance service delivery, reduce costs, and improve overall efficiency. At the forefront of this transformation is Government Process Automation (GPA) as a cross-border approach that leverages technology and shares process knowledge to streamline and optimize administrative workflows.

Data and artificial intelligence: Catalysts for innovation and strategic autonomy

Data is the backbone of the digital economy, driving innovation across industries. However, much of this data – particularly industrial and urban data – is extracted and monetized by non-European platforms. While Europe generates a significant portion of global industrial data,[129] much of it is processed and monetized by foreign entities. This reliance on U.S. and Chinese cloud providers not only limits Europe's economic gains but also raises concerns about data sovereignty and security.

To counter the dominance of extractive data practices and proprietary ecosystems, Europe is advancing an ambitious data sovereignty framework. The European Union's data strategy aims to establish a unified data ecosystem that enhances competitiveness, protects citizens, and ensures data sovereignty, supported by strong legislation such as the GDPR. Far from being a limitation, the GDPR has become a global benchmark for data protection, inspiring similar legal frameworks worldwide. However, challenges remain in its effective implementation and in addressing power imbalances in an opaque data marketplace where privacy and rights are frequently violated, often in contravention of European laws.

A significant shortcoming of the EU's strategy is its inability to develop robust, independent data infrastructures, leaving it reliant on major Big Tech companies for cloud and data processing services. This dependency undermines Europe's autonomy within the digital economy. While initiatives like the Data Governance Act and the Data Act (effective January 2024) aim to democratize data access and foster innovation, the lack of independent infrastructure perpetuates asymmetries of power in the global data economy.[130] To achieve true sovereignty and competitiveness, Europe must pair its legislative leadership with tangible advancements in independent, energy-efficient, and secure data infrastructure.

Key efforts include the development of Common European Data Spaces,[131] intended to enable secure and interoperable data sharing across sectors such as health, energy, and agriculture. These data spaces are presented as tools to foster innovation and economic growth, yet doubts persist regarding the speed of their implementation and their ability to scale sufficiently to serve as viable alternatives to extractive global data platforms.

Standards form a critical aspect of the rapidly evolving data landscape. The EU's Data Act, Data Governance Act, and Open Data Directive aim to harmonize frameworks for IoT-generated data sharing and reuse, as does the Cyber Resilience Act for the cybersecurity of IoT solutions. However, harmonized implementation and the minimization of bureaucratic obstacles are not guaranteed.

Industrial data, critical for sectors like manufacturing, energy, and mobility, is one of Europe's most valuable assets. Initiatives such as Catena-X,[132] Manufacturing-X,[133] and EONA-X[134] exemplify progress in industrial data ecosystems, demonstrating the potential of industrial data spaces to reduce inefficiencies and drive competitiveness in Europe's industrial heartlands, These initiatives aim to lower barriers, foster trust, and drive adoption and competitiveness for European providers.

In addition to industrial data, urban data holds strategic significance, with many cities advancing

129 European Commission, "Data Act: Measures for a Fair and Innovative Data Economy", Text, 23 February 2022, https://ec.europa.eu/commission/presscorner/detail/en/ip_22_1113.

130 Miguel Otero Iglesias and Agustín González-Agote, "The Future Data Economy – Competitive, Fair, Safe" (IE CGC, April 2024).

131 European Commission, "Common European Data Spaces | Shaping Europe's Digital Future", accessed 12 January 2025, https://digital-strategy.ec.europa.eu/en/policies/data-spaces.

132 See: "Catena-X Your Automotive Network – Homepage", accessed 12 January 2025, https://catena-x.net/de/.

133 See: Germany's Federal Ministry for Economic Affairs and Climate Action and Federal Ministry of Education and Research, "Manufacturing-X", accessed 12 January 2025, https://www.plattform-i40.de/IP/Navigation/EN/Manufacturing-X/Manufacturing-X.html.

134 See: "Eona-X, Homepage", accessed 12 January 2025, https://eona-x.eu/.

the development of urban digital twins – virtual replicas of physical urban environments that integrate real-time data into simulations to support decision-making.[135] These platforms leverage open data and real-time integrations to enable informed, data-driven decisions, enhance transparency, and foster collaborative urban planning. European cities are at the forefront of this field, generating massive volumes of data through smart city technologies like IoT sensors for traffic management, energy optimization, and public services. The SynchroniCity project, funded under Horizon 2020, is an example of a pan-European initiative creating frameworks for smart cities to share data in consistent formats. It involves cities like Milan, Helsinki, and Eindhoven, where data-sharing platforms are enabling innovations in mobility, waste management, and energy efficiency.

Amsterdam, a leader in smart city development, has implemented an open urban data platform that empowers citizens and local businesses while maintaining strong data governance.[136] By prioritizing data sovereignty and interoperability, these projects showcase how urban data spaces can enhance livability and collective empowerment. In Barcelona, the DECODE project and Decidim platform have empowered citizens to take control of their data, repurposing it as a public good for urban planning and participatory democracy.[137] These experiments have been subsequently replicated globally and extended to AI through the Cities for Digital Rights Coalition.[138] Similarly, Hamburg has used mobility data to enhance public services while safeguarding data privacy. Portugal, Estonia, Slovakia and Ukraine have drawn attention for their high growth in open data maturity scores.[139] These examples highlight how cities can leverage data governance to benefit communities.[140]

Gaps in European data infrastructure

Despite these promising examples, Europe's data infrastructure remains underdeveloped. To close these gaps, Europe must accelerate investment in sovereign data infrastructure. Decentralized and edge computing technologies, which process data locally, are critical for ensuring compliance with EU regulations and enhancing data security. For example, edge computing can support real-time decision-making in manufacturing and smart cities while minimizing the dependence on data data transfer to centralized foreign platforms. An illustrative example of decentralized sovereign data management is Inrupt, founded by Sir Tim Berners-Lee, the creator of the World Wide Web. Inrupt advances data sovereignty through the Solid protocol, enabling individuals to control personal data via decentralized "Pods." Collaboration efforts like the Athumi initiative with the Flanders government empower citizens to manage data securely, fostering innovation in public and private services.[141] In healthcare, Inrupt's pilot with the United Kingdom's NHS allows patients to control access to their medical records, enhancing privacy and care. Similarly, its work with the BBC demonstrates how user-controlled data can transform digital experiences. These efforts align with Europe's vision for a trusted, interoperable data commons.

135 OECD, Smart City Data Governance: Challenges and the Way Forward, OECD Urban Studies (OECD, 2023), https://doi.org/10.1787/e57ce301-en.

136 Jutta Ravelli, "City Data: A Treasure Full of Data about the City", Amsterdam Smart City, 15 August 2017, https://amsterdamsmartcity.com/updates/news/city-data-a-treasure-full-of-data-about-the-city.

137 Fernando Monge et al., "A New Data Deal: The Case of Barcelona", IIPP WP, no. 2022/02 (18 February 2022).

138 See: "Cities for Digital Rights – Homepage", accessed 12 January 2025, https://citiesfordigitalrights.org/.

139 European Data Portal et al., Open Data Best Practices in Europe: Estonia, Slovenia and Ukraine (Publications Office of the European Union, 2022), https://data.europa.eu/doi/10.2830/277405; Publications Office of the European Union et al., 2023 Open Data Best Practices in Europe (Publications Office of the European Union, 2024), https://data.europa.eu/doi/10.2830/68229.

140 Francesca Bria, "Governing Urban Data for the Public Interest", 26 October 2023, https://thenew.institute/en/media/the-new-hanse-final-report-out-now.

141 Inrupt, "Flanders Government Strengthens a Trusted Data Economy", accessed 12 January 2025, https://www.inrupt.com/case-study/flanders-strengthens-trusted-data-economy.

The EU's emphasis on FAIR data principles – making data findable, accessible, interoperable and reusable – is supported by organizations like MyData Global, Finland's SITRA, and Project Liberty, which champion human-centric data governance. While these efforts align with the EU's vision for data sovereignty, they face significant practical hurdles, including aligning diverse stakeholders and addressing technical and legal interoperability challenges. The risk of fragmentation, both within the EU and globally, remains a major barrier. Structural challenges persist as well. Initiatives such as the Interoperable Europe Act,[142] which prioritizes and promotes open standards and open source for cross-border digital services and public administrations, and the Open Data Directive, which promotes the reuse of high-value public datasets, hold promise but require substantial political and technical coordination to succeed. Europe's vision for ethical and inclusive data governance hinges on overcoming these barriers and ensuring frameworks gain public and private sector buy-in while remaining globally competitive.

Policymakers and organizations must transform data from a tool of exploitation into a shared resource for societal progress. By addressing monopolistic practices and unethical product design while improving infrastructure and policies, Europe has a unique opportunity to create a fairer and more sustainable data economy. With regulatory frameworks already recognized as global benchmarks, Europe is well-positioned to lead the implementation of an interoperable data commons ecosystem, setting a global standard for ethical and collaborative data governance.

142 EU, "Regulation (EU) 2024/903 of the European Parliament and of the Council of 13 March 2024 Laying down Measures for a High Level of Public Sector Interoperability across the Union (Interoperable Europe Act)" (2024), http://data.europa.eu/eli/reg/2024/903/oj/eng.

Artificial intelligence: Opportunities and challenges for the EuroStack initiative

AI is a transformative technology capable of analyzing vast amounts of structured and unstructured data while dynamically adapting to new conditions without requiring reprogramming. By revolutionizing how information is processed and synthesized, AI has the potential to reshape the digital industry, creating new markets and potentially displacing established products. For instance, the success of generative models such as OpenAI's ChatGPT has introduced the possibility of challenging the previously unassailable online search market. Furthermore, the versatility of general-purpose foundation models promises to drive transformation across the economy, influencing sectors as diverse as healthcare, manufacturing, food production, and autonomous systems.

The prospect of far-reaching market shifts has spurred massive investments. In 2023, private AI investment reached €62.5 billion in the United States, €7.3 billion in China, and €9 billion across the European Union and the United Kingdom.[143] The resulting expansion of the industry is extraordinary. Valued at €234 billion in 2025, the global AI market is projected to grow at a CAGR of 27.67% through 2030, underscoring its central role in the modern economy.[144]

In this digital gold rush, new players are seeking to establish themselves in the AI-powered economy, while existing tech giants work to defend their market positions by integrating AI into their products and shaping the technology's development to their advantage. However, because the development and training of AI models rely heavily on other elements of the digital stack, incumbents with dominant

143 Nestor Maslej, et al., "AI Index Report 2024 – Artificial Intelligence Index" (Stanford: AI Index Steering Committee, Institute for Human-Centered AI, April 2024), https://aiindex.stanford.edu/report/.

144 Statista, "Artificial Intelligence – Global", accessed 12 January 2025, https://www.statista.com/outlook/tmo/artificial-intelligence/worldwide.

positions in related markets enjoy a significant competitive edge.[145]

As AI models grow increasingly complex, computational power – referred to as "compute" – has become the primary input. For instance, OpenAI's ChatGPT-3.5, with 175 billion parameters, was succeeded by ChatGPT-4, which incorporates 1.75 trillion parameters at an estimated training cost of $100 million.[146] This exponential demand for computational power is creating a significant bottleneck, as the market is dominated by U.S. cloud providers such as AWS, Google Cloud, and Microsoft Azure. Even well-funded firms face constraints in accessing high-performance compute. For example, the Emirati AI holding company G42, despite its vast financial resources, entered in a €1.5 billion partnership with Microsoft in 2024 to expand its AI infrastructure.[147] In turn, data centers source specialized chips, primarily from NVIDIA, or design proprietary hardware while also developing software to optimize performance and enable additional software layers by third parties.

In January 2025, OpenAI announced the Stargate Project, a joint venture in partnership with SoftBank, Oracle, and MGX aiming to invest $500 billion over the next four years to build advanced AI infrastructure in the United States. The project will commence with an immediate deployment of $100 billion, focusing on constructing state-of-the-art data centers and energy facilities to support the next generation of AI models. The Stargate Project aims to overcome current bottlenecks in AI development, ensuring that the United States remains at the forefront of technological innovation.[148]

Initiatives like Microsoft's Founders Hub, Google Cloud for Y Combinator startups, and Northern Data's AI accelerator program aim to ease access to AI resources by offering free or subsidized GPU clusters. For example, Microsoft's Founders Hub, launched in February 2022, offers up to $150,000 in Azure credits over four years, while Google Cloud provides Y Combinator startups with access to subsidized NVIDIA H100 GPU clusters. These programs, however, risk fostering dependency on Big Tech infrastructure, potentially hindering the emergence of an independent AI ecosystem. Moreover, by offering these resources, Big Tech firms gain valuable insights into startup activities, enabling them to influence the direction of AI innovation to align with their strategic interests. While such programs may provide short-term benefits, AI developers remain heavily reliant on a small group of suppliers. Nearly all AI startups, including OpenAI, Anthropic, and the French firm Mistral, depend on U.S.-based cloud infrastructure.[149] In 2023, Alphabet CEO Sundar Pichai revealed that over 70% of generative AI startups rely on Google Cloud.[150]

While AI models are typically characterized by high setup and training costs, Europe-originated Stable Diffusion offers a compelling alternative. Developed through academic research at Munich's Ludwig Maximilian University and Heidelberg University, in collaboration with the open-source community, it democratizes access to advanced image creation.[151] The open-source nature of Stable Diffusion, supported by the CompVis group, Stability AI, and EleutherAI, fosters transparency and community-

145 Fausto Gernone and David Teece, "Competing in the Age of AI: Firm Capabilities and Antitrust Considerations", in Artificial Intelligence and Competition Policy (Concurrences, 2024).

146 Olena Zherebetska, "100 ChatGPT Statistics to Know in 2025 & Its Future Trends", Intelliarts, accessed 12 January 2025, https://intelliarts.com/blog/chatgpt-statistics/.

147 "Microsoft, UAE's AI Firm G42 to Set up Two New Centres in Abu Dhabi", Reuters, 17 September 2024, sec. Technology, https://www.reuters.com/technology/microsoft-uaes-ai-firm-g42-set-up-two-new-centres-abu-dhabi-2024-09-17/.

148 "Announcing The Stargate Project".

149 The German startup Aleph Alpha is a notable exception in this regard, boasting to be technologically independent of US Big Tech. See: Georgia Butler, "Aleph Alpha and Cerebras Systems to Develop Sovereign AI Solutions", Data Center Dynamics, 17 May 2024, https://www.datacenterdynamics.com/en/news/aleph-alpha-and-cerebras-systems-to-develop-sovereign-ai-solutions/.

150 Johan Moreno, "70% Of Generative AI Startups Rely On Google Cloud, AI Capabilities", Forbes, 2023, https://www.forbes.com/sites/johanmoreno/2023/07/25/70-of-generative-ai-startups-rely-on-google-cloud-ai-capabilities-says-alphabet-ceo-sundar-pichai/.

151 See: Stability AI, "Stable Diffusion Launch Announcement", 10 August 2024, https://stability.ai/news/stable-diffusion-announcement.

driven development. Additionally, online developer communities are refining methods to set up bespoke AI models locally, running on users' machines using open-source frameworks such as Meta's Llama. While these developments hint at a future in which AI resources are more affordable and accessible, the scale and reliability required by organizations currently demand substantial investment.

DeepSeek, a Chinese startup founded in 2023, claims to have overcome the barrier of exorbitant training costs of generative AI. DeepSeek's flagship model, DeepSeek-R1, delivers performance comparable to OpenAI's ChatGPT but at a fraction of the development cost. Notably, DeepSeek trained its model using approximately 2,000 Nvidia H800 GPUs over 55 days, incurring a cost of around $5.6 million – significantly less than the estimated $100 million spent on training models like ChatGPT-4.[152] Since the energy consumption of AI datacenters is proportional to the computational requirements, these advancements indicate that overall power demand for AI might be less than expected.[153] This efficiency has been achieved through innovative training methods and the utilization of less advanced hardware. The open-source nature of DeepSeek-R1 has further accelerated its adoption, leading it to surpass ChatGPT as the top free app on the iOS App Store in the United States. Moreover, other Chinese firms, such as Zhipu AI and Bytedance have launched AI video-generation tools to rival OpenAI's Sora, while Baichuan, Zhipu AI, Moonshot AI and MiniMax have been celebrated by investors as China's new "AI Tigers."[154] The recent accomplishments of Chinese AI models has highlighted the geopolitical dimension of the AI race, provoking strong reactions in the media and markets regarding the U.S.' narrower-than-expected technological lead.[155]

Access to data, alongside computational power and talent, is a critical factor shaping the AI landscape. Frontier AI models are highly data-intensive, often trained on massive datasets scraped from the internet.[156] This practice raises ethical and legal concerns surrounding copyright and ownership, particularly as internet data becomes increasingly enclosed. Resources that were once freely available are now being monetized, with platforms like Reddit limiting access to their valuable data. As a result, AI firms are increasingly competing for data acquisition through exclusive licensing agreements or outright purchases. For instance, Elon Musk's xAI leverages proprietary user content from X (formerly Twitter) to train its models, underscoring the strategic importance of data ownership and governance in the AI race.[157] This trend toward data exclusivity not only raises barriers to entry for smaller players but also consolidates power among those who control these critical resources.

Europe's AI ecosystem

Despite these challenges, Europe has made progress in building an AI ecosystem aligned with its values. European firms have concentrated on specialized markets, leveraging AI to address domain-specific needs. Mistral, a Paris-based AI company, has emerged as a key player in open-weight language models, prioritizing efficiency and adaptability for European languages and regulatory environments. Its models, such as Mistral 7B and Mixtral, are

152 James Vincent, "The DeepSeek Panic Reveals an AI World Ready to Blow", The Guardian, 28 January 2025, sec. Opinion, https://www.theguardian.com/commentisfree/2025/jan/28/deepseek-r1-ai-world-chinese-chatbot-tech-world-western.

153 Ian Johnston, Malcolm Moore, and Laura Pitel, "DeepSeek Threat Exposes Guesswork on AI Power Demand, Says IEA", Financial Times, 29 January 2025, sec. Artificial intelligence, https://www.ft.com/content/0cc897c2-e12d-4143-81ff-e56c5381a5a1.

154 Ben Jiang, "China's 4 New 'AI Tigers' Emerge as Investor Favourites", South China Morning Post, 19 April 2024, https://www.scmp.com/tech/big-tech/article/3259499/chinas-four-new-ai-tigers-baichuan-zhipu-ai-moonshot-ai-and-minimax-emerge-investor-favourites.

155 Dan Milmo et al., "'Sputnik Moment': $1tn Wiped off US Stocks after Chinese Firm Unveils AI Chatbot", The Guardian, 28 January 2025, sec. Technology, https://www.theguardian.com/business/2025/jan/27/tech-shares-asia-europe-fall-china-ai-deepseek.

156 Pablo Villalobos et al., "Will We Run out of Data? Limits of LLM Scaling Based on Human-Generated Data" (arXiv, 4 June 2024), https://doi.org/10.48550/arXiv.2211.04325.

157 Courtney Radsch, "Dismantling AI Data Monopolies Before It's Too Late | TechPolicy.Press", Tech Policy Press, 9 October 2024, https://techpolicy.press/dismantling-ai-data-monopolies-before-its-too-late.

designed to provide high-performance alternatives to closed-source offerings, supporting applications in business automation, translation, and multilingual content generation. Meanwhile, iGenius, an Italian AI company, focuses on developing enterprise AI solutions tailored for highly regulated industries such as finance, healthcare, and government. By incorporating explainable AI and compliance-driven architectures, iGenius aims to bridge the gap between cutting-edge machine learning and the stringent regulatory requirements that govern sensitive data environments. Another notable area of strength lies in industrial AI applications, with companies like Bosch and Siemens integrating AI into manufacturing, robotics, and predictive maintenance, reinforcing Europe's leadership in industrial automation and AI-powered efficiency.

Europe's reliance on foreign semiconductors and computational infrastructure highlights critical vulnerabilities in its AI ecosystem. Efforts are underway to address these challenges and strengthen digital sovereignty.[158] Aleph Alpha has partnered with Cerebras Systems to deploy sovereign AI solutions using advanced supercomputers housed in HPE-built data centers in Berlin. This partnership aims to promote AI transparency and develop solutions that operate independently of U.S. Big Tech while complying with European data protection regulations.

Recently, Aleph Alpha has shifted its focus from developing its own LLMs to supporting other organizations in deploying existing AI models. This shift is exemplified by the launch of PhariaAI, an end-to-end platform designed to help enterprises and governments integrate AI solutions effectively. European HPC clusters such as LUMI in Finland and Leonardo in Italy provide cutting-edge public computational capacity for training and deploying AI models. Meanwhile, Mistral AI collaborates with providers like CoreWeave and Scaleway to diversify its computing resources, reducing dependence on non-European platforms. However, what secures Mistral's ability to train its own models is its partnership with Microsoft. This collaboration allows Mistral to benefit from Microsoft's cloud resources for research and provides access to Microsoft's customer base. In exchange, Microsoft gains exclusive access to some of Mistral's models, a move aimed at reducing its reliance on OpenAI. While this partnership ensures Mistral's short-term viability, it raises concerns about its openness and long-term commitment to European sovereignty.

Future European initiatives like the recently announced new IPCEI on AI and edge computing could further solidify a sovereign AI ecosystem[159] empowered by a large European network of green public compute. To lead in sustainable and ethical AI deployment, Europe must prioritize green computing and generativity.[160] Optimizing data center design for energy efficiency, transitioning to renewable energy, and adopting advanced cooling systems to reduce water consumption are essential measures.[161] Developing energy-efficient AI models can further reduce electricity use while maintaining performance, aligning with Europe's climate goals, and minimizing the environmental impact of its AI ecosystem. The challenge for Europe is to pursue these sustainability goals while remaining competitive and innovative, thus ensuring that it leads in green AI without ceding ground to global rivals.

Europe is advancing its AI capabilities through targeted investments, infrastructure development, and strategic partnerships. A flagship initiative, the AI Factories, aims to integrate computing power, vast datasets, and skilled talent to train large models for

158 See, for example: "OpenGPT-X", accessed 12 January 2025, https://opengpt-x.de/en/.

159 Margrethe Vestager, "Statement by EVP Margrethe Vestager at the Joint European Forum for IPCEI", IEU Monitoring, n.d., https://ieu-monitoring.com/editorial/joint-european-forum-for-ipcei-statement-by-evp-margrethe-vestager/478623?utm_source=ieu-portal.

160 Fieke Jansen and Michelle Thorne, "IV. Predatory Delay and Other Myths of 'Sustainable AI'", AI Now Institute (blog), 15 October 2024, https://ainowinstitute.org/publication/predatory-delay-and-other-myths-of-sustainable-ai.

161 IEA, "Electricity 2024 – Analysis", IEA, 24 January 2024, https://www.iea.org/reports/electricity-2024.

sectors like healthcare, energy, and manufacturing. These factories leverage EuroHPC, Europe's HPC infrastructure, to enhance competitiveness in advanced AI applications.[162]

However, Europe's scale of investment – €750 million – remains modest compared to the enormous spending by Big Tech, such as Microsoft and OpenAI's $100 billion data center projects. Competing directly with such vast expenditures would neither be sustainable nor strategically prudent for the EU.

Instead, Europe can turn its relative vulnerability in computing resources into an opportunity by leveraging its collective purchasing power and expansive public compute network to shape global industry standards[163] – a concept referred to as conditional computing.[164] For instance, rather than relying on NVIDIA GPUs, which are locked into the proprietary CUDA ecosystem, Europe could prioritize GPUs developed through open-source initiatives, promoting transparency, interoperability, and sovereignty over critical technologies.

The European Union is intensifying its investment in AI to enhance competitiveness and uphold ethical standards. Through the InvestEU program, €26.2 billion has been earmarked as an EU budget guarantee, with the aim of mobilizing over €372 billion in public and private investments across various sectors, including AI. Private sector engagement is also on the rise. For instance, German AI startup Aleph Alpha has secured over $500 million in a Series B funding round,[165] while Mistral and DeepL have also attracted significant investment. Although private investments signal growing confidence, Europe's AI funding still trails its global competitors. In 2023, generative AI investments in Europe amounted to just $2.4 billion, compared to $22.4 billion in the United States. However, European funding is growing at a faster pace. Europe's approach reflects its unique emphasis on aligning technological progress with ethical, regulatory, and sustainability principles. While the strategy is sound, scaling these efforts to match the transformative potential of AI requires bolder investments, improved coordination among member states, and more streamlined pathways for public-private partnerships. Without addressing these gaps, Europe risks losing control over sovereign AI capabilities and its own development model, even as it upholds its commendable commitment to ethical and accountable AI. Initiatives like the AI Factories are still in their early stages, and their success will depend on overcoming structural barriers such as fragmented data ecosystems, limited cross-border collaboration, insufficient investments, and restricted access to local computational resources compared to global hyperscalers.

AI's societal and economic benefits will be maximized, and risks minimized, if its deployment in businesses and public sector agencies is decided collaboratively by workers and managers. Encouraging co-determination of technological changes in the workplace can help ensure a fair digital transition for all workers and unlock AI's potential to enhance productivity and efficiency. Public policy has a role to play in fostering this collaborative approach. Particular attention should also be paid to SMEs. AI deployment will be more effective if it has an overarching "directionality" – a sense of purpose in which businesses, workers, and citizens view AI as part of a broader social project aimed at achieving collective goals.

162 EuroHPC JU, "Selection of the First Seven AI Factories to Drive Europe's Leadership in AI", 10 December 2024, https://eurohpc-ju.europa.eu/selection-first-seven-ai-factories-drive-europes-leadership-ai-2024-12-10_en.

163 Mariana Mazzucato and Fausto Gernone, "Governments Must Shape AI's Future", Project Syndicate, 12 April 2024, https://www.project-syndicate.org/onpoint/governments-must-shape-ai-future-by-mariana-mazzucato-and-fausto-gernone-2024-04.

164 Van Djjck et al. 2024, Conditional computing: a new paradigm for public-interest AI in the EU in Francesca Bria et al., "Time To Build A European Digital Ecosystem", 9 December 2024, https://feps-europe.eu/wp-content/uploads/2024/12/Time-to-build-a-European-digital-ecosystem.pdf.

165 "Aleph Alpha Raises a Total Investment of More than Half a Billion US Dollars from a Consortium of Industry Leaders and New Investors", Aleph Alpha, 6 November 2023, https://aleph-alpha.com/aleph-alpha-raises-a-total-investment-of-more-than-half-a-billion-us-dollars-from-a-consortium-of-industry-leaders-and-new-investors/.

Box 3 – **Biotechnology and medtech: Precision and dependency**

Biotechnology and medtech are among the most innovative and transformative industries, influencing sectors such as healthcare, agriculture, and life sciences. Europe has emerged as a global leader in areas uch as genomics and biomanufacturing, exemplified by the German company BioNTech, which developed the first COVID-19 vaccine authorized for regular use. However, despite these achievements, the sector remains heavily reliant on foreign technologies at critical stages of the value chain.

Specialized inputs, including chemicals, reagents, and biological samples, are predominantly sourced from major U.S. firms such as Merck and ATCC. These dependencies also extend to digital infrastructure, where network systems facilitate real-time data sharing, and AI workloads demand substantial computational power. AI is playing an increasingly central role in drug discovery and biological research, as demonstrated by AlphaFold's groundbreaking protein-structure predictions – a product of the London-based DeepMind, now owned by Alphabet. While Bayer's collaboration with Microsoft in agricultural AI demonstrates Europe's innovation potential, it also underscores the persistent reliance on third-country technology.

Cloud services, dominated by U.S. companies such as AWS, Microsoft Azure, and Google Cloud, are vital for genomics and drug discovery. In the field of human genomics, the Chinese company BGI is becoming increasingly dominant. Reliance on non-European platforms for high-throughput data analysis and storage poses a significant challenge to European sovereignty. At the same time, imaging and monitoring equipment critical to healthcare – where European firms like Siemens Healthineers and Philips Healthcare are leaders – relies on digital systems that are increasingly cloud-integrated. Cybersecurity remains paramount for protecting sensitive research and patient data; however, Europe continues to depend on non-European solutions in this domain.

The EuroStack offers an opportunity to address these vulnerabilities by fostering an ecosystem that integrates European digital infrastructure with the biotechnology and medtech value chain. Strengthening AI and cloud services within Europe and ensuring secure data flows can enable the sector to flourish while safeguarding European sovereignty and innovation leadership.

Cybersecurity: The cornerstone of digital resilience and autonomy

Cybersecurity is a critical component across the stack and serves as both a conditio sine qua non and an opportunity for EU strategic autonomy. Technically, it encompasses a wide range of software and hardware, including secure access, device-level data encryption, end-to-end secure communications, system and device sensors, firewalls, antivirus solutions, and cyber-incident monitoring and analysis (e.g., Security Information and Event Management, or SIEM). Many of these components are increasingly reinforced by, and in some cases dependent on, artificial intelligence. Cybersecurity also includes governance, encompassing standardized procedures, processes, and EU legislation. However, oversight is generally imposed by national rather than EU authorities, reflecting a decentralized approach. Governance and technology are closely linked.

Europe is home to numerous cybersecurity companies, including large firms such as Thales, but the majority are small and face significant challenges in scaling within the European market. These challenges include a lack of risk capital, fragmented

regulations, and the need to build trust with buyers. European firms also compete with well-established global suppliers, particularly from the United States and Israel, who benefit from global brand recognition, substantial resources, access to scale-up capital, and extensive legal expertise.

Despite extensive EU cybersecurity legislation[166] and financial support through EU programs, the absence of a coherent EU cybersecurity industrial policy remains a critical gap.[167] Such a policy is urgently needed to address the risk of long-term erosion of European autonomy while acknowledging the immediate necessity of robust cyber-resilience amid rising geopolitical tensions, widespread cybercrime, and outright war. A comprehensive industrial policy would not only enhance adoption at scale through public procurement and defense spending but also ease legislative compliance within the internal market. Furthermore, it could foster synergies between cybersecurity in the internal market and digital diplomacy,[168] and make the sector more attractive to European investors by demonstrating that EU-made cybersecurity solutions are viable and competitive.

166 Paul Timmers, "EU Cybersecurity Policy", in The Making of a Global Digital Rulebook: Digital Sovereignty and International Action in the EU, Thibaut Kleiner and Andrea Garcia Rodriguez (Eds) (Springer, 2025); Christina Rupp, "Navigating the EU Cybersecurity Policy Ecosystem", 27 June 2024, https://www.interface-eu.org/publications/navigating-the-eu-cybersecurity-policy-ecosystem.

167 Paul Timmers, "EU Cybersecurity Policy".

168 See also the program of the Polish Presidency of the Council, Polish Presidency, "Polish Presidency of the Council of the European Union", Polish presidency of the Council of the European Union, 2025, https://polish-presidency.consilium.europa.eu/en/.

Defense: Strengthening strategic capabilities

Geopolitical tensions and the war in Ukraine have underscored Europe's military vulnerabilities. In response, defense investment has been increasing, with annual growth exceeding 15% in recent years.[169]

In addition, civil-defense synergies are expanding.[170] At the European level, related funding includes the European Defense Fund (€8 billion through 2027), the EU Space Programme (€13 billion through 2027), and EU Secure Connectivity, which incorporates quantum communications (€2 billion through 2027). EU-NATO collaboration is also advancing, with joint European Investment Fund (EIF)-NATO investments in the private sector and the development of shared strategies, such as those for undersea cables. Total defense expenditures by EU member states are projected to rise significantly, from €326 billion in 2024.[171] Entrepreneurial and risk capital investments in defense-related technologies are also increasing. A notable example is the Germany-based AI company Helsing, whose valuation tripled to $4.5 billion in 2024.

There is an increasingly urgent call for action to strengthen Europe's civil and military preparedness and readiness, as emphasized by the 2024 Niinistö report. Defense funding, both at the national level and through mechanisms like the European Defense Fund and NATO, is beginning to flow across the spectrum, from advanced research to scaling up promising technologies. Defense requirements are increasingly overlapping with civil R&D efforts.

169 EDA, "2024 Defence Review Paves Way for Joint Military Projects (CARD 2024)", 19 November 2024, https://eda.europa.eu/news-and-events/news/2024/11/19/2024-defence-review-paves-way-for-joint-military-projects.

170 Reference documents at EU level are Examples are the 2021 Action Plan on Synergies between Civil, Defence and Space Industries, the Observatory for Critical Technologies across civil, defence and space industries programmes, CARD – the Coordinated Annual Review of Defence in the EU, and the European Defence Industrial Strategy 2024.

171 European Defence Agency EDA, "Coordinated Annual Review on Defence (CARD)", Default, 19 November 2024, https://eda.europa.eu/what-we-do/EU-defence-initiatives/coordinated-annual-review-on-defence-(card).

Examples from other countries demonstrate that adopting an early adopter role in defense – by defining requirements, piloting technologies, and validating innovations – can help unlock markets, enhance security, and bolster sovereignty.

However, Europe remains highly dependent on imports: 78% of its military equipment and services (many of them digital) are imported, with two-thirds sourced from the United States. Only 18% of these goods and services are procured from other EU countries. The European Defense Industrial Strategy has outlined ambitious objectives to address this dependency by 2030:

- at least 50% of member states' procurement should come from the European Defense and Technology Industrial Base (EDTIB);
- the value of intra-EU defense trade should account for at least 35% of the EU defense market;
- member states should procure at least 40% of defense equipment through collaborative mechanisms.

Challenges in stepping up civil-military cooperation in the EU include aligning military innovation with the speed of market developments and ensuring adherence to ethical standards – particularly as technology evolves in areas such as AI, drones, sensors, and satellites. A significant challenge is the reluctance of conventional banks to invest in the defense sector. The European Commission (EC) has outlined options for R&D focused on technologies with dual-use potential. At the same time, the League of European Research Universities has emphasized the need for a careful approach, advocating safeguards to clearly demarcate civil and military research.[172]

Quantum technologies: Unlocking tomorrow's potential

Quantum technologies (QT) represent a transformative force within the technology stack. By leveraging quantum mechanics, they enable radically new approaches to computing, communications, and sensing, addressing problems that are beyond the capabilities of conventional systems. For instance, quantum computing could significantly accelerate drug discovery and materials development, while quantum sensing has the potential to revolutionize navigation, medical diagnostics, subsea cable surveillance, and industrial quality control.

Quantum communications, particularly through QKD, already enable unbreakable secure communications and are beginning to be commercialized. China leads in this area, operating a 2,032 km QKD ground link between Beijing and Shanghai. The EU is advancing its capabilities through initiatives like the **European Quantum Communication Infrastructure** (EuroQCI),[173] which will integrate with the **EU's IRIS2 satellite program**.[174]

However, QKD alone is insufficient to address all security challenges posed by quantum technology, and its merits remain the subject of ongoing debate.[175] It is urgent to also adopt PQC to secure existing systems and encrypted data, as quantum computing has the potential to break widely used traditional encryption methods. This urgency exists even though quantum computing at scale may still be five to ten years away. PQC also serves as a necessary

172 LERU, "Enhancing Dual Use Technologies: Leveraging Synergies in EU Funding Streams", LERU, April 2024, https://www.leru.org/publications/options-for-enhancing-support-for-research-and-development-involving-technologies-with-dual-use-potential.

173 European Commission, "The European Quantum Communication Infrastructure (EuroQCI) Initiative | Shaping Europe's Digital Future", 23 April 2024, https://digital-strategy.ec.europa.eu/en/policies/european-quantum-communication-infrastructure-euroqci.

174 EU Agency for the Space Programme, "IRIS2 | EU Agency for the Space Programme", 2024, https://www.euspa.europa.eu/eu-space-programme/secure-satcom/iris2.

175 Renato Renner and Ramona Wolf, "The Debate over QKD: A Rebuttal to the NSA's Objections" (arXiv, 27 July 2023), https://doi.org/10.48550/arXiv.2307.15116.

complement to QKD.[176] The U.S. National Institute of Standards and Technology has already issued three PQC standards, highlighting the strategic importance of early preparedness.

The economic dynamics of quantum technologies

Global public investment in QT reached over $42 billion in 2023, with China as the leading investor[177] and Europe in second place. Private funding is also growing, fueled by the recognition that QT has the potential to redefine industries. However, no single EU member state can match the resources of China or the United States. Initiatives such as the EU Quantum Flagship, supported by €1 billion in funding, and the 167-member Quantum Industry Consortium reflect Europe's commitment to QT. Nonetheless, a lack of coordination persists in translating research into market-ready applications.

With more than 500 scientists from over 100 institutions collaborating across Europe, EBRAINS 2.0 is accelerating breakthroughs in neuroscience, brain medicine, and brain-inspired technologies. Supported by advanced infrastructure, such as Jülich's quantum computing ecosystem in Germany – home to Europe's first quantum computer integrated with a supercomputing environment – EBRAINS 2.0 exemplifies Europe's strategy to leverage cutting-edge computing and quantum innovation for transformative solutions in healthcare and neuroscience.[178]

However, demand-side fragmentation within the EU remains a significant barrier. Public and defense procurement is inconsistent, and there is no unified goal for quantum computing by 2030 – an ambitious „moonshot" initiative that could serve to galvanize efforts. Additionally, QT development depends on critical materials and high-precision components, where Europe faces supply constraints.

Building resilience and strategic interdependencies

To strengthen its position, Europe must adopt a coordinated approach that balances self-reliance with strategic partnerships. Exclusive control over quantum technologies critical to national security, such as QKD and quantum hardware secure modules, is essential. For other areas, Europe should foster mutual interdependencies with like-minded countries, such as the UK and Switzerland, leveraging their expertise to build a competitive quantum ecosystem. The UN Year of Quantum in 2025 offers a platform for global collaboration to harness quantum technologies in addressing humanity's most pressing challenges.[179] Europe's leadership in this effort could align its strategic interests with broader international goals, positioning it as a key player in shaping the future stack.

Quantum's integration into the EuroStack should account for its current nascent stage while recognizing its long-term transformative potential. In the medium term, embedding quantum technologies within existing layers (e.g., networks and chips) will ensure seamless integration into today's stack. In the long term, as quantum capabilities mature, elevating it to a distinct layer would underscore its role as a foundational pillar of Europe's digital sovereignty.

Given the EuroStack's emphasis on strategic autonomy, sustainability, and resilience, quantum technologies represent a critical enabler of these goals. Whether incorporated into existing layers or designated as a dedicated layer, quantum's inclusion

176 Georg Serentschy, "Unraveling the confusion around Quantum-Safe Encryption – Serentschy Advisory Services", 2024, https://www.serentschy.com/unraveling-the-confusion-around-quantum-safe-encryption/; Bart Preneel, "The Quantum Threat and Post-Quantum Cryptography (PQC)", 2024.

177 World Economic Forum, "Explainer: What Is Quantum Technology and What Are Its Benefits?", World Economic Forum, 3 July 2024, https://www.weforum.org/agenda/2024/07/explainer-what-is-quantum-technology/.

178 See: "EBRAINS Research Infrastructure Secures €38 Million in Funding for New Phase of Digital Neuroscience", Forschungszentrum Jülich, 9 January 2024, https://www.fz-juelich.de/en/news/archive/press-release/2024/ebrains-research-infrastructure-secures-20ac38-million-in-funding-for-new-phase-of-digital-neuroscience.

179 United Nations, "International Year of Quantum Science and Technology", 7 June 2024, https://quantum2025.org/en/.

should be explicitly articulated in the EuroStack framework to reflect its transformative potential.

The evolution of the digital stack is a defining challenge for Europe's digital sovereignty. By prioritizing edge cloud computing and quantum technologies, the EU can carve out a competitive position in a landscape currently dominated by centralization and integration. Achieving this vision requires significant investments, harmonized regulation, and clear strategic goals.

Financial power: The driver of digital dominance

Financial power is a cornerstone of technological dominance, determining which companies and regions lead in innovation, shape ecosystems, and set global standards. U.S. and Chinese firms have not only achieved technological breakthroughs but have also leveraged substantial financial resources to secure supremacy across the digital stack. Their access to venture capital (VC), sovereign wealth funds (SWFs), and robust equity markets has enabled aggressive investments in research, acquisitions, and talent – often at scales Europe struggles to match.[180]

Venture capital and sovereign wealth funds as strategic levers

Venture capital serves as the engine of innovation, fueling the rapid growth and global dominance of U.S. and Chinese tech companies. In 2023 alone, U.S. AI startups attracted approximately €62.5 billion in private investment, compared to Europe's €9 billion in cumulative VC investment in AI startups (including the UK).[181] While Europe has experienced growth in VC funding, its fragmented financial markets and risk-averse culture, rooted in its bank-based financing system, continue to hinder large-scale investments. This disparity undermines Europe's ability to nurture startups capable of achieving successful exits on European stock exchanges and scaling globally. Instead, promising companies often become acquisition targets for foreign players, further eroding Europe's innovation ecosystem. While achieving exits on European stock exchanges is feasible, it remains challenging due to fragmented equity markets, lower valuations, and a preference for short-term returns, which can disincentivize long-term growth and innovation.

The dominance of U.S. VC ecosystems allows firms to pursue bold, long-term projects, fostering foundational research that redefines industries. OpenAI exemplifies this dynamic, leveraging substantial VC funding to develop large language models such as GPT-4, which have been integrated into Microsoft's Azure platform. Microsoft's multibillion-dollar investment in OpenAI has facilitated the development of advanced AI models and their training and deployment at scale, reshaping computational power and AI.[182] The partnership between OpenAI and Microsoft has led to concerns about potential monopolistic practices and the centralization of AI resources.[183] These developments underscore the importance of scrutinizing such alliances to ensure they foster a competitive and diverse technological ecosystem.[184]

In contrast, Europe's fragmented and less dynamic capital markets often hinder similar trajectories, leaving startups undervalued, underfunded, and

180 Douglas J. Cumming and Pedro Monteiro, "Sovereign Wealth Fund Investment in Venture Capital, Private Equity, and Real Asset Funds", SSRN Scholarly Paper (Rochester, NY: Social Science Research Network, 24 October 2022), https://doi.org/10.2139/ssrn.4258254., https://papers.ssrn.com/sol3/papers.cfm?abstract_id=4258254&utm_source=chatgpt.com.

181 Maslej, et al., "AI Index Report 2024 – Artificial Intelligence Index".

182 Jai Vipra, "Computational Power and AI", AI Now Institute (blog), 27 September 2023, https://ainowinstitute.org/publication/policy/compute-and-ai.

183 Charles Duhigg, "The Inside Story of Microsoft's Partnership with OpenAI", The New Yorker, 1 December 2023, https://www.newyorker.com/magazine/2023/12/11/the-inside-story-of-microsofts-partnership-with-openai.

184 Tejas N. Narechania and Ganesh Sitaraman, "An Antimonopoly Approach to Governing Artificial Intelligence", SSRN Scholarly Paper (Rochester, NY: Social Science Research Network, 17 January 2024), https://doi.org/10.2139/ssrn.4597080, https://papers.ssrn.com/sol3/papers.cfm?abstract_id=4597080.

vulnerable to acquisition by foreign players.[185] High-profile acquisitions of European tech firms underscore the challenges of scaling independently in a fragmented market. Google's acquisition of DeepMind significantly enhanced its AI capabilities, while NVIDIA's purchase of Dutch-based Bright Computing strengthened its leadership in semiconductors and data center networking. Although Mellanox Technologies is based in Israel, its strong European presence further reinforced NVIDIA's regional influence. These acquisitions, combined with NVIDIA's involvement in European supercomputing projects like LUMI in Finland and Leonardo in Italy, have cemented its position in global AI and high-performance computing innovation. Similarly, Apple's acquisition of Xnor.ai enabled the integration of energy-efficient AI into its devices, deepening user dependency on its ecosystem. These examples highlight how Big Tech leverages strategic acquisitions to dominate the digital stack. In Europe, the loss of critical companies such as ARM and DeepMind underscores the urgent need for stricter merger oversight and strategic protections to safeguard technological sovereignty and critical assets.

Without robust policies, Europe risks losing its most promising innovations to foreign control, further eroding its competitive position. Limited access to growth capital is a significant barrier for European startups, leaving them exposed to external acquisition. The European Investment Bank has highlighted that Europe's fragmented financial system restricts startups from securing the funding necessary to scale, underscoring the urgent need for more integrated and dynamic capital markets to retain and grow innovation within the region.[186]

Equity markets play a pivotal role in sustaining technological dominance by enabling high valuations and sustained R&D investments. NVIDIA, with a market capitalization of approximately $3 trillion as of February 2025, exemplifies this dynamic.[187] Its substantial valuation has supported aggressive acquisitions and ambitious ventures in AI and cloud technologies. In contrast, Europe's fragmented equity markets often impede similar growth trajectories. European firms frequently face lower valuations and pressure for short-term returns, limiting their capacity for long-term innovation. This disparity leaves promising startups vulnerable to foreign acquisitions, further eroding the region's innovation ecosystem and weakening its digital sovereignty.

The European Investment Bank notes that Europe's fragmented financial system restricts startups' ability to access the necessary funding to scale, leaving them exposed to external acquisition. However, it is important to consider whether replicating the U.S. model of high-growth markets is desirable – or even feasible – for Europe.[188] While high valuations can drive innovation, they also pose risks, including the potential for financial bubbles. Therefore, while addressing the challenges in Europe's equity markets is crucial to enhancing competitiveness, it is equally important to consider the advantages of a balanced approach. Building a stable, innovation-driven ecosystem may better align with Europe's economic values and long-term strategic interests than pursuing rapid and potentially unsustainable growth.

Sovereign wealth funds are increasingly influential in shaping global digital ecosystems through strategic investments in transformative technologies.[189] They

185 European Investment Bank, Financing the Digitalisation of Small and Medium-Sized Enterprises: The Enabling Role of Digital Innovation Hubs (European Investment Bank, 2020), https://doi.org/10.2867/210258, https://www.eib.org/attachments/thematic/financing_the_digitalisation_of_smes_summary_en.pdf.

186 European Commission: Directorate-General for Research and Innovation, Science, Research and Innovation Performance of the EU, 2024 – A Competitive Europe for a Sustainable Future (Publications Office of the European Union, 2024), https://doi.org/10.2777/965670, https://op.europa.eu/en/publication-detail/-/publication/c683268c-3cdc-11ef-ab8f-01aa75ed71a1/language-en.

187 CompaniesMarketCap, "NVIDIA (NVDA) – Market Capitalization", accessed 12 January 2025, https://companiesmarketcap.com/nvidia/marketcap/.

188 BCG, "Europe's Growth Equity Landscape", BCG Global, 4 March 2024, https://www.bcg.com/publications/2024/opportunity-in-europes-growth-equity-landscape.

189 H. Kent Baker, "Sovereign Wealth Funds: An Overview", in The Palgrave Handbook of Sovereign Wealth Funds, ed. H. Kent Baker, Jeffrey H. Harris, and Ghiyath F. Nakshbendi (Cham: Springer International Publishing, 2024), 3–18, https://doi.org/10.1007/978-3-031-50821-9_1.

are emerging as powerful geopolitical tools in the global race for technological dominance, particularly against the backdrop of intensifying U.S.-China competition. Traditionally focused on financial returns, these state-owned funds have become integral to national strategies aimed at securing supply chains and establishing leadership in transformative technologies such as semiconductors, artificial intelligence, cloud infrastructure, and defense technologies. The strategic deployment of SWFs highlights a broader global trend: the fusion of economic and technological competition with geopolitical strategy. These developments underscore the growing interdependence of financial resources, technological leadership, and geopolitical power in the 21st century.[190]

China's National Integrated Circuit Industry Investment Fund, known as the "Big Fund," exemplifies this strategic use of SWFs. With its latest $47.5 billion phase launched in 2024, the fund seeks to strengthen domestic semiconductor production and reduce reliance on foreign technology, aligning with China's ambition for technological self-sufficiency.[191] This comes as the United States tightens export controls on advanced technologies, seeking to curtail China's tech ambitions. The United Arab Emirates' Mubadala Investment Company and Saudi Arabia's PIF are leveraging sovereign wealth funds to reshape global competitive dynamics in technology.

Mubadala has acquired key assets, such as GlobalFoundries, to strengthen its technological footprint and influence supply chains,[192] while the PIF pursued investments in fast-growing AI startups. Recent data highlights a fivefold increase in Middle Eastern SWF funding for AI companies in the past year. These investments align with broader national strategies like Saudi Vision 2030, which aims to diversify the Gulf economies and reduce their dependency on oil revenues.

In contrast, Europe's sovereign wealth funds lack the scale and strategic focus to drive a similar impact. Norway's Government Pension Fund, the world's largest SWF, prioritizes diversified financial returns over transformative technology investments.[193] [194] The deployment of SWFs in this geopolitical context underscores their dual role as financial instruments and strategic levers capable of shaping technological standards, securing supply chains, and gaining a decisive edge in the global competition for digital dominance. To remain competitive, Europe must adopt a more strategic SWF model, pooling resources and prioritizing investments in critical technologies such as AI, semiconductors, and quantum computing to strengthen its digital sovereignty.

The EIF, while instrumental in supporting innovation, remains limited in scope compared to global counterparts. To enhance its competitiveness, Europe could explore collaborative pooling of SWF resources across EU member states, combined with a stronger mandate for strategic investments in transformative technologies. Such initiatives could significantly bolster Europe's capacity to compete in the global digital economy, despite the previous failure of similar efforts under EU President von der Leyen.[195]

190 Brad Setser, "A Taxonomy of Sovereign Wealth Funds", Financial Times, 25 September 2024, sec. FT Alphaville, https://www.ft.com/content/a65135e9-1fde-4aee-a422-b0d783c62e14.

191 Reuters, "China Sets up Third Fund with $47.5 Bln to Boost Semiconductor Sector", 27 May 2024, sec. Technology, https://www.reuters.com/technology/china-sets-up-475-bln-state-fund-boost-semiconductor-industry-2024-05-27/.

192 Arab Gulf States Institute in Washington, "The Emergent Gulf Sovereign Wealth Fund-Global Tech Nexus", Arab Gulf States Institute in Washington (blog), 2 May 2024, https://agsiw.org/the-emergent-gulf-sovereign-wealth-fund-global-tech-nexus/.

193 Norway's Ministry of Finance, "Investment Strategy", Redaksjonellartikkel, Government.no (regjeringen.no, 17 April 2023), https://www.regjeringen.no/en/topics/the-economy/the-government-pension-fund/government-pension-fund-global-gpfg/investment-strategy/id696849/.

194 David Chambers, Elroy Dimson, and Antti Ilmanen, "The Norway Model", The Journal of Portfolio Management 38, no. 2 (31 January 2012): 67–81, https://doi.org/10.3905/jpm.2012.38.2.067.

195 Luigi Serenelli, "European Commission President's Plan for Common SWF Stalls", IPE, 27 March 2024, https://www.ipe.com/news/european-commission-presidents-plan-for-common-swf-stalls/10072442.article.

Addressing Europe's financial gaps

To reclaim digital sovereignty, Europe must adopt a bold, coordinated financial strategy that addresses structural weaknesses in its venture capital ecosystem. Scaling up late-stage funding and fostering risk-taking are critical for enabling European tech firms to grow and compete globally. While initiatives like the European Scale-Up Initiative and InvestEU provide a foundation, their mandates and resources remain insufficient compared to the financial power of global competitors.

The European Tech Champions Initiative (ETCI), a €10 billion fund-of-funds launched in 2023, represents a significant step forward. By supporting high-growth technology companies, the ETCI aims to retain innovation within Europe, offering late-stage funding to prevent promising startups from seeking capital or exits outside the continent. Similarly, the European Innovation Council (EIC) Venture Fund, with a €10 billion budget for 2021-2027, supports transformative innovations from early research to scaling. Complemented by Horizon Europe with its €95.5 billion budget, these initiatives address Europe's funding deficit but require greater ambition and alignment into a cohesive strategy to achieve meaningful impact.

Expanding the role of the European Investment Fund and fostering cross-border collaboration among sovereign wealth funds can provide the scale needed for Europe to compete globally. The Pan-European VC Funds-of-Funds Programme (VentureEU), launched by the Commission and EIF, aims to boost investment in startups and scaleups across Europe. The European Investment Bank (EIB) also supports early-stage innovation through equity investments, while InvestEU (€26.2 billion) guarantees investments to commercialize research, digitize industries, and scale innovative companies. Additionally, the European Defense Fund (€8 billion) promotes cutting-edge defense technologies and encourages startups and SMEs to participate in collaborative projects.

A unified strategy is essential to pool resources and focus investments on critical technologies. Establishing a European Tech Sovereignty Fund under the European Competitiveness Fund could bridge gaps in sectors such as AI, cloud infrastructure, and semiconductors. This fund would offer patient capital to drive long-term innovation while safeguarding Europe's technological independence. This funding could potentially be linked to the recently announced European Competitiveness Fund as well as the TechEU investment program deployed by the EIB, which aims to expand Europe's industrial capacity by supporting key technology sectors, such as AI, robotics, clean energy, space, and quantum technologies.[196]

National Promotional Institutions and the EIB should play a proactive role by acquiring equity stakes in strategic companies. For example, Bpifrance has invested in AI startups like Mistral, while Germany's KfW has supported semiconductors, satellites, and renewable energy. A similar coordinated approach across Europe could foster homegrown innovation and protect critical industries.

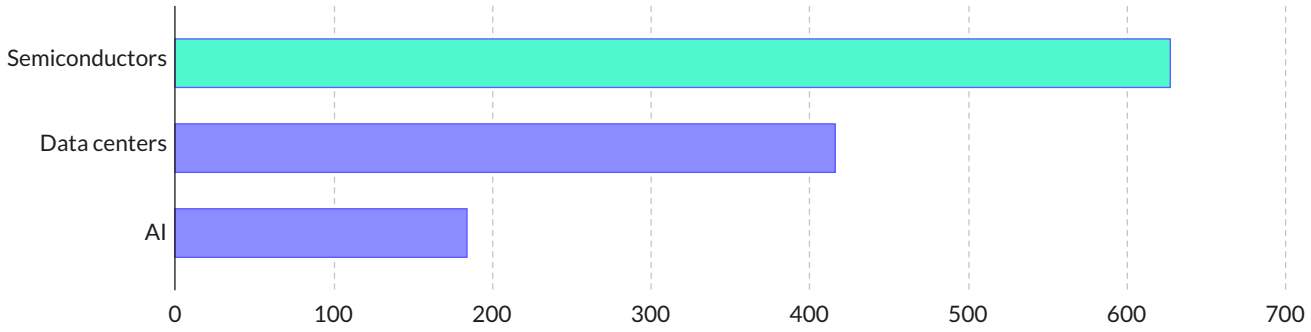
Europe must also ensure rigorous merger controls to prevent foreign acquisitions of strategic assets. Regulations should prioritize long-term innovation and ensure key technologies remain under European control. Public procurement policies must emphasize European solutions, creating demand for domestic innovations in cloud services, AI applications, and network infrastructure, as outlined in subsequent policy chapters.

Lessons can be drawn from countries like South Korea and Japan, which have successfully aligned financial and industrial strategies to maintain technological independence. South Korea's support for conglomerates like Samsung and LG, combined with targeted investments in semiconductors and AI, demonstrates how strategic alignment can achieve global leadership. Similarly, Japan's focus on

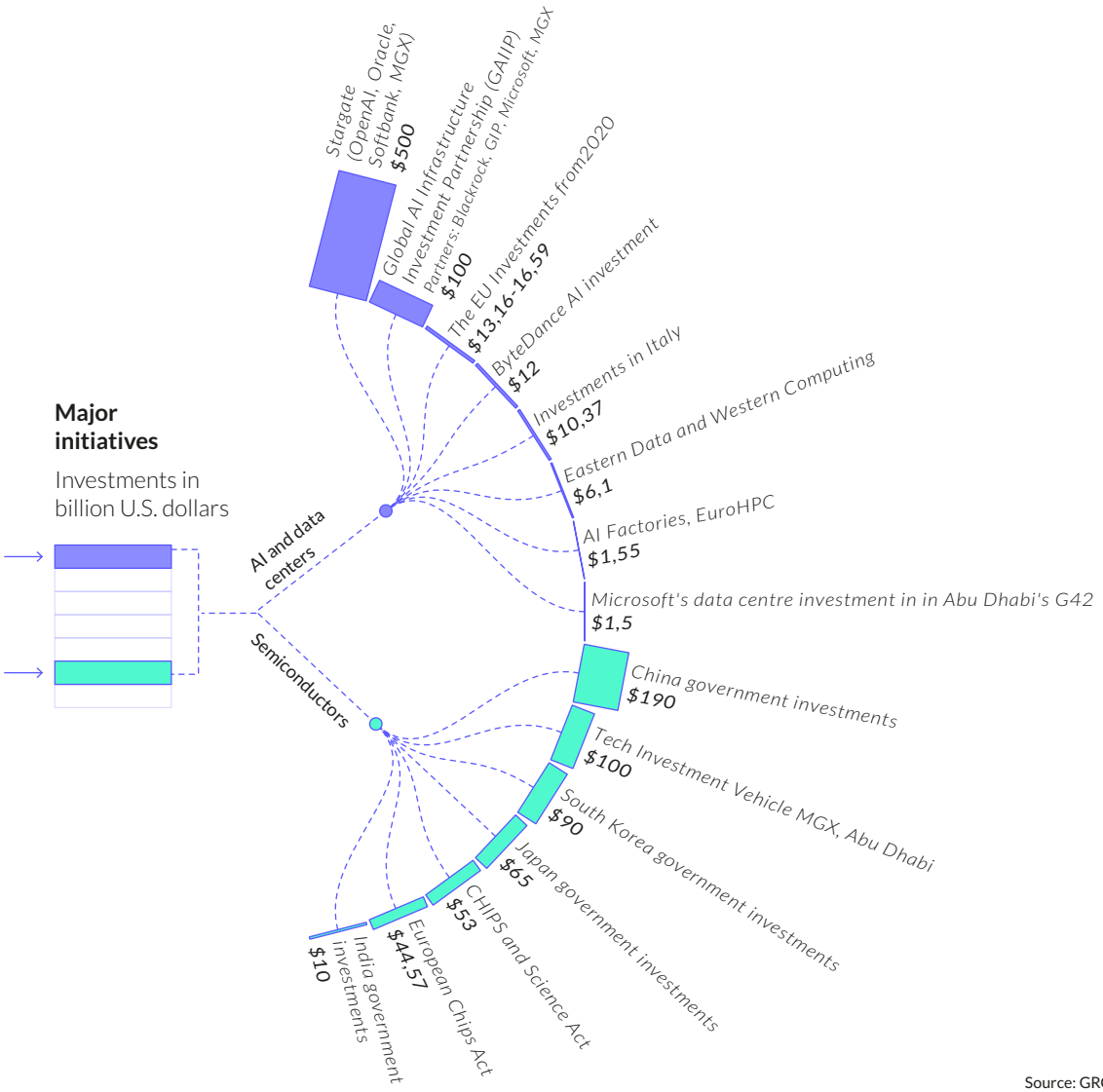
196 https://commission.europa.eu/document/download/10017eb1-4722-4333-add2-e0ed18105a34_en

The financial dimension

Market size of certain digital sectors, 2024
in billion U.S. dollars

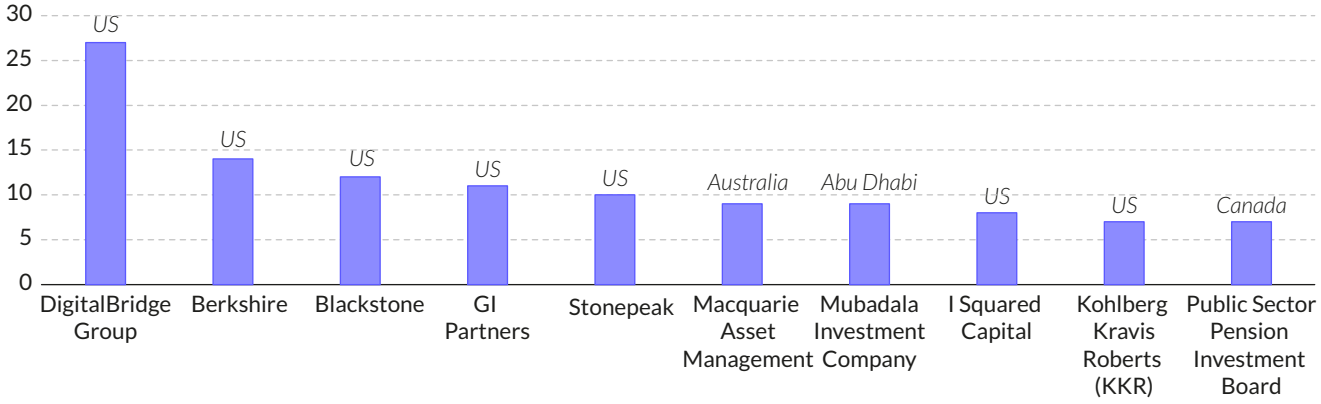


Source: Statista



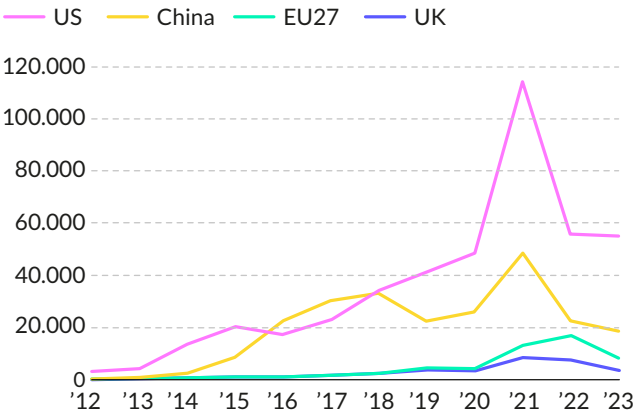
Source: GRC

Most active investors in data centers and their country of origin
Number of PE deals since 2018



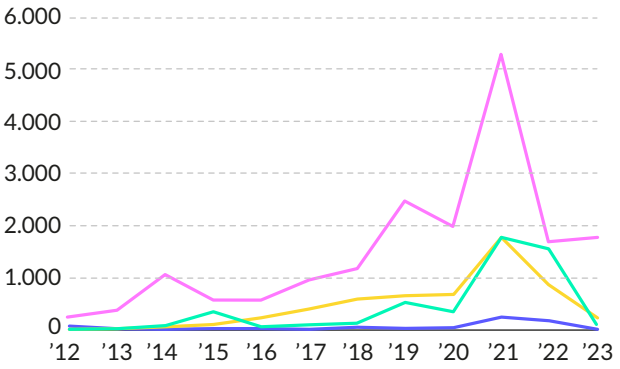
Source: Pitchbook

VC investments in AI by region
in million U.S. dollars



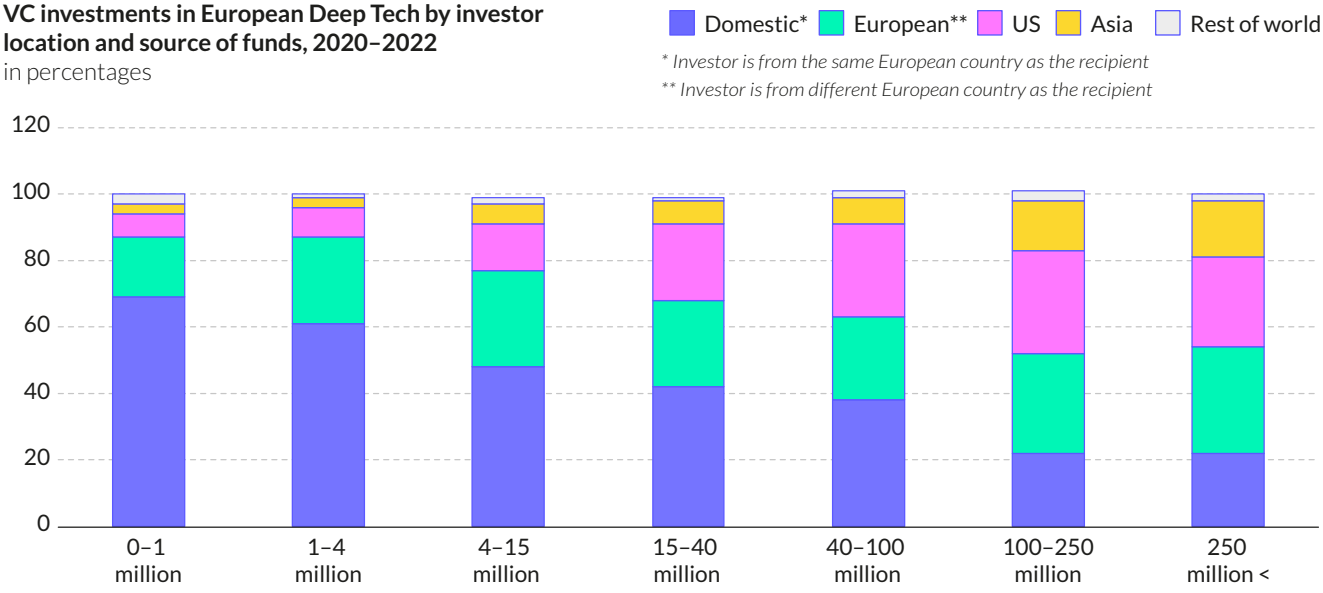
VC investments in data startups by region
in million U.S. dollars

R&D INVESTMENT GAP
The share of global venture capital funds raised in the EU is only 5%, compared to 52% in the US and 40% in China.



Source: OECD

VC investments in European Deep Tech by investor location and source of funds, 2020–2022
in percentages



Source: Dealroom.co

robotics and precision engineering has preserved its competitive edge in key industries.

Europe's financial strategy must recognize the interconnectedness of investment, innovation, and sovereignty. Mobilizing financial resources, fostering a culture of long-term risk-taking, and implementing coordinated industrial policies are essential to reclaiming technological leadership. By expanding its VC ecosystem, empowering SWFs, and protecting its innovation assets, Europe can position itself as a competitive global player while safeguarding its strategic interests. Achieving this requires not only funding but also vision, collaboration, and the ability to translate financial power into sustained technological leadership.

The geopolitical dimension: Shaping Europe's multipolar vision

In the global race for technological dominance, two powers – China and the United States – are vying for control across all layers of the digital stack.

China, under state-led initiatives like Made in China 2025,[197] has rapidly expanded its capabilities in semiconductors, telecommunications, advanced manufacturing, and emerging technologies such as quantum computing. These efforts, often dual-use in nature, are supported by significant public funding and aggressive talent acquisition strategies targeting Europe and the United States. At the same time, China has tightened market access and strengthened its control over critical raw materials through initiatives like the Belt and Road Initiative and export restrictions, using these dependencies as tools of economic and political leverage. Under the banner of the Digital Silk Road, Chinese firms have entered numerous overseas markets, exporting cloud, telecommunications, and AI technologies.

The United States, through measures like the CHIPS Act,[198] is shoring up its semiconductor production and bolstering the global dominance of its tech giants in AI, cloud infrastructure, and advanced chip manufacturing. Increasingly stringent export controls targeting high-tech industries also impact European companies, as do industrial policy measures such as the massive Inflation Reduction Act[199] and tariffs affecting strategic user industries such as energy and automotive. Additionally, President Trump's pledge to return to tariff wars underscores the ongoing competitive and protectionist nature of U.S. policies, posing further challenges to global trade stability and supply chain resilience.

Europe, while unable to compete head-to-head with these nations across the entire digital stack, must focus on reducing dependencies, safeguarding its strategic assets, and strengthening domestic capabilities. Internationally, Europe should prioritize partnership alliances that share its values, respect international rules, and aspire to balanced, inclusive and resilient digital ecosystems. Europe must reduce dependencies on digital superpowers while fostering values-driven cooperation. Partnerships with democratic nations are vital for securing supply chains, co-developing technologies, and shaping global standards, with a strong emphasis on mutual respect in market access, data governance, and technology transfer.

Engaging rising powers such as Brazil, Chile, India, South Africa, and Singapore offer opportunities to diversify dependencies and expand influence. These partnerships should support industrial capacity-building and sustainable, non-extractive supply chains, aligning with shared priorities in clean energy, climate adaptation, and digital public services.

197 China State Council, "Made in China 2025", 2015, http://english.www.gov.cn/2016special/madeinchina2025/.

198 In full: Chips and Science Act, US Congress, "CHIPS and Science Act", 9 August 2022, https://www.govinfo.gov/content/pkg/PLAW-117publ167/html/PLAW-117publ167.htm.

199 USG, "Inflation Reduction Act of 2022", 16 August 2022, https://www.regulations.gov/document/EPA-HQ-OAR-2023-0434-0066.

Amid the dominance by U.S. Big Tech and China's state-driven model, Europe has the opportunity to lead an alliance for digital strategic autonomy. This vision emphasizes fair technology transfer, robust digital public infrastructures, democratic data governance, and global regulatory frameworks to curb tech monopolies. By advancing shared governance in AI, cybersecurity, and sustainability, Europe can set a global standard for ethical, inclusive, and sustainable digital leadership while navigating the complexities of diverse partnerships.

Value-added for partner nations in Europe's digital foreign policy

India: India's transformative **India Stack**,[200] the Aadhaar digital identity system and Unified Payments Interface (UPI) payments platform, demonstrates how scalable public digital goods can drive financial inclusion and innovation. In 2022 alone, UPI processed over $1.5 trillion in transactions. However, Europe's collaboration with India must consider differences in governance frameworks. Europe's GDPR prioritizes privacy, decentralized systems, and user consent, in contrast to Aadhaar's centralized, biometric-based model, which, while impactful, has raised concerns about surveillance and inclusion. Europe's Digital Identity Wallet offers a privacy-first alternative that India could adopt elements of to enhance Aadhaar's transparency and trustworthiness. Collaboration between Europe and India provides opportunities for mutual learning: Europe can benefit from India's experience with large-scale digital ecosystems built on decentralized protocols, while India can leverage Europe's expertise in privacy-enhancing technologies and data governance. Joint innovation in areas such as fintech, health tech, and interoperable digital services could combine India's scalability with Europe's regulatory strengths, fostering interoperable, privacy-centric solutions that set global standards.

Brazil: Brazil's PIX payment system,[201] with over 142 million users and daily transactions exceeding $9.5 billion, exemplifies its leadership in digital financial inclusion. Developed by the central bank of Brazil, PIX has transformed financial access and could benefit from interoperability with Europe's Digital Euro, facilitating cross-border payments and reducing remittance costs. Conversely, Europe can draw valuable insights from Brazil's success in scaling user-driven financial solutions across diverse economic contexts.

Beyond payments, Brazil's National Artificial Intelligence Strategy underscores its growing role in digital innovation, with applications in agriculture, healthcare, and financial services. This aligns with Europe's priorities for ethical, human-centric technologies. Joint efforts could focus on integrating AI into broader industrial policies, addressing supply chain dependencies, and adhering to privacy standards under Europe's GDPR and AI Act. The ongoing EU-Brazil Digital Dialogue expands this partnership, targeting connectivity in underserved regions, 5G/6G advancements, and HPC collaboration. However, disparities in governance, scalability, and regulatory approaches challenge harmonization. To move beyond symbolic gestures, the partnership must prioritize measurable objectives, particularly in diversifying semiconductor supply chains, fostering interoperable and independent digital systems, and advancing AI governance. Collaborative efforts should also address shared challenges such as financial inclusion and climate adaptation.

Latin America, Africa, Indonesia and Australia: Resource-rich nations such as Chile and Argentina (lithium), Indonesia (nickel), and the Democratic Republic of Congo (cobalt) are advancing domestic industrial capacities to create value locally. Europe can support these efforts through investments in processing and refining technologies, clean manufacturing expertise, and co-developing green

200 See: "India Stack", accessed 12 January 2025, https://indiastack.org/.

201 See: "Pix", Banco Central do Brasil (BCB), accessed 12 January 2025, https://www.bcb.gov.br/en/financialstability/pix_en.

technologies, aligning with climate goals while ensuring secure access to critical materials. Chile and Europe are already collaborating under the EU-Chile Advanced Framework Agreement for sustainable lithium extraction, while Argentina is exploring ways to expand its battery value chain through the EU-CELAC partnership. Similarly, Indonesia has partnered with BASF and Eramet to develop nickel refining powered by renewable energy, and the EU's Global Gateway Initiative supports ethical cobalt sourcing in the DRC. Meanwhile, Europe is working with Australia through the EU-Australia Partnership on Sustainable Critical and Strategic Minerals to diversify and green supply chains.

Japan and South Korea: Japan and South Korea are key partners in addressing Europe's semiconductor vulnerabilities. South Korea's Samsung and Taiwan's TSMC dominate over 70% of global advanced chip production, while Japan leads in critical materials such as silicon wafers and photoresists. These capabilities complement Europe's Chips Act, which aims to increase Europe's global market share in semiconductor production to 20% by 2030. Collaborative initiatives, such as the EU-Japan Green Alliance and R&D agreements with Samsung, enhance supply chain resilience and foster innovation. Europe's expertise in ethical AI and secure data-sharing frameworks aligns with Japan's and South Korea's advancements in AI-driven manufacturing and edge computing. Beyond semiconductors, joint efforts in quantum technologies, high-performance computing, and advanced AI could strengthen Europe's position as a global leader in critical digital capabilities.

Middle East: Emerging digital hubs Saudi Arabia and the United Arab Emirates (UAE) are rapidly advancing as digital innovation hubs through state-led initiatives like Saudi Vision 2030 and UAE's smart city projects. Programs like Saudi Arabia's NEOM and Project Transcendence aim to integrate AI and modernize infrastructure, while partnerships with firms like Huawei drive progress in 5G and cloud infrastructure. However, these centralized, state-driven and often surveillance-oriented approaches contrast sharply with Europe's decentralized, rights-based frameworks, including GDPR and ethical AI standards. Concerns about data sovereignty, privacy, and the governance of AI and digital platforms highlight key areas of divergence. Constructive collaboration should leverage Europe's strengths in data governance, sustainable urban planning, and renewable energy technologies, aligning innovation with shared values of transparency and sustainability. Diplomatic engagement must ensure that projects address these concerns while fostering balanced and forward-looking partnerships.

Africa: Africa offers numerous opportunities for mutually beneficial partnerships across its diverse countries. The Africa-EU Partnership and EU-Africa Business Forum provide overarching governmental and private sector frameworks, complemented by a range of bilateral agreements and financial support through initiatives like the Global Gateway and other EU programs. Key areas of collaboration include high-tech R&D, with South Africa serving as the EU's largest research and innovation partner on the continent; digital and legislative capacity-building, as exemplified by cooperation with Ghana; digital infrastructure development, including undersea cables and related operational capabilities, such as projects with Senegal; and rare mineral exploration, including partnerships with the Democratic Republic of Congo.

Cross-layer opportunities

Europe's leadership in data privacy and governance aligns with global efforts to establish ethical digital ecosystems. Initiatives such as International Data Spaces position Europe as a frontrunner in developing interoperable and secure data-sharing frameworks. Collaborating with key partners like India, Brazil, and other emerging powers strengthens this position by fostering systems that emphasize inclusivity, privacy, and resilience.

Governance and steering efforts

Europe's digital foreign policy must balance reducing dependencies on digital superpowers with fostering cooperative, values-based relationships with a diverse range of global actors. A coordinated governance structure is crucial to achieving these objectives.

- **Existing units for coordination:** Europe already has an institutional framework in place within the European External Action Service, including units dedicated to digital foreign policy and cybersecurity cooperation. Furthermore, European Commission directorates and units play pivotal roles in coordinating international activities across the European Commission.

- **Enhanced coordination:** Strengthening these existing structures can improve high-level steering and decision-making in digital foreign policy. This includes aligning internal policies, such as foreign direct investment (FDI) screening and state aid, with external initiatives like the joint procurement of raw materials under the proposed Critical Raw Materials Platform, as proposed in the Draghi Report.

- **Strategic dialogue:** To advance synergies, systematic dialogue among industry, research, civil society, and governance bodies across Europe must be prioritized. These discussions should focus on accelerating the implementation of international cooperation frameworks, advancing the EuroStack initiative, and ensuring alignment between Europe's digital foreign policy and its internal regulatory priorities.

- **Review of existing external strategies:** Current strategies, such as those addressing the Indo-Pacific region and Latin America, should be reassessed in light of evolving geopolitical realities and the objectives of Europe's digital foreign policy.

Section 3 – European digital industrial policy blueprint

What worked, what failed, what's next

As the analysis of the competitiveness and strength of Europe's tech players and digital assets in section two reveals, Europe's digital policies have faced persistent challenges that have limited their effectiveness from an industrial policy point of view. Internal market fragmentation, characterized by complex regulations and excessive red tape, has stifled competition and restricted market access. A lack of coordinated commitment to market success has further hindered progress, with sectoral silos obstructing cross-industry collaboration and innovation.

Support for small and medium-sized enterprises has been inadequate, leaving these critical economic drivers struggling to scale. Simultaneously, short-sighted financial markets have resulted in chronic underinvestment and insufficient growth financing, restricting Europe's ability to retain top talent and foster transformative innovation. Opportunities to decentralize and diversify innovation by leveraging regional and local potential have also been largely neglected.

Globally, Europe's digital achievements have suffered from limited visibility due to under-resourced international diplomacy in this domain. Domestically, policy efforts have often been confined to mid-level technologies, rather than targeting the radical breakthroughs needed in deep-tech sectors. This issue is further compounded by the neglect of engineering and scientific talent development, leaving Europe ill-equipped to meet the demands of the digital age.

A reluctance to embrace EU-wide cooperation in industrial policy has also impeded progress, while disproportionate influence from larger member states, notably France and Germany, has undermined balance and inclusivity. Weak EU mandates and a shortage of digitally literate policymakers have exacerbated these structural weaknesses. Furthermore, policies have often prioritized short-term wins over the strategic, long-term planning necessary for sustainable growth.

Europe has also underestimated the geopolitical dimensions of technology, leaving itself vulnerable to dependencies and intensifying global competitive pressures. This vulnerability has become especially apparent amid rising trade wars, the resurgence of populist nationalism, and escalating geopolitical rivalries.

To address these challenges, Europe must adopt a unified, forward-looking digital industrial strategy that is ambitious, inclusive, and effectively implemented.

Analysis

Internal market fragmentation continues to stifle innovation across Europe. Divergent national regulations and inconsistent public procurement practices hinder scalability and competitiveness, particularly in critical areas such as data sharing, cloud standards, IoT, and security-by-design. This fragmentation is even more pronounced in defense and security markets, where decentralized policies and stringent security restrictions obstruct the scaling of vital technologies.

Three primary factors contribute to this persistent fragmentation. First, the inconsistent enforcement of harmonized implementation, even in areas where the EU holds a strong mandate, undermines cohesion. Second, the European Commission's Regulatory Fitness and Performance (REFIT) commitment to legislative simplification has not been pursued sufficiently, often leaving regulatory complexity unaddressed. Third, the EU's limited mandate in key areas such as taxation, public funding for health, social welfare, education, justice, and security – sectors that collectively account for approximately half of a country's GDP – further constrains its ability to act decisively.

Investment remains another major bottleneck. Europe has consistently fallen short in providing the risk capital necessary to scale innovative firms or adequately fund infrastructure for networks, semiconductors, and advanced manufacturing. This lack of financial and structural support has left Europe dependent on external providers, undermining its strategic autonomy. The disparity in investment capacity compared to global competitors has also allowed foreign investors to attract Europe's top talent, acquire startups, and capture scaleups. These foreign investments often amplify the resources initially allocated by European public and private funding, resulting in the loss of strategic European technological capabilities. Notable examples include the acquisitions of ARM and DeepMind, along with other innovative companies, which have shifted control of critical technologies outside Europe. This creates a glaring paradox: Europe possesses all the ingredients for success – world-class talent, a large internal market, innovative startups, and a vibrant scientific research ecosystem – yet lacks the mechanisms to protect, adequately fund, and scale its digital ecosystem. Addressing this gap is essential to safeguard and fully unlock the potential of Europe's technological and industrial capabilities.

At the same time, not everything has been a failure. The EU and its member states have demonstrated the ability to act decisively and achieve notable successes, as highlighted in the previous section of this report and further illustrated below. Understanding the underlying factors that contributed to both successes and failures is essential for shaping effective future policies. A thorough analysis must carefully disentangle cause and effect, considering a wide range of influences. These include neoliberal ideologies, geopolitical shifts, technological trajectories, and organizational as well as managerial changes within companies. While a fully comprehensive and universally accepted analysis may remain unattainable, state-of-the-art evaluations provide critical insights that can inform more effective strategies moving forward.

Building on these insights, the EuroStack initiative is uniquely positioned to address many of the challenges outlined above. By leveraging Europe's assets and learning from past successes and failures, the initiative can drive forward a robust and adaptive strategy. At the same time, it must remain flexible, evolving in response to new insights, shifting global dynamics, and technological advancements.

Europe faces significant gaps in innovation, implementation, and fairness within its industrial policy (Schwaag-Serger et al. 2024), Key contributing factors include the underutilization of synergies for innovation across sectors, particularly between digital infrastructures and user industries. Additionally, while significant attention is given to drafting regulations, there is insufficient emphasis on ensuring their proper and harmonized implementation. Another missed opportunity lies in underestimating the potential of regional and local levels, which act as critical intersections for supply and demand dynamics.[202] Mario Draghi (2024) identifies persistent fragmentation within the internal market and lagging productivity growth as critical challenges. These issues lead to the underutilization of Europe's domestic market potential, burdensome compliance efforts that hinder innovation, and a consequent decline in competitiveness in the global economy.

202 Sylvia Schwaag-Serger, Luc Soete, and Johan Stierna, "Scientific Report – For an Innovative, Sustainable and Fair Economy in Europe", 2024, https://doi.org/10.2760/0336180.

Such analyses do not solely attribute these challenges to past policy decisions at the EU and national levels. Instead, they acknowledge that the world has undergone significant changes over the past two decades. Awareness of the profound impact of geopolitics and Big Tech on industry, the economy, and technological development has only intensified in recent years. Strategic autonomy has only fairly recently emerged as a top priority – what Germans refer to as "Chefsache" (a matter for top leadership). Similarly, neoliberal ideology and the associated push for globalization have only rather recently been subjected to critical reassessment. This shift has created space for the development of new industrial policies, such as those proposed here, and for what Dani Rodrik (2023) refers to as "economic nationalism done the right way."

It would also be a mistake to overlook the successes of EU and national policies. The Single Market program has been a tremendous achievement, particularly during its peak decades. Past industrial policies have played a key role in creating global champions such as Airbus and ARM. Similarly, the EU's European Fund for Strategic Investments has had a remarkable impact, leveraging €35 billion in EU public funding to generate over €500 billion in total investment, particularly in physical infrastructure – a leverage factor of approximately 15.[203]

In high-performance computing, the EU has made significant progress, advancing from having no representation in the global top ten supercomputers in 2016 to securing three entries today. At the national level, supportive policies have fostered thriving, world-class startup ecosystems in cities such as Paris, Berlin, Stockholm, Amsterdam, Barcelona, Munich, Helsinki, Dublin, Tallinn, and others (StartupBlink, 2024). Additionally, Europe boasts a robust digital commons ecosystem and highly efficient, citizen-centric digital public services. Cities like Barcelona, Hamburg, Amsterdam, Helsinki, and Paris have been at the forefront of this transformation, leveraging digitalization to serve people and society effectively.

The EU has demonstrated remarkable decisiveness in times of crisis. In the early 2010s, it restored eurozone credibility by committing to do "whatever it takes" during the financial crisis. During the COVID-19 pandemic, the EU swiftly organized joint vaccine procurement and rolled out a unified COVID app within three months, despite its limited public health mandate. The creation of the Recovery and Resilience Fund (RRF) also broke the long-standing taboo on shared EU debt to address common, future-oriented goals.

The EU has also acted decisively in areas with limited mandates, such as reducing dependence on Russian gas and oil following the invasion of Ukraine. This was accompanied by a strong push for renewable energy and clean technologies across the continent. In cybersecurity, despite its strong connection to national security,[204] the EU adopted demanding laws, recognizing that cyber threats are too significant for any single country to address alone.

Furthermore, the EU has increasingly shifted from using Directives, which allow for national variations, to Regulations, which mandate harmonized implementation across member states. This shift ensures greater consistency in policy execution.

203 European Commission, "Ex-Post Evaluation of the European Fund for Strategic Investments, the European Investment Advisory Hub and the European Investment Project Portal", December 2022, https://commission.europa.eu/about/departments-and-executive-agencies/economic-and-financial-affairs/evaluation-reports-economic-and-financial-affairs-policies-and-spending-activities/ex-post-evaluation-european-fund-strategic-investments-efsi-european-investment-advisory-hub-eiah_en.

204 On national security Article 4(2) of the Treaty on the European Union states: "The Union […] shall respect their essential State functions, including ensuring the territorial integrity of the State, maintaining law and order and safeguarding national security. In particular, national security remains the sole responsibility of each Member State."

Examples

Case studies in the digital domain illustrate how future industrial policy can and should be improved.

The **GDPR** has undoubtedly strengthened personal data protection in Europe. However, as a standalone and relatively complex regulation, it placed significant burdens on smaller companies, which lacked adequate support to ease compliance. In contrast, larger firms with substantial resources found the Regulation easier and more affordable to implement. Moreover, the GDPR was not accompanied by an industrial policy aimed at ensuring that EU companies could thrive in the internal market opened up by their privacy-enhancing solutions, many of which are open source.

In **cybersecurity policy**, the EU is a global leader, at least in terms of regulation. The EU's Horizon Europe and Digital Europe Programmes provide substantial support for cybersecurity research and innovation (R&I). However, few EU-based cybersecurity companies have achieved global success. To scale, these companies often rely on risk capital from the United States, Israel, and Singapore. When approaching EU investors, these companies struggle to „make the investment case," facing challenges from fragmented implementation of security policies across the internal market and a lack of international promotion through EU cyber-capacity-building initiatives.[205] At the same time, there is considerable market potential. Critical infrastructure providers and governments are increasingly compelled to invest in cybersecurity solutions due to mounting espionage from China and sabotage by Russia. However, this demand is predominantly met by non-EU companies. As a result, while member states may buy resilience, they simultaneously risk selling out on sovereignty.

EU R&D programs have long adhered to the principle of being "open to the world." However, a more critical and strategic approach is now emerging. Economic security considerations are increasingly influencing the scrutiny of participants and restricting access to certain areas of Horizon Europe. Closer civil-military linkages, as well as stronger requirements for IP protection and FDI scrutiny, are also being considered. Nevertheless, a policy that effectively leverages synergies between public investment in R&D and public procurement remains far from widespread.

The **EU Chips Act** represents a more modern industrial policy, addressing not only supply-side interventions but also emphasizing international cooperation and incorporating economic security considerations. While the Act demonstrates geopolitical awareness, it lacks the flexibility to adapt to geo-economic developments, such as subsidy wars. Additionally, it has weak connections to demand-side industries, including automotive and telecommunications.[206]

What's next: Toward a new industrial policy

Fontana and Vannuccini (2024) define industrial policy as: "Industrial development involves the percolation of technologies across user industries and the provision of key inputs, such as critical raw materials and computing infrastructure that drive the digital economy and applications like artificial intelligence."[207]

While this definition highlights supply-side inputs and demand-side diffusion, the EuroStack initiative adopts a more integrated approach. It proposes an industrial policy that combines supply- and demand-side interventions with traditional

205 Paul Timmers, Matthijs Punter, and Claire Stolwijk, "Cybersecurity and Digital Sovereignty – Bridging the Gaps" (TNO, 2024), https://publications.tno.nl/publication/34643188/DvSKsfCM/timmers-2024-cybersecurity.pdf.

206 Paul Timmers, "Digital Industrial Policy for Europe | CERRE Report" (CERRE, 12 December 2022), https://cerre.eu/publications/digital-industrial-policy-for-europe/.

207 Olimpia Fontana & Simone Vannuccini, 2024. "How to Institutionalise European Industrial Policy (for Strategic Autonomy and the Green Transition)," Journal of Industry, Competition and Trade, Springer, vol. 24(1), pages 1-30, December.

industrial policy tools such as R&D and investment support, while also incorporating strategies for market access, trade, economic security, and international collaboration. EuroStack emphasizes coordinated action, the removal of internal market barriers, significant investment mobilization, and adaptability to evolving geopolitical and technological contexts.

This new industrial policy prioritizes removing market entry barriers and deepening market integration by aligning industrial, competition, and trade policies as complementary rather than conflicting. As the Letta Report on the future of the Single Market suggests, regulatory frameworks should enable innovation and entrepreneurship rather than merely constraining them.

EuroStack also adopts a "Europe-first" approach to ensure capability building and sovereignty in critical domains. Inspired by Mazzucato and Rodrik,[208] it introduces conditionalities for investments and procurement, such as equitable access, reinvestment mandates, data sovereignty, and shared risk-reward mechanisms. Public procurement follows a comply-or-explain principle to ensure investments generate public value and drive strategic autonomy for Europe.

By aligning stakeholders, fostering demand for European solutions, and enhancing interoperability across sectors, the EuroStack initiative aims to reduce dependency on external providers and reclaim leadership in critical technologies. This approach is essential for Europe's resilience and competitiveness in the global digital economy.

A need for new instruments?

Over the past decade, the EU and member states have introduced a range of industrial policy instruments. In research and innovation, initiatives such as IPCEI, the EDIC, and the Strategic Technologies for Europe Platform (STEP), alongside joint undertakings through public-private partnerships, have been prominent. In the defense sector, NATO, partially in collaboration with the EIF, has introduced instruments such as the Defence Innovation Accelerator for the North Atlantic (DIANA). For deployment investments, EU financial instruments like the former European Fund for Strategic Investments, the RRF, and InvestEU have effectively leveraged public funding. The EU has also developed tools to support venture capital, including the EIC and the European Tech Champion Initiative, addressing the critical need for late-stage growth capital.

Some of these instruments, such as ESFI, have been evaluated and shown to deliver remarkable financial leverage. However, many others have yet to prove their effectiveness. The success of centralized vaccine procurement during COVID-19 highlighted the benefits of collective bargaining, inspiring the EU to explore similar approaches for other essential goods, such as critical raw materials and semiconductors. Proactive measures, including European Commission recommendations, legislative revisions, and cross-stack monitoring, are beginning to address regulatory inconsistencies and lay the groundwork for enhanced interoperability and market access. The European Commission has also announced that it is taking major steps forward in regulation-related simplification . Additionally, Europe's regulatory leadership, exemplified by the GDPR and sustainability-focused policies, has set global benchmarks, creating a competitive advantage in shaping the ethical use of technology.

Despite these achievements, many existing instruments remain slow, rigid, and overly complex, unable to keep pace with rapid technological, market, and geopolitical developments. This rigidity often impedes implementation and results in missed opportunities. Furthermore, Europe lacks integrated, agile, and coordinated industrial policy instruments capable of effective execution.

208 Mazzucato, Mariana; Rodrik, Dani; (2023) Industrial Policy with Conditionalities: A Taxonomy and Sample Cases. (Working Paper Series 2023-07). UCL Institute for Innovation and Public Purpose: London, UK.

The EuroStack initiative does not call for more bureaucracy. On the contrary, it advocates for an agile and innovative approach to equip Europe with the critical digital infrastructures essential for competitiveness, security, and democracy. Rather than waiting for existing instruments to overcome their challenges, EuroStack proposes a proactive strategy. It seeks to leverage existing tools, build on the institutional flexibility demonstrated during crises, and, over the longer term, contribute to improving the speed, flexibility, feasibility, and relevance of industrial policy instruments.

The proactive digital industrial policy proposed here is articulated around four main pillars that address Europe's key technology gaps:

1. From research and development to scaling European platforms and products

Europe has demonstrated excellence in research but struggles to translate innovation into globally competitive platforms. A lack of integration across the digital stack hinders its ability to scale and commercialize technologies, creating critical gaps. To address these challenges, Europe must:

- **Build competitive platforms:** Establish EuroStack to unify existing initiatives such as EuroHPC and the Quantum Flagship under a single governance framework. This would streamline innovation, set shared priorities, and ensure coordinated resource allocation to accelerate commercialization.

- **Leverage public procurement:** Use procurement strategically to prioritize European solutions, particularly in developing federated cloud systems and sovereign data spaces. A "Europe-first, comply-or-explain" framework can reduce reliance on foreign providers, while public incubators can support the early adoption and scaling of European technologies.

- **Close talent and investment gaps:** Address critical shortages in talent for AI, quantum computing, and HPC by offering competitive salaries, increasing R&I funding, and launching global talent attraction programs. Strengthening commercialization pathways will also attract private and institutional investors.

- **Set global standards:** Leverage Europe's leadership in privacy and ethical governance to establish standards in emerging fields such as quantum computing, edge computing, and AI. Independent governance models, shared IP frameworks, and open-source initiatives can promote collaboration and equitable innovation.

- **Strengthen cybersecurity:** Conduct a comprehensive cross-stack security audit, complemented by periodic reviews, to identify vulnerabilities and guide resilience-building measures. Robust cybersecurity frameworks will enhance trust and interoperability across all layers of the tech stack.

- **Align defense and space strategies:** Develop a unified EU defense and security market to foster innovation and scale critical technologies. Closer coordination between the defense and space industries will bolster Europe's strategic autonomy and support the broader goals of the EuroStack initiative.

By addressing these critical gaps and building on its existing strengths, Europe can transform its innovation ecosystem, secure digital sovereignty, and assume leadership in the global digital economy.

2. Bridging the investment gap: The case for a European Sovereign Tech Fund

Europe's venture capital ecosystem must scale significantly to remain competitive on the global stage. For instance, in 2023, the United States invested €62.5 billion in AI startups, compared to Europe's €9 billion.[209] This critical disparity undermines Europe's ability to lead in high-tech innovation. The European Commission's Coordinated Plan on AI aims to address this issue by committing

209 Maslej, et al., "AI Index Report 2024 – Artificial Intelligence Index".

€1 billion annually from EU programs, with the goal of scaling public and private investments to €20 billion annually by the end of the decade.

According to Atomico, there is a €375 billion shortfall in European deep-tech growth-stage funding compared to the United States. Of this gap, €75 billion is currently filled by foreign capital, highlighting Europe's reliance on external resources.[210] To bridge this investment gap, particularly in critical technologies such as AI, semiconductors, and IoT, a coordinated and robust approach is essential. Existing programs like VentureEU – a partnership between the European Commission and the European Investment Fund – aim to mobilize €6.5 billion for startups and scaleups. Similarly, public-private partnerships offer the opportunity to pool resources and expertise, accelerating innovation.

National governments and institutions such as the European Investment Bank also play a pivotal role in reducing fragmentation and driving investment. InvestEU, with its €26.2 billion in guarantees, aims to attract investments in key areas such as research commercialization, industry digitalization, and the scaling of innovative companies. However, bridging Europe's competitive gap requires more than these fragmented efforts. The Draghi Report estimates that an additional €150 billion in investment will be needed between 2025 and 2030 for Europe to position itself as a global leader in digital technologies. Achieving this will require targeted support for foundational technologies such as cloud infrastructure, data management, and advanced semiconductors, alongside efforts to develop European platforms and products capable of competing on the global stage.

While initiatives such as the European Innovation Council are promising, they must evolve to be more mission-oriented, akin to DARPA in the United States. Aligning these efforts with the EuroStack initiative would focus innovation on strengthening Europe's strategic autonomy and achieving technological sovereignty.

The case for a European Sovereign Tech Fund

To address these systemic gaps, the establishment of a European Sovereign Tech Fund is imperative. This fund would consolidate funding mechanisms, streamline efforts, and align investments with Europe's strategic priorities. Its objectives would be twofold:

1. Short-term scaling
Provide patient capital to startups and scaleups in critical sectors such as AI, IoT, and cloud-edge infrastructure. This approach would ensure innovations scale effectively and reach the market.

2. Long-term strategic investments
Focus on transformative technologies, including quantum computing, next-generation semiconductors, and advanced AI. These investments would secure Europe's leadership in high-impact fields.

An initial capitalization of €10 billion would serve as a catalyst for early progress. Over five years, investments would scale to €150 billion, ultimately reaching €300 billion over a decade, aligning with the EuroStack vision. Funding would be pooled from EU member states, the EIB, national promotional institutions, institutional investors, and private capital. Public-private partnerships would amplify the impact and mitigate risks.

As a cornerstone of the EuroStack vision, the European Sovereign Tech Fund would address critical gaps in Europe's innovation pipeline. By fostering industrial champions, reducing dependencies, and bridging short-term scaling needs with long-term strategic investments, the fund would position Europe as a global leader in the digital economy while ensuring its technological sovereignty.

210 Niklas Zennström, "European Tech's Confidence Crisis Is Its Biggest Challenge", 10 December 2024, https://atomico.com/insights/european-techs-confidence-crisis-is-its-biggest-challenge.

3. Addressing Europe's talent and innovation gaps
Europe faces critical challenges with regard to its shortage of skilled talent in key fields such as quantum computing, AI engineering, and semiconductor design, and the loss of IP to global competitors. Addressing these gaps requires a coordinated European strategy that strengthens innovation, retains IP and talent within Europe, and ensures public investments support economic and strategic autonomy.

Germany's Federal Agency for Disruptive Innovation (SPRIND) offers a compelling model for bridging these gaps. By focusing on high-risk, high-reward projects, SPRIND fosters breakthrough innovations capable of creating new markets or transforming industries. Its approach combines long-term funding, rapid decision-making, and interdisciplinary collaboration to accelerate transformative ideas. Scaling this model to the European level could significantly enhance the continent's innovation capacity. A European Disruptive Innovation Agency would pool resources from multiple countries, create a pan-European network of innovators and researchers, and align disruptive technologies with the EU's strategic goals. Integrated into the EuroStack framework, such an agency could prioritize breakthrough areas like AI, quantum computing, and advanced biomaterials, positioning Europe as a leader in next-generation technologies.

To build the skills pipeline necessary for the EuroStack's success, such agencies should prioritize competitive salaries, substantial research grants, and advanced training and acceleration programs in emerging technologies. Mobility initiatives should foster cross-border collaboration, creating dynamic hubs of innovation across Europe. EU funding mechanisms, including the Digital Europe Programme, Horizon Europe, and the CEF, must embed conditionalities that prioritize digital skills development while leveraging AI-enhanced EuroStack technologies to reduce the demand for highly specialized skills. Security-by-default market requirements will further incentivize the development of technologies that minimize advanced skill dependencies.

Safeguarding European intellectual creations is crucial. Publicly funded innovation outcomes must be valorized within Europe, supported by open standards and shared IP frameworks that encourage ethical, collaborative development while preserving sovereignty. To secure long-term strategic autonomy, the European Commission and the EIB should take equity stakes in companies of critical importance – including startups and scaleups – in sectors such as semiconductors, AI, quantum computing, and cloud infrastructure. This approach would enable these companies to scale globally while ensuring European control over essential technologies and products.

By addressing talent shortages, protecting intellectual property, and aligning investments with strategic priorities, Europe can secure its position as a global leader in innovation. This coordinated approach is critical to ensuring the success of the EuroStack initiative and safeguarding Europe's digital sovereignty in an increasingly competitive landscape.

4. Reducing dependencies and building sustainable interdependencies
Europe remains heavily dependent on foreign suppliers for semiconductors, cloud infrastructure, AI, and critical raw materials. These dependencies expose the region to significant vulnerabilities, particularly in the context of geopolitical tensions and supply chain disruptions.

To mitigate these risks, Europe must strengthen domestic capacity while forging sustainable interdependencies with resource-rich nations such as Argentina, Australia, and China. Joint ventures and co-investments in sustainable extraction and processing technologies, aligned with the EU Critical Raw Materials Act, can improve supply chain resilience. However, Europe must accelerate its efforts to match competitors such as the United States and China, which are rapidly

securing resources through direct and transactional agreements.

Domestically, the European Chips Act must prioritize high-value niches, such as AI-optimized and energy-efficient chips, leveraging Europe's strengths in advanced semiconductor manufacturing, exemplified by global leaders like ASML. Addressing high capital costs and skilled labor shortages requires targeted public-private investments and robust training programs to support long-term competitiveness.

A cohesive economic foreign policy is vital to advancing the EuroStack initiative and increasing the global presence of European technologies. Limited EU support has hindered the success of European digital solutions in international markets. To address this, Europe must ensure its technologies are integrated into global initiatives like the Global Gateway, cybersecurity capacity building, international standard-setting, and trade agreements. Promoting European technologies requires active outreach. EU institutions, in collaboration with the private sector, should facilitate and support trade promotion missions to diversify the supply of critical goods and position EuroStack solutions on the global stage. This strategy will not only enhance Europe's competitiveness but also contribute to a fairer and more balanced global digital ecosystem. The success of the EuroStack initiative also depends on its ability to adapt to political, economic, technological, and environmental changes. The initiative must actively monitor and interpret external trends, ensuring alignment with broader EU priorities such as the green agenda, multilateral cooperation, and defense strategies.

Policy recommendations

Actions within the EuroStack

The EuroStack represents a modern industrial policy strategically designed to achieve digital sovereignty. Each industrial policy outlined here contributes to building the capabilities, capacities, and control necessary to enhance EU competitiveness, security, democracy, and environmental sustainability.

The EuroStack initiative prioritizes two forms of agency. Operational agency focuses on leveraging the EU mandate for the internal market, directing limited resources toward areas of strategic importance. Geo-economic agency aims to reduce dependencies on foreign technologies, foster sustainable interdependencies, and promote European solutions in areas where external dominance threatens strategic autonomy.

The EuroStack initiative does not seek to address all necessary actions within the digital domain – some are already being pursued in other initiatives, while others fall outside the scope of industrial policy. Instead, this report identifies four key areas of action:

1. **Strengthening capabilities within individual layers of the digital stack,** such as AI, semiconductors, and cloud infrastructure.

2. **Delivering synergies across layers** to create an integrated and interoperable digital public infrastructure.

3. **Ensuring coherence and consistency in EuroStack implementation and MVPs.**

4. **Aligning with broader agendas** in areas such as competition policy, trade, sustainability, and global digital governance.

Given the interconnected nature of the tech stack, where layers are typically linked by input-output complementarities, strengthening capacity in one layer often produces positive externalities and spillover effects on adjacent layers. For instance, bolstering the supply-side of a specific segment, such as cloud infrastructure, increases demand and improves market conditions for upstream suppliers and downstream application developers. This dynamic creates a virtuous cycle of investment and innovation across the ecosystem. Enhanced output and efficiency in one layer reduce per-unit costs and attract further complementary specialization in related layers, leading to aggregate productivity gains and improved competitiveness for the entire EuroStack. Ultimately, this cascading economic impact amplifies the benefits of industrial policy interventions. A strategic focus on a single layer reverberates throughout the interconnected network of digital capabilities, driving systemic growth and innovation.

1. **Policy action: Smart and sustainable resource stewardship**
   Set clear targets and provide financial incentives for optimizing energy, water, and critical raw materials within the EuroStack, aligning with EU Green Deal goals, and support these efforts through robust monitoring mechanisms.

- **Focus on efficiency:** Ensure EuroStack technologies achieve measurable reductions in energy use, water waste, and reliance on raw material imports.

- **Procurement standards:** Mandate energy-efficient, recyclable, and circular-compliant technologies at the national level to benefit from EuroStack support.

- **Investment alignment:** Link funding to clear climate and resource efficiency outcomes, leveraging EU instruments such as Horizon Europe and Green Bonds.

2. **Policy action: Strengthening advanced semiconductor capabilities to drive AI and HPC innovation**
   Focus on advancing semiconductor technologies and integrating ecosystems to reduce dependency, enhance Europe's digital sovereignty, and drive innovation in AI and high-performance computing.

- **Invest in advanced nodes**
  - Prioritize open hardware architectures, providing incentives for advanced manufacturing in areas such as RISC-V, photonics, neuromorphic chips, and quantum chips.
  - Prioritize cross-stack synergies by promoting collaboration among European chipmakers, software developers, and cloud providers to align design and manufacturing capabilities.

- **Stimulate demand through public procurement**
  - Require that 50% of processors and accelerators used in critical infrastructure, defense, public administration, and strategic systems be European-made by 2030. Use defense and strategic digital technology procurement to create sustained demand for domestic production.

- **Integrate supply and demand ecosystems**
  - Build and financially incentivize demand-supply partnerships that link semiconductor advancements to key sectors like automotive (37% of Europe's semiconductor consumption) and expand to emerging sectors such as biotech, gaming, space economy, and advanced manufacturing.

- **Safeguard strategic assets**
  - Strengthen FDI scrutiny and controls to protect critical European IP and startups, particularly in quantum and AI chips.
  - Establish a database of strategic assets within the EuroStack to ensure resilience and maintain European control over critical technologies.

3. Policy action: Strengthening industrial IoT and connected devices

To foster a secure and competitive IoT ecosystem within the EuroStack initiative, it is essential to implement harmonized regulations, establish robust cybersecurity measures, and assume leadership in global standards.

- **Ease the application of IoT-related legislation**
  - Simplify the application of EU IoT-related regulatory frameworks (e.g., energy, safety, security, privacy), aiming to reduce compliance costs for businesses by up to 20%.
  - Promote IoT trust labeling aligned with the Cyber Resilience Act, NIS2, and GDPR. Provide compliance assistance for SMEs through automated toolkits and centralized support platforms, and internationally advocate for a Trust-in-EU mark.

- **Enhance participation in global standards**
  - Allocate financial resources and encourage companies to increase EU representation in international IoT standardization bodies.

- **Support IoT innovation**
  - Incentivize the development of secure and innovative IoT solutions through Horizon Europe and Digital Europe programs, with the goal of achieving a 25% increase in EU IoT patents by 2030. Monitor and report the utilization of these patents in European and global markets.

4. Policy action: Enhancing sustainable competitiveness in the network layer

Strengthen EU telecom competitiveness, security, and sustainability through harmonized regulation, strategic investments, and synergies within EuroStack layers.

- **Promote cross-sector synergies**
  - Coordinate telecom security and resilience with defense, energy, and cloud sectors through a cross-border European Digital Infrastructure Consortium.

- **Accelerate 5G adoption and demand-supply synergies**
  - Cross-stack: Financially support large-scale pilots for standalone industrial 5G networks integrated with edge cloud technologies to achieve low latency and high availability. Target deployment in 80% of industrial hubs by 2030.
  - Cross-stack: Promote edge cloud integration in 5G rollouts, aligning with EuroStack's cloud layer actions. Position telecoms as a key consumer of semiconductors, applied AI, and secure quantum communications within EuroStack.
  - Promote SCION architecture: Advance the adoption of SCION, redefining how data is transmitted across the internet to enhance scalability, control, and security.

5. Policy action: Achieving strategic autonomy in the cloud layer

Develop a cohesive strategy to strengthen Europe's cloud ecosystem, prioritizing edge cloud development, strategic integration with HPC, AI, quantum technologies, and ensuring alignment with EU digital sovereignty objectives.

- **Implement a European sovereign cloud initiative**
  - Promote and, where feasible, mandate preferential public procurement for European cloud solutions using a comply-or-explain framework. The goal is to ensure that 50% of public cloud spending is allocated to EU-based providers by 2030. To support the initial phase of adoption and infrastructure development, governments should commit to €500 million annually over 5-7 years for the procurement of European cloud solutions.
  - Provide public procurement guidance to boost adoption of GDPR-compliant and energy-efficient EU-based solutions.

- **Promote an edge cloud paradigm**
  - Cross-stack: Financially support pilots for edge-enabled 5G networks tailored for industrial and public service applications, integrating them with decentralized cloud services.

- **Adopt decentralized edge solutions**
  - Establish a pan-European Multi-Provider Cloud-Edge Continuum (8ra Initiative) to reduce latency by up to 50% and improve resilience by decreasing reliance on centralized infrastructure.
  - Focus on critical sectors such as healthcare, public safety, and transportation, where decentralized solutions can enhance response times and mitigate operational risks.

- **Promote and require open API ecosystems**
  - Promote and require open APIs for cloud providers to ensure interoperability, support cross-border data flows, and prevent vendor lock-in, which currently affects over 75% of enterprises using proprietary platforms.
  - Align with EU initiatives for data sovereignty and digital interoperability, which are critical for enhancing cross-sector collaboration.

- **Strengthen linkages to HPC, AI, and quantum**
  - Cross-stack: Align cloud initiatives with HPC, AI, and quantum technology programs to enhance Europe's competitive edge in processing complex workloads.

6. Policy action: Building a sustainable software industry ecosystem

Strengthen Europe's open software ecosystem to enhance digital sovereignty, reduce dependency on proprietary solutions, and foster public trust and industrial innovation.

- **Adopt an open-source first policy**
  - Promote and, where necessary, mandate open-source software for public services and critical infrastructure by 2026 at both the member state level and (ideally) EU levels.
  - Prioritize European open-source solutions through preferential procurement and incentives for private adoption.

- **Govern key digital commons**
  - Establish public-private-commons partnerships to manage federated AI platforms, supported by €1 billion funding to ensure transparency and alignment with EU values, and continued support for common EU services.

- **Promote global standards leadership**
  - Advocate for open software principles in global standards-setting bodies to position the EU as a leader in shaping digital governance.

7. Policy action: Achieving AI sovereignty and harnessing data as a strategic asset

- **AI strategy**
  - Cross-stack: Develop a unified strategy integrating AI, HPC, AI cloud, AI chips, and data governance to create scalable, secure, and interoperable infrastructure. This approach ensures European leadership in AI and data while safeguarding digital rights, accountability, and sovereignty.

- **Public interest data as public good:**
  - Establish EU-wide Data Trusts to treat public interest data as a shared resource, enabling secure data pooling and public-private data sharing while ensuring GDPR compliance. Include data access requirements in public procurement contracts. While there is value in sharing public interest data, ensuring the protection of data is equally important, especially intrinsically sensitive types such as biomedical and geolocation data.
  - Cross-sector data sharing must adhere to impact assessments, data minimization protocols, and sector-specific guidelines while ensuring interoperability. Robust safeguards against surveillance and unauthorized use should include strict access controls, comprehensive audit trails, transparency reporting, and legal protections against unauthorized monitoring or profiling.
  - Ensure data transparency and accountability by including provisions in procurement contracts, public tenders, and licensing agreements that specify how data will be used for AI model training.

  - Build a European data ecosystem to support the training sovereign AI models, leveraging federated data platforms for cross-border and cross-layer data exchange of authorized data (e.g., IoT, cloud, AI). This effort should be linked to and reinforce the European Data Spaces Program, which aims to create sector-specific data ecosystems in health, finance, energy, and mobility. Prioritize interoperability and secure data exchange within these spaces to ensure collaboration, enhance innovation, and maintain data sovereignty across critical sectors.

- **Data as a European asset**
  - Clarify the use of large European data assets and evaluate the benefits of preferential access in EuroStack for European innovators.

- **Enable interoperable data exchange, speeding up data spaces execution**
  - Promote cooperation and provide incentives for the development and deployment of federated data platforms to ensure secure, sovereign data sharing across IoT, cloud, and AI ecosystems.

- **Unify governance across AI infrastructure**
  - Cross-stack: Link IPCEI projects in AI, quantum, chips, and HPC to ensure alignment with GDPR, the AI Act, and data sovereignty objectives.
  - Join-up already existing public-private collaborations to reduce fragmentation and accelerate development of AI hardware, cloud, and HPC infrastructure.

- **Build AI cloud and chips**
  - Cross-stack: Develop integrated platforms combining AI-specific HPC resources, sovereign AI cloud capabilities, and specialized AI chips to support compute-intensive applications like large language models.
  - Focus on strategic applications in healthcare, mobility, biotech, and public services while ensuring data remains secure and localized.

- **Federated and interoperable AI systems**
  - Deploy federated AI models that train on localized data without transferring raw data, ensuring GDPR compliance and minimizing risks of data misuse.
  - Integrate federated AI with edge cloud systems to enable real-time decision-making in critical sectors like manufacturing, smart cities, and public safety.

- **Establish a truly open public AI marketplace for Europe**
  - Develop a fully open AI marketplace powered by federated AI models and open APIs, utilizing public domain and CC0-licensed datasets. This platform will provide accessible, trustworthy AI tools for SMEs, public cultural institutions, and media organizations, fostering innovation across diverse sectors. The AI systems will be trained using the EuroHPC network, ensuring HPC resources are leveraged for European-led advancements.
  - Cross-stack: Integrate the marketplace with IoT, cloud, and edge systems to create a cohesive and scalable environment for innovation. Enhance real-time AI applications in industries like smart cities, healthcare, and cultural heritage digitalization.

- **Invest in AI- driven IPCEIs**
  - Allocate large-scale investments for AI infrastructure innovation, targeting HPC, quantum technologies, energy-efficient AI chips, and scalable AI applications in alignment with the European Sovereign Tech Fund.
  - Set a target for creating 500 AI startups, scaleups and SMEs by 2030 under the European Innovation Council, boosting competitiveness and innovation.
  - Strengthen growth fund investments and link scaleups to key industries via Corporate Venture Capital (CVC) and strategic industrial policy initiatives. Ensure the EIB and EIC take equity stakes in European AI champions, safeguarding their growth and preventing foreign takeovers of strategic assets.

  - Ensure AI leadership through integrated infrastructure: Promote open, transparent, and secure systems that align with European values to counter the dominance of Big Tech's proprietary ecosystems.
  - Advocate globally for data sovereignty and the adoption of open, accountable AI standards in line with the AI Act by leveraging EU leadership within international standards bodies.

- **European AI for All Initiative**
  - Launch a European AI for All initiative to democratize access to AI technologies and foster widespread adoption across industries and public services.
  - Establish a network of AI innovation hubs across EU member states that provides resources, expertise, and computing infrastructure for SMEs and public sector organizations to develop and implement AI solutions.
  - Develop open-source, pre-trained AI models and datasets tailored to European languages, industries, and use cases, thereby reducing barriers to entry for smaller organizations.
  - Launch an AI skills program to train and upskill the European workforce, focusing on both technical and ethical aspects of AI development and deployment.
  - Implement a voucher system for SMEs to access AI consulting services and cloud computing resources, thereby accelerating adoption in traditionally less digitalized sectors.

8. Policy action: Strengthening leadership in quantum technologies

Enhance EU leadership in quantum technologies by aligning supply-side innovation with demand-side adoption through targeted actions and coordinated governance.

- **Accelerate lab-to-market transition**
  - Expand EU quantum initiatives under the Quantum Flagship with €5 billion in EU funding by 2030 focusing on quantum computing, sensing, and secure communications.

- **Develop common procurement standards and Europe-first procurement:**
  - Establish shared public procurement specifications under a Quantum Act, beginning with secure quantum communications, to encourage the early adoption of EU-developed quantum solutions.
  - Implement a comply-or-explain framework within the Quantum Act, requiring governments to prioritize EU-funded quantum solutions unless justified otherwise.

- **Foster collaboration across stakeholders and stimulate demand**
  - Link the Quantum Flagship with national initiatives through a Europe-wide Quantum Innovation Network to facilitate the sharing of best practices, cross-border R&D, and pilot projects.
  - Cross-stack: Boost quantum adoption by linking quantum initiatives to critical sectors such as telecoms, cloud infrastructure, semiconductors, cybersecurity, and AI. Aim to achieve a 25% EU share of the global quantum market by 2035.

The EuroStack

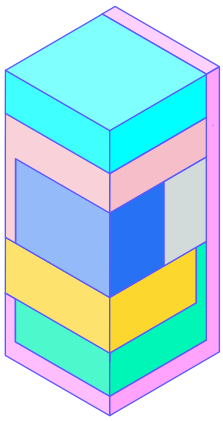
European policies shaping the stack

Legend

Policy type:

- *Strategy*
- *Funding program*
- *Investment*
- *Funding instrument*
- *Legislation*
- *Deployment*

1 Policies that apply to the entire stack



- Digital Decade
- A New European Innovation Agenda, European Innovation Ecosystems (EIE)

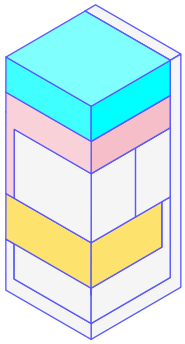
- Digital Europe Programme (DIGITAL)
- Horizon Europe

- InvestEU
- The Recovery and Resilience Facility (NextGenerationEU)
- VentureEU
- European Innovation Council (EIC) Fund
- European Tech Champions Initiative

- EU Cybersecurity Strategy, Cyber Security Act, Action Plan Cybersecurity and Health

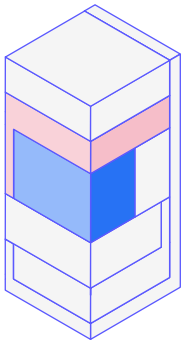
2 Policies that apply to multiple stack layers

Data and artificial intelligence, software, networks



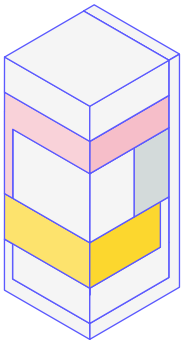
- The Common Security and Defence Policy (CSDP)
- European Defence Fund

Software, cloud



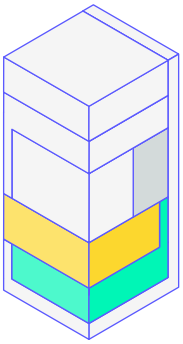
- Digital Services Act (DSA)
- Digital Markets Act (DMA)
- EU Cloud and AI Development Act

Software, internet of things & devices, networks



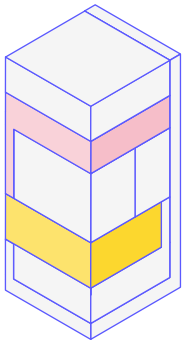
- Network and Information Systems Directive (NIS2 Directive)
- Digital Operational Resilience Act (DORA)

Internet of things & devices, networks, chips



- Quantum Technologies Flagship

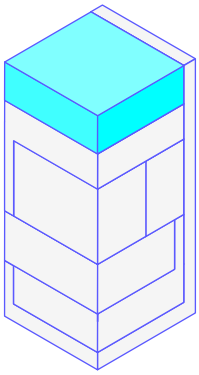
Software, networks



- Connecting Europe Facility (CEF)

3 Policies that influence specific stack layers

Data and artificial intelligence

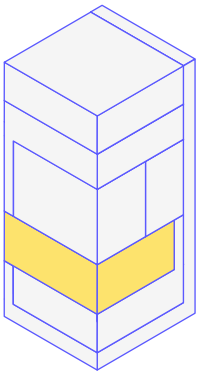


- European AI strategy (2021 Review)
- EU Artificial Intelligence Act
- AI Innovation Package

- Data Governance Act (DGA) + Data Act
- General Data Protection Regulation (GDPR).

- European Strategy for Data (European Health Data Space)
- AI Factories Initiative
- Apply AI
- AI in Science
- Data Union Strategies

Networks

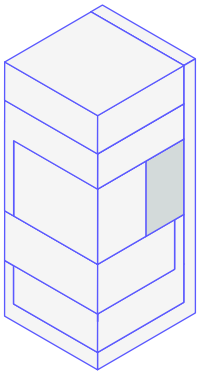


- European Quantum Communication Infrastructure (EuroQCI)

- CASSINI (Space and Defence innovation)

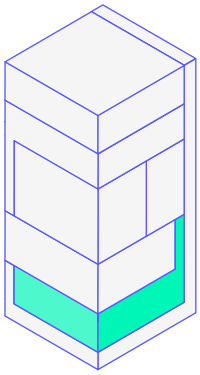
- 5G Action Plan
- 5G PPP
- European Electronic Communications Code

Internet of things & devices



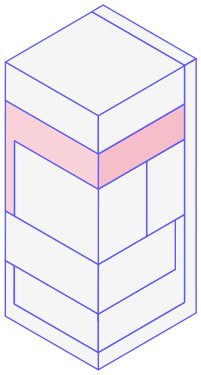
- Cyber Resilience Act

Chips



- Chips Act
- Chips for Europe Initiative

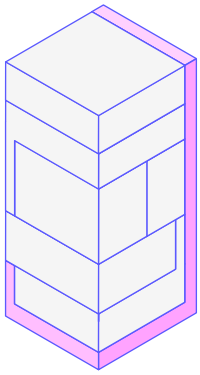
Software



- eIDAS 2.0
- EU Digital Identity Wallet (EUDI)

- The Common Foreign and Security Policy (CFSP)
- European Peace Facility (EPF)

Raw materials, energy, and water



- Critical Raw Materials Act

Cross-stack strategic initiatives

Along with demand-supply and Europe-first procurement strategies, the following cross-stack actions are needed:

1. **Unified compliance frameworks**
   - Simplify pathways for public-private partnerships within the EuroStack and enable SMEs to adopt legally compliant solutions more efficiently. Provide European Commission recommendations for streamlined compliance processes.

2. **Green by design**
   - Require energy efficiency across all layers of the EuroStack, ensuring alignment with EU Green Deal goals and targeting a 30% reduction in energy use by 2030. Require transparency measures, such as those outlined in the EU's Corporate Sustainability Reporting Directive. Sustain investments in renewable energy and carbon-aware computing technologies. Require AI companies to publicly disclose resource usage and emissions across their entire lifecycle, from manufacturing to training and inference.

3. **Cross-layer federated architecture and digital commons for Europe:**
   - Interoperable data exchange and data commons: Develop federated data platforms for secure cross-layer data sharing while maintaining GDPR compliance and ensuring data sovereignty. Establish related data commons with appropriate governance structures, such as the EU Health Data Commons for federated research in genomics and precision medicine, or EU Cities Data Commons for urban digital twins and interoperable local public services.
   - Public procurement for digital commons: Use smart public procurement to pool resources and fund collaborative digital commons initiatives.

4. **Cross-layer resilience framework**
   - Design a pan-European framework to address cybersecurity, redundancy, and resilience across all layers, fostering strategic autonomy in critical infrastructures.

5. **Empowering ecosystem players**
   - Support SMEs and startups: Provide funding, technical support, and compliance assistance to drive innovation and accelerate adoption across multiple layers.
   - Actively build and maintain digital commons: extensive repositories of digital public goods governed to ensure inclusivity, transparency, and protection from monopolistic capture. Digital commons include software, hardware, open data, educational resources, digital cultural content, and media. The policy shift is evident: the focus is no longer solely on fostering openness but on building sustainable platforms maintained by European institutions to support the development and maintenance of digital commons.

6. **Interplay with defense**
   - Integrate defense requirements into EuroStack layers through shared standards, pilot projects, and early adoption programs.

7. **Strategic investment: European Sovereign Tech Fund**
   - Set an ambitious target of €300 billion in investments over 10 years to drive innovation and secure Europe's strategic autonomy.
   - Initiate the European Sovereign Tech Fund with an initial €10 billion investment, prioritizing EuroStack common services and MVPs to ensure early, tangible outcomes, with incremental increases as implementation progresses.
   - The European Tech Sovereignty Fund should:
     - focus its investments on key areas to enhance Europe's digital independence and competitiveness. These include advanced semiconductor R&D, innovations in cloud and edge computing, GDPR-compliant infrastructure, sovereign AI models and applications, interoperable data platforms, and

digital commons. Examples of digital commons include the EU Health Data Commons, the EU Cities Data Commons, and the rollout of the EU Digital Identity and the Digital Euro. The overarching goal is to scale European sovereign products and platforms, ensuring they align with Europe's values of privacy, transparency, and inclusivity;
- co-invest with the EIB and EIC to scale 500 AI and quantum startups by 2030 and prevent foreign takeovers of critical assets;
- allocate funding for energy-efficient technologies, targeting a 30% reduction in stack-wide energy use by 2030.

Implementation roadmap

The EuroStack initiative presents a strategic, phased roadmap designed to transition Europe from technological dependency to digital strategic autonomy. At the core of this effort are the **EuroStack** digital infrastructure and its **MVPs**. This roadmap strikes a balance between ambition and feasibility, providing Europe with a clear and sustainable path to lead in digital innovation while safeguarding its independence. By integrating robust governance, strategic investments, and well-defined milestones, the plan consolidates fragmented efforts into a cohesive strategy for Europe's digital future.

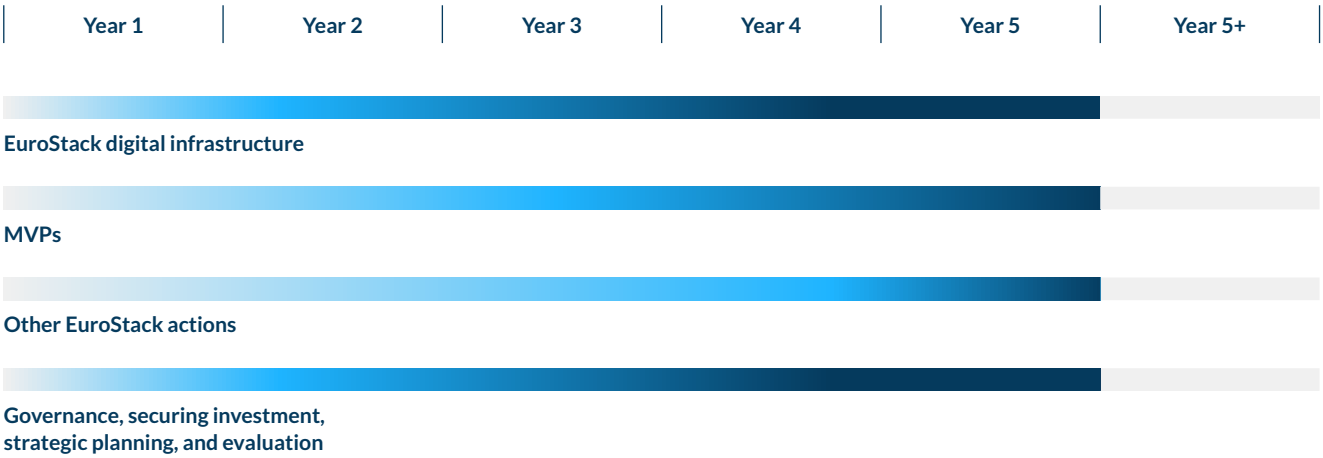
Crucially, the EuroStack roadmap operates through parallel streams that evolve over time. Implementation begins immediately, focusing on deploying mature solutions while concurrently pogressing research and development for more advanced contributions. Governance structures will also be established from the outset, designed to grow, adapt, and evolve in tandem with the initiative's progress.

Stream 1: EuroStack digital infrastructure (from year 1)

Objective: Establish the EuroStack Digital Infrastructure (EDI) to enable interoperable digital services, hardware, and software.

- **Develop, deploy, upgrade:** The EDI will evolve to meet the needs of digital strategic autonomy, starting with an initial set of services and technologies.
  - **Digital Euro:** Accelerate the rollout to enable secure, fee-free cross-border transactions across services.
  - **Sovereign Digital Identity Wallet:** Develop a privacy-preserving, interoperable wallet integrating electronic identification, payment systems, and access to public and private services.
  - **Federated data spaces:** Build GDPR-compliant platforms for secure cross-border data sharing

EuroStack implementation roadmap



in healthcare, education, mobility, and climate. Foster a coalition of cities and regions to adopt common procurement frameworks for implementing these standards.
  - **Sovereign cloud infrastructure:** Expand decentralized cloud systems, such as IPCEI-CIS and European Open Clouds, to ensure critical data remains within Europe's jurisdiction.
  - **Sovereign, federated AI:** Develop and implement sovereign AI solutions by prioritizing decentralized training of AI models across diverse hardware environments. This approach ensures resilience, adaptability, and energy efficiency while safeguarding data privacy and maintaining control over critical AI infrastructure.
  - **International partnerships:** Forge alliances with key global players, such as South Korea, Taiwan, Chile, and Brazil, to address supply chain vulnerabilities, particularly in semiconductors and raw materials.

- **Widespread adoption:** Leverage strategic public procurement and regulatory incentives to promote widespread adoption across public and private sectors. Align investments with EU market regulations and competition policy to curb monopolistic practices and foster competition.

- **Sustainability:** Invest in long-term maintenance of the EDI, notably sovereign AI models and infrastructure, decentralized platforms, and data commons to ensure resilience and reliability.

Stream 2: MVPs (from year 1)

Objective: Develop and deploy EuroStack digital MVPs in strategic sectors as they reach readiness, while refining their components. MVPs will evolve in stages, beginning with mature technologies (Technology Readiness Level [TRL] 9) and later integrating advanced solutions currently at TRL 6 or below.

- **Sectoral challenge for the EuroStack digital trailblazers or MVPs, the EuroStack Challenge:** Launch a competition to fund innovative ideas for running MVPs and use cases on top of sovereign EuroStack building blocks. Potential MVPs could address strategic priorities in sectors such as healthcare, education, climate and energy, fintech, media, and culture. Each deployment could focus on feasible collaborations, leveraging Europe's strengths in research, industry, and public institutions to advance sovereign digital services and ensure the success of the EuroStack MVP initiative.

- **Advanced development and testing locations:** Advance the MVPs in a range of locations, focusing on scalability and interoperability.

- **Expand capabilities:** Integrate post-quantum cryptography, QKD, advanced AI, and other gamechangers into the MVPs to secure data exchanges and enhance operational efficiency. Extend these applications to sectors like biotech and clean tech to ensure leadership in industrial IoT and renewable energy.

Stream 3: Other EuroStack actions within and across the stack

Objective: Advance the range of actions within and between individual layers of the stack and cross-stack actions.

- **Build commitments:** As the EuroStack community grows and investments increase, establish firm commitments to ensure the timely launch and execution of planned actions.

- **Advanced technologies:** Focus on next-generation AI, post-quantum cryptography, edge cloud solutions, advanced semiconductor technologies, and other emerging technologies to secure the future of EuroStack, enhance resilience, and strengthen Europe's innovation capacity.

- **Widespread adoption:** Use strategic public procurement and regulatory incentives to drive adoption across both public and private sectors. Align investments with EU market regulations and competition policies to curb monopolistic practices and foster competition.

- **Sustainability:** Invest in long-term maintenance to ensure resilience and reliability.

Stream 4: Governance, securing investment, strategic planning, and evaluation (from year 1)
Objective: Mobilize investment and funding commitments while ensuring alignment with long-term strategic goals of digital strategic autonomy. This includes fostering broad stakeholder involvement, establishing robust governance mechanisms, maintaining flexibility to adapt to geopolitical and technological developments, and conducting ongoing performance evaluations.

Governance

The EuroStack initiative is both a vision and an actionable plan, requiring the active participation of committed stakeholders. These stakeholders include industry leaders, innovators, civil society organizations, member states, and the European Commission, all of whom are called upon to support and contribute to the EuroStack initiative.

Several EuroStack actions can be implemented through extensions of existing initiatives, while others will necessitate the creation of new instruments or projects. These may be supported by EU programs focused on investment, deployment, development, or research. The success of EuroStack depends on broad collaboration, mutual commitment, and strategic leadership.

- Independent governance body: Establish a centralized governance structure, modeled after the European Central Bank, to oversee key aspects such as interoperability, public accountability, and the ethical implementation of digital technologies. A transitional governance body should be introduced at the launch stage and evolve into a permanent structure with broad support.

- Governance foundations: Following the initial phase, establish a EuroStack EDIC to coordinate member state efforts, set shared priorities, and ensure resource alignment.

Securing investment

As highlighted in the Draghi Report, an additional €150 billion investment is required between 2025 and 2030 to establish Europe as a global leader in digital technologies. Building on this foundation, the EuroStack initiatives aim to secure €300 billion over a decade through the establishment of a European Sovereign Tech Fund, ensuring Europe not only achieves digital sovereignty but also remains competitive in the global tech landscape.

To jumpstart this ambition, the EuroStack proposes the creation of an initial €10 billion European Tech Sovereignty Fund. This fund will be strategically allocated to develop EuroStack common services and MVPs, laying the groundwork for a self-sufficient and interoperable European tech ecosystem. The fund will pool resources from multiple channels, including Horizon Europe, the Digital Europe Programme, EIC investments, national contributions, and private investment ensuring a unified and efficient approach to resource mobilization and impact generation.

Strategic planning, monitoring, and evaluation

- **Maintain and update the EuroStack strategic plan:** Extend the current document to include more specific allocations of actors, resources, and timelines to ensure clear accountability and effective execution.

- **Adaptation:** Ensure the strategic plan remains responsive to geopolitical, market, and technological changes. Identify barriers and refine strategies to address dependencies and challenges arising from these developments.

- **Evaluation and Adaptation:** Conduct a comprehensive evaluation to assess user adoption, scalability, and economic impact. A mid-term evaluation is planned for year 3.

Section 4 – Additional readings

Readings on Europe's digital sovereignty for policymakers

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Annex A – Strategies of dominance among selected Big Tech

This section outlines the primary elements of the business strategies employed by the key dominant companies within the digital stack. These strategies represent a blurring of traditional boundaries – between hardware and software, platforms and infrastructure, consumer and enterprise markets, and national borders. Their integrated ecosystems foster significant innovation while effectively rewriting market rules, accumulating and leveraging data at scale, and entrenching high switching costs. his concentration of power has led to growing calls from regulators, policymakers, and civil society to better understand and govern the multifaceted power these firms wield.

Amazon holds a dominant position in cloud infrastructure, e-commerce, logistics, and AI. As an early mover in cloud computing, AWS commands over 30% of the global market. AWS bundles raw computing power with specialized chips, storage solutions, machine learning frameworks (e.g., Amazon SageMaker), and integrated dev-ops tools. This integration makes migrating workloads away from AWS both costly and complex, creating significant switching barriers. AWS's privileged position also allows Amazon to gain strategic insights into broader market trends, shaping its decisions on where and how to invest in capacity. In e-commerce, Amazon's control over fulfillment, warehousing, and last-mile delivery not only reduces internal costs but also imposes stringent terms on third-party sellers who rely on its logistics infrastructure. By managing both the marketplace and the rules that govern it, Amazon can subtly prioritize its private-label products and services, extracting rents and gathering data that informs its advertising and retail strategies.

Microsoft wields a comparable level of infrastructural dominance, anchored by Windows, which has maintained approximately 70% of the global desktop operating system market share for decades.[211] This dominance is reinforced by its integration with productivity tools, cloud services, and AI capabilities. Azure, which holds 24% of the global cloud market,[212] integrates seamlessly with Office, Teams, and other Microsoft products , embedding its services into business operations. Microsoft's partnership with OpenAI further enhances its AI capabilities across its ecosystem, with advanced models such as GPT-4 integrated into Azure and productivity tools like Word and Teams. Microsoft's significant investments in data centers and custom AI chips enable it to meet increasing demand while cementing its control over critical layers of the digital stack.

At the core of **Google's** model is its flagship search engine, which commands roughly 90% of the global market.[213] By channeling the immense volume of search queries into Google Ads, supplemented by data from its video platform YouTube, the company refines its targeting algorithms to deliver highly

211 StatCounter, "Desktop Operating System Market Share Worldwide", accessed 12 January 2025, https://gs.statcounter.com/os-market-share/desktop/worldwide/.

212 Synergy Research Group, "Cloud Market Gets Its Mojo Back; AI Helps Push Q4 Increase in Cloud Spending to New Highs".

213 StatCounter, "Search Engine Market Share Worldwide", accessed 12 January 2025, https://gs.statcounter.com/search-engine-market-share.

relevant advertisements, driving both click-through rates and advertiser demand. Google also capitalizes on its Android operating system, which powers over 70% of smartphones worldwide.[214] This enables the seamless integration of services such as Search, Chrome, and the Play Store, embedding its ecosystem into billions of devices while consolidating control over app distribution and user data. Beyond mobile, Google dominates in cloud and AI with platforms like Google Cloud and TensorFlow, embedding its technologies into business operations. Advanced AI models like Bard address disruptions to its core search business, which commands 90% of the market. Google's dominance in digital advertising, driven by Google Ads and YouTube, is fueled by data collected across its ecosystem. This data powers precise targeted advertising, reinforcing its market position across the stack.

Apple's tightly controlled ecosystem integrates hardware such as the iPhone, iPad, and Mac with its operating systems (iOS, macOS) and services like the App Store and iCloud. This vertical integration ensures a superior user experience, cultivates strong customer loyalty, and creates significant barriers for competitors. Apple's exclusive control over the App Store enables it to impose terms on third-party developers, including commission rates of up to 30%, extracting substantial financial rents and further consolidating its market power.

Meta extends its dominance in social media by monetizing user data and integrating open-source AI models like Llama to attract developers and enhance its services. The company's investments in virtual reality aim to complement its existing platforms, fostering deeper integration between social media and immersive technologies. Additionally, Meta's control over undersea cable infrastructure bolsters its global reach, further reinforcing its influence across digital ecosystems.

NVIDIA, the leader in GPU chip design, extends its dominance through an integrated software ecosystem, including CUDA, which fosters customer lock-in and enhances AI capabilities. By tightly aligning its hardware and software offerings, NVIDIA secures its position at the forefront of the AI-driven computing market.

Tesla leads innovation in electric vehicles through its advanced software ecosystem and AI-powered features like Autopilot. SpaceX leverages Tesla technologies and expands global connectivity through Starlink, which operates over 60% of the world's active satellites, dominating satellite communications.[215] Musk's AI venture, xAI, increasingly supports this broader ecosystem by advancing Tesla's autonomous driving capabilities and exploring wider AI applications. This ecosystem is further fueled by data from X (formerly Twitter), a social media platform Musk aims to transform into a hub for communication, payments, and AI services. However, X's role in amplifying unregulated or harmful content has attracted significant scrutiny. Together, these strategies consolidate control across transportation, connectivity, AI, and communication, raising pressing concerns about regulatory oversight and the ethical implications of concentrated power in critical technologies.

China also boasts a number of influential Big Tech firms that rely on infrastructural dominance. Supported by ambitious industrial policies and large-scale investment, these companies exemplify China's pursuit of technological self-reliance and vertical integration. By leveraging dominance in core areas, they consolidate power across the digital stack.

Originally gaining prominence through telecommunications equipment, **Huawei** has leveraged its infrastructure expertise to expand into consumer electronics, cloud computing, AI, and domestic chip manufacturing – often bolstered by state-led industrial policies. In telecommunications, Huawei's d dominance grew through its cutting-edge

214 StatCounter Global Stats, "Mobile Operating System Market Share Worldwide", accessed 12 January 2025, https://gs.statcounter.com/os-market-share/mobile/worldwide.

215 Werner, "Want to Challenge Starlink in the Satcom Market?"

5G technology and turnkey solutions for telecom carriers worldwide, embedding its equipment deeply into global communication networks. Beyond telecom, Huawei diversified its portfolio to include smartphones, tablets, and laptops, powered by its proprietary HarmonyOS operating system and Kirin chips developed by its subsidiary HiSilicon. U.S.-led restrictions on semiconductor supply chains spurred Huawei to intensify its domestic R&D efforts and chip fabrication capabilities, a strategy aligned with Beijing's emphasis on technological self-reliance. Today, Huawei's cloud platform integrates AI accelerators, data analytics tools, enterprise services, and IoT frameworks, effectively replicating the global cloud ecosystem within China's "walled garden" of technology. Through these initiatives, Huawei positions itself as a vertically integrated, end-to-end solutions provider, spanning critical infrastructures from network layers to consumer-facing services.

Initially celebrated as an e-commerce pioneer, **Alibaba** spans digital commerce, cloud computing, fintech, logistics, and media. At the core of its ecosystem are the Taobao and Tmall marketplaces, which process an immense volume of transactions and generate data streams that drive the development of Alibaba's other businesses. Alibaba Cloud, the leading cloud provider in China, delivers compute, storage, AI services, and database solutions. It serves as the backbone of an ecosystem where merchants depend on Alibaba's infrastructure for payment processing (via Alipay), supply chain management, and customer analytics. Over the years, Alibaba has expanded its operations to include Cainiao, a logistics network integrating delivery partners and warehouses, as well as ventures into entertainment (Youku, Alibaba Pictures), education technology, and enterprise software. Each segment feeds into the other: the cloud business profits from the enormous traffic and data generated by e-commerce and financial services, and the marketplace benefits from the cloud's capacity, scalability, and analytical insights. Together, these integrations create a near-seamless environment for consumers, businesses, and developers, allowing Alibaba to extract rents, shape standards, and reinforce switching costs within China's digital economy.

Tencent initially emerged as a social and gaming powerhouse before branching into infrastructure and enterprise solutions. It dominates social media and messaging through WeChat, a "super-app" integral to daily life in China. WeChat integrates chat, mobile payments (WeChat Pay), mini-programs, e-commerce and, increasingly, business services. This ecosystem, by design, captures comprehensive user data, enabling granular personalization and targeted advertising. In parallel, Tencent's gaming portfolio – encompassing both domestic titles and global investments – serves as a major revenue driver while also acting as a testing ground for advanced technologies, such as cutting-edge graphics, network scaling, and AI-driven matchmaking. Tencent's expansion into cloud computing and AI leverages this platform advantage, offering solutions to enterprises that want to tap into its vast user base and computational power. Beyond IT infrastructure, Tencent maintains a diverse portfolio with stakes in fintech, music streaming, video platforms, healthcare, and numerous startups aligned with its ecosystem strategy. This integration results in a multifaceted digital empire that not only sets rules for content distribution, social interactions, and commerce but also acts as a critical layer of digital infrastructure for other businesses.

Often referred to as "China's Google," **Baidu** initially built its reputation on search, advertising, and mapping services before expanding into AI, autonomous driving, and cloud solutions. As the dominant player in China's search market, Baidu's algorithms continuously refine user intent and data mining capabilities, providing an advertising backbone that funds R&D in emerging technologies. Building on its robust data analytics and natural language processing expertise, Baidu launched Baidu Brain and a suite of AI platforms that contribute to industries like healthcare, finance, and urban planning. The company's Apollo platform leads the domestic autonomous driving initiative, utilizing

extensive real-world data gleaned from its mapping and location-based services. In addition, Baidu Cloud offers enterprise-level solutions – ranging from machine learning frameworks to IoT services – that capitalize on Baidu's research labs and AI know-how. Through this integrated stack of products and services, Baidu extends its algorithms and data applications beyond search, influencing everyday life and infrastructure. This creates a virtuous cycle of user engagement and technological advancement, strengthening its market position and deepening customer lock-in.

Best known internationally for TikTok, **ByteDance** leveraged its success in short-form video and sophisticated recommendation algorithms to build a diverse digital ecosystem. Its offerings include Douyin (the Chinese counterpart to TikTok), Toutiao (a leading content aggregator), and other niche apps that cater to various verticals. ByteDance's AI recommendation engines, powered by granular data collection and massive user engagement, deliver highly personalized content feeds with remarkable precision. This sophisticated personalization has proved easily transferable to new domains: ByteDance invests in ed-tech, enterprise software, and e-commerce, integrating shopping features into its short-video platforms and branching out into livestreaming sales. Meanwhile, the firm's entry into cloud services and enterprise AI tools builds on its algorithmic expertise, effectively turning its consumer-facing successes into a foundation for B2B solutions. ByteDance is thus emerging as both a media and tech infrastructure player, powering new digital business models and reinforcing its role as a standard-setter for content discovery, user engagement, and targeted advertising.

Annex B – Ongoing EU policy actions and key stakeholders

The EuroStack flagship will build upon ongoing policy actions and initiatives in Europe such as the following:

Semiconductors

- Accelerate the development of 2nm and below technologies critical for AI and HPC, with the goal of increasing Europe's global chip production share from 10% to 20% by 2030 (EU Chips Act / EC + industry)
- Align procurement with EU regulatory frameworks, including the GDPR, AI Act, and Green Deal, to ensure compliance, incentivize innovation, and support sustainability (EU Chips Act / member states).
- Focus on AI-capable and energy-efficient chips, aligning with sustainability goals and supporting Europe's leadership in strategic industries (EU Chips Act / EC + industry + Joint Undertaking).
- Integrate semiconductor initiatives with the Green Deal to promote a sustainable digital transformation (EU Chips Act / EC).
- Advance a comprehensive strategy for chip design, production, and ecosystem collaboration, leveraging European strengths, such as expertise in EUV lithography (EU Chips Act / Joint Undertaking).

IoT and connected devices

- Prioritize IoT and connected devices in high-impact sectors such as smart cities and healthcare, which alone are expected to contribute €250 billion to IoT economic value in Europe by 2028 (Horizon Europe and Digital Europe Programme / EC).

Network layer

- Leverage EU funding mechanisms, using the STEP instrument and Cohesion Funds, for R&D and to scale deployment (EU R&D and Cohesion Programs / industry + member states).
- Advance work on open standards for standalone 5G networks to avoid vendor lock-in and ensure compatibility with edge computing and quantum-secure systems (EU Standardization / Industry and member states in ETSI+ GSMA in ITU).
- Facilitate the replacement of copper networks with fiber, reducing energy consumption by up to 85% (private sector funding / industry).
- Build redundancy and resilience in critical infrastructure by utilizing EU funding sources, such as the Connecting Europe Facility, and aligning efforts with the forthcoming Digital Networks Act (DNA) (DNA, CEF / EC + industry).

Cloud layer

- Target high-growth sectors with edge cloud such as healthcare and industrial manufacturing to demonstrate operational efficiencies (IPCEI / member states + industry).
- Encourage edge-native applications to reduce latency by up to 50% and improve resilience by

decreasing reliance on centralized infrastructure (IPCEI / member states + industry).

- Focus on critical sectors such as healthcare, public safety, and transportation, where decentralized solutions can enhance response times and reduce operational risks (IPCEI / member states).

- Align with EU initiatives for data sovereignty and digital interoperability to enhance cross-sector collaboration (forthcoming EU Cloud and AI Act / EC).

Open software industry ecosystem

- Roll out a unified Digital Identity Wallet by 2025, enabling seamless and secure access across public services and digital layers (eIDAS2 Act / EC + member states + industry).

AI and data

- Promote adherence to EU digital rights principles, including transparency, accountability, and privacy, to strengthen public trust (EU AI Act, Data Act, Data Governance Act, Open Data Act / EC).

- Focus on strategic applications in healthcare, mobility, and public services while ensuring data remains secure and localized (EU funding programs / EC).

Defense

- Foster technology transfer and align funding with dual-use technologies that address both defense and civilian needs (Horizon and European Defense Fund / EC + EDA).

Consortium partners

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The Bertelsmann Stiftung is committed to enabling social participation for everyone – politically, economically and culturally. Our programs span key areas such as Education and the Next Generation, Democracy and Social Cohesion, Digitalization for the Common Good, Europe's Future, Health, and Sustainable Social Market Economies. At the heart of our work are people – because real change begins with them. We generate knowledge, foster expertise and develop actionable solutions to drive meaningful progress. A nonprofit foundation, the Bertelsmann Stiftung was established in 1977 by Reinhard Mohn.

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About CEPS

Founded in Brussels in 1983, the Centre for European Policy Studies (CEPS) is a leading European think tank and forum for debates on EU and global affairs. Over the years, CEPS has amply demonstrated its ability to anticipate trends and to analyze policy questions well before they become topics of general discussion. CEPS' key assets include its complete independence to set its own research priorities and freedom from any outside influence; an eminently qualified, deeply interdisciplinary research team of around 90 researchers from more than 23 different countries; its membership of various networks of research institutions from all over Europe and beyond; and an extensive membership base with some 120 corporate members and over 100 institutional members.

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About the UCL IIPP

The Institute for Innovation and Public Purpose (IIPP) at University College London (UCL) rethinks the role of the state in tackling societal challenges by combining academic research with teaching and policy practice. IIPP develops frameworks that challenge traditional economic thinking, aiming to foster innovation-led, inclusive, and sustainable growth by creating and shaping public value.

Its work spans innovation and industrial policy, macroeconomic reform, and sustainable development, viewing markets as co-created by various actors rather than naturally occurring systems. IIPP emphasizes mission-driven public policy to tackle global challenges. Through research, teaching, and a global network of partners, IIPP translates groundbreaking ideas into real-world solutions.

IIPP is a department within UCL, and part of The Bartlett, ranking number one in the world for architecture and the built environment in the world.

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About Stiftung Mercator

Stiftung Mercator is a private, independent, and non-profit foundation that acts on the basis of scientific expertise and practical project experience. Since 1996, it has been advocating for a society based on solidarity and participation. To this end, it supports and develops projects that improve participation and cohesion in an increasingly diverse community. Stiftung Mercator stands up for a cosmopolitan, democratic Europe, a digital transformation of state and society based on fundamental rights, and socially just climate change mitigation. Stiftung Mercator pursues activities in Germany, Europe and worldwide. It feels particularly connected to the Ruhr area, home of its founder's family and the foundation's headquarters.

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