DIGITALEUROPE

THE EU'S CRITICAL TECH GAP

Rethinking economic security to put Europe back on the map

Foreword

From protectionism to a digital powerhouse

European innovations have transformed the world, but we now face formidable challenges in the digital era. As I write this, only 11 of the world's largest 100 tech companies by market cap are from the EU, and since 1992 our share of global GDP has dropped from 29 per cent to 17 per cent.[1] This is no coincidence. The EU's economic security strategy names three Ps – protect, promote and partner – but focuses mainly on 'protect,' and offers very little on 'promote' and 'partner.'

This study – focusing on eight critical technologies like AI, quantum and biotech, based on meticulous research and expert interviews – shows that we cannot solve our issues without looking seriously at our competitiveness.

Wrong diagnosis, wrong treatment

Diagnosing our weak economic security as solely stemming from an external supply chain crisis is only half true, and leads to the wrong treatment of the illness, relying only on restrictive trade and investment measures.

The irony is that this only adds further burden to those European companies who are leading in their sectors, further weakening Europe's position in the supply chain.

A defensive strategy won't win. **We must ensure that technology companies, across the whole supply chain, can be born, scale and stay in Europe, supported by partnerships with likeminded countries.**

We identify three key challenges the EU must overcome to once again be a technology leader:

- **Lack of scalability in the EU:** The EU struggles to scale and consolidate companies due to the fragmentation of the single market and a lack of a unified strategy, limiting EU companies' ability to scale and compete globally.
- **Investment shortfall:** Europe significantly trails the US and China in investments in critical technologies, which tend to be capital intensive. EU has no common capital market; public funding for R&D is nationally fragmented, and inefficient; and innovations are not commercialised enough to maintain Europe's competitive edge.
- **Tough playing field for European businesses:** European companies face a competitive disadvantage because of stringent regulations that have no equivalent in other geographies and keep them from growing and scaling at home.

From risk to opportunity

Economic security is not only about risk mitigation, it is a **huge opportunity for Europe to get back on the map. Back to the original promise of forming one scalable single market, and to refocus on creating the next wave of world-leading tech companies.**

Europe is at the forefront of connectivity and wind energy and competes with leaders on space technologies. It has also been a pioneer in additive manufacturing. This positions us to be in the driving seat of critical technology areas provided that investments are increased and barriers are addressed. Cracking the code on quantum will bring untold scientific breakthroughs and protect our most sensitive data. Biotech will allow for a next generation of tailored medicines. Although the EU underperforms in Artificial Intelligence and Advanced Semiconductors, the battle is not lost if we can leverage our strategic position in key segments of the value chain and continue to partner with our allies.

Our Manifesto aims for Europe to be A Digital Powerhouse by 2030.[2] To get there, Europe must be the creator of, and have access to, the critical technologies that will define our future.

We have everything we need to succeed – we just need a change in mindset.

Cecilia Bonefeld-Dahl
Director General
DIGITALEUROPE

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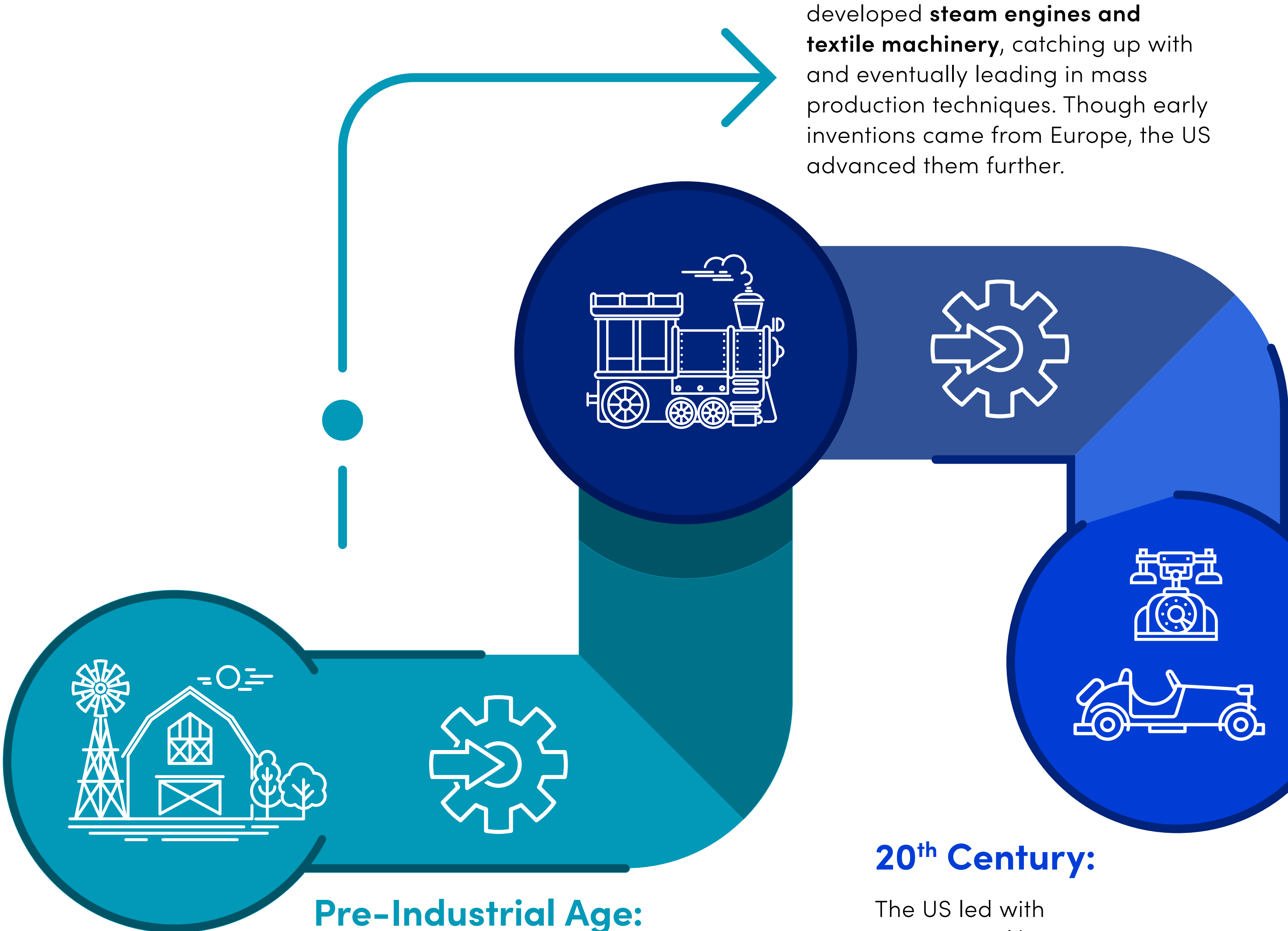
[1] See https://companiesmarketcap.com/ and Hugo Dixon, 'What to do about the EU's relative decline,' Reuters, available at: https://www.reuters.com/breakingviews/what-do-about-eus-relative-decline-2024-04-22/.
[2] See DIGITALEUROPE, *Europe 2030: A Digital Powerhouse – 20 solutions to boost European tech leadership and resilience*, available at: https://cdn.digitaleurope.org/uploads/2024/04/DIGITAL-EUROPE-MANIFESTO-2024-FULL-FINAL-2024-UPDATE.pdf.

Table of Contents

Technological leadership throughout history



Pre-Industrial Age:

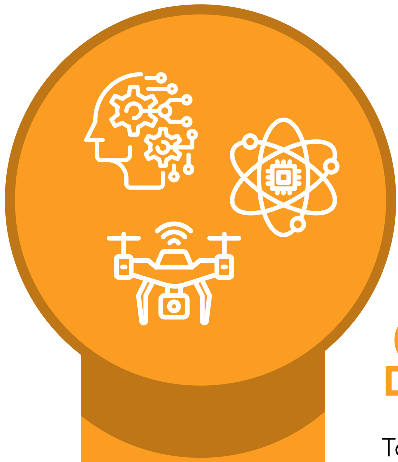
Europe led with **simple tools and agricultural innovations**, including the plough.

Industrial Revolution:

The US quickly adopted and further developed **steam engines and textile machinery**, catching up with and eventually leading in mass production techniques. Though early inventions came from Europe, the US advanced them further.

20th Century:

The US led with innovations like **automobiles, telecommunications, and the early development of computers and internet technology.**

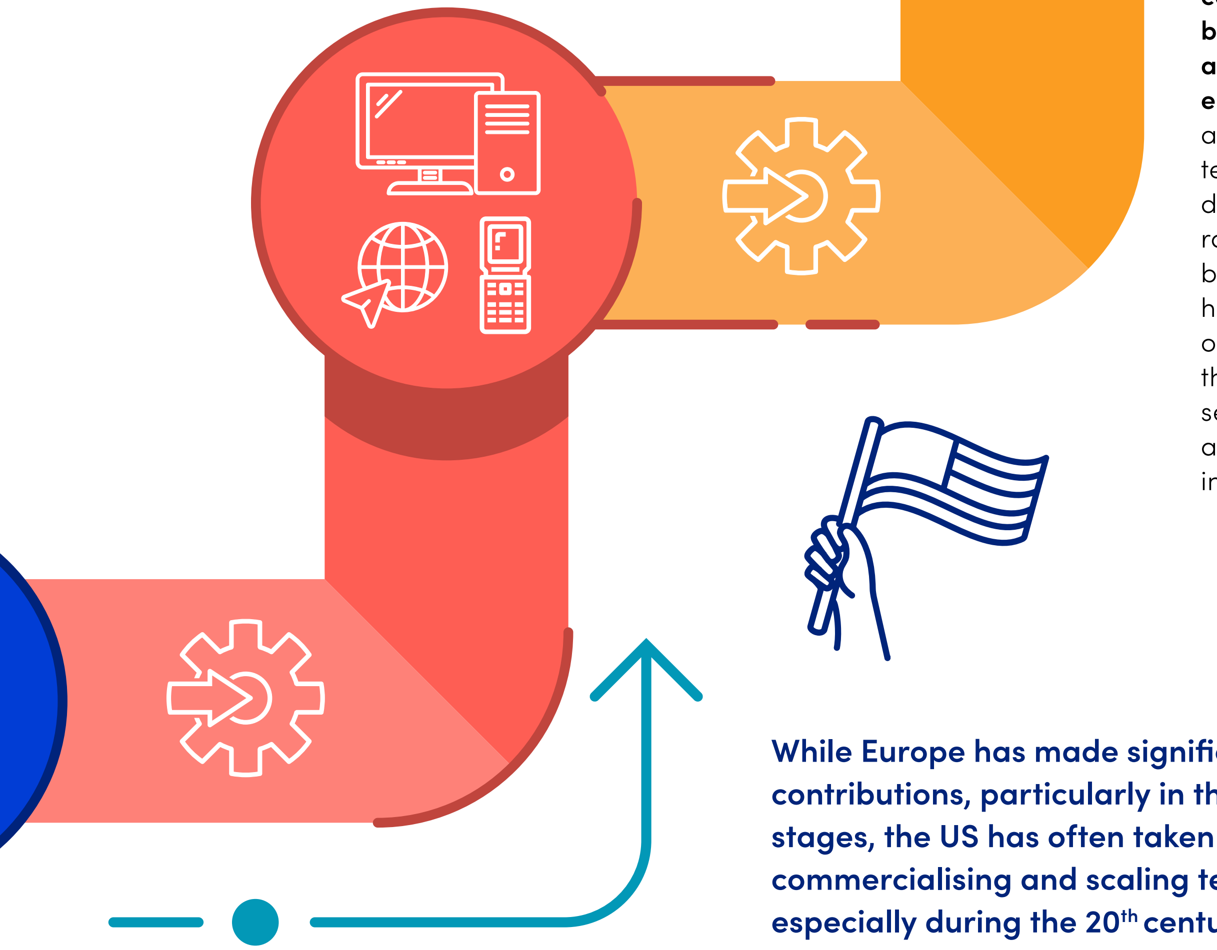


Late 20th – Early 21st Century:

The US was at the forefront of **personal computing, mobile technology, the internet boom, and social media.**

Today (Modern Day Era):

Today's technologies, such as **AI, quantum computing, blockchain, and renewable energy**, represent a new wave of technological development. The race to lead has begun, and Europe has a crucial opportunity to seize this new wave and secure its position at the forefront of innovation.



While Europe has made significant contributions, particularly in the early stages, the US has often taken the lead in commercialising and scaling technologies, especially during the 20th century and beyond. The fact that Europe did not keep pace with the United States during the first technology wave centred on the internet and software has left Europe in a weakened position in key technologies across sectors. Our analysis examines 8 technological areas on which Europe's future economic prosperity hinges.

Executive summary

The tides of technological innovation are reshaping the global landscape, demanding a recalibration of the EU's economic strategy. The EU faces a stark reality: its digital competitiveness lags global leaders like the US and China. The European Commission's 2023 Joint Communication on a European Economic Security Strategy recognises this, proposing a three-part approach: promoting competitiveness, protecting against risks and partnering with like-minded countries.[3]

This report analyses Europe's current position within global value chains for critical technology areas identified by the Commission.[4] Through market analysis and expert interviews with leading European players, it describes Europe's position relative to the global leaders, and highlights the challenges and opportunities Europe faces.

Main findings

- **The EU is lagging in most critical technologies:** The US leads globally in all but three areas – advanced connectivity (where the EU leads but struggles with uptake), additive manufacturing (where the EU has pioneered but faces market consolidation challenges) and energy technologies (where China leads, especially in solar power). As a result, the EU has fallen behind in overall competitiveness across multiple technology sectors, often ranking lower in metrics such as private investment into start-ups and scale-ups, patent activity and market share of global added value of related products.
- **There is a significant shortfall in public and private investment across several critical technologies**, including artificial intelligence (AI), quantum computing and space technologies. This financial gap affects the EU's ability to develop robust industries and compete globally.
- **The EU is strong in R&D, but weak in manufacturing and commercialisation:** The EU excels in research and development, often leading in scientific performance. However, this strength is not matched by equivalent capabilities in manufacturing and commercialisation, limiting value capture within the EU.
- **Regulation and a poor business environment are damaging the EU's competitiveness.** Complex regulatory frameworks hinder growth and scalability for European companies, which often look out for other markets. Restrictive funding also affects Europe more than other regions.
- **Europe faces a critical tech talent shortage** in key areas like AI engineering, quantum computing and additive manufacturing and semiconductor specialists.
- **The EU must strategically collaborate to limit supply chain disruption.** The value chains of critical technologies are complex and global. Strengthening partnerships and collaboration within the EU and with global leaders is essential to limit risks and build competitive technology ecosystems, particularly in those technology areas where the EU is not present in critical segments of the supply chain, like semiconductors.
- **The EU is a leader in the development of global standards**, particularly in areas like advanced connectivity. Leveraging these strengths can help the EU maintain a competitive edge in global markets.

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[3] JOIN/2023/20 final.
[4] C(2023) 6689 final and its annex.

Overview of EU leadership, supply chain risks and recommendations across technologies

An economic security strategy must balance two core components: enhancing the economic base and industry competitiveness, and mitigating supply chain risks:

- **Enhancing competitiveness:** This involves capturing a greater share of the value generated by a given technology, ultimately supporting competitive businesses.
- **Mitigating supply chain risks:** These risks may arise from various factors, such as the likelihood of supply chain disruption due to a lack of substitute products or limited suppliers, and the level of impact of such disruptions. Our analysis, summarised in the figure below, considers these two elements by evaluating:

  1. **The EU's competitiveness, measured through two main indicators**
  2. **The EU's exposure to supply chain risks**

1. The EU's competitiveness, measured through two main indicators:

- **EU proximity to the global best practice:** Based on a detailed quantitative analysis by Frontier Economics, we assess the EU's competitiveness across various metrics for each technology area. The metrics assess the EU's comparative performance on science (weighted 33 per cent of the score) and industry strength (weighted 67 per cent) by looking at elements such as funding for start-ups and scale-ups, market share of global exports, or the proportion of global value added of related products. As a whole, the score indicates how the EU compares to global leaders. A 100 per cent score would be reached if the EU were the top performer on each metric, although this is unlikely and in practice a score above 70 per cent indicates high competitiveness.[5]
- **EU value chain presence:** Based on expert interviews and secondary research, we assess the EU's presence and ability to capture economic benefits across the entire value chain of each critical technology analysed, or only certain stages where most of the value is created.

2. The EU's exposure to supply chain risks:

Drawing on input gathered via interviews with market leaders and secondary research, we assess the EU's exposure to potential disruptions to the broader supply chain in each technology area. Risk exposure is evaluated based on the availability of substitutes and concentration of suppliers (in terms of number of suppliers and geographical presence) and the EU's position in the value chain (upstream or downstream, with downstream presence entailing higher risk).

	Competitiveness		Security / Resilience
Technology area	EU's proximity to global best practice	EU value chain presence	Supply chain risk for EU
Additive manufacturing	69%		Moderate
Advanced connectivity*	71%		Low to moderate
Advanced semiconductors*	45%		High
Artificial Intelligence*	53%		Moderate to high
Energy technologies	61%		Moderate to high
Health biotechnologies	57%		Moderate
Quantum computing*	57%		Moderate
Space technologies	69%		Moderate to high

Figure 1: Assessment of EU's competitiveness and supply chain risk by technology area

*Priority critical technology areas according to the European Commission and covered more in-depth in this study. Health biotechnologies were also analysed as a priority area.

[5] See Frontier Report for more details on the metrics and how the proximity to the global best practice is calculated.

Takeaways and recommendations per technology

Additive manufacturing

Despite once being a pioneer in this technology, which is reflected in the still relatively positive figures, the EU's leadership is rapidly being overturned. While the EU maintains a strong presence in raw materials supply and design software, it is weaker in manufacturing and industry adoption, and highly affected by market consolidation trends. To retain its leadership, the EU needs increased public investment in manufacturing capabilities, incentives for technology adoption, and education initiatives to address the skills gap.

Advanced semiconductors

The EU stands at 45 per cent of the global leadership, making it the worst performing critical technology area assessed in this report. Strong in machinery equipment and some speciality semiconductors, the EU lags in design and manufacturing capabilities for small-sized chips. Improving competitiveness involves incentivising local chip manufacturing and fostering collaboration between chip users and manufacturers to establish a European foundry model.[6] Partnerships with experienced countries to bring in the necessary expertise and investment in Europe are seen as essential in this regard.

Advanced connectivity

Leading with 71 per cent competitiveness, the EU excels in R&D and network innovation. However, it lags in connectivity services due to a poor business environment and weak user demand. Enhancing competitiveness requires fostering an investment-friendly climate, encouraging market consolidation, and improving return on investment (ROI) in the sector.

Artificial intelligence

The EU is an AI laggard, standing at only 53 per cent of the global leadership. Whilst strong in B2B solutions, the EU lags in early parts of the value chain, like advanced processing units and data centre capabilities, which are crucial for large language models (LLMs). Enhancing competitiveness requires increased public and private investment, regulatory sandboxes, a streamlined regulatory compliance system, and strengthened global partnerships.

[6] A foundry is a semiconductor manufacturer that only produces chips for third parties and not for its own products.

Energy technologies

The EU's global energy competitiveness stance is at 61 per cent. A leader in wind technology, but lagging in solar due to reliance on Chinese materials, components and module manufacturing capabilities, the EU must streamline permitting, rethink price-driven auction designs, and enhance local material sourcing and recycling to compete globally.

Quantum computing

Whilst strong in R&D and with a growing start-up ecosystem, the EU falls behind in hardware development, which necessitates high investments, leading to a moderate performance with a global stance of 57 per cent. Ensuring future competitiveness requires increased investment focused on centralised quantum chip manufacturing facilities and go-to-market applications, beyond just primary research.

Health biotechnologies

Despite being home to large and world-leading pharma and biotech companies, the EU shows a moderate performance in health biotech at 57 per cent of the global leadership. Strong in R&D but reliant on US and Chinese raw materials, the EU lacks in process development and manufacturing. To boost competitiveness, the EU must create a business-friendly environment for biotech, foster closer collaboration between industry and academia, and review its funding schemes to make them attractive for biotech manufacturers.

Space technologies

The EU stands at 69 per cent of the global leadership, and is particularly strong in navigation, Earth observation and satellite communications. It is weaker in launch services and space surveillance, and highly dependent on external manufacturers for the supply of critical service components. To improve, the EU needs increased public investment in manufacturing capabilities, STEM (science, technology, engineering and mathematics) talent and a review of procurement policies to avoid inefficiencies.

Key policy recommendations

The European Commission's Economic and Security Strategy largely prioritises measures aimed at protecting the EU's economic security, rather than promoting industry competitiveness or partnering with allies.[7] However, these tools offer an overly reactive approach and might even lead to retaliation, ultimately backfiring on the EU. Furthermore, these measures will not in themselves generate European innovation, and may in turn hinder Europe's ability to expand to key global markets or restrict the supply of essential inputs currently not available in Europe.

In light of the above, our analysis and interviews recommend a set of proactive measures to strengthen the EU's intrinsic competitiveness across the critical technologies considered. These measures are listed below in three main categories according to their business value (impact) and feasibility or ease of implementation.[8] Additionally, for each technology area we detail a list of targeted measures that take into account the opportunities and risks associated with each technology. These specific recommendations by technology area are presented in subsequent sections.

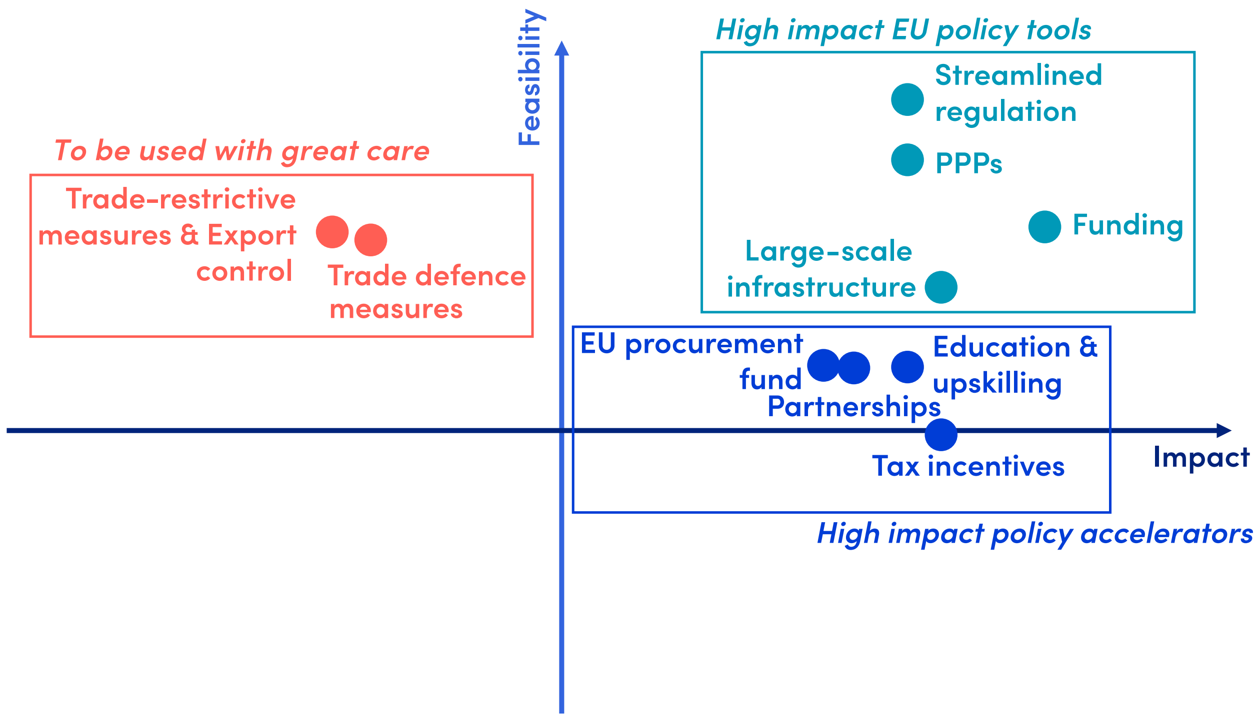

Figure 2: Impact and feasibility analysis of proposed measures

[7] The five elements of the economic security package released in January include a legislative proposal to strengthen foreign direct investment (FDI) screening, two White Papers (one on the monitoring and assessment of outbound investment risks and another to enhance export controls of dual-use goods) and a proposal to issue research security guidance for the research and innovation sector in order to prevent vulnerabilities. Only one out of five measures envisaged in the Commission's package is oriented towards enhancing support for R&D in critical technologies in Europe and developing internal capabilities by putting forward a review of the existing EU funding programmes. See European Commission, 'Commission proposes new initiatives to strengthen economic security,' 24 January 2024, available at: https://ec.europa.eu/commission/presscorner/detail/en/ip_24_363, and DIGITALEUROPE, *The Download: The EU's Economic Security Strategy*, February 2024, available at: https://cdn.digitaleurope.org/uploads/2024/04/The-Download-European-Economic-Security_Web.pdf.

[8] More information on the assessment model is presented in the Annex.

EU policy tools with high impact: Highly feasible measures at EU level, considering the EU's competences and a favourable political climate, which are also highly impactful. As such, these measures could be the first that the EU should consider:

1. **Streamlined regulation:** Regulatory complexity and national variations within the EU create damaging burdens for businesses. To strengthen the single market and make it easier for companies to operate across borders, the EU should remove barriers and regulatory overlaps.[9] Streamlining administrative procedures for establishing and operating businesses within the EU would further incentivise investment and growth. Additionally, the EU should avoid premature regulation of emerging technologies, allowing them to develop before their innovation potential is contained.
2. **Public-private partnerships (PPPs):** All critical technologies are nowadays largely driven by the private sector, but require collaboration between industry and the public sector to succeed. The EU should better harness PPPs, as opposed to regulation, to accelerate the development and deployment of cutting-edge technologies, address critical infrastructure needs, and ensure that innovation aligns with public interests and policy objectives.
3. **Targeted funding:** The EU's current funding model often discourages businesses due to complex access requirements, and a focus on fundamental research over research-to-market and commercialisation activities.[10] To empower businesses, the EU should review its funding instruments, prioritising accessibility, volume and profitability. Shifting away from a solely research-focused approach is crucial. Additionally, fostering a vibrant European venture capital market comparable to other regions is essential.
4. **Large-scale infrastructure investment:** Technologies like AI and quantum computing require access to expensive, capital-intensive infrastructure such as data centres and advanced foundries. To overcome this challenge, the EU should invest directly in deploying these critical infrastructures. A strategic approach focusing resources on a few common facilities at the EU level, rather than spreading funding thinly across many players, will ensure maximum impact and cost-effectiveness.

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[9] See DIGITALEUROPE, *The Single Market love story: 10 digital actions to save the 30-year marriage*, available at: https://cdn.digitaleurope.org/uploads/2024/02/DIGITAL-EUROPE-THE-SINGLE-MARKET-LOVE-STORY-FINAL-WEB.pdf.
[10] See DIGITALEUROPE, *The Download: Funding Europe's Digital Transition – Investing in the future not the past*, available at: https://cdn.digitaleurope.org/uploads/2024/04/DIGITALEUROPE-THE-DOWNLOAD-ISSUE-2-FINAL-WEB.pdf.

High impact policy accelerators: Measures with high impact potential, but which are harder to implement since they mostly tend to fall under Member States' remit. However, it is crucial for the Commission to act as a facilitator and coordinator of Member State actions for the EU to become truly competitive and safeguard economic security in these technologies.

5. **Education and upskilling:** A skilled workforce is vital for Europe's technological advancement. To attract and retain top tech talent, the EU should make itself an attractive destination by encouraging competitive salaries, modernising education systems, positioning itself as a pioneer of life-long learning, fostering closer collaboration between academia and research, and simplifying the hiring of global talent. For example, promoting STEM careers amongst students from a young age is crucial to build a strong pipeline of future talent. Initiatives encouraging up- and re-skilling of existing IT professionals, particularly in areas like AI and quantum, are also essential to bridge the current skills gap.

6. **Partnerships with third countries:** Technological development benefits from global collaboration, which is why the EU should strengthen partnerships with allies. The EU-US Trade & Technology Council and the EU-Japan Digital Partnership offer valuable tools to enhance and coordinate economic security initiatives, for instance early warning mechanisms to spot supply chain disruptions. Through cooperation with partners, the EU can drive forward collaboration on AI, 6G, data interoperability and the green economy, and lift data localisation restrictions that hurt data-reliant European industries.[11] However, the success of global partnerships depends on many uncontrolled factors, such as political will amongst global leaders or external shocks limiting the necessary momentum.

7. **Common EU procurement:** Having a common procurement approach would enhance innovation and competitiveness within European industry by creating economies of scale and fostering a more integrated and consolidated market. However, it requires political will by Members States to surrender existing prerogatives in favour of a common instrument for public purchases, which may be contentious and cumbersome.

8. **Tax incentives:** EU-wide tax breaks and incentives could significantly boost investments in R&D and manufacturing capabilities, as well as in technology adoption, making the EU more competitive globally. The EU does not, however, have the necessary competences to give such incentives, and may only create an enabling framework supporting these measures at national level.

[11] See DIGITALEUROPE, *Data flows and the Digital Decade*, available at: https://cdn.digitaleurope.org/uploads/2021/06/DIGITALEUROPE_Data-flows-and-the-Digital-Decade.pdf.

Policy measures to be used with great care: Measures with low impact, or even potentially harmful to the EU's industrial competitiveness, existing trade-defensive instruments could be relatively easy to implement, even if they are often complex to trigger or enforce in practice. Potential new instruments such as outbound investment screening should be considered with caution.

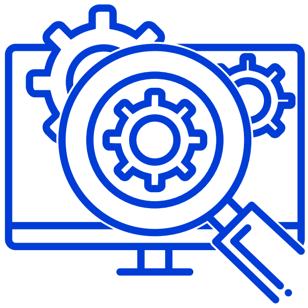
9. **Trade-restrictive measures:** New export control measures might harm the EU's competitiveness. The EU should target controls narrowly and apply them consistently to maintain a level playing field. These controls should include general licences for cooperation with like-minded countries and measures to boost domestic capabilities. Additionally, the EU needs to minimise legal instruments and separate the frameworks for sanctions and export controls. Whilst addressing non-controlled research partnerships, policies must consider the impact on EU businesses. Greater consistency and cooperation in inward investment screening are welcome, but procedures should be swift and criteria specific. Similarly, outward investment screening requires careful, data-backed consideration.

10. **Trade defence measures:** The EU already has the vested authority to implement trade defence measures, such as anti-dumping, anti-subsidy duties or safeguards, to protect European production against international distortions. Whilst these measures can protect EU industries from unfair competition, they do not address competitiveness issues and could lead to retaliation.

Clarifying some concepts

The report frequently refers to the concepts outlined below. For the sake of clarity, a short definition is provided for each:

- **Competitiveness:** Ability of European industries and businesses to maintain and improve their position in global markets by capturing value along crucial parts of the value chain in relevant critical technologies.
- **Critical technologies:** Technologies which are necessary to ensure the competitiveness of European industry on a global scale and/or crucial to guarantee the security of the European economy to produce basic products and services and/or to ensure the reliance of critical infrastructure.
- **Economic security:** Europe's ability to reduce or limit the impact of, or exposure to, external and geopolitical risks on supply chains. Exposure to external risks may include: risks to critical infrastructure (e.g. connectivity, energy supply, healthcare); risks compromising European or national security; and risks to the effective functioning of economic supply chains.
- **Global best practice:** Target competitiveness performance established for each critical technology area. This value is a composite indicator built with the figures for the top performer country across each set of considered metrics. The global best practice looks at who the global leaders are in a given critical technology across a set of scientific performance indicators (5) and industry strength indicators (10). Refer to the methodological section for further details.
- **Supply/value chain:** A supply chain refers to the set of consecutive activities required for the commercialisation of a finished product or service, from initial product design and various stages of processing inputs or manufacturing operations to its sale. The value chain identifies each step in the supply chain at which value is added.



About the methodology

This study has been prepared by DIGITALEUROPE in partnership with Frontier Economics. The findings are based on an extensive quantitative analysis by Frontier, commissioned by DIGITALEUROPE, using secondary data from various international and European databases such as the OECD, Eurostat's business statistics, EU PRODCOM, and UN Comtrade. Additionally, a series of interviews with market leaders and consultations with DIGITALEUROPE's members were conducted. Details on the companies and associations interviewed can be found in the Acknowledgments section.

The study evaluates the EU's performance across eight critical technology areas against global best practice standards considering top-performing OECD countries plus China and Taiwan. The technology areas considered stem from the Commission's list of technologies identified as critical on grounds of their enabling and transformative nature, as well as their inherent high security risks.[12] Specifically, the study focuses on one or several specific technologies within each technology area. These are defined at the beginning of each technology section. In addition to assessing the EU's relative competitiveness to leaders, the study also examines the EU's presence in value chains and its exposure to supply chain risks, and identifies key European and global players present in each segment of the target technologies.

The global best practice used to assess the EU's relative competitiveness is a composite indicator that includes two dimensions: scientific performance (33 per cent, covering five metrics related to research output and quality) and industry strength (67 per cent, covering ten metrics related to patent activity, finance for start-ups and scale-ups, market share of global value added and exports market share of related products). This indicator captures the top-performing country in each metric, therefore not reflecting a particular country, but representing the sum of the best available capabilities across all metrics.[13] To support the interpretation of the results, the EU's proximity to this theoretical indicator is compared to an estimated US benchmark, which is identified as the global leader with the highest average score across all indicators for five out of the eight technology areas considered.[14] From a timeframe perspective, the scientific indicators are based on academic papers published between 2018 and 2022, and industry indicators are collected for the latest time period available, which varies from 2020 to 2023 depending on the specific metric.

For five priority technology areas – AI, advanced semiconductors, quantum computing, advanced connectivity and health biotechnology – the study also qualitatively analyses the EU's presence in the value chain. To do so, we assessed the extent of the EU's participation in all segments of the value chain and its presence in segments where most value is added. The study further assesses the EU's exposure to supply chain shocks, according to the degree of geographic concentration (a small number of countries accounting for a large proportion of supply), and market structure (a small number of companies accounting for a large proportion of supply).

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[12] European Commission, Recommendation on critical technology areas for the EU's economic security for further risk assessment with Member States, C(2023) 6689 final.
[13] The analysis of secondary data covered Member States and non-EU OECD countries, plus China and Taiwan.
[14] The US appears as the overall leader across all technology areas considered, except for energy technologies led by China, and advanced connectivity and additive manufacturing led by the EU. This is why the EU's competitiveness stance is always compared against that the US' performance. Furthermore, due to data gaps, it was not always possible within the scope of this study to calculate the EU's relative overall competitiveness in comparison to other countries.

This assessment is also provided for the other three technology areas – additive manufacturing, energy technologies and space technologies – but to a less granular level of detail, relying mainly on the input collated through interviews with market leaders.

Lastly, the study puts forward a set of recommendations to enhance the EU's leadership and capabilities in the analysed critical technology areas. These recommendations are presented according to their impact and feasibility or ease of implementation. Market leaders and consulted members were first asked to assess the impact of the proposed measures using a scale of 1 to 5, and these were then evaluated against feasibility considerations by our policy and legal experts on a scale of 1 to 10. See the Annex for the results of the impact and feasibility assessment.

The full Frontier Economics study, including an in-depth methodology description and specific metrics, is available on DIGITALEUROPE's website.

frontier economics

Additive manufacturing

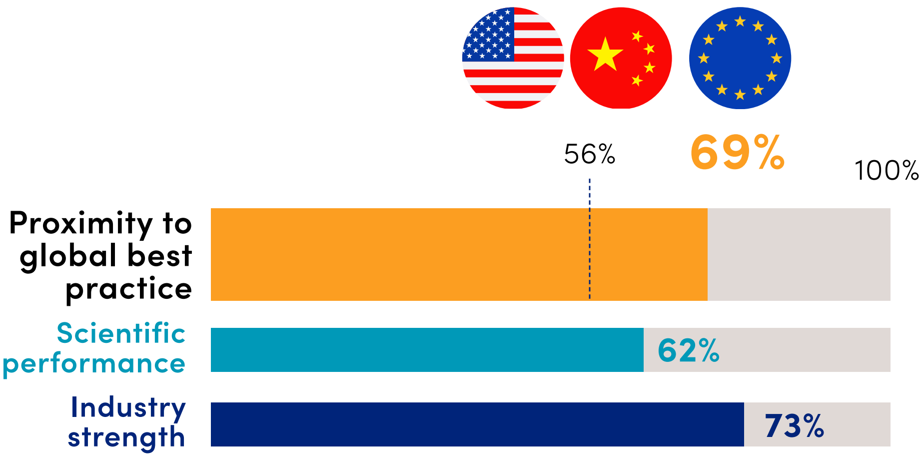
The EU's competitiveness in additive manufacturing stands at 69 per cent, ahead of the US and China. Being home to pioneer companies in this technology, the EU has traditionally enjoyed a robust value chain, and still has a good presence in raw materials supply and design software. However, it faces growing competition from the US and China, and risks losing its historical leadership due to the ongoing market consolidation trends. The main challenges are a lack of coordinated support for European manufactures and insufficient industry uptake. Recommended solutions include providing incentives for adoption, enabling market consolidation, and investing in education to up- and re-skill professionals.

About additive manufacturing

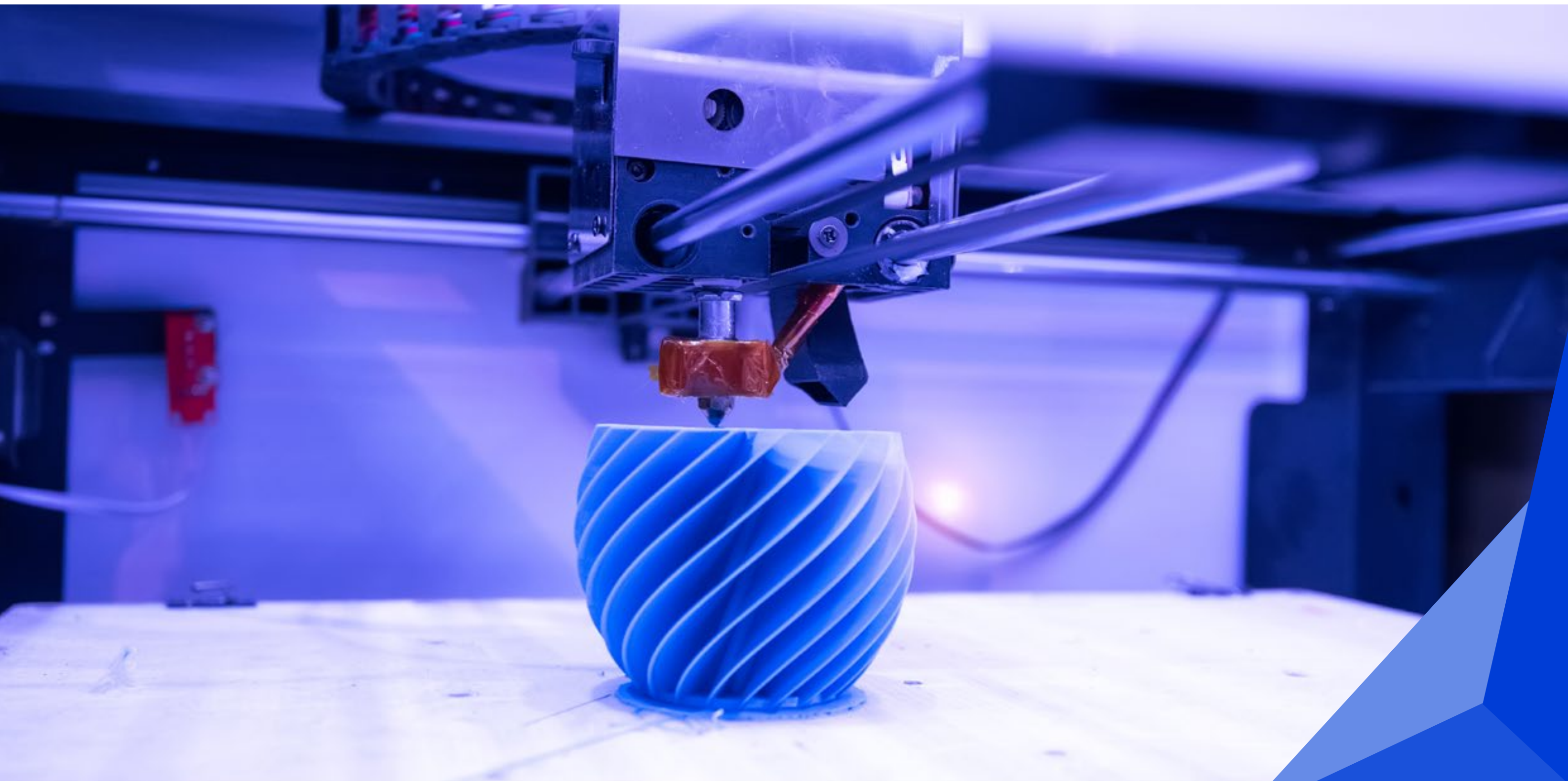
This study delves into additive manufacturing, a sub-category of technologies listed under the Commission's critical technologies, categorised as 'advanced materials, manufacturing, and recycling technologies.' Also known as 3D printing, additive manufacturing is an industrial process that builds three-dimensional products and parts layer by layer using 3D model data. This method offers benefits like enhanced design flexibility, optimised material usage, durability, sustainability and shorter lead times.

Additive manufacturing finds applications across various sectors, including automotive, fashion, defence, healthcare, chemistry, construction and aviation. It's worth noting that whilst specific data on additive manufacturing or 3D printing is used for some indicators, more aggregated data on broader manufacturing processes is used for others due to data availability constraints.

EU global competitiveness



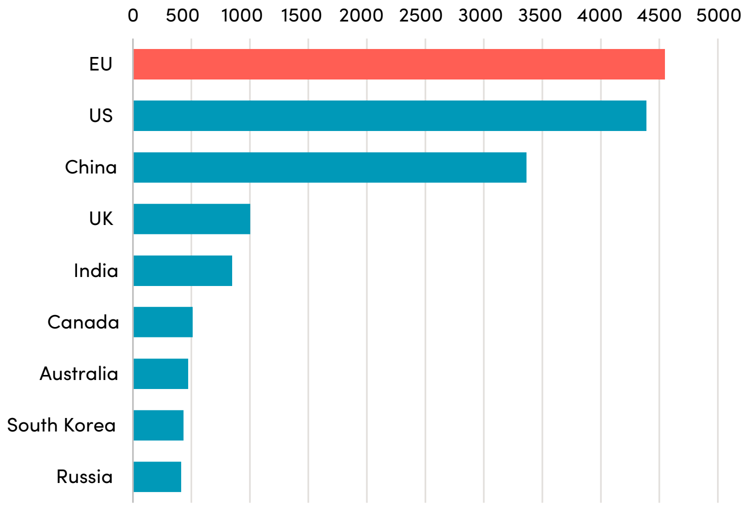
The EU leads in additive manufacturing with a global competitiveness score of 69 per cent, surpassing the US and China, both at 56 per cent. However, this leadership stance is already in question in light of ongoing consolidation trends in the market and increased innovation and adoption in other regions, as discussed below.'



It boasts a strong heritage in this field, with pioneer companies like EOS in Germany, Ultimaker in the Netherlands and Materialise in Belgium. Europe enjoys a robust presence across the value chain and hosts global manufacturers like HP Inc., with its global 3D printing office located in Spain. EY's 2019 study revealed Europe as the region with the highest share of advanced manufacturing firms worldwide (55 per cent).[15]

The EU leads in research output

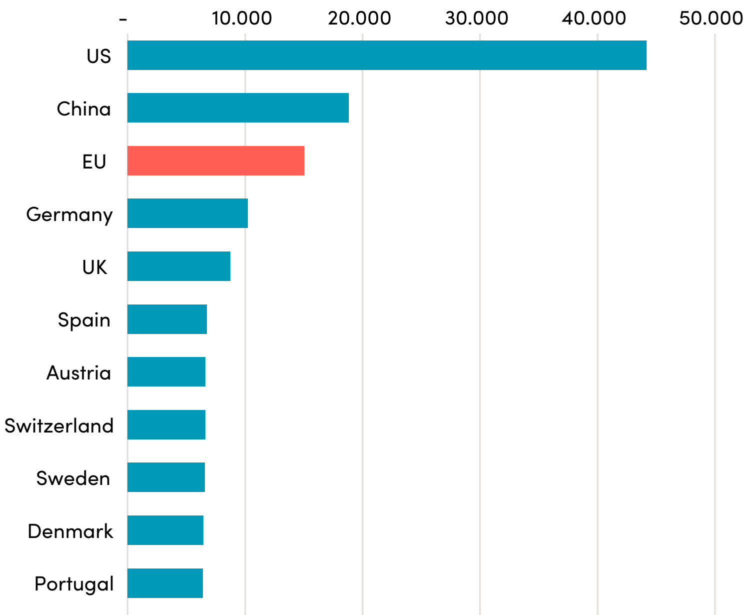
Number of scientific publications



Source: Frontier Economics analysis of ASPI data

The US files 3x more patents for 3D printing products than the EU

Number of patents filed for additive manufacturing by country



Source: Frontier Economics analysis of iam-media.com data

The EU also leads in absolute research output and competes on a similar footing with the US and China in terms of volume of leading publications.

However, the EU's leadership faces challenges from the US, China and Japan, with a growing concentration trend in the market that is either pushing out smaller players or resulting in their acquisition by larger groups.[16] A 2023 study by the European Patent Office found the US leading in 3D printing innovation, slightly ahead of Europe.[17] Currently, four of the top five revenue-generating 3D printing companies are based in the US.[18] Moreover, China is surging as an emerging leader in this field, boasting promising manufacturing capabilities and industry uptake.

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[15] Global EY Report 2019, 3D printing: hype or game changer?, available at: https://assets.ey.com/content/dam/ey-sites/ey-com/en_gl/topics/advisory/ey-3d-printing-game-changer.pdf.
[16] As an example, the German 3D printing manufacturer SLM was acquired by Japanese Nikon in January 2023 and German Concept Laser 3D printing firm was acquired by General Electric in 2016.
[17] "EPO study: Patent filings in 3D printing grew eight times faster than average of all technologies in last decade", September 2023, available at: https://www.epo.org/en/news-events/press-centre/press-release/2023/885238.
[18] Investopedia, "5 Biggest 3D Printing Companies", available at: https://www.investopedia.com/articles/investing/081515/three-biggest-3d-printing-companies.asp.

China dominates global production and exports of 3D printing equipment and leads in the number of businesses with significant R&D spending in this sector.[19] Additionally, Asian businesses, particularly Chinese and South Korean firms, surpass Europe in 3D printing experience and adoption within their industries.[20]

Key hindrances to the EU's leadership include a lack of coordinated support for small-and-medium-sized manufacturers, insufficient funding for start-ups and scale-ups, and a lack of incentives for a higher industry uptake.[21] EU-based additive manufacturing start-ups receive only 1 per cent of the funding available to their US counterparts and 14 per cent of that available to Chinese start-ups.[22]

EU's leadership in additive manufacturing is increasingly contested by other global leaders

Indicator	Leader per indicator	EU Position
Market share of global value added	China	2
Count of leading global R&D businesses	China	3
Patent applications	United States	3
Patent applications, per 1 million people	Switzerland	4
Value of Start-up & Scale-up funding	United States	8
Start-up & Scale-up funding as % GDP	Norway	16
Global gross exports market share	China	2
Exports for the technology as a % of country exports	EU	1
Domestic value added embodied in foreign exports as a share of gross exports	EU	1
Global exports of intermediate goods market share	EU	1

Source: Frontier Economics analysis of OECD, ASPI, Crunchbase, COMTRADE and EU R&D Scoreboard data

[19] 31 per cent of global value added in related manufacturing products (OECD Trade in Value Added data) and 46 per cent of global exports of 3D printing equipment (Comtrade data). 36 of the top 2,500 businesses spending the largest amounts on research and development are Chinese additive manufacturing businesses. The EU has 9 additive manufacturing businesses in the list of top 2,500 businesses. Source: Frontier Economics analysis of EU R&D Investment Scoreboard data).
[20] Global EY Report 2019, op. cit.
[21] See for instance US' Federal AM Forward Initiative to improve the resilience of the US supply chain in additive manufacturing, notably by investing in SMEs and providing technical assistance to support adoption of this technology. Using Additive Manufacturing to Improve Supply Chain Resilience and Bolster Small and Mid-Sise Firms | CEA | The White House.
[22] Frontier Economics calculations using data downloaded from Crunchbase on funding for start-ups and scale-ups, by location of headquarters.

The additive manufacturing value chain

Value chain steps	Main players
1 Raw Materials Supply Sourcing of key materials (e.g. metallic powder, thermoplastic, aluminium, titanium alloys, resins, etc.)	General Electric ATI, Stratasys, Carbon Hoganas, GKN, Sandvik AB, EVONIK, ARKEMA
2 R&D / Design & prototype Product design optimisation with software or other simulation software tools	Autodesk, Altair Materialise, Dassault Systemes, Siemens
3 Manufacture of printing solutions Providers of 3D printing solutions and software	3D systems corporation, HP Inc, Stratasys, Desktop Metal, Markforged, Concept Laser/GE **Asia:** SLM/Nikon, Union Tech, Farsoon, BLT EOS, Ultimaker, Renishaw, Trumpf, Prodways Group
4 Printing Actual printing process where the digital design is turned into a physical object. Some users are also involved in R&D for their own needs and/or provide requirements to manufacturers. Some users outsource printing to service providers in step (7)	Align technologies GM, Ford, Stryker Materialise, Airbus, Bosch, BMW, Siemens, Philips, Volkswagen
5 Post-processing Product finishing, assembling, cleaning of 3D printed parts, grinding and polishing	PostProcess Technologies AMT Kft/Ltd DyeMansion, Volkmann
6 Quality control & inspection Checking printed parts for defects and ensuring they meet quality standards	FARO technologies Reinshaw
7 Distribution & Service Distributing the printed parts and providing support and services to customers, often acting as intermediaries	3D systems, Protolabs, Stratasys Direct Quickparts WeNext Siemens, Materialise, Prototal, Sculpteo, GKN

The EU is present all along the value chain of additive manufacturing, being particularly strong in raw materials supply through prominent Scandinavian suppliers, as well as in design software vendors, with leading names such as Belgian Materialise. The EU also has prominent players in post-processing, quality control and distribution, but increasingly lags in the manufacturing segment, despite notable businesses mainly in Germany and France, due to growing competition from more consolidated markets like the US and China. Lastly, despite having been a frontrunner in additive manufacturing, the EU is quickly losing ground to the US and Asia in the actual industry adoption of this technology beyond prototyping, where the true added value lies.

Risk assessment

The overall risk to the EU's additive manufacturing supply chain is assessed as **moderate**. This is because the EU is rapidly losing ground to other regions that have been heavily investing in domestic manufacturing capabilities and fostering industry adoption over the past decade, as well as to the global consolidation trend that is forcing smaller European players to exit the market or undergo acquisitions by larger foreign groups. Unless the EU significantly invests in manufacturing capabilities, there is a looming concern that the few European players left will disappear.

Recommended measures

To regain its pioneering position in additive manufacturing, the EU should consider the following measures:

1. **Offer incentives and subsidies to EU companies to adopt additive manufacturing**, offsetting its higher costs compared to traditional methods. For instance, Italy's 'Piano transizione 4.0' provides tax credits up to 20 per cent for adopting advanced manufacturing technologies, and offers interest-free loans and grants to innovative start-ups.
2. **Facilitate market consolidation in Europe to align with global trends**, enabling European manufacturers to compete with larger companies and prevent foreign acquisitions, thereby preserving the existing industrial base.
3. **Invest in education and reskilling to address the shortage of engineers.** Integrating additive manufacturing into curricula is crucial, as few engineers possess the necessary competencies. As of 2019, only a minority of technical universities had included additive manufacturing in their programmes.[23]

[23] EY, '3D printing: hype or game changer? – A global EY report 2019,' available at: ey-3d-printing-game-changer.pdf

Advanced connectivity

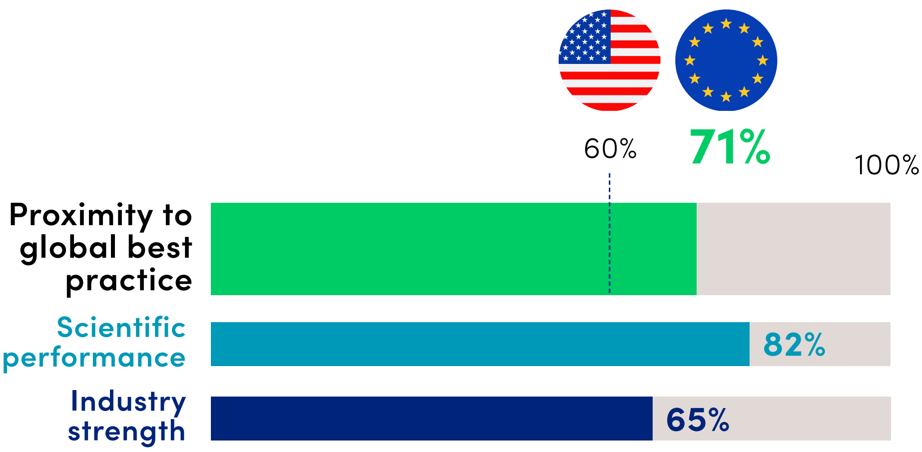
Whilst mainly relying on raw materials and components imported from the US and China, the EU is a leader in R&D for communications networks, as well as in standardisation and network innovation, being home to leading firms in telecoms equipment and services. Despite this, the EU lags in the connectivity services sector, outpaced by the US, China and India, due to a poor business environment largely caused by a lack of market concentration and insufficient user demand, making new technology investments less appealing. Whilst the risk of supply chain disruption is low, the potential impact on critical sectors like defence and healthcare is significant, To enhance competitiveness in connectivity services, the EU should foster a more investment-friendly climate, encourage market consolidation and improve return on investment in the sector.

About advanced connectivity technologies in scope

Advanced connectivity technologies are networks and devices that enable fast, reliable and secure communication between devices, systems and individuals. Whilst there are a range of advanced connectivity technologies, our definition focuses on radio access network (RAN) technology. This is a part of the mobile telecommunications system that uses cellular radio connections to link end-user devices to other parts of the network.

It should be noted, though, that whilst the secondary data used to build the global performance indicator for this technology area includes specific data on advanced radiofrequency communications, it also includes data for broader telecommunications. This is due to constraints over data availability.

EU global competitiveness

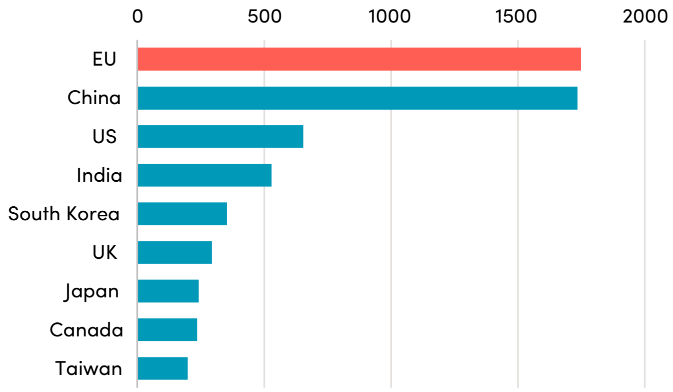


Advanced connectivity is the critical technology where the EU shows the highest competitive performance compared to global practice (71 per cent), ahead of the US at 60 per cent. The EU's overall score is driven by its scientific performance, ranking first in terms of research output both before China and the US.

In terms of industry strength, whilst still registering the highest score across the considered technology areas, the EU is outperformed by global leaders like the US, China, Japan and South Korea in some of the metrics considered, including on patent activity and world's share of value added of related products, as well as on start-up and scale-up funding. Nonetheless, the EU still features in the top two countries in 4 out of the 10 industry strength indicators considered.

The EU is the global leader in research output

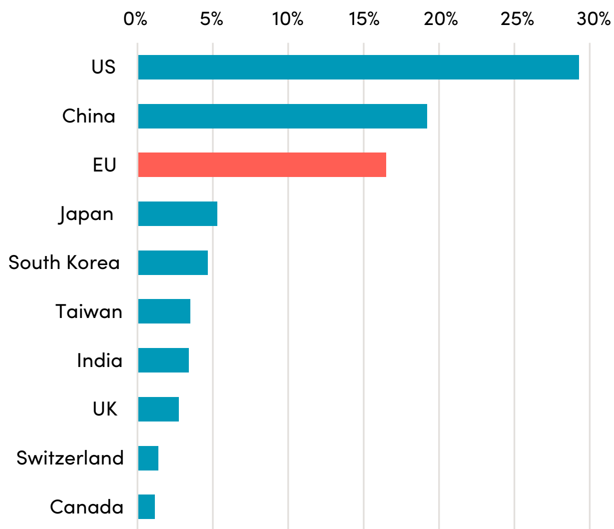
Number of publications



Source: Frontier Economics analysis of ASPI data

While the EU is a leader in advanced connectivity, the US & China are able to capture a greater share of the economic value

Market share of global value added by country



Source: Frontier Economics analysis of OECD data

The EU is a leader in R&D and design for communications networks, including RAN and fibre, as well as in standardisation and system/network innovation, being home to two world leaders in equipment manufacturing. However, the EU lags in 5G infrastructure deployment and fibre rollout compared to other global counterparts such as South Korea, Japan and China, whilst it is approximately on par with the US. Importantly, Europe's competitive advantage in R&D does not translate into market capitalisation, limiting European vendors' options for non-organic growth.

Hindering factors explaining the EU's moderate value capture from advanced connectivity deployment include an overregulated and fragmented telecoms market in the EU, which makes investments in new technologies less attractive and profitable than in more liberal and consolidated markets like the US. This is compounded by uncertainty around European vendors' ability to recoup their R&D investments.

The advanced connectivity value chain

Value chain steps	Main players
1 Raw Materials Supply • Silicon, platinum group metals, gallium, germanium (for chipsets) • Examples of capital equipment: lithography tools, metrology and inspection equipment	
2 R&D Development and standardisation of connectivity technologies, including fixed and mobile.	**RAN vendors** (Ericsson, Huawei, Nokia and ZTE)
3 Components supply Source the required physical hardware: chipsets, antennas, cables, connectors, etc.	**Chipset manufacturers:** Qualcomm, MediaTek, Samsung, Intel, TSMC (TW) **Infrastructure cloud ecosystem:** Intel and AMD + Webscalers (Google, Amazon) **Antennas:** Amphenol
4 Equipment manufacturing Manufacturing RAN & fibre equipment, to be integrated within network infrastructure	**RAN vendors** (Ericsson, Huawei, Nokia and ZTE) **Open RAN vendors** (e.g. Airspan, Parallel Wireless) **Fibre vendors** (Prysmian Group, Nexans, Hexatronic Group)
5 Software development Develop the supporting software to be used in association with technology	**RAN vendors** (Ericsson, Huawei, Nokia and ZTE) **Software specialists** (e.g. ASOCS, Airspan, Altiostar, Mavenir, VMWare, Parallel Wireless, Fujitsu)
6 Infrastructure management & maintenance Infrastructure deployment of 5G networks and fiber roll-out & maintenance. May be done by telecom operators OR by tower companies that sell it as a service (IaS) to telecoms	**Telecom operators** (e.g. Telefónica, Deutsche Telecom, Orange, Vodafone) **Tower companies** (e.g. Cellnex, Inwit, Vantage Towers, GD towers, etc.) **RAN vendors** (Ericsson, Huawei, Nokia and ZTE) **Systems integrators** (Cisco, Wipro, Juniper...)
7 Connectivity services Interconnecting new technology into existing networks	**Telecom operators** (Telefonica, Deutsche Telecom, Orange, Vodafone...)

The EU has substantial presence all along the value chain, with the exception of raw materials and components, which are mostly imported from the US and China. Crucially, it is home to two of the three world leaders in the development and deployment of telecommunications equipment and services, excelling at research, development and standardisation of connectivity technologies. However, **the EU is not a main player in the most profitable step in the value chain, connectivity services**, where the US, China and India are better positioned in terms of business environment and industry uptake.

"We have major assets as global and innovative connectivity leaders in Europe and worldwide. We need to build on our strengths to keep our strong competitive position in the global value chain. Connectivity solutions and mission critical networks are general-purpose technology that will continue to drive and enable economic growth across sectors. In the interest of economies of scale and interoperability, EU regulation should support and foster industry-led global standardisation, a market-driven licensing regime, and timely availability of licensed spectrum in the mid-bands."

Volker Ziegler,
Senior Advisor & Chief Architect, Nokia

Risk assessment

Low to moderate

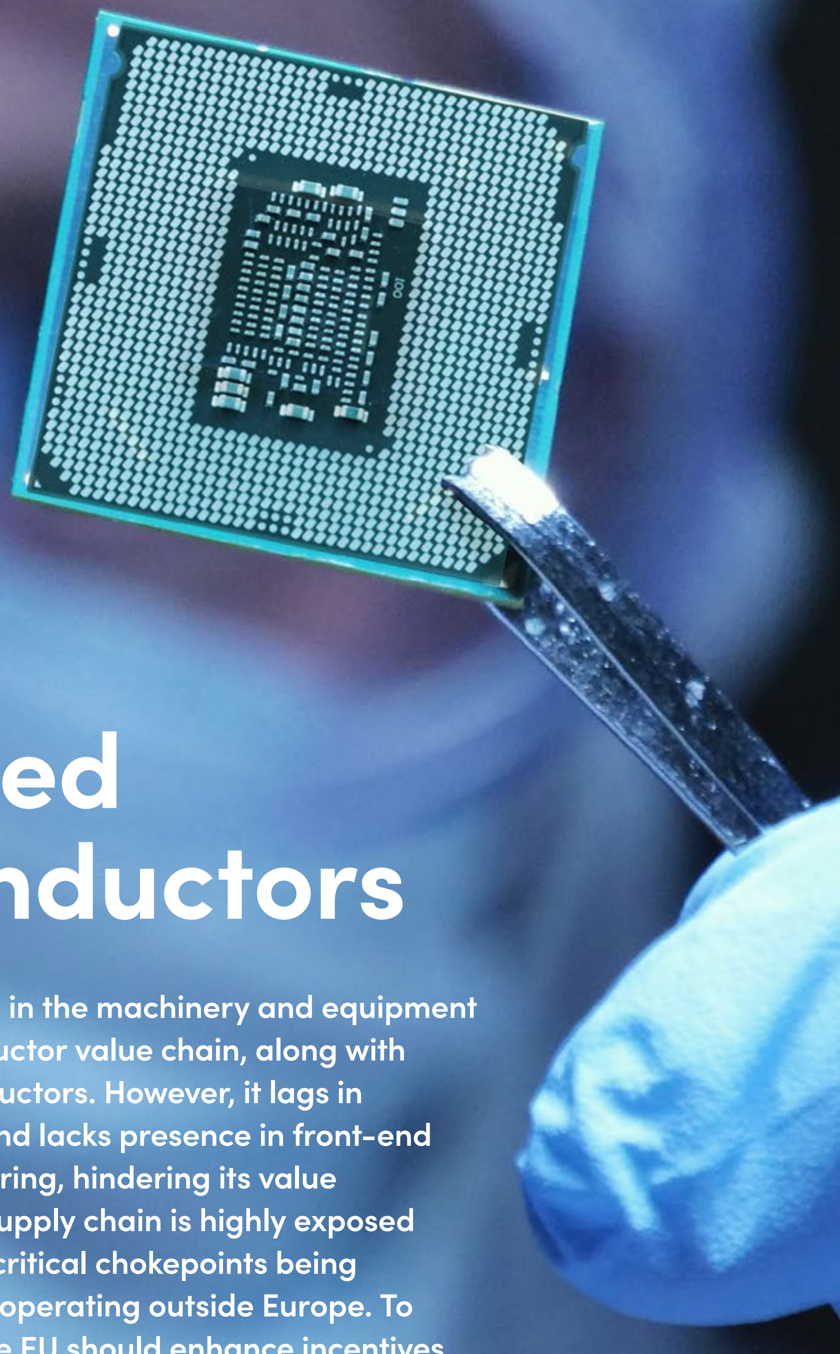
The EU's exposure to supply chain disruption is assessed as **low to moderate**. Whilst the EU is home to two of the world's biggest RAN providers, Chinese players account for a large share of the 5G equipment market in Europe.[24] Additionally, the EU has a high dependency on most raw materials and components required in the manufacture of connectivity solutions. The latter risk is however perceived as low as long as these dependencies stem from like-minded partner countries, and most companies have been adopting supply chain derisk strategies to minimise disruptions.

Recommended measures

For the EU to be competitive in advanced connectivity services, it should:

1. **Foster an investment-friendly environment** by enabling companies to recoup their R&D investments, streamlining regulations, promoting market consolidation and providing favourable deployment conditions. This will make Europe a more attractive location for connectivity vendors to test and roll out their innovative products here before considering other markets.
2. **Partner with third countries** to continue to ensure global standards and scalable markets.
3. **Invest in PPPs** to boost network deployment and demand for connectivity in critical sectors.

[24] For instance, in 2022, 59 per cent of the 5G RAN equipment in Germany was sourced from Chinese vendors. Overall, 41 per cent of mobile subscribers in Europe have access to 5G networks using Chinese equipment (Strand Consult).



Advanced semiconductors

The EU primarily engages in the machinery and equipment segment of the semiconductor value chain, along with some speciality semiconductors. However, it lags in small-node chip design and lacks presence in front-end and back-end manufacturing, hindering its value capture ability. The EU's supply chain is highly exposed to disruption risks due to critical chokepoints being controlled by few players operating outside Europe. To boost competitiveness, the EU should enhance incentives for manufacturers to remain in Europe, and strengthen collaboration between chip customers, designers and manufacturers for a viable foundry model in Europe.

About semiconductors in scope

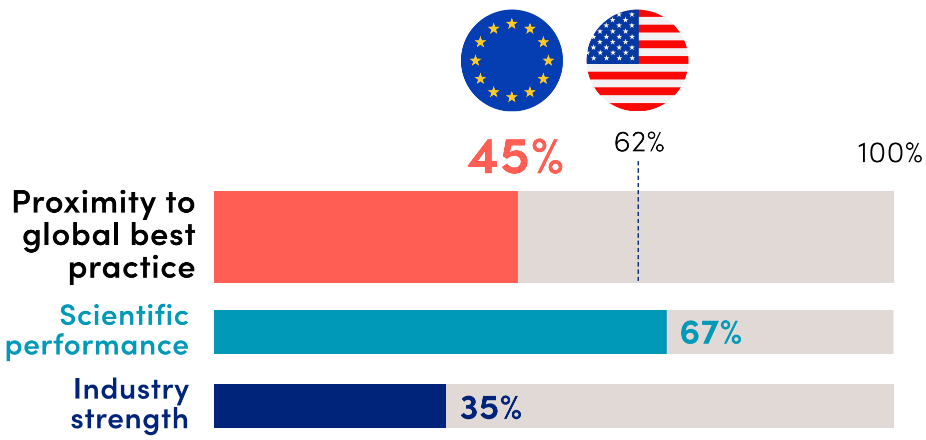
Semiconductors or chips are strategic assets for key industrial value chains, being not only the backbone of computers, smartphones and other electronic devices, but also an enabler of several industries (from automotive to healthcare, space or defence) as well as a crucial input for several critical technology areas, notably AI, advanced connectivity or quantum.

There are at least four dimensions considered as relevant by industry players to distinguish an advanced chip from other chips:

1. **Computing power:** These may include, but are not limited to, the node size of the semiconductor. Advanced chips involve extreme miniaturisation, down to nanometre-scale features. This miniaturisation allows more transistors to fit on a chip, enhancing computational power and efficiency.
2. **Energy efficiency:** These may include, but are not limited to, the architecture of the semiconductor. Advanced chips utilise cutting-edge designs and integrate multiple functions and components, improving overall performance and reducing power consumption. All this leads to greater energy efficiency.
3. **Energy and environmental gains:** These may include, but are not limited to, advanced materials and innovative substrates that offer superior electrical properties compared to traditional silicon and improve chip performance.
4. **Performance:** Advanced chips significantly outperform previous technology, either by leveraging 1), 2) and 3) or by conceptual changes in the overall device, such as new sensor principles or different approaches to electron mobility in power semiconductors.

In our value chain mapping, we focus on semiconductor chips that fulfil a combination of two or more of the dimensions above. It should be noted, however, that the secondary data collected via desk research and used to construct the EU's competitiveness indicators covers a wider range of semiconductor products, and is therefore less specific.

EU global competitiveness

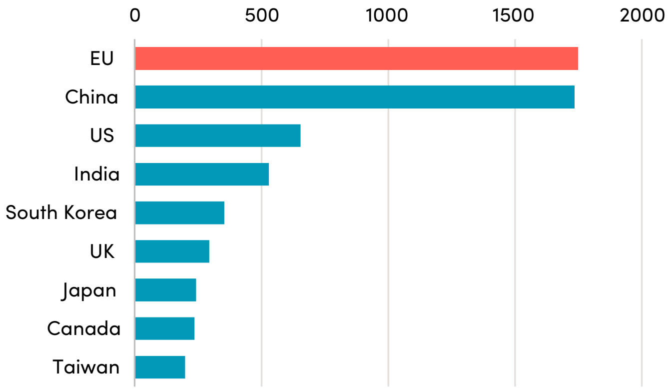


The EU's global competitiveness in semiconductors is at 45 per cent of the global best practice across the considered metrics, with the US ahead at 62 per cent.

The EU ranks first globally in terms of total research output, and competes on a similar footing with other global leaders (the US and China) in leading publications volume, with leading specialised research institutes such as IMEC or Fraunhofer. Additionally, the **EU has significant presence in the upstream stage of the semiconductor value chain**, being home to a key world supplier of essential semiconductor equipment.

The EU is among the top performers in terms of publications

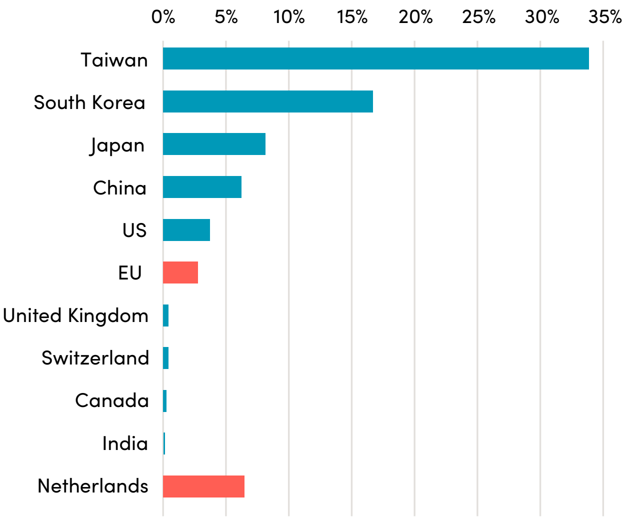
Number of publications



Source: Frontier Economics analysis of ASPI data

Semiconductors represent only 3% of the EU's exports

Share of semiconductor exports out of country exports



Source: Frontier Economics analysis of Comtrade & OECD data

However, the EU shows an overall lower industry strength compared to leaders, due to its limited or no presence in key chokepoints in the supply chain, notably in chip design and in front-end and back-end manufacturing, which mostly concentrates in the US, South Korea and Taiwan. The higher business specialisation and concentration of semiconductor products in Asian countries compared to the EU is shown in the graph on the left, which displays the share of related exports out of a country's total exports, with Taiwan as the global leader. This ultimately hinders the EU's ability to capture value along the value chain, particularly considering that significant value is added at the design stage, where the EU has limited presence.

The main hindering factors for Europe are primarily two. First, the lack of manufacturing incentives on par with those in other regions risks pushing EU-based chip players to prioritise US operations. Second, the foundry model lacks stronger customer buy-in in Europe.

The advanced semiconductors value chain

1 Raw materials and machinery

Raw materials and capital equipment sourced

Equipment:
Applied Materials, LAM Research, Tokyo Electron , ASML (NL)

Raw materials:
Shinetsu, Siltronic (DE), Sumco, GlobalWafers, AT&S (AT), Freiberger Coopound Materials (DE)

2 R&D

Research and innovation in innovative chip technology (e.g. nanoelectronics)

IMEC (BE), Leti (FR), Fraunhofer (DE)

3 Chip design

Development on the design and performance of chips, through specialised software

Electronic design automation:
In US: Cadence, Synopsys
In Europe: Siemens

Chip design:
In US: NVIDIA, Broadcom, Qualcomm, AMD, Apple silicon

In Europe: ARM, RISC-V

4 Front-end manufacturing (foundries)

Wafer foundry, printing (or "etching") the integrated circuit on a silicon wafer

Global: TSMC (TW), GlobalFoundries (US), United Microelectronics Corporation (TW), Intel Foundry Services (US)

Full stack providers:
Global: Samsung (KR), Intel (US), Micron (US), SK Hytexanix (SK)

In Europe: Infineon, NXP, STMicroelectronics, ASM International, Bosch

5 Back-end manufacturing

Assembly, testing and packaging

Advantest (JP), ASE Group (TW), JCET Grup (China), Siliconware (TW), PTI (TW), Teradyne (US), Amkor (US)

6 End use application/ consumption

Assembly of chips onto printed circuit boards, then integrate into high-tech products

The EU's presence is mostly focused on the machinery and equipment segment of the value chain, with a world-leading supplier, ASML. However, the EU has a limited footprint in chip design, the most profitable step in the value chain, with one prominent player in the Netherlands (NXP), another in Germany (Infineon) and two more in wider Europe if architecture and IP development are considered: ARM in the UK and RISC-V in Switzerland. Siemens should also be mentioned as a prominent player in the provision of electronic design automation services that are used in chip design. Despite these players, though, only an estimated 10 per cent of global chip design is carried out in Europe,[25] and only about 1 per cent of global chip design is done by European companies. Additionally, there is negligible turnover of EU-owned chip producers,[26] and the EU's share of semiconductor manufacturing production has fallen from 24 per cent in 2000 to 8 per cent in 2021.[27] In some speciality semiconductor technologies, like MEMS-based sensors or power semiconductors, Europe has global leading players, but still requires back-end processes and compute chips from Asia.

The EU is absent from both front-end and back-end manufacturing of logic chips of the smallest size, despite some US players like Intel or GlobalFoundries having or developing facilities in the EU, and TSMC's recent joint venture with European players to develop an advanced semiconductor fab in Europe. As a result, the EU's current ability to capture value along the advanced chips value chain is low to medium but offers a positive outlook.

Risk assessment

The overall risk to the EU's advanced semiconductor supply chain is assessed as **high** due to a combination of factors. First, capabilities are concentrated in a few large companies, which make up a big share of global semiconductor added value and handle multiple stages of production. Second, these companies are also concentrated in a few countries: the US, Taiwan, China, the Netherlands, Japan and South Korea. Taken together, these countries account for over 75 per cent[28] of global semiconductor added value by geography. One country and company outside the EU alone is responsible for nearly 60 per cent of the front-end manufacturing stage, whilst the EU is mainly present in the upstream part (chip equipment production)[29]. Steps are being taken to increase native EU capabilities in chip manufacturing. For example, TSMC has recently launched a joint venture with European players in chip design (NXP, Infineon and Bosch) to develop advanced chip manufacturing capabilities in Europe.

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[25] ESPAS, 'Global Semiconductor Trends and the Future of EU Chip Capabilities,' *ESPAS Ideas Paper Series*, 2022.
[26] Ciani, A. and Nardo, M., 'The position of the EU in the semiconductor value chain: evidence of trade, foreign acquisitions and ownership,' 2022, available at: https://joint-research-centre.ec.europa.eu/system/files/2022-04/JRC129035.pdf.
[27] Institut Montaigne, 'Semiconductors in Europe: the return of industrial policy,' March 2022, available at: https://www.institutmontaigne.org/ressources/pdfs/publications/europe-new-geopolitics-technology-1.pdf.
[28] A. Haramboure, G. Lalanne et al., OECD Science, Technology and Industry Working Papers 2023/05 Vulnerabilities in the semiconductor supply chain, 2018, available at: https://www.institutmontaigne.org/ressources/pdfs/publications/europe-new-geopolitics-technology-1.pdf.
[29] Ibid, OECD working papers 2018.

Being completely independent in advanced chips manufacturing in Europe is unrealistic. It's not just a matter of investments, but also of having the necessary talent and expertise and to enable EU companies to innovate from a solid base. The EU will continue to rely on specialised fabs located outside of Europe, but we are working with partners on the development of front-end capabilities in Europe that will allow us to produce a wide range of advanced chips products locally.

Stefan Joeres,
Vice President for Semiconductors Strategy, Bosch

Recommended measures

To enhance its competitiveness in advanced semiconductors, the EU should consider the following measures:

1. **Offer direct and indirect incentives and increase investment support for first-of-a-kind chip-related facilities and operations in the EU.** The Chips Act should help accelerate momentum towards pioneering chip facilities in the EU.[30] To attract companies to expand production or establish a presence in Europe, incentives should address both capital (e.g. building or upgrading high-cost manufacturing facilities) and operational expenditures (e.g. measures to mitigate Europe's higher energy costs).[31] This approach will enhance the EU's presence in a highly profitable segment of the value chain.
2. **Facilitate demand commitment for EU-based foundries.** The EU should leverage its convening power to bring together chip customers, designers and manufacturers, and secure commitment for a successful foundry model in Europe. This is vital for the EU to gain presence in a key segment of the value chain, namely front-end manufacturing, where it is currently dependent on other regions. Additionally, the EU should continue to promote closer collaboration between research organisations and industry.
3. **Strengthen partnerships with like-minded countries.** The EU should continue to nurture its alliances and deepen digital partnerships with like-minded partners to ensure the security of the supply chain and its access to the final product. This should be done in conjunction with the other measures outlined above to mitigate the current high market and geographical concentration risk, and be able to produce advanced chips in Europe in the future.
4. **Coordinated Member State efforts in education and upskilling.** The semiconductor industry faces a skills shortage in Europe, with 100,000 new jobs needed annually.[32] It is critical to upskill existing workers, improve mobility of specialists across the EU, and attract global talent with easier procedures.

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[30] Regulation (EU) 2023/1781.
[31] Electricity can account for up to 30 per cent of a facility's total operating costs. See Schneider Electric Reference Guide, Innovative Power Solutions for Semiconductor Fabrication Efficiency, available at: https://download.schneider-electric.com/files?p_Doc_Ref=SPD_RBRO-AY8RJM_EN&p_enDocType=Brochure&p_File_Name=RBRO-AY8RJM_R0_EN.pdf.
[32] Deloitte, "The global semiconductor talent shortage", 2022, available at: https://www2.deloitte.com/us/en/pages/technology/articles/global-semiconductor-talent-shortage.html.

Artificial intelligence

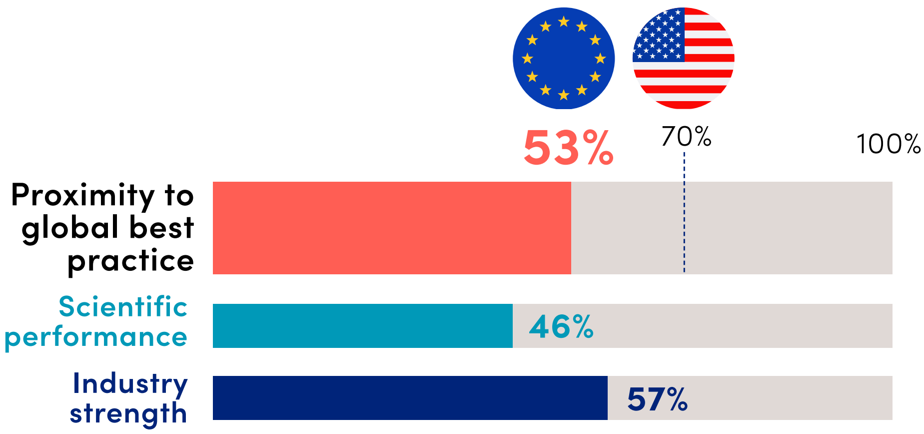
With some of the leading development and integration of business-to-business (B2B) solutions, the EU could become a leader in integrating AI in a myriad of business practices. Yet the EU lacks presence in the early stages crucial for the development of LLMs, such as the supply of advanced processing units. Also, it lacks data centre capabilities which are necessary for the training and inference stages of LLM development. This limits Europe’s ability to fully capitalise on its B2B strengths. To overcome these challenges and boost competitiveness, the EU should increase public and private investments, especially in upstream value chain activities, implement regulatory sandboxes and a one-stop shop for regulatory compliance, and strengthen partnerships with global leaders to ensure its ability to remain at the leading edge.

About AI applications in scope

AI relates to the development of computer systems able to perform tasks normally requiring, or akin to, human intelligence, such as visual perception, speech recognition, decision-making and analytics, and translation between languages. In this report we focus specifically on generative AI, namely AI systems that generate synthetic audio, image, video or text content for a wide range of possible uses and in response to a user prompt.

The AI value chain covers high-performance computing, including cloud, developing and training AI models, developing AI applications and deploying them. In this report, we present the generative AI value chain, which is similar to the broader AI value chain, but with additional complexity of distinction between foundation models and applications, which create greater potential for supply risks.

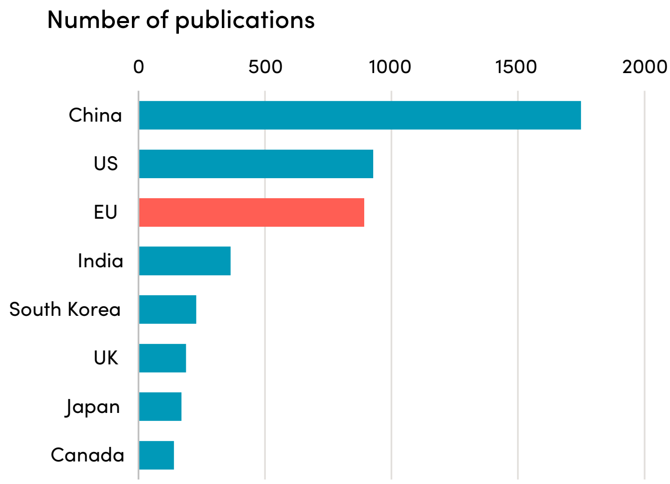
EU global competitiveness



The EU's global competitiveness in AI is at 53 per cent of the global best practice, with the US ahead at 70 per cent.

The EU's **research performance** is similar to that of the US, but is behind China in total output and falls short of countries like South Korea, Australia and Canada when it comes to research intensity (output relative to their population).

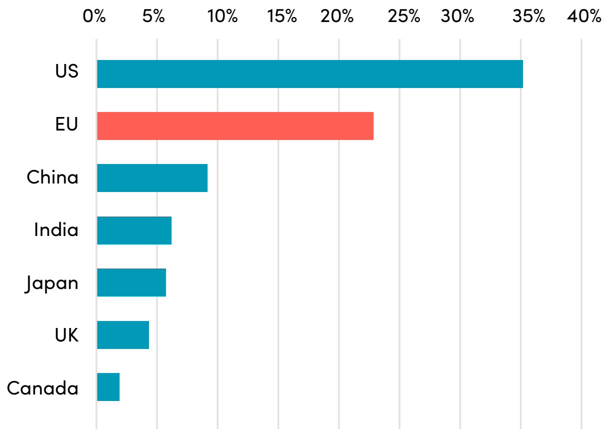
China leads in research output, with the EU closely competing with the US.



Source: Frontier Economics analysis of ASPI data

The US captures 1/3 of the world's value-added in AI-related products

Market share of global value added by country

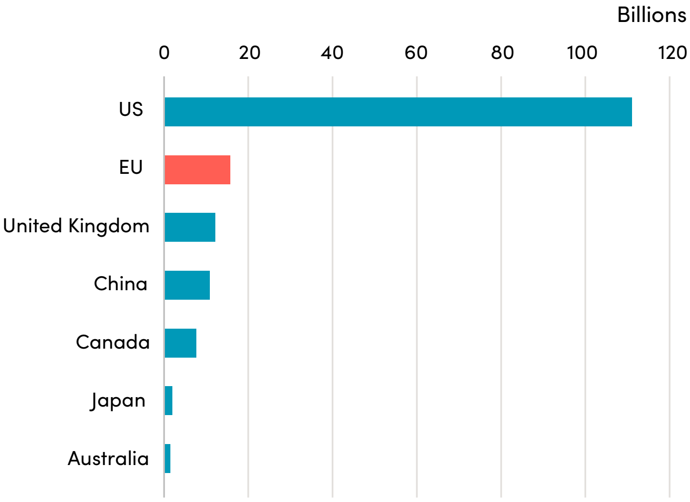


Source: Frontier Economics analysis of OECD data

From an **industry strength** perspective, despite its absence in early value chain stages like advanced processing units and foundation model development, the EU captures significant value in later stages, with strong B2B companies. This is reflected in the EU's relatively high share of the world's total value added of related AI products and services, albeit significantly behind the US.

The US invests about seven times more in AI start-ups and scale-ups than the EU

Start-up and scale-up funding (USD)



Source: Frontier Economics analysis of Crunchbase data

The **main hindering factors** to a higher EU competitiveness are a lack of access to private investment by start-ups and scale-ups compared to the US, a more risk-averse culture, and excessively ambitious expectations for return on investment. Notably, private investment into AI start-ups and scale-ups in the US is approximately seven times larger than in the EU. Private investment in AI has been consistently lower in the EU-27 than in the US and China since 2015.[33] Additionally, the complex EU regulatory framework for data processing makes it more difficult for companies in the EU to use data necessary to train AI systems compared to more liberal regimes like the US.

[33] See the European Court of Auditors' special report, *EU Artificial intelligence ambition: Stronger governance and increased, more focused investment essential going forward*, available at: https://www.eca.europa.eu/ECAPublications/SR-2024-08/SR-2024-08_EN.pdf.

The artificial intelligence value chain

Value chain steps	Main players
1 Semiconductors & advanced processing units supply Development and deployment of gen AI models requires specialised processing units (GPUs)	**Global leaders in processing units:** NVIDIA, AMD **Other players:** Intel, Qualcomm **Interconnection**: Broadcom, Marvell **Potential entry:** Microsoft, Google, AWS designing their custom chips, Groq
2 Data centres & supercomputers Combining hardware components into a supercomputer/data centre Design and implement software to optimise computation	**Cloud computing providers/hyperscalers:** AWS, Microsoft Azure, Google Cloud, IBM, Oracle SAP and big telecom providers (Orange, Deutsche Telecom)
3 Foundation model development Developing and deploying foundation models	OpenAI, Google Deepmind, Anthropic, Meta Llama GLM by Tsinghua University, Huawei Mistral, Aleph Alpha, LightOn, Stability AI
4 AI engineering Tools to curate, host, fine-tune, or manage the foundation models	**Cloud computing providers**, broader IT companies (e.g. Oracle, SAP) **Manufacturing companies** developing sector-specific models (e.g. Bosch, Siemens)
5 Development & integration of GenAI applications Development of software applications for business users or final consumers	Very broad area with many players. Applications are most mature in software development (coding assistants), marketing & advertising and enterprise productivity e.g. SAP, Bosch, Siemens
6 End use applications: deployment & maintenance Use of gen AI applications by end users (business/consumer)	**8% of all enterprises that employ 10+ people in the EU use AI as of 2023** Important market for consulting firms and hyperscalers

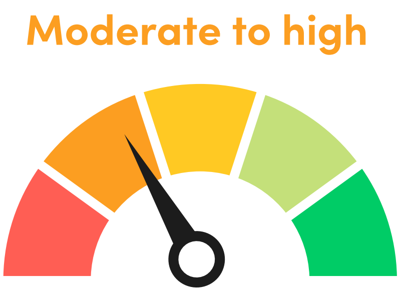
> "To enhance its global competitiveness in generative AI, the EU should invest in cloud infrastructure, regulatory sandboxes, and upskilling to foster innovation and enable companies and start-ups to create powerful and trustworthy AI solutions that strengthen the European industry."

Dr. Philipp Herzig,
Chief AI Officer, SAP SE

The **EU's presence in the AI value chain is predominantly on the application side**, focusing on AI engineering and the development, integration and deployment of generative AI applications. This allows European companies to still capture a significant part of the economic value of AI. The EU particularly excels in the B2B segment, with global leaders such as SAP.

However, the EU lacks presence in the early stages of the value chain, particularly in the supply of advanced processing units essential for developing LLMs. This market is currently consolidated with few suppliers, all located outside the EU. Despite having some capabilities in developing foundation models, with start-ups like Mistral and Aleph Alpha, the EU lacks data centre and supercomputing capabilities, which are critical for LLM development.

Risk assessment



Potential risks to the EU's AI supply chain are assessed as **moderate to high**. EU companies are mainly active in the later stages of the supply chain, making them vulnerable to supply risks from earlier stages. The EU heavily relies on advanced semiconductors crucial for generative AI applications, but is taking steps to enhance its semiconductor supply capabilities.[34] This issue affects most critical technologies, not just AI.

Furthermore, the EU lacks the cloud hyperscaler and data centre capabilities needed for developing LLMs. To ensure a diversified and resilient supply chain, the EU must collaborate with like-minded partners, especially the US given its leadership on the AI field. The most immediate risk to the EU's competitiveness is lagging in AI implementation and business uptake, missing out on productivity gains and economic value.

[34] See for instance the EU Chips Act.

Recommended measures

To enhance its competitiveness, the EU should consider the following measures:

1. **Establish sandboxes and a one-stop shop for regulatory compliance.** AI-related regulations, such as the AI Act and the Data Act,[35] should be implemented simply and uniformly across the EU, avoiding stricter rules than other regions. This will allow EU businesses to compete on a level playing field. Companies should have a single contact point for compliance checks and information, enabling confident growth without legal concerns. The EU and Member States should also promote sandboxes as secure environments for companies to test and refine products, facilitating a business-friendly regulatory approach.[36]
2. **Bridge the funding gap and invest in large-scale infrastructure.** Private investment into AI start-ups and scale-ups in the EU is only a fraction of that in the US (about one-seventh).[37] The EU can lead in later stages of the value chain, especially in the B2B segment, but must ensure companies have the resources and incentives to develop technology within its borders and stay globally competitive. A recent European Court of Auditors report supports this, calling for AI-focused capital support and higher investment targets to match those of global leaders.[38]
3. **Grow AI skills.** The EU must implement measures to attract and retain top talent educated in Europe, by enabling companies to offer competitive conditions and salary packages vis-à-vis other regions. Without these measures, talent will migrate to Asia and the US, causing the EU to lose the return on its investment in high-quality education.
4. **Maintain and nurture cooperation with like-minded partners.** The EU should strengthen collaborations with leading global players, particularly the US. Given the high investment required in hardware and the EU's current limitations in key parts of the supply chain, these partnerships are essential. They will help secure critical tech supplies, maintain a strong value chain and leverage the latest technological advancements.

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[35] COM/2021/206 final (awaiting publication in the Official Journal of the EU) and Regulation (EU) 2023/2854, respectively.
[36] See DIGITALEUROPE, Sandboxing the AI Act: testing the AI Act proposal with Europe's future unicorns, available at: https://cdn.digitaleurope.org/uploads/2023/06/DIGITAL-EUROPE-SANDBOXING-THE-AI-ACT_FINAL_WEB_SPREADS.pdf.
[37] Frontier Economics economic analysis carried out for this study.
[38] European Court of Auditors special report, EU Artificial intelligence ambition, op.cit.

Energy technologies

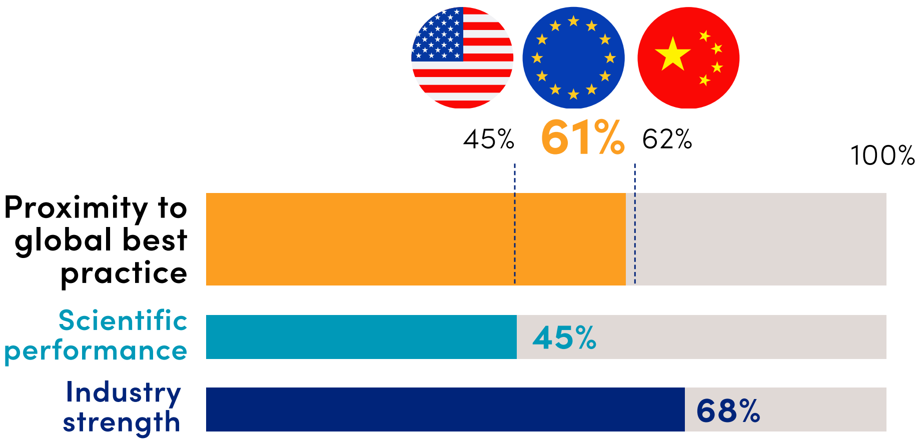
Despite being a global leader in wind power technology and manufacturing, the EU lags China in solar energy due to lower investment and dependence on Chinese materials for solar modules, though it excels in inverter production. Both sectors face high dependence on pre-components and fierce price competition from China. To maintain its competitive edge in clean technologies, the EU should streamline permitting for projects, redesign energy auctions to value more than just price, and incentivise local solar manufacturing. Diversifying supply chains for wind turbine materials and enhancing recycling capabilities in Europe are also crucial. Whilst dependence on China for solar panels may not pose an immediate security risk, the EU's wind sector remains vulnerable to supply chain disruptions.

About energy technologies in scope

The Commission's list of critical technology areas for the EU's economic security includes 'energy technologies,' covering nuclear energy, hydrogen, net-zero technologies, smart grids and batteries. This report focuses on solar and wind energy, which are major renewable sources for the EU, providing 27 per cent of the EU's electricity in 2023 (17 per cent from wind and 10 per cent from solar).[39]

The global best practice score uses a mix of renewable sources, including photovoltaics, electric batteries and biofuels, due to data limitations. These metrics offer context for the EU's overall renewable energy performance, complemented by insights from market leaders on wind and solar.

EU global competitiveness



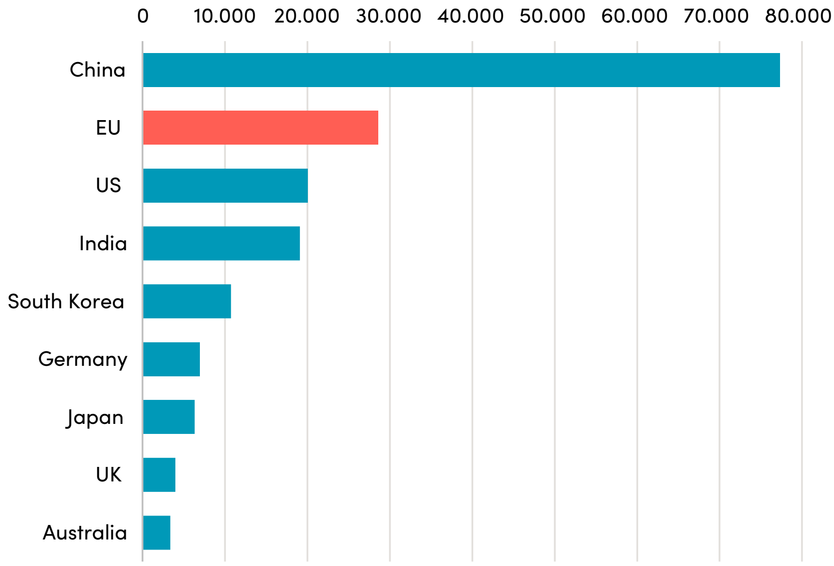
The EU's competitiveness in renewable energies is at 61 per cent of the global best practice, close to China and ahead of the US.[40] The EU outperforms globally in industry strength by 12 per cent, whilst China leads in scientific performance by 28 per cent. This varies by energy source.

[39] EMBER, *European Electricity Review 2024: Europe's electricity transition takes crucial strides forward*, available at: https://ember-climate.org/insights/research/european-electricity-review-2024/#supporting-material
[40] For this specific technology area, China's estimated benchmark is also added.

For **solar power**, the EU excels in inverter production – accounting for 73 per cent of total solar manufacturing jobs[41] – but lags significantly in solar panel manufacturing, relying heavily on imports from China, which produces over 80 per cent of the world's solar PV capacity and 95 per cent of the wafers that are required to produce PV modules.[42] The EU's lower performance in solar panel manufacturing is due to three factors: a significant investment gap compared to leading countries like China, the US, India and Canada, which heavily subsidise PV capacity development or promote local module manufacturing; two-to-three-times higher energy costs than in China or the US;[43] and a significant lack of facilities for raw material extraction and processing, mostly imported from China.

China leads in research output on renewables by a long margin

Number of scientific publications



Source: Frontier Economics analysis of ASPI data

Although Europe has some extraction sites and a polysilicon leader in Germany, it lacks capacity for producing ingots, wafers and solar cells, which are essential components of solar panels. Partly due to regulatory and social barriers against such facilities.

In **wind power**, the EU is the global leader, with a robust value chain and over 250 factories adhering to high sustainability and quality standards.

However, this leadership is threatened by high costs, slow permitting processes, reliance on imports for critical materials (mainly from China), and poorly designed energy auctions. Additionally, the EU's wind turbine recycling capabilities fall short of circular economy targets. All these factors have led to a stagnation in the development of new wind farms in Europe.

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[41] SolarPower Europe, EU Solar Jobs Report 2023 – Bridging the solar skills gap through quality and quantity, September 2023, available at: https://api.solarpowereurope.org/uploads/1823_SPE_Jobs_report_09_0953d35b2a.pdf.
[42] International Energy Agency, "Surging investment in manufacturing of clean energy technologies is supporting economic growth", May 2024, available at: https://www.iea.org/news/surging-investment-in-manufacturing-of-clean-energy-technologies-is-supporting-economic-growth.
[43] SolarPower Europe, "#MakeSolarEU – Rebuilding European solar manufacturing", available at: https://www.solarpowereurope.org/advocacy/make-solar-eu.

The solar power value chain

Value chain steps	Main regions & players
1 Raw materials & extraction Extraction of raw materials required for construction: Steel, cooper, brass, quartzite sand, cement, silica, synthetic oil, cables, etc.	China, US, Brazil & Australia (Unimin, Sibelco, Badger Mining Corporation, US. Silica, Fairmount Santrol, VRX Silica) Norway (Elkem Solar, NorSun, Ferroglobe, etc.)
2 Processing & manufacturing of components • Processing raw materials into precursors • Fabrication of polysilicon into wafers for production of cells • Manufacturing of components for balance of plants (e.g. mounting structure, cables, inverters)	• **China:** 95% of ingot & wafer production • **Others**: Brazil, India, Malaysia, Philippines, USA, Taiwan & South Korea Relevant companies: Tokuyama, Hemlock, ScanWafer, Jinzhou Rixin, etc. **Solar polysilicon:** Wacker(DE) **Ingot & wafer**: NorSun, Norwegian crystal, Nexwafe, Astrasun Solar, Meyer Burger
3 Assembly & finished products Assembling of cells to produce PV **modules & inverters**	China, Brazil, India, Malysia, Philippines USA, Taiwan & South Korea (e.g. Sharp, Kyocera, Sanyo, Panasonic, Mitsubishi) Meyer Burger, Oxford PV, Valoe, SolarWatt, SoliTek, Astrasun Solar, Holosolis
4 Engineering procurement & construction Civil engineering and site preparation, **most value in Europe is captured in this step**	Rooftop market (small companies) & Ground mounted systems (e.g. Enel, Engie, etc.)
5 Distribution and System installation Construction and panel installation	**Local utility/Transmission system operators (TSOs)** e.g. Elia, REE, RTE, Elering, REN, etc. **Energy storage providers:** Sharp, Kyocera, Sanyo, SolEnergy, Shell Solar, Panasonic, Mitsubishi Electronic, etc
6 Grid connection / End use / Storage Connection to the grid to make the energy available to the users	**Utility companies** (e.g. e.on, ENEL, ENGIE, holaluz, Schneider Electric, Vattenfall) **Energy Storage providers:** Tesla, Huawei, OX2
7 Operations & Maintenance & (silicon) recycling Plant decommissioning, recovery of materials/metal and critical minerals	**O&M providers** (e.g. Laketricity, Kastus, SUNOTEC, etc.) **Manufacturers**

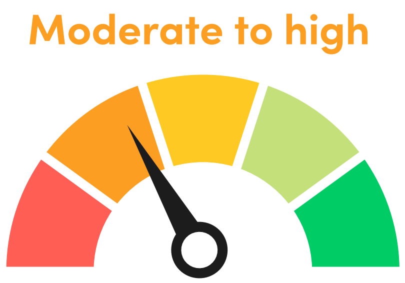
The wind energy value chain

Value chain steps	Main regions & players
1 Raw Materials supply Steel, fiberglass, cooper, ceramics, permanent magnets, aluminum, resins, rare Earths, etc.	**Mainly steel and cooper:** Aurubis AG, Thyssenkrupp, Salzgitter **High dependence on all other materials particularly from China**
2 Raw materials processing Raw materials, manufacturing components, supporting infrastructure & technology for chip and processor fabrication	ArcelorMittal (LU), Thyssenkrupp (DE), LM Wind Power (DK), NLMK (DK), Gurit (SZ), Salzgitter (DE) Tata Steel (India) Hexcel (US)
3 Component design & manufacturing Including: rotor & blades, nacelles, electrical components, steel foundations and substations, large casting components, bearings, etc.	LM Wind Power, Vestas, Nordex, CS wind, WindarRenovables, ABB, Schneider Electric, Siemens Gamesa, Siemens Energy, Smulders, Navantia, GE Vernova, Senvion, SKF, Scheffler TPI composites (US) Hitachy Energy (Japan)
4 Turbine design & manufacturing Developing the control system behind the quantum engine	Siemens Gamesa Renewable Energy, Vestas, Enercon, Nordex, GE Vernova Envision, MingYang, Sany
5 Project development & deployment Site assessment, Land leasing Geotechnical services, Logistics Construction, Offshore wind facilities Auxiliary systems supply	**Wind farm owners:** Orsted, Vattenfall, Enel, RWE, EDP **Deployment of wind farms:** Van Oord, Jan de Nul, Fred Olsen **Site studies & measurements:** mostly small companies (e.g. Vaisala) **Balance of Plant suppliers**
6 Operations & Maintenance	Vestas, Siemens Gamesa, Enercon, Nordex, Vattenfall RWE, GE Vernova **Utility companies** (e.g. EDF, Iberdrola, E.ON)
7 End uses Energy utility companies typically provide this service. Additionally, Power Purchase Agreements (PPAs) are signed between wind farm owners and companies for high-intense uses	**Utility companies** (EDF, Iberdrola, E.ON) **Wind farm owners**
8 End of life - recycling Wind turbine's lifespan is 25-30 years. They need to be decommissioned and become waste or input materials for new production processes	**Highly specialised companies, mostly SMEs:** Veolia, Neowa, Stena Recycling US mainly recycling blades Growing second-hand market going to Africa and South America

In solar power, the EU is present across the value chain, including raw materials extraction, processing, and operations and maintenance, supported by robust R&D. However, it heavily relies on China for materials, with over 90 per cent of global solar polysilicon supply sourced from there. Most EU PV module manufacturers import from cheaper Asian locations.[44] Despite this, the EU leads in inverter production, employing about 70 per cent of solar-related manufacturing professionals.[45] The engineering, procurement and construction (ECP) segment contributes most to added value and jobs in the EU solar sector.

Similarly, in wind power, the EU depends on China for key materials, with over 90 per cent of glass fibre roving and permanent magnets sourced from there.[46] Despite a strong presence in other segments, European wind turbine manufacturers face tough competition from Chinese rivals offering lower prices and favourable payment terms.

Risk assessment



The EU's reliance on China for solar panel manufacturing, whilst concerning, may not immediately jeopardise its competitiveness or security, given the EU's leadership in inverter production and presence in the solar market value chain. However, developing an internal solar panel manufacturing market is essential, although it cannot fully meet EU demand. Currently, Europe has less than 2 per cent of the required integrated module capacities,[47] necessitating partnerships with other countries. In wind energy, the EU's heavy dependence on non-European sources for key materials and pre-components (notably glass fibre rovings and permanent magnets) poses a significant risk, especially for existing wind farms. Efforts to diversify supply sources under the Critical Raw Materials Act are underway,[48] but their impact will take years to materialise. In the meantime, any supply chain disruption in these components could halt wind turbine production or repairs by European manufacturers.

[44] SolarPower Europe, Market Outlook Solar Power 2023-2027, available at: https://www.solarpowereurope.org/insights/outlooks/eu-market-outlook-for-solar-power-2023-2027/detail.
[45] SolarPower Europe, EU Solar Jobs Report 2023, op.cit.
[46] CEPS, *Developing a supply chain for recycled rare earth permanent magnets in the EU*, December 2022, available at: https://cdn.ceps.eu/wp-content/uploads/2023/07/CEPS-In-depth-analysis-2022-07_Supply-chain-for-recycled-rare-earth-permanent-magnets-1.pdf and Wind Europe, "Ensuring access to critical materials for steel and wind sectors essential for EU clean-tech economy", January 2023, available at: https://windeurope.org/newsroom/press-releases/ensuring-access-to-critical-materials-for-steel-and-wind-sectors-essential-for-eu-clean-tech-economy/.
[47] SolarPower Europe, Market Outlook Solar Power 2023-2027, op.cit.
[48] Regulation (EU) 2024/1252.

Recommended measures

For the EU to be competitive in clean energy technologies, it should

On both solar and wind power:

1. **Simplify regulation to facilitate the construction of new solar factories and wind farms in Europe,** as the current permitting process is too cumbersome and long compared to other regions.
2. **Review the design of renewable energy actions to reward project bidders on other criteria than just price,** including sustainability, safety or efficiency, to ensure a level playing field for European manufacturers that are subject to stricter quality requirements compared to manufacturers in cheaper locations.

Additionally on wind power:

1. **Encourage local material sourcing**, by setting regulatory thresholds and offering tax incentives to European manufacturers to support the development of selected materials and pre-components made in Europe until they become competitive on price at the global scale. This would allow the EU to diversify its supply chain and be less exposed to disruptions affecting its manufacturing industry.
2. **Improve grid development planning and buildout**, by leveraging both private finance and public funding from the European Investment Bank. The electrical grid expansion pace emerges as a main bottleneck that is slowing down the connection of new wind farms and is a major challenge for project developers across Member States.[49]
3. **Increase investment in recycling capabilities in Europe for wind turbine components** to truly support the growth of a circular economy aligned with ambitious regulatory targets. At the moment the market for recycling is small given the long lifespan of wind turbines, and it is mostly being handled by specialised SMEs. This market is expected to grow in the coming years, from 2030, and Europe must ramp up its capabilities.

[49] WindEurope, Wind energy in Europe: 2023 Statistics and the outlook for 2024-2030, available at: https://windeurope.org/intelligence-platform/product/wind-energy-in-europe-2023-statistics-and-the-outlook-for-2024-2030/.

Health biotechnologies

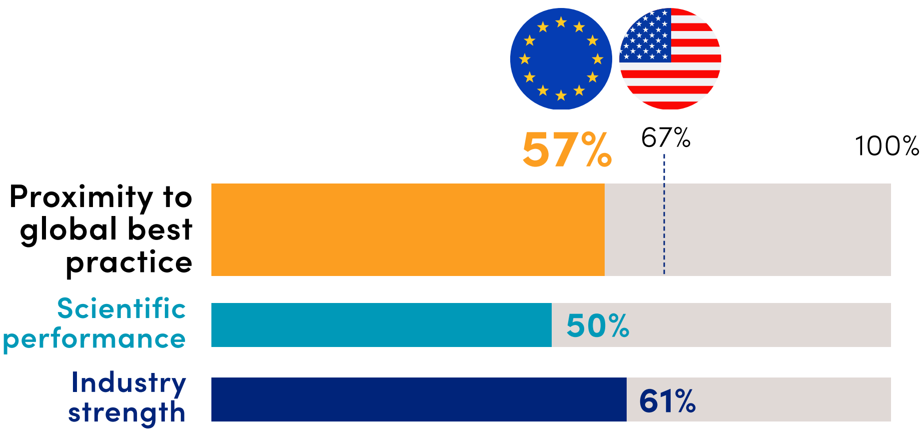
Though strong in R&D, the EU heavily relies on raw materials from US and Chinese biobanks, and lacks greater capabilities in both process development and manufacturing compared to the US. The region's biotech sector suffers from an unfavourable business environment and restrictive, burdensome and research-focused funding, driving large EU biotech firms to develop and scale their products and therapies in the US. To improve its competitiveness, the EU needs to develop local biotech processes and manufacturing through a business-friendlier environment and adequate funding support to manufacturers.

About health biotechnologies in scope

Biotechnology is defined by the OECD as 'the application of science and technology to living organisms, as well as parts, products and models thereof, to alter living or non-living materials for the production of knowledge, goods and services.'[50] This is a broad technological field, with a range of techniques and applications across sectors.

Our report specifically examines health biotechnology, which utilises living cells and materials to produce medicines or develop therapies. Whilst the global performance analysis includes data on synthetic biology, it also includes aggregated biotechnology data for some indicators due to limitations. This approach ensures findings closely relate to health biotechnologies whilst encompassing a broad set of indicators.

EU global competitiveness

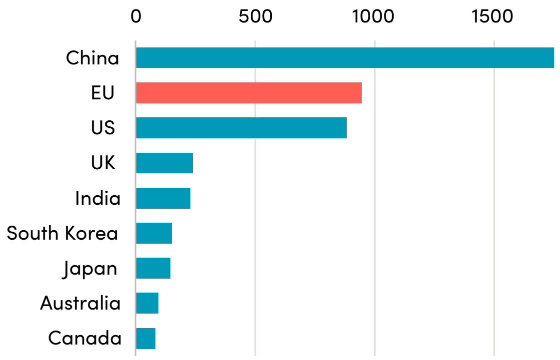


The EU's global competitiveness in health biotechnologies is at 57 per cent of the global best practice, with the US ahead at 67 per cent.

[50] OECD, "Key biotechnology indicators", November 2023, available at: https://www.oecd.org/science/keybiotechnologyindicators.htm.

The EU competes with the US on research output

Number of publications

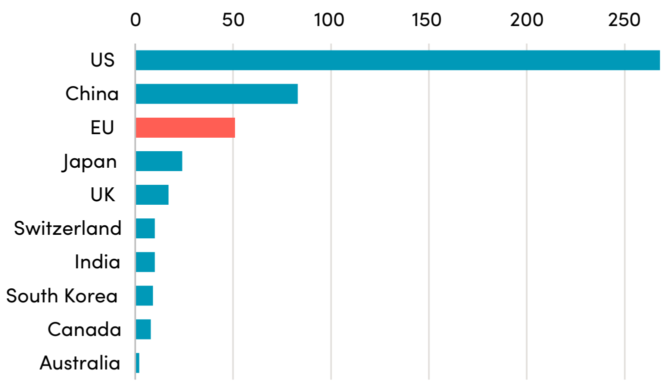


Source: Frontier Economics analysis of ASPI data

In terms of research output, the EU closely competes with the US at 59 per cent, but both lag significantly behind China. This disparity may be attributed to China's increased clinical trial activity for advanced therapies medicinal products (ATMPs), where the number of trials is nearly three times that of Europe and twice that of the US.[51]

The US has 5x more global R&D spenders in pharma & biotech than the EU

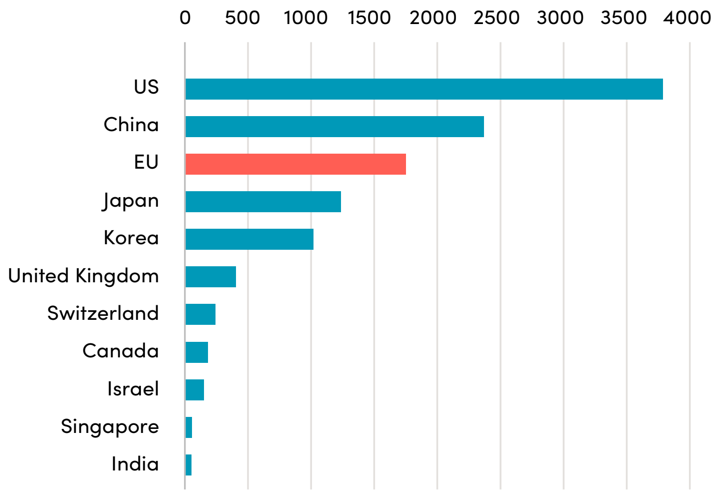
Count of leading R&D businesses in Pharma & Biotech (out of 2,500 top)



Source: Frontier Economics analysis of EU Innovation Scoreboard data

The EU lags in patent activity

Number of patents



Source: Frontier Economics analysis of OECD data

However, the EU falls short compared to the US in scaling up new products and therapies, where the true added value lies. This is evident in its lower patent activity and a smaller share of added value from related products. Additionally, the US leads with over 250 of the largest R&D pharma and biotech businesses globally, compared to 50 in the EU. About 50 per cent of the world's ATMP manufacturing capabilities are concentrated in the US.[52]

Because of these factors, the EU's ability to capture value along the value chain is **moderate**, despite it being home to large and world-leading pharma and biotech companies. Many of these companies prefer the US as a manufacturing location due to its more favourable business environment in terms of regulation, timelines and funding support, including access to venture capital. EU funding is considered restrictive, limited in size and overly research-driven, which is not attractive for manufacturers.

[51] EFPIA, "Europe's share of global medicines R&D shrinks by a quarter in 20 years – as sector's declining trends continue", November 2022, available at: https://www.efpia.eu/news-events/the-efpia-view/efpia-news/europe-s-share-of-global-medicines-rd-shrinks-by-a-quarter-in-20-years-as-sector-s-declining-trends-continue/.
[52] Ibid.

The health biotechnologies value chain

Value chain steps

1 Sourcing & procurement of raw materials

Supply of consumables (e.g. cells, vectors, Active Pharmaceutical Ingredients, etc.).

2 Research & Development

Discovery and preclinical research, clinical trials and regulatory approval

3 Process development and manufacturing

Biotech processes for the manufacturing of *Advanced Therapeutical Medical Products* (ATMPs) are very specialised and unique and increasingly based on single-use technologies

4 Distribution and logistics

Packaging, distribution, storage and preservation

5 Patient administration

On-time delivery of the drug or therapy to the end user (e.g. hospital or patient)

Main players

Biobanks:
Global: Shanghai Zhangjiang Biobank, China Kadoorie Biobank, All of Us (US), The International Agency for Research on Cancer Biobank (IARC)

In Europe: Biobank Graz (AT)

Other specialist companies:
US: Twist Bioscience, Gen9, DNA2.0, Genscript

Specialist biotech companies & software service providers:

Global: Riffyn, Thermo Fischer, Synthetic Genomics, BeiGmene, Chongqing Biological Products, Cytiva

In Europe: Desktop Genetics, Algenuity, BioNTech, Synthace

Contract Development & Manufacturing Organisations (CDMOs):
Global: Wuxi, Catalent, Patheon

In Europe: Lonza, Fareva, Recipharm AB, Ingenza, Delpharm

Large pharmaceutical companies:
Global: Eli Lilly, Johnson&Johnson, Merck, Pfizer, Chugai Pharmaceutical, Takeda, Jiangsu Medicine

In Europe: Novo Nordisk, Roche, AstraZeneca, Novartis, Amgen, Sanofi, Bayer

Specialised logistics companies:

Global: UPS healthcare, FedEx

In Europe: Kuehne+Nagel, DHL Global Forwarding, DB Schenker

The EU excels in R&D, yet approximately 90 per cent of clinical trials occur outside Europe, mainly in China and the US. The EU faces a significant dependency on raw materials, such as Active Pharmaceutical Ingredients (APIs), procured mostly from biobanks in the US and China, with limited facilities in Europe. Moreover, the EU lags in process development and manufacturing, crucial segments where added value is captured, often dominated by the US, despite leading European pharma and biotech companies.

Global companies consider various factors when selecting their manufacturing locations, including regulatory aspects, proximity to contract development and manufacturing organisations (CDMOs), technology suppliers, patients and final delivery points. Specialised companies providing custom processes and single-use technologies for new cell and gene therapies are not all based in Europe, driving manufacturing capabilities beyond the EU.

Risk assessment

Moderate

The overall risk to EU's health biotech supply chain is assessed as **moderate**, primarily due to its dependence on raw materials and manufacturing capabilities from the US and China. Furthermore, for certain diseases, clinical trials are the only treatment option for patients. If clinical trials continue to trend towards non-EU locations, the EU risks losing scientists and missing opportunities to offer experimental drugs to patients. Additionally, the EU's relatively limited manufacturing capabilities for new biological products and therapies, especially compared to the US, poses a risk to its public health system, considering that an estimated 6,000 diseases remain without treatment. Lastly, lagging in health biotech could potentially threaten the EU's national security, given the potential for future weaponisation of this technology for human enhancement purposes.

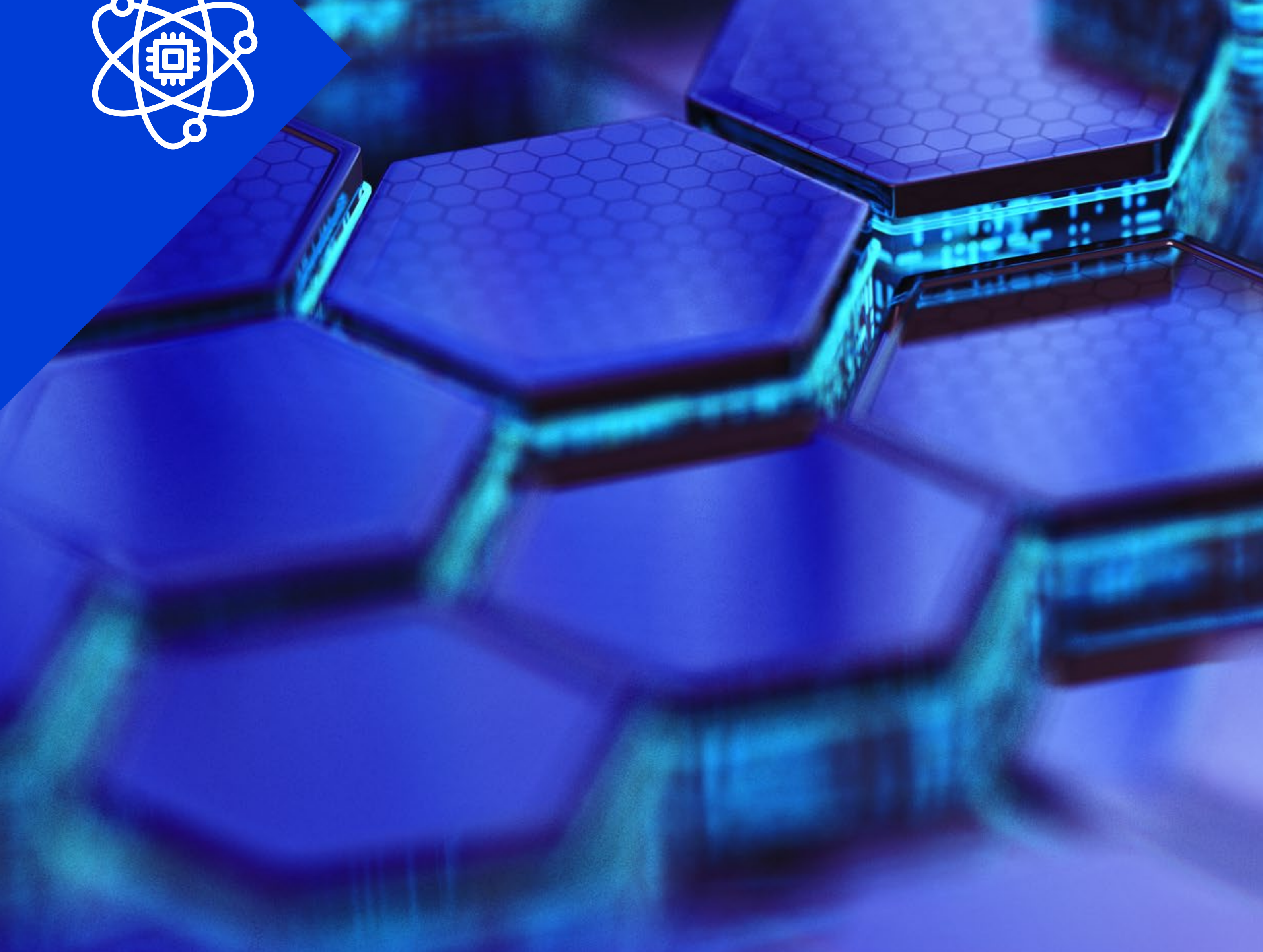
Recommended measures

To enhance its competitiveness in health biotechnology, the EU should:

1. **Revolutionise the current EU funding model,** by substantially increasing the size of support and making it more attractive for biotech manufacturers to apply for funding. EU funding instruments are restrictive and mainly research-driven, and become inaccessible for biotech start-ups progressing their therapies beyond research.
2. **Foster the use of PPPs in the health biotech field,** enabling joint innovation and the development of new products combining private investment with public funds, as opposed to the current model driven by private investment, as well as a stronger collaboration between industry and academia in support of effective innovation.
3. **Develop a holistic approach to biotech at EU level,** seeing it as not only a source of economic growth, but also a strategic area with public health and national security implications, like other leading regions do. The EU should aim at ensuring end-to-end presence in the supply chain by controlling the key steps in the process.
4. **Create a more enabling regulatory environment for biotech players,** by removing entry barriers and reducing long time-to-market timelines. This would make the EU attractive for start-ups, which are important partners to big manufacturers, allowing the EU to compete with other regions like the US, which benefit from an active and larger start-up biotech ecosystem.

Quantum computing

Although quantum is a nascent industry, the EU is currently competitive in R&D and component development, with a fast-growing start-up ecosystem along the value chain. Despite this, the EU falls behind in hardware development, where the future competitive advantage lies. Supply chain stability is currently ensured, yet vulnerable without equivalent investments to those of the US and China. To stay competitive, the EU should consolidate its market by increasing the size of investments and focusing them on centralised manufacturing facilities and go-to-market applications, moving beyond primary research. In short, the EU should support and secure domestic quantum chip fabrication capabilities now to avoid undergoing the same fate of chips.

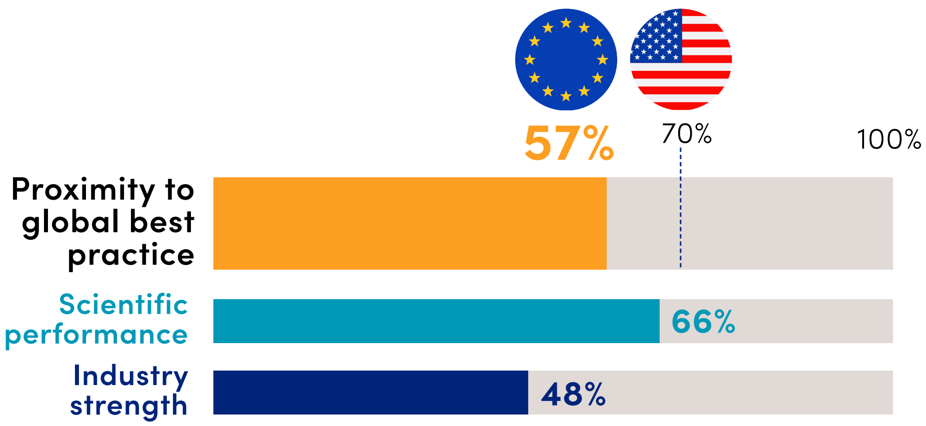


About quantum technologies in scope

Quantum computing utilises quantum mechanics to solve complex problems faster than on classical computers. Our definition of the quantum computing critical technology is centred on the development and manufacturing process to build a quantum computer, with associated software to run the quantum computer and applications using quantum computers.

Quantum cryptography and quantum communications are both noted as applications of quantum computing, but are not subject to supply chain risk analysis. This is because these are substantial advanced technological fields in their own right, with their own supply chains and applications.

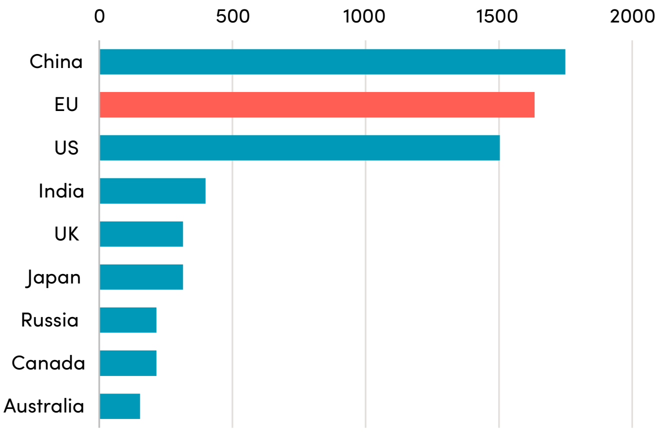
EU global competitiveness



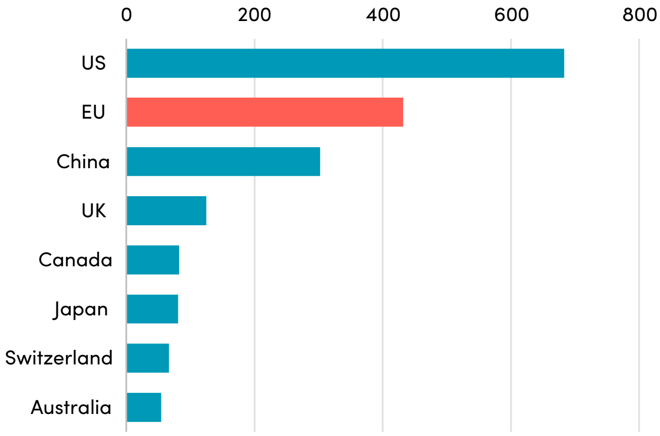
The EU's global competitiveness in quantum computing is at 57 per cent of the global best practice, with the US slightly ahead at 70 per cent per cent compared to the ideal competitiveness target.

The EU excels in research output in quantum along China but lags behind the US in quality

Number of publications



Number of leading publications



Source: Frontier Economics analysis of ASPI data

The EU leads alongside China in research output, whilst the US excels in leading publications.

From an **industry strength** perspective, the EU ranks third after the US and China in terms of world’s share of value added in related products. The EU's market share of global added value in quantum computing is particularly concentrated in Germany and France, who have the largest national quantum programmes in Europe.

In contrast to the US, where several big tech players dominate the quantum computing space, Europe’s quantum industry is largely start-up based, with many smaller players – mainly concentrated in France, Finland, the Netherlands, Germany and Spain – operating in different steps of the value chain.

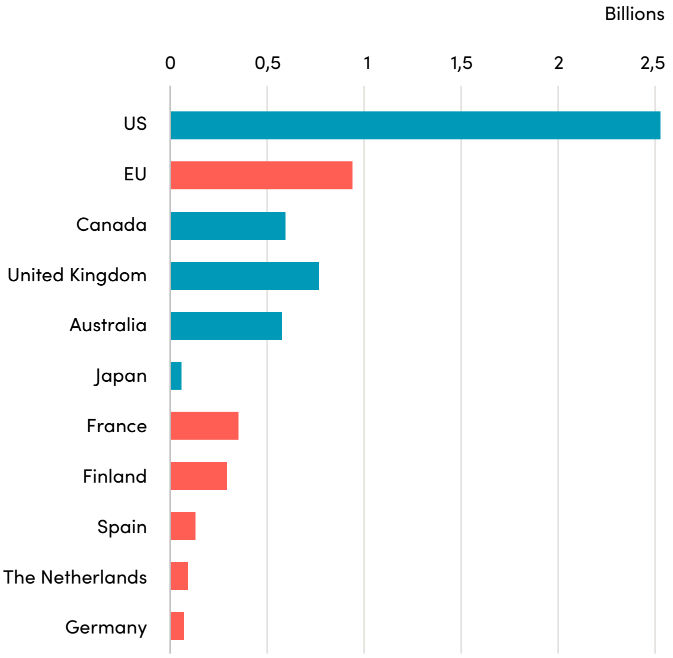
Whilst quantum computing is still in an early stage of development, the US is leading the world’s race in this technology, powered by a stronger presence along the value chain through global business leaders and a more consolidated market than the EU.

Whilst the EU still stands a chance to compete with the US, large and focused investments in facilities and systems for quantum processor fabrication comparable to those in the US or China and a strategic approach on quantum are needed at EU level. At present, companies can raise almost three times more private investment in the US than in the EU. From a public sector perspective, both the US and Chinese governments are heavily subsidising quantum computing, with the US having already committed about €4 billion in funding for quantum projects and China expected to invest at least €14 billion over the next five years.[53]

[53] Nancy Liu, “China invests billions in quantum computing, race with US now neck-and-neck”, SDxCentral, February 2024, available at: https://www.sdxcentral.com/articles/analysis/china-invests-billions-in-quantum-computing-race-with-us-now-neck-and-neck/2024/02/.

Quantum companies in the US are raising almost three times more private investment than those in the EU

Start-up & scale-up funding (in USD)



Source: Frontier Economics analysis of Crunchbase data

The Quantum computing value chain

The **EU is currently present all along the value chain with the exception of raw material sourcing**, and competes on an equal footing with global leaders like the US and China in R&D and components development. However, the EU **lags particularly in hardware development**, with very limited presence and smaller players especially compared to the US.

This is the most crucial and unresolved step in the value chain that will shape future profitability prospects. Nonetheless, the EU shows an overall medium ability to capture value along the value chain under present circumstances due to its vibrant start-up ecosystem, particularly in the software development segment.

Quantum sovereignty will become a critical success factor for the competitiveness and the security of Europe. Quantum technologies will drive the next strategic and military superiority, making also quantum processor fabrication facilities an essential infrastructure and Europe needs to have a viable and sovereign solution for it.

Jouni Flyktman,
Vice President, Defence and Security at IQM Quantum Computers

Value chain steps	Main players
1 Quantum Mechanics R&D Foundational/ Theoretical research on quantum mechanics and physics	**IBM, Google, Honeywell**, MIT, Harvard, Max Planck Society, Chicago, California, Chinese Academy of Sciences Oxford, Aalto University, Ludwig Maximilian University
2 Inputs, components, support technologies Raw materials, manufacturing components, supporting infrastructure & technology for chip and processor fabrication	**IBM, Google, Honeywell**, Cyromech, Lake Shore, Cryotonics, Quantum Design, Keysight, Veeco, Quantum Machines (IL) Oxford Instruments, Zurich Instruments, Qblox, Delft Circuits, Bluefors, Riber, **IQM** Quantum Computers
3 Hardware platform & assembly Designing and fabricating the quantum computing platform, where calculations are made.	**IBM, Google, Honeywell**, IonQ, Microsoft, D-wave system, Rigetti, Quantum, Quantinuum, Origin Quantum QuTech, Oxford Quantum Circuits, Pasqal, plaqc, QuantWare, Quandela, Alice & Bob, ORCA computing, AQT, **IQM**
4 Management platform & system access Developing the control system behind the quantum engine	**IBM, Google, Honeywell**, Amazon Bracket, Microsoft Azure, Quantum, Strangeworks, Quantinuum, IonQ Quantum AI (India), Q-CRTL (Australia) ParTec, Qmware, Qilimanjaro, Oxford Quantum Circuits, **IQM**
5 Software development & application discovery Designing and writing software used in quantum computing	Zapata Computing, QC-Ware, 1QBit, QxBranch, Xanandu, SandboxAQ, Entropica Labs (Singapore) Cambridge Quantum Computing, Riverlane, Atos Quantum Learning Machine, Terra Quantum, Multiverse Computing, Quantagonia, QuantrolOx, Algorithmiq, **IQM**
6 End uses Business and research uses for quantum computing and software	

Risk assessment

The overall risk to the EU's quantum computing supply chain is assessed as **moderate**. This is due to high non-EU market concentration at the complex and capital-intense hardware development stage. Whilst the EU has some presence along the supply chain through a buoyant start-up ecosystem, its global position is highly vulnerable unless backed by a higher level of investment as already committed by the US and China, allowing it to match the clean room facilities needed to produce quantum chips and processors to the required capabilities and size. Losing the quantum advantage could pose a risk to the EU's future competitiveness, by exposing EU businesses in the quantum computing value chain to potential access limitations to the required quantum chips, or to higher access costs. Lastly, whilst quantum technologies are still a nascent industry, they are expected to be central in military and defence terms, with crucial implications for the EU's security.

Recommended measures

To remain a key player in the quantum computing global race, the EU should:

1. **Substantially step up investments to match those in the US and China, and consolidate its market.** The EU should increase the volume of investments and concentrate them in building centralised facilities for quantum chip fabrication. This would strengthen the EU in a crucial and unresolved segment of the supply chain that is prohibitively expensive and poses high market entry barriers for any small player. Additionally, the EU should focus funding on building state-of-the-art and large-scale quantum computing systems, as well as on go-to-market applications rather than only on research, where Europe is already excelling.
2. **Encourage a coordinated EU strategy on quantum**, by addressing the current fragmentation of national plans and by bringing corporate players closer to research institutions to accelerate innovation.
3. **Avoid regulating this novel technology too early** prior to understanding its potential, as doing so could undermine the EU's ability to gain a quantum advantage.

Space technologies

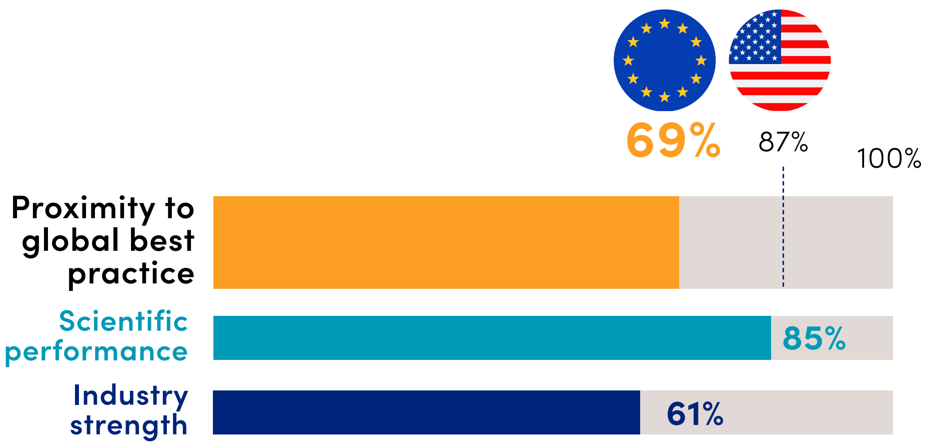
The EU excels in navigation technologies through its Galileo programme, and is competitive globally in Earth observation and satellite communications. However, its capabilities in launch services and space surveillance are moderate, with expectations for Ariane 6 to address this gap. Despite this, the EU faces a significant public investment shortfall compared to the US, spending about 6-7 times less. This, coupled with reliance on non-European sources for key components, challenges the EU's space sector performance. To enhance competitiveness, the EU should increase public investments, especially in critical component manufacturing capabilities, invest in STEM talent, and foster profitability and a level playing field for European manufacturers.

About space technologies in scope

Aerospace technology includes the research, design, manufacture, operation or maintenance of both aircraft and spacecraft, as well as satellites. This study addresses the 'space and propulsion technology' category within the Commission's list of critical technologies, focusing specifically on the manufacture of satellites and the associated navigation, space surveillance and Earth observation technologies.

It should be noted that the secondary data used for global performance indicators includes specific data on small satellites for some indicators and aggregated aerospace data for others due to data availability constraints.

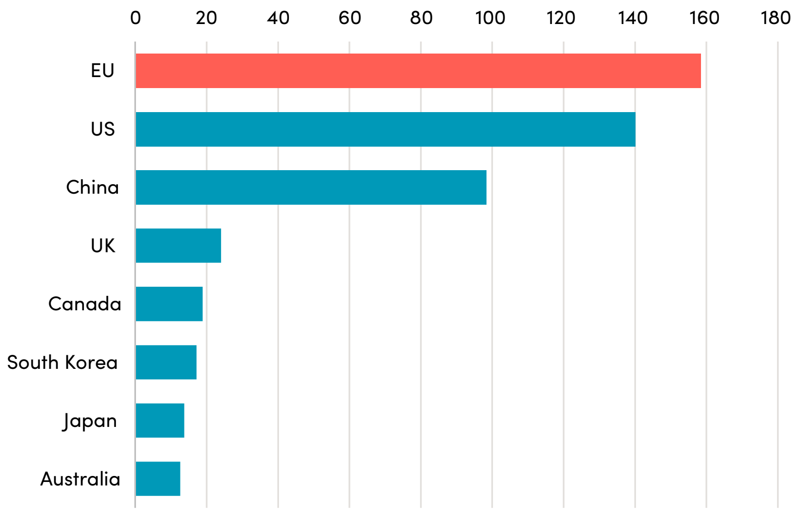
EU global competitiveness



The EU's global competitiveness in space technologies is at 69 per cent, trailing significantly behind the US at 87 per cent, despite showing stronger research performance.

The EU is the global leader in the quality of space research

Number of leading scientific publications

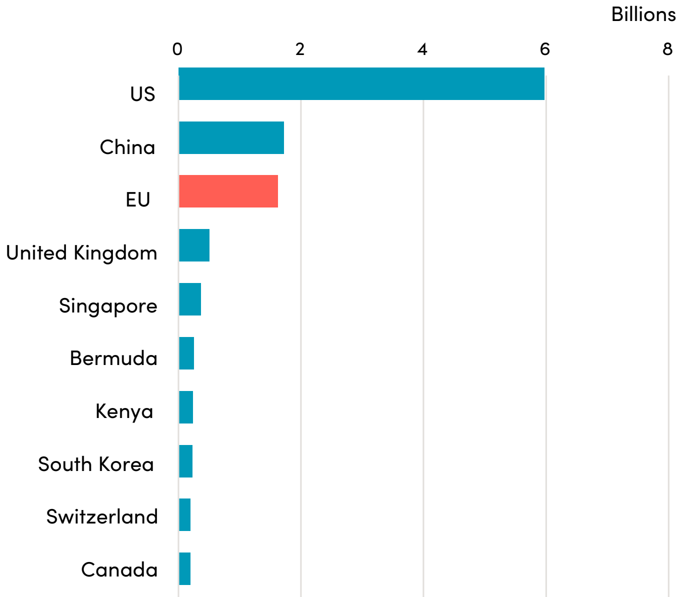


Source: Frontier Economics analysis of ASPI data

Notably, the EU leads in space research quality, boasting a 7-percentage-point difference compared to the US. Whilst excelling in navigation technologies, Earth observation and satellite communications through programmes like Galileo and Copernicus, the EU's leadership in launch services and space surveillance is more moderate, partly due to delays in the Ariane 6 launch.

Private investment for space companies in the US is over three times greater than in the EU

Start-up and scale-up funding (in USD)



Source: Frontier Economics analysis of ASPI data

However, the EU's global leadership position in space technologies is threatened by a significant gap in public investment levels compared to the US and China. Europe invests approximately €12 billion annually in space technologies, mainly through the European Space Agency (ESA) and the EU Space Programme, whilst the US allocates around $70 billion to its space programmes.[54] Additionally, US space companies attract over three times more private investment than EU counterparts.[55]

Regulatory constraints further hinder the EU's competitiveness compared to the more flexible environment in the US.

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[54] Statista, "Government expenditure on space programs in 2022 and 2023, by major country", December 2023, available at: https://www.statista.com/statistics/745717/global-governmental-spending-on-space-programs-leading-countries/#:~:text=In%202023%2C%20global%20government%20expenditure,space%20expenditure%20in%20the%20world.

[55] Data collected by Frontier Economics for this study.

Source: Frontier Economics analysis of ASPI data

The space technologies value chain

Value chain steps	Main players
1 Research & Development Fundamental and applied research & scientific and engineering support	**US:** Boeing, Lockheed Martin, Northrop Grumman, Raytheon Technologies, Maxar **Japan:** Mitsubishi **In Europe:** Thales, Airbus, OHB, Ariane Group, Telespazio, GMV, Beyond Gravity, Avio
2 Manufacture of components Supply of components (e.g. cables, connectors, relays, diodes, transistors, semiconductors, sensors)	**Global:** Comtech, Honeywell Aerospace, Cobham Advanced Electronic Solutions, Teledyne, Sierra Nevada Corporation, MDA **In Europe:** Beyond Gravity, Safran, JenaOptronik, Sodern, TSD, DHV, AAC Clyde Space
3 Satellite & spacecraft manufacturing Design, develop and manufacture of launch vehicles rockets **4 Launch services** Sell satellite capacity to service providers (e.g. raw data, wholesale bandwidth), manage in-space activities (in-orbit servicing)	**Large satellite manufacturers:** • **In Europe:** Airbus, Thales, OHB, • **US:** Boeing, Lockheed Martin, SSL, Raytheon, Northrop Grumman **Small satellites manufacturers:** • **In Europe:** SSTL, AAC Clyde Space, GomSpace, Alén Space, SITAEL, NanoAvionics • **US:** Tyvak, Orbital AKT **Ground systems:** • **In Europe:** GMV, Thales, Airbus • **US:** Raytheon, Northrop Grumman **Launchers:** • **In Europe:** Ariane Group, Avio, Isar Aerospace, Orbex, PLD Space, RFA • **Global:** SpaceX, United Launch Alliance, ISRO/Antrix
5 Lease or sale of satellite capacity Satellite communications, Earth observation, navigation	**Satellite operators:** • **In Europe:** SES, Inmarsat, Eutelsat, Hispasat, Eumesat • **Global:** Intelsat, Telesat, Asiasat, ISRO, China Satcom **SATCOM terminal supply:** **US mostly:** Hughes Network Systems, ViaSat, Gilat, ST iDirect, L3Harris, General Dynamics **Navigation receivers:** **US & China:** Qualcomm, Broadcom, Intel, Trimble, Garmin, NovAtel, MediaTek, ComNav, Quectel
6 Value added services Provide connectivity or data analytics services to end users - Commercial & public users	**Big telco operators** **Earth observation:** Telespazio, Airbus, Planet, Airbus, Iceye, Maxar, HawkEye 360, BlackSky, Orbital Insight **Navigation services:** GMV, Orolia, U-blox, Garmin, Trimble, NovAtel, Hemisphere, etc.

The EU is well represented across the value chain of space technologies, with prominent aerospace manufacturers such as Airbus, Thales, OHB and ArianeGroup. However, Europe falls short in the manufacture of Satcom user terminals and navigation receiver chipsets, where it is highly dependent on US and Asian suppliers. These are essential components of the space industry value chain, as they enable a wide range of applications and services that rely on satellite communications and navigation capabilities. As such, their price directly determines competitiveness in related services.

Risk assessment

Moderate to high

The overall risk to the EU's space supply chain is assessed as **moderate to high**, primarily for two reasons. Firstly, there's a significant public and private investment gap in the sector compared to other regions, which could result in a few well-funded players dominating the space industry. Secondly, there's a heavy reliance on non-European manufacturers for critical service components. These components are pivotal for competitiveness, yet lack local alternatives in Europe, exposing the EU to vulnerabilities in the supply chain. Additionally, regulatory constraints in Europe limit competition in the space industry.

"If Europe wants to play any significant role in critical space technologies, it is necessary to heavily increase public and private investment. The most effective way to do so is by means of large, ambitious programs such as Galileo and Copernicus, with priority in satellite communications and space surveillance and tracking."

Jorge Potti,
Chief Strategy Officer, GMV

Recommended measures

To enhance its competitiveness in space technologies, the EU should consider the following measures:

1. **Boost public investment in strategic technology development,** prioritising areas of EU deficiency like Satcom user terminals and navigation chipsets manufacturing.
2. **Enhance talent investment to tackle the shortage of engineers,** critical not only for the space sector but also for STEM-dependent industries.
3. **Revise the EU regulatory framework,** especially addressing 'georeturn requirements' in ESA procurement policies to eliminate inefficiencies and enhance competitiveness in the European space sector.

Detailed assessment of policy measures and impact

Market leaders and DIGITALEUROPE members consulted to produce this report were asked to evaluate proposed measures to enhance EU competitiveness and security, rating their impact from 1 to 5. Our policy experts then evaluated the feasibility of these measures at EU level, assigning scores from 1 to 10. Here are the summarised results, organised from highest to lowest based on their combined impact and feasibility:

1. Streamlined regulation
(Feasibility: 10/10 – Impact: 3.8/5)

Streamlining and consolidating regulations requires political will, particularly at the inception stage of legislative proposals from the European Commission as well as from Member State governments, who have a crucial say in how rules are to be enforced. It involves overcoming bureaucratic resistance and local interests that obstruct broader benefits for the entire EU. This being said, there are little or no legal impediments to a significant simplification of Europe's regulatory environment in a number of policy areas. Simplified regulations would greatly reduce barriers for businesses, fostering a more attractive environment for innovation and investment in Europe.

2. Public-Private Partnerships
(Feasibility: 9/10 – Impact: 3.8/5)

The EU has experience in fostering PPPs, making them a feasible approach for technology development. PPPs can mobilise additional resources, drive innovation and facilitate the commercialisation of new technologies.

3. Targeted funding
(Feasibility: 8/10 – Impact: 4.3/5)

The EU has a history of providing targeted funding through various programmes, making this measure highly feasible. Effectively targeting and distributing funds requires precise identification of needs and impact areas. Well-directed funding can address specific gaps in technology sectors, enhance innovation, and accelerate development and commercialisation.

4. Large-scale infrastructure investment
(Feasibility: 7/10 – Impact 3.9/5)

Large-scale projects are feasible with EU-wide cooperation, though securing the necessary funding can be difficult in times of economic constraint. Investing in joint EU infrastructure (e.g. data centres, manufacturing plants) can directly improve the EU's capacity to develop and scale critical technologies.

5. Education and upskilling (Feasibility: 6/10 – Impact: 3.8/5)

Education and training initiatives require coordination amongst Member States and their institutions, and are a long-term process. Investing in education and upskilling ensures a skilled workforce capable of driving innovation and maintaining competitive industries long-term.

6. Partnerships with third countries (Feasibility: 6/10 – Impact: 3.6/5)

The EU can leverage its diplomatic and economic relationships to form strategic partnerships. Establishing and maintaining these partnerships involves navigating complex geopolitical landscapes and their success depends on the level of ambition sought. Collaborations can enhance joint technology research, market access and resource availability, and help manage dependency risks.

7. Common EU procurement (Feasibility: 6/10 – Impact: 3.5/5)

Establishing common EU-wide procurement requires political consensus amongst Member States, each with its procurement history and prerogatives, which can be contentious. However, a collective procurement approach would enhance innovation and competitiveness within European industry by creating economies of scale and fostering a more integrated market.

8. Tax incentives (Feasibility: 5/10 – Impact: 3.9/5)

More aggressive, EU-wide tax breaks and tax incentives would significantly boost investments in R&D and manufacturing capabilities, making the EU more competitive globally.

It will require an ambitious political drive from Member States to agree on policies which currently sit outside the EU's core competencies. Tax policy primarily remains under the jurisdiction of individual Member States. Whilst the EU can set broad guidelines and frameworks to encourage cooperation and alignment, such as through the Temporary Crisis and Transformation Framework for State Aid,[56] it presently does not have the authority to impose uniform tax rates or detailed tax regulations across Member States.

9. Trade-restrictive measures and export controls (Feasibility: 8/10 – Impact: 1.9/5)

Within the framework of their international obligations, the EU and Member States control the export of dual-use items to contribute to international peace and security and prevent the proliferation of weapons of mass destruction. Dual-use items are goods, software and technology that can be used for both civilian and military applications. Export controls on dual-use items are primarily driven by security considerations rather than economic objectives.

10. Trade defence measures (Feasibility: 8/10 – Impact: 1.9/5)

The EU can implement trade defence measures, e.g. anti-dumping or anti-subsidy duties, within a framework that is grounded in the rules of the World Trade Organization.[57] Under EU law, the Commission has the authority to initiate investigations into unfair trade practices, such as dumping or subsidisation, and to impose trade defence measures if evidence of harm to EU industries is found. Whilst these measures can protect EU industries from unfair competition, they do not address competitiveness issues and could lead to retaliation.

[56] 2023/C 101/03.
[57] European Commission, "Trade defence", available at: https://policy.trade.ec.europa.eu/enforcement-and-protection/trade-defence_en.

Acknowledgements

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Bosch, Stefan Joeres (Vice President of Semiconductor Strategy) and Michael Pfeiffer (Head of AI Research at Bosch Centre for Artificial Intelligence)

Ericsson, Per Beming, Chief Standardisation Officer

GMV, Jorge Potti, Chief Strategy Officer

HP, François Minec, Global Head of Polymers 3D Printing

Intel, Riccardo Masucci, Director of Security and Technology Policy

IQM Quantum Computers, Jouni Flyktman, Vice-President Defence and Security

Multiverse, Gianni del Bimbo, COO

Nokia, Volker Ziegler, Senior Advisor and Chief Architect

Quantum Foundry, Andreas Clausen Boor, Head of Partnerships and Executive Assistant to the CEO

Roche, Yeliz Turgut Noto, Head of Network Strategy at Genetech, member of Roche group

SAP, Sebastian Wieczorek (Vice-President for AI Technology) and Susanne Beckers (AI Strategy Expert)

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Solar Power Europe, Naomi Chevillard (Head of Regulatory Affairs) and Emma Dominici (Policy Advisor on Supply Chain Diversification)

Terra Quantum, Markus Pflitsch, Chairman and CEO

Wind Europe, Phil Cole, Director of Industrial Affairs

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