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WORLD ECONOMIC FORUM

Europe in the Intelligent Age: From Ideas to Action

WHITE PAPER

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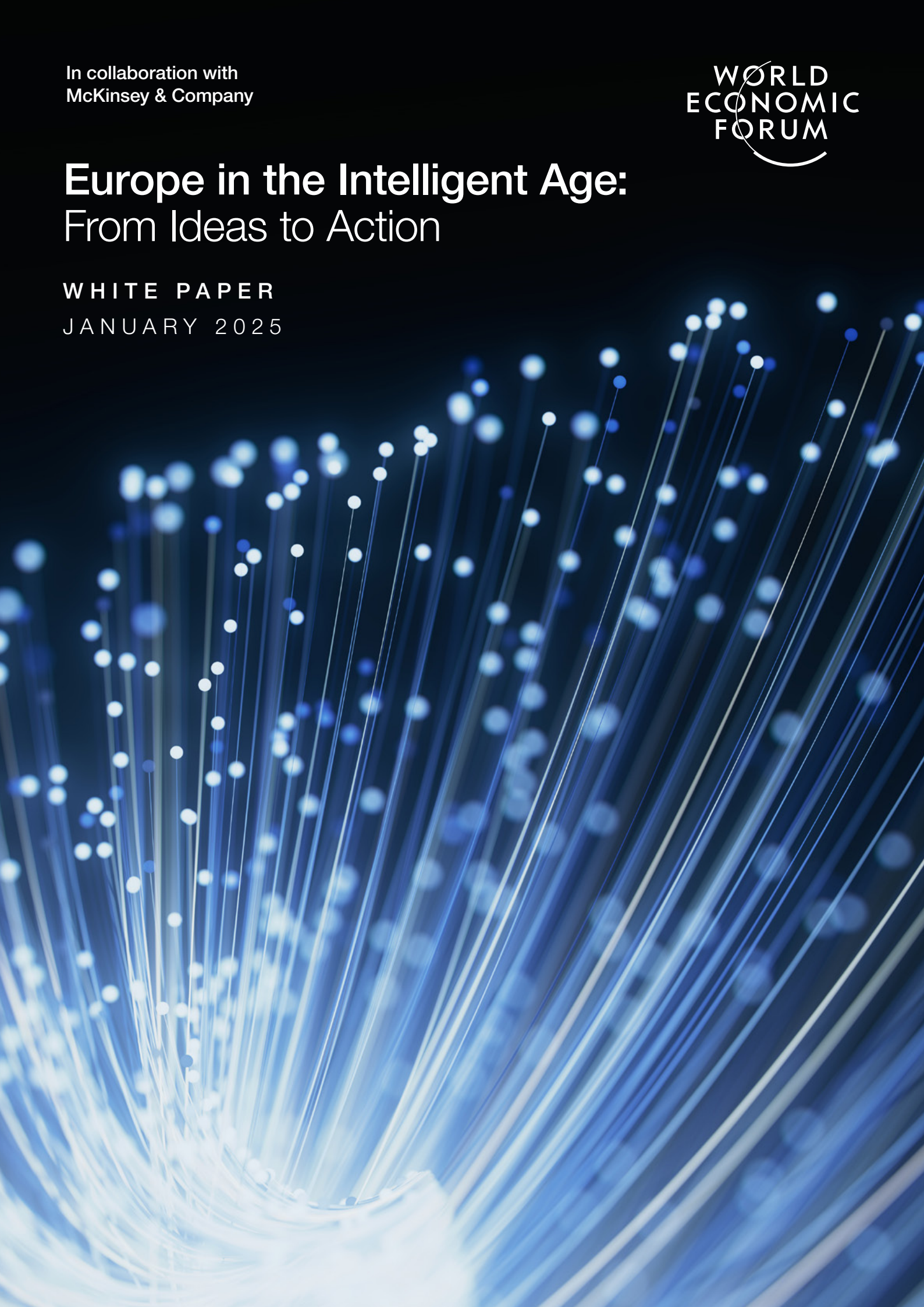

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Foreword

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Strategic focus and private sector-led lighthouse initiatives can change the Old Continent's trajectory – if the public sector radically changes the investment environment with a handful of priority initiatives.

The rising economic stakes of the Intelligent Age have made competitiveness, especially in technology, a top priority across Europe. At its core, competitiveness is driven by investment – specifically in productive infrastructure and innovation. Competitive economies become magnets for further investment because of their skilled workforce, advanced infrastructure and culture of innovation. This reinforces growth, securing and improving living standards, and decreasing an economy's strategic dependencies on others.[1]

Europe's strengths in areas such as the industrial sector, sustainability and education provide a necessary but insufficient competitive foundation to offset the growing challenges posed by deficits in innovation, production and adoption of technology, as well as geopolitical shifts.

Recent reports by Mario Draghi and Enrico Letta detail important policy proposals to help address this fundamental issue. An increasing urgency exists among European leaders to figure out what tangible actions Europe can take to turn ideas into impact – at speed and at scale. Our research sought to advance this debate by examining two overarching questions: Where could Europe focus to best compete, and in which technologies? How could the private and public sectors mobilize for action and unlock investment and innovation at scale?

This paper adds to the work of the World Economic Forum and McKinsey & Company over the past seven years to provide insights for increasing European competitiveness, including the joint 2018 "Renew Europe" and 2019 "Innovate Europe" reports. It also builds on discussions at a high-level dialogue on "Europe in the Age of Intelligent Economies" hosted by the World Economic Forum in October 2024, and nearly a decade of research by the McKinsey Global Institute on the subject, including our recent report, "Accelerating Europe: Competitiveness for a New Era".

Our thanks go to the more than 100 public and private sector leaders across Europe for providing feedback and ideas to help shape these insights.

The level of engagement by these leaders from European institutions and corporations has been inspiring. This paper aims to serve as a starting point for a joint multistakeholder, multi-year acceleration of Europe's trajectory. We are inviting leaders from across sectors and institutions across the continent to collaborate with us on the journey ahead.

Executive summary

This paper emphasizes strategic focus, private sector-led lighthouse initiatives, and 10 public sector “grands projets” as near-term proposals to accelerate Europe’s competitiveness and investment environment.

Technology is increasingly shaping the prosperity and sovereignty of nations. The development of disruptive technologies such as artificial intelligence (AI), along with geopolitical events, is creating new arenas of competition, centred on investment into the innovation, production and adoption of advanced technologies.[2]

However, large European corporations invested €700 billion a year – or €3,000 per capita – less than their United States (US) counterparts between 2015 and 2022, particularly in technology, as returns on invested capital (ROIC) for corporate Europe trailed the US’s by 4 percentage points.[3] Europe currently competes effectively with the US and China in only four out of 14 technologies considered critical to the future of the global economy.[4]

These gaps create strategic dependencies for Europe and threaten to leave €2 to €4 trillion on the table through foregone gross domestic product (GDP) contributions per annum by 2040,[5] an amount that exceeds the continent’s current annual funding needed for Net Zero, defence and healthcare combined.

As Europe charts its course to increase economic and technological competitiveness, consensus is emerging on the broad categories of levers required to drive change.[6] Hundreds of concrete proposals have been laid out in recent reports by Mario Draghi,[7] Prime Minister of Italy (2021-2022); Enrico Letta,[8] Prime Minister of Italy (2013-2014); the McKinsey Global Institute,[9] and others. Completion of the single market could overcome current fragmentation.[10] Streamlined regulation could enable a substantial increase in investments.[11]

Yet, real impact remains unrealized. This paper aims to start the journey of turning ideas into action with a sharp focus on impact, both at speed and at scale. It proposes a strategic framework for where to play and how to win; a list of private-sector lighthouse initiatives to kick-start momentum; and 10 public-sector “grands projets”[12] to unleash European competitiveness and entrepreneurship, aligned with six priority areas for spurring innovation and investment:

1 Where to play and how to win: Targeted strategy for key technologies.

Europe can neither lead across all technologies, nor apply the same recipe for them all. This paper identifies tailored strategic choices for 14 significant technologies based on their respective strategic importance, maturity and Europe's starting point.

- Where Europe has a lead, it should defend and expand its global scale and leadership positions, for example in private wireless rollout – carefully reconsidering the potential trade-offs between the benefits of global scale and the risks of domestic market concentration.
- Where Europe has strengths in nascent technology areas, it should go all-in on scaling up and commercializing as fast as possible while defending strategic capabilities, such as in quantum sensing.
- Where Europe is trailing, this could involve leapfrogging to the next generation of technology in a nascent area (like optical computing in semiconductors) or focusing on vertical niches of strengths, such as industrial AI.
- Where Europe is far behind in the race, it might be time to reallocate resources from trying to catch up, for example in cloud computing, towards ensuring investment and capability transfer from global front-runners.

2 Mobilizing action: Private sector-led lighthouse initiatives to create momentum for critically needed change in the investment environment.

Private sector-led efforts around a select number of high-impact lighthouse initiatives can help create momentum and lay the foundation for larger-scale progress. Such initiatives could include creating advanced industrial or vertical AI applications and integrated stacks in finance or healthcare, or launching an industry-driven semiconductor skills and global exchange programme. These initiatives can also pinpoint where the investment environment may need to change to make private business cases positive.

3 Unleashing investment – Ten public sector *grands projets* to create a more investment- and innovation-friendly environment.

These could rapidly change the investment environment as a prerequisite for success. Among many ideas for public sector initiatives, this paper identifies 10 that deserve priority because of their potential to deliver impact at scale fast. Front and centre among these is the need to build and implement a uniform set of investment-friendly rules and regulations across Europe. As ongoing efforts for harmonization and simplification remain challenging, European Union (EU) leaders could choose to put in place a "greenfield 28th regime"[13] of unified and radically simple business rules and standards across the EU to move quickly. Other examples include a greenfield time-bound EU-wide digital permitting and approvals system, or the public sector turning into an at-scale anchor customer for radical innovation in healthcare, defence or energy.

All stakeholders will need to work hand-in-hand to move from ideas to action. The private sector is well-positioned to identify where and how Europe can best compete and provide an impetus. The public sector is seeking to be bold, as the Letta and Draghi reports show, yet closing the gap may need an audacious mindset, akin to the one that led to the introduction of the Euro, focusing energy on achieving an equally lofty ambition despite all the complexities and risks.

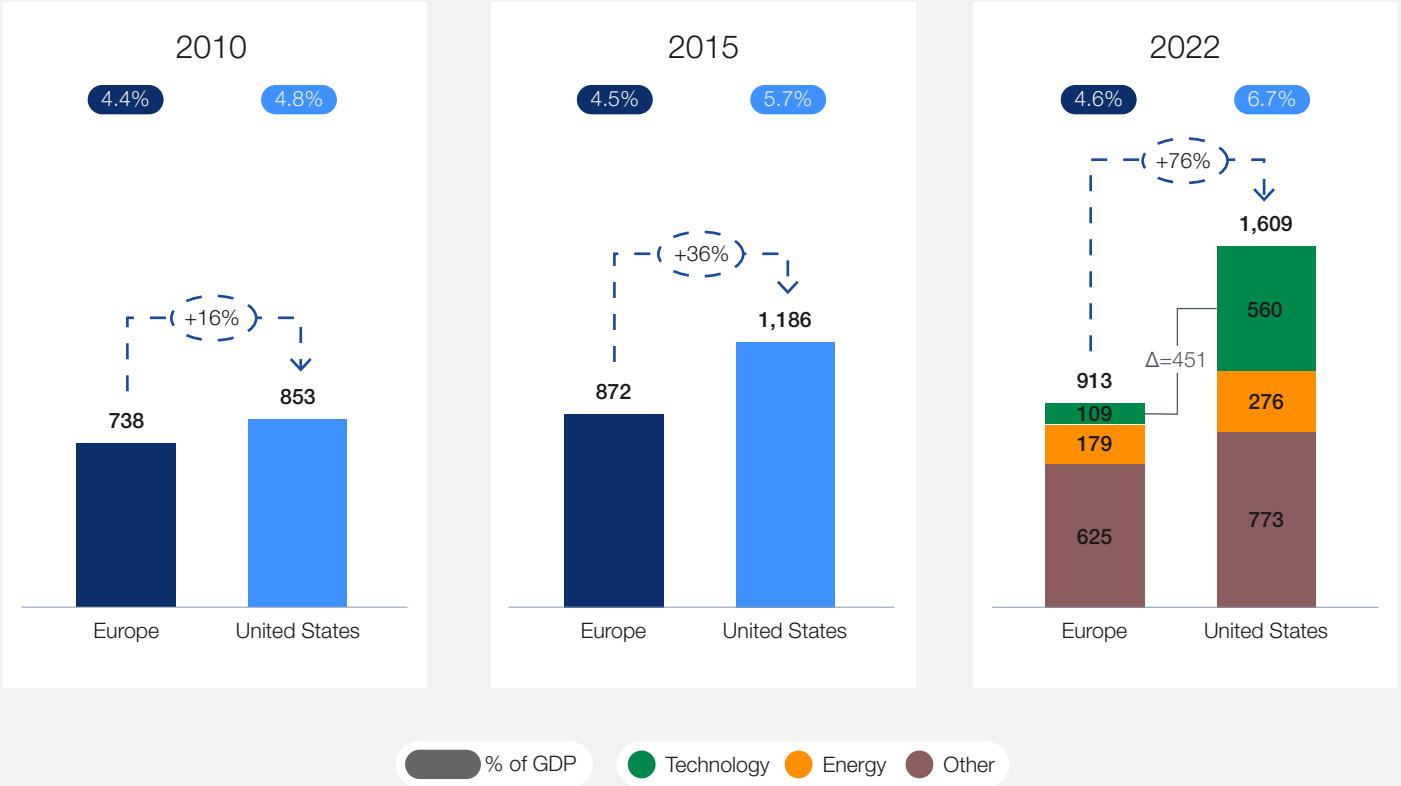
Introduction: From broad diagnostics to focused action

Europe is at a turning point – and will need to act now to close a €700 billion investment gap, regain competitiveness and capture €2-4 trillion of value at stake.

Corporate investment in research and development (R&D) and capital formation by large European firms used to be broadly on par with US firms, but in 2022 trailed by €700 billion, with the gap continuing to widen (Figure 1). The difference is starkest in technology, accounting for €450 billion of the disparity. Filling this gap is fundamental to building a private sector that can scale to become world-leading.

FIGURE 1 **Growing corporate investment gap, notably in technology**

2010-2022 capital expenditure and R&D spend of European[1] and US corporates[2] with revenue > $1 billion, €1 billion in 2022 prices[3]



1. EU27 + United Kingdom, Switzerland and Norway (EU30) **2.** Only considering public companies, excluding intangible assets **3.** Historical spending for both EU30 and US has been adjusted for inflation; for US, spending was converted from euros (EUR) to US dollars (USD) using the foreign exchange rate for each individual year, then deflating for each year with USD inflation rates, and finally converting the deflated US spending figures back to EUR based on 2022 foreign exchange rates.

Source: McKinsey Value Intelligence Platform, S&P Global Market Intelligence, World Bank, AMECO

On 14 significant technologies, Europe lags either the US and/or China in 10 (Figure 2).[14] This assessment is based on private and public market capital raised, research, publication and patent outputs, and expert judgement per technology domain (see Box 1. Technology assessment methodology).

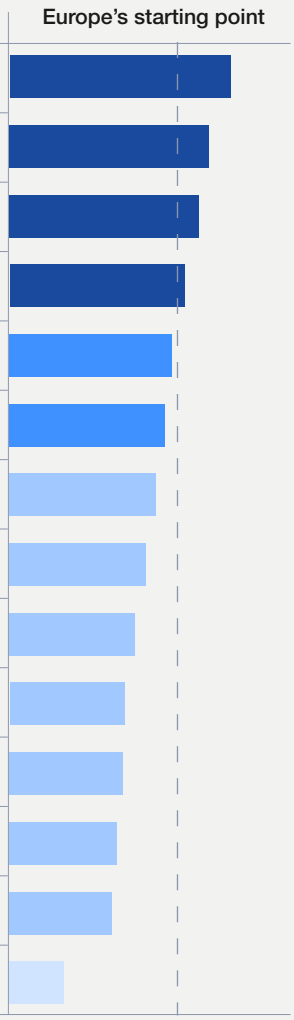
Europe's market share in new arenas of competition that are set to grow to $30 trillion in market size by 2040 is no more than 9%.[15] AI is a case in point: Europe's market share in most parts of the value chain is less than 5%,[16] and the largest corporate investors in Europe spent €25 billion on the technology in 2024, compared with more than €150 billion by the largest US technology firms.[17]

Also, adoption of technology is lagging in Europe. As one crude indicator, European corporations have invested less than half as much into information and communication technology (ICT) equipment as US firms.[18]

FIGURE 2 **Europe is competitive only in 4 of 14 technology domains**

Based on private- and public-market investments,[1] number of research publications and patents, and expert interviews

Technology domain	Subdomains in scope (most important categories)
Quantum technologies	Quantum computing, quantum communications, quantum key distribution, quantum sensing
Climate technologies[2]	CCUS,[3] circular technologies, natural climate solutions, engineered carbon removal
Future of bioengineering	Genomics, proteomics, gene editing, tissue engineering, biomaterials
Advanced connectivity	Optical fibre, LPWAN, HAPS, 5G/6G cellular, Wi-Fi 6 and 7, satellite connectivity
Future of robotics	Industrial robots, collaborative robots, mobile robots, human-hybrid robots
Semiconductors	Microchips, integrated circuits, technologies for semiconductor manufacturing
Future of space technologies	Satellites, launch technologies, remote sensing, habitation technologies
Future of mobility	Autonomous driving, electric vehicles, urban air mobility, shared-mobility technologies
Electrification and renewables	Renewables, batteries, hydrogen, sustainable fuels, nuclear fission, heat pumps
Artificial intelligence (AI)	Applied AI technologies, GenAI technologies, industrializing machine learning
Digital trust and cybersecurity	Technologies behind trust architectures, digital identity, cybersecurity, Web3
Immersive-reality technologies	Augmented reality, virtual reality, mixed reality, spatial computing
Next-generation software development	AI-generated code, low/no-code platforms, infrastructure as code, microservices
Cloud and edge computing	Data centres, mobile edge computing (MEC), device edge, metro edge



1. Includes private-market and public-market capital raises (venture capital and corporate and strategic M&A, including joint ventures), private equity (including buyouts and private investment in public equity), and public investments (including initial public offerings); doesn't include financing of big programmes by large tech companies (cash flow transactions are not reflected) **2.** Climate technologies beyond electrification and renewables **3.** Carbon capture, utilization and storage.

Source: Pitchbook, Lens.org, Patsnap, McKinsey Tech Outlook 2024, expert interviews

BOX 1 **Technology assessment methodology**

To assess Europe's starting point per technology domain, this paper analyses three datasets: investments, research publications and patents. For each measure, a defined set of data sources is used to find occurrences across a set of over 1,000 keywords associated with the 14 technology domains:

- *Investment*. Data on private-market and public-market capital raised (venture capital and corporate and strategic mergers and acquisitions (M&A), including joint ventures), private equity (including buyouts and private investment in public equity), and public investments (including initial public offerings (IPOs)) are sourced from PitchBook, cumulative over the period 2018-2023.
- *Research publications*. Data on published research articles is sourced from Lens, cumulative over the period 2018-2023.
- *Patents*. Data on patent filings is sourced from Patsnap, highlighting only the number of granted patents, cumulative over the period 2018-2023.

In addition to these metrics, this paper relies on interviews with subject-matter experts and facilitated dialogues with over 40 industry leaders across technology domains. This was calibrated against the data analysis to formulate the scoring of Europe's starting point on a scale of 1 to 5.

The investment and innovation environment no longer seems at par with other regions

As a matter of fact, European corporations earn about one-third lower returns on invested capital than their competitors domiciled in the US.[19] For a similar business opportunity, European companies face higher regulatory restrictions and cost, and a more limited upside, not least due to fragmentation and barriers to scale.

Restoring the European investment environment will require leadership from both the private and public sectors to address well-known challenges and work towards six key outcomes: overcoming fragmentation to enable scale, simplifying and speeding up the regulatory and permitting environment, increasing innovation capital and investment, driving commercialization, strengthening research and talent, and cultivating ecosystems and global leaders.

But the one issue that is top of mind among chief executive officers (CEOs) and entrepreneurs and would need to be addressed first and foremost, is to create a more conducive landscape to scale up innovative businesses in Europe.

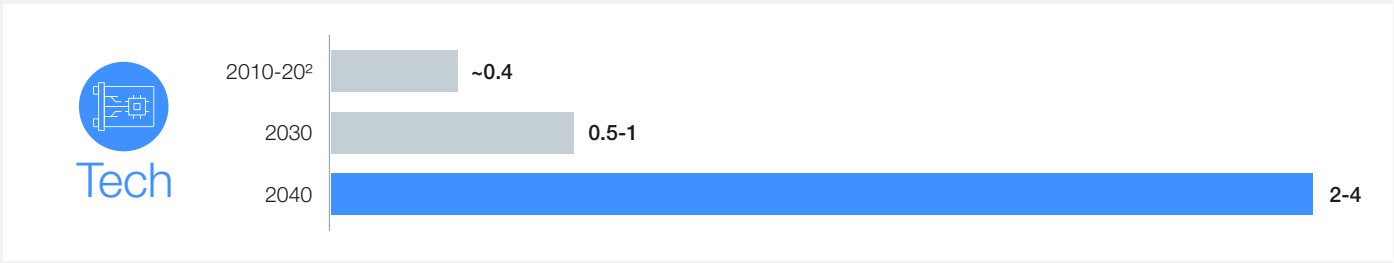
The value at stake is higher than healthcare, defence and Net Zero spending combined

The value at stake may dwarf spending on many European priorities in the long run. Already over the past decades, the tech sector alone has contributed around 0.4 percentage points more to productivity growth in the US than in the EU.[20]

Europe's current slow pace of tech investment and adoption puts more than €2 trillion to €4 trillion in value-add at stake annually by 2040.[21] This amount exceeds Europe's annual healthcare[22] and defence spending,[23] as well as funding requirements to reach Net Zero.[24] Failure to close gaps could impact Europe's standard of living, values and safety[25] (Figure 3).

FIGURE 3 **Filling the tech gap could already have a material impact on Europe in 2030, with a significant compounding effect by 2040**

Annual value at stake from lagging in tech,[1] gross value-add (GVA), in € trillion



GVA at stake represents a significant share of Europe's welfare spend, in € trillion

1. The corporate (gross) value-added (GVA) opportunity European firms could miss out on if Europe fails to improve on transversal technologies **2.** Annual European GDP/productivity loss due to technology lag vs the US during 2010-20 (corresponding to gap of 0.2-0.6% in productivity growth per year) **3.** Based on estimations from the North Atlantic Treaty Organization (NATO) from June 2024 using EUR/USD = 0.93 **4.** Based on an estimate of annual gross investment needed for Europe to reach Net Zero by 2050 in the article "The net-zero transition: What it would cost, what it could bring", by MGI (2022)

Source: McKinsey Global Institute, Eurostat, NATO

What can Europe do to change its current trajectory?

To become more competitive over the next 15 years and capture the value at stake, European private and public sector leaders should consider making calculated choices, recognizing that their resources cannot be spread across every frontier, and that they cannot prioritize hundreds of initiatives in the same way. Beyond dealing with the energy shock and changing geopolitical environment, which are beyond the scope of this paper, this research suggests that a three-pronged approach may help Europe begin to regain technology competitiveness:

1. **Where to play and how to win: Targeted strategy for key technologies.** Europe could benefit from tailoring how it invests in, deploys and adopts specific technologies. The right approach and prioritization depend on how large markets are likely to become, the strategic importance of a given technology for Europe, technology maturity and Europe's starting point.

2. **Mobilizing action: Private sector-led lighthouse initiatives to create momentum and unleash critically needed change in the investment environment.** A select number of high-impact, private sector-led model projects aimed to accelerate Europe's position within strategic technologies may help rally support for transformative change and lay the foundation for larger-scale progress.

3. **Unlocking investment: Ten European public sector *grands projets* to create a more innovation-friendly environment.** Success would require a bold commitment to public-sector initiatives that can be launched soon to materially change the investment environment within the next two to three years. The analysis behind this paper shows that to succeed, these efforts need to be focused on six priority areas for reducing Europe's tech deficit: overcoming fragmentation and building scale, simplifying and speeding up the regulatory and permitting environment,[26] increasing innovation capital and investment, driving commercialization, strengthening research and talent, and cultivating ecosystems and global leaders.

1 Where to play and how to win: Targeted strategy for key technologies

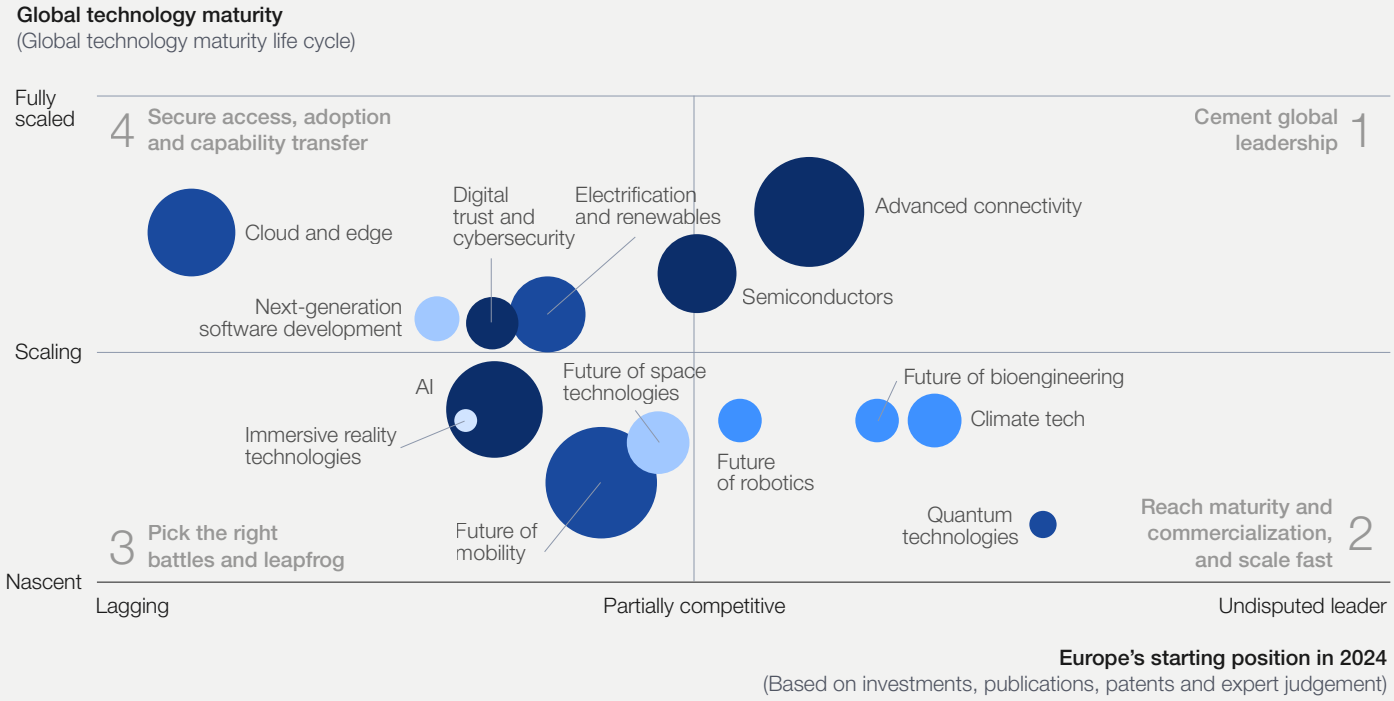
Europe will need to take a tailored strategic approach – from securing capability transfer where it lags to cementing global scale and leadership where it leads.

Rather than a one-size-fits-all approach, Europe's leaders could benefit from applying the appropriate strategic posture for each technology depending on technology maturity and Europe's starting point. Leading in frontier technologies within scaled areas, for example, requires different approaches than trying to catch up from a lagging position in a nascent technology (Figure 4).

In addition, the right level of prioritization and resourcing will depend on expected market size and strategic importance. To assess technologies on these dimensions, this paper relies on industry expertise for understanding maturity; builds on separate McKinsey research for market sizing;[27] uses the approach outlined in the previous chapter to assess Europe's starting point; and examines strategic importance based on how much the technology underpins Europe's economic growth and sovereignty.[28]

FIGURE 4 | **Europe could benefit from sharpening strategic postures per technology**

Assessment of European position in 14 significant technology domains



1. Contribution to European sovereignty (based on analysis of import/export tariffs) **2.** Market size by revenue based on estimates in MGI reports "The next big arenas of competition" (2024) and "Securing Europe's competitiveness" (2022)

Source: McKinsey, MGI, expert interviews

The same approach can then be applied at the value chain level within each technology domain to identify concrete opportunities for action based on Europe's competitive position. For each of these technologies, the business case of key investments (e.g. building out semiconductor manufacturing) should be assessed to clarify which factors make it uncompetitive versus other regions. This will allow for targeted actions to remove barriers and reduce the impact of these factors.

This paper offers deep dives into value chain opportunities for four technologies, one for each position in the matrix – advanced connectivity, quantum technology, AI and semiconductors – as examples of this approach.

Corporate and policy leaders may benefit from tailoring their strategic posture in line with such assessment:

1. **Cement global leadership for scaled up technologies where Europe has at least partial leadership positions**, such as parts of the advanced connectivity and semiconductor value chains. This could include creating demand for Europe's own products by incentivizing corporate investments, e.g. in private wireless, and thus driving adoption and growth in high potential tech products with competitive margins.

   Companies could benefit from deploying programmatic M&A approaches, e.g. consolidating programmatic semiconductor R&D in new materials for optical and power electronics as well as semiconductor equipment for the most advanced nodes.

   Policy-makers may wish to enable domestic and EU-wide adoption; facilitate the growth of large-scale companies successful in global markets – rethinking protecting against domestic concentration at the expense of achieving global scale at competitive prices; or pursue commercial diplomacy for global market access and working towards global standards that support European strengths.

2. **Reach maturity and commercialization, and scale as fast as possible in nascent technologies where Europe is well positioned to lead**, such as parts of quantum, climate tech and bioengineering sectors.

Companies may wish, for example, to make strategic investments in frontier technologies with defined use cases for commercialization, form consortia and alliances, and drive standardization to achieve their goals, e.g. in quantum sensing for disease detection.

Policy-makers may deploy at-scale pre-commercial procurement of technologies in areas from defence to energy and healthcare in order to create new markets and revenue streams and foster end-user adoption. They may create Europe-wide regulatory sandboxes to allow rapid experimentation and innovation. They could also explore co-funding R&D at scale and, where needed, protecting European capabilities and assets from relocation and takeover.

3. **Pick your battles and leapfrog for nascent technologies where Europe is starting to fall behind**, such as parts of AI and mobility. This can include skipping to the next-generation technology to get ahead (such as neuromorphic and optical computing) or focusing on specific niches or industrial stronghold domains, such as deployment of AI in industrial areas.

   Corporations in industry verticals and technology areas could benefit from collaborating to gain an edge and create products and at-scale use cases jointly, such as in predictive analytics in additive manufacturing.

   Public sector leaders could further support innovation and commercialization by coordinating and providing the ground for the creation of alliances; co-fund research and development within strategic domains; and ensure that regulation, including data policies, is apt to drive responsible innovation in Europe. They may also consider creating demand and becoming anchor customers for innovation in selected domains, e.g. pre-commercial procurement of AI applications in defence or energy systems.

4. **Secure access, capability transfer and adoption for scaled-up technologies where Europe needs to catch up**, such as parts of the semiconductor, cloud, renewables (e.g. photovoltaics), cybersecurity or next-generation software value chains.

   Corporations could focus on strengthening long-run partnerships with globally leading firms while building alternative supplier options and in-house capacity to better manage risk and enhance their bargaining position, for example by attracting edge computing leaders to create European hubs.

   In cases where Europe is trailing global peers, public sector leaders could focus on attracting global investment and ensuring capability transfer more than trying to fund domestic efforts. This may include incentives for investment in R&D and manufacturing (e.g. front-end and back-end manufacturing for semiconductors) by global leaders in Europe, as well as policies encouraging technology transfer and domestic capability build-up. They can also ensure fair access for European innovators to global platforms and gatekeepers, e.g. building on the Digital Markets Act.

2

Mobilizing action: Private sector-led lighthouse initiatives to create momentum

Aspirational industrial endeavours can rally resources around common goals – and reveal shortcomings in the investment environment that need to be addressed.

Success can breed success. Early achievements often create momentum, reduce uncertainty and lay the foundation for larger-scale progress. One way to demonstrate tangible successes quickly in the technology sector is through lighthouse initiatives:[29] model projects that can kickstart efforts, build public and industry confidence, and drive broader innovation, investment and adoption of new technologies.

In many of these technologies, there are exponentially rising investments and strong winner-takes-most effects,[30] making bold action vital. These initiatives must be ambitious. Figure 5 offers an initial set of lighthouse ideas for the four technology examples used in this paper (one per strategic posture quadrant) to help leaders begin to imagine the possibilities.

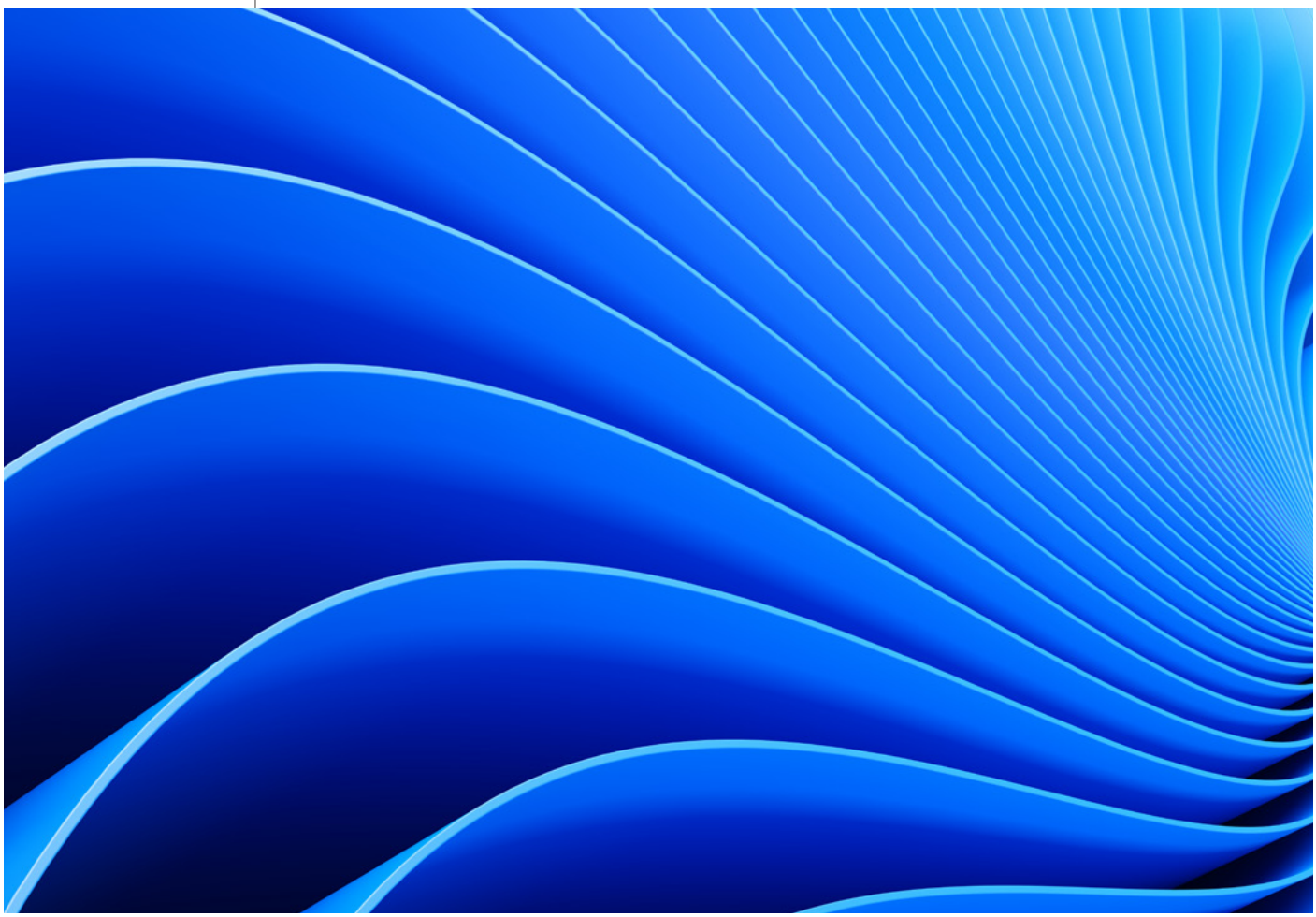


FIGURE 5 | **Examples of private sector-led lighthouse initiatives for Europe**

Technology	AI (Applied AI, generative AI and industrialized ML)	Semiconductors	Quantum technology	Advanced connectivity
Lighthouse initiatives	**Building globally leading industrial AI** Become the centre of industrial AI through a consortium that builds at-scale applied AI solutions leveraging existing research strengths in applications such as pharmaceuticals manufacturing	**Imparting semiconductor skills and capability** Launch an industry-driven semiconductor skills programme to attract, develop and retain world-class talent of the future	**Scaling quantum hubs** Build globally leading hubs in quantum computing, quantum sensing and quantum communications, driven by tech leader consortia and public-private co-investments	**Building next-generation digital infrastructure** Co-fund a next-gen digital infrastructure joint venture with Europe's leading companies, with support from regulators, to build out necessary infrastructure to create the data for new productivity-related business models
	Accelerating AI in healthcare Redirect a portion of healthcare spending to developing AI-based diagnostic and treatment pathways	**Playing to strengths** Strengthen and scale European strongholds in early-stage R&D, equipment, industrial, automotive and power electronics	**Forming quantum coalitions** Forge cross-sector coalitions for companies that share a common quantum tech backbone	**Creating API ecosystems** Build an API alliance among equipment manufacturers, operators and select industrial verticals (e.g. automotives) to jointly develop an investment roadmap for developing and scaling use cases leveraging this technology across Europe
		Building out semiconductor manufacturing Ensure sufficient specific front-end and back-end manufacturing capabilities for strategic autonomy		

Lighthouse initiatives are typically driven by private sector leaders. But they can benefit from the public sector providing co-funding and a supportive environment. They can take many forms, and should take into consideration the strategic posture per technology, for example:

– **Next-generation digital infrastructure joint venture:** In scaled technologies where Europe has at least partial leadership positions, such as advanced connectivity, efforts could focus on driving further scale and adoption. For instance, Europe's leading companies could co-fund a joint venture, with support from regulators, to build out data collection infrastructure necessary for new business models that drive productivity in public- or private-sector verticals.

  To provide just a few examples, this could mean deploying smart city sensors across all major European urban areas that collect urban movement data to predict and limit incidents (road conditions, accidents, public transport delays, etc.), or data related to the management of water systems that could be piloted in "a model city" to showcase the art of the possible. Such a platform for data collected by millions of sensors across regions could be leveraged for a host of new business models and drive productivity by saving on costs and waste.

– **Scaling quantum hubs:** In nascent technologies where Europe is well positioned to lead, such as quantum, lighthouse initiatives might focus on building scale (including consolidating today's relatively fragmented set-up) and enabling commercialization. To do so, for instance, public-private partnerships could enable the creation of globally-leading hubs in quantum computing, quantum sensing and quantum communication for the development of interdisciplinary solutions. These hubs could support scale and rapid commercialization of frontier tech like diamond nitrogen vacancy (NV) centres in sensing or quantum key distribution in communications. Large industrial players could, in partnerships, drive demand by procuring the tech of tomorrow for, say, sensing in healthcare

and optics. And the public sector can support investments in secure communications for defence.

– **Building globally leading industrial AI:** In nascent technologies where Europe is starting to fall behind, such as AI, innovators may leverage the region's industrial strengths to build hubs in areas like pharmaceuticals, finance and energy efficiency. This may follow the visionary example seen with the Airbus A300 programme, where collaborators from across the continent identified an emerging market need and built innovative aircraft at scale. For instance, in finance, private sector firms could collaborate to build market-ready advanced financial analytics based on AI innovations in predictive models, processors, automation tools and decision-making. For its part, the public sector could propel such AI efforts by allocating access to public compute infrastructure, harmonizing regulatory frameworks, or creating regulatory sandboxes so consortium members can easily test and develop innovations.

– **Semiconductor skills and capability transfer:** In scaled technologies where Europe needs to catch up, one focus could be on capability transfer. For instance, an industry-driven, semiconductor and applications skills and talent programme could attract top global talent, leveraging Europe's established leadership in CPU IP[31] and its existing relationships with downstream players. Such a programme could provide EU-wide scholarships for postgraduate students, semiconductor talent visas, early-work internships and temporary contracts with research centres. This would help to address the talent and skills issue commonly mentioned by European semiconductor leaders as a crucial challenge,[32] particularly in critical capabilities like semiconductor front-end and back-end manufacturing.

3 Unlocking investment: Ten European public sector *grands projets*

Rapidly implementing a small number of ambitious, high-impact initiatives can accelerate Europe's journey from ideas to action and impact.

Various policy ideas have been presented to improve Europe's competitiveness. These proposals have been documented in EU-commissioned reports such as those from Mario Draghi[33] and Enrico Letta,[34] and published as research from organizations such as the McKinsey Global Institute.[35] They have also been the subject of recent World Economic Forum dialogues.[36] As public and private leaders collaborate on lighthouse initiatives, they might also consider providing the necessary framework conditions to improve the investment landscape.

Discussions with government and business leaders highlight 10 ideas and proposals that, if acted on, could help to rapidly catalyse investment and innovation in Europe's key technological sectors. If stakeholders can work together with the required focus and efficiency, outcomes could begin to be realized within two to three years (Figure 6). They all have one overarching goal: creating an environment for innovation and investment that makes it attractive to build new technologies and business cases in Europe rather than elsewhere.

FIGURE 6 **Ten proposed *grands projets***

1. **Unleashing entrepreneurship:** Creating a 28th regime of uniform and radically simple business rules
2. **Scaling up:** A pro-investment stance on European M&A could drive scale and returns to accelerate investments
3. **Speeding up:** EU-wide, digital, time-bound approvals could reduce costly complexity
4. **Simplifying:** Opportunity cost-based stance in regulation could reduce the risk of falling behind
5. **Funding risks:** Instituting a pension booster could gear capital for investments towards venture capital and private equity
6. **Creating markets:** Government as at-scale anchor customer could create new markets and revenue streams
7. **Building talent magnets:** Developing tech "CERNs" could attract top tech talent in priority areas
8. **Securing skills:** Reskilling 1 million Europeans could close the skills gap and solidify the tech talent baseline
9. **Securing know-how:** Global capability transfer could build out European ecosystems and capabilities
10. **Driving action:** Deploying a nerve centre and implementation governance could strengthen competitiveness

Building scale. In 2023, the so-called "Magnificent Seven"[37] US companies spent as much on R&D as half of all of Europe's public and private sector R&D spending in technology and other areas combined.[38] To allow for a similar scale, Europe could explore simplifying cross-border growth and supporting market consolidation, even as it continues its work to complete a single market. Two ideas being debated across Europe that could deliver impact:

1. **Unleashing entrepreneurship: A 28th regime of uniform and radically simple business rules.**[39] Creating a harmonized, and investment friendly, framework across Europe by fully completing the single market is difficult and takes time. A greenfield approach may be faster and bolder. This could involve a coalition of the willing across Europe to develop common greenfield tax policies, labour rules and regulatory standards to create a unified environment that supports the growth and scaling of tech companies – effectively acting as a 28th regime alongside existing national frameworks.

   With such an initiative, an AI scale-up firm, for instance, could register one legal entity and have one set of labour market rules and stock option taxation – ideally investment-friendly ones – regardless of where in Europe its employees reside. It could also pay value-added taxes (VAT) at the EU level. And it could abide by one AI regulation without national-level additions – or even operate in an EU regulatory sandbox. Such a 28th regime could be broad in scope to make a difference for tech firms, but narrow in applicability – for instance, only allowing tech scale-up firms in specific domains to be eligible for this simplified treatment – to avoid hollowing out domestic standards built over decades of democratic consensus-seeking.

2. **Scaling up: A pro-investment stance on European M&A.** In investment-intense or winner-take-most industries, scale and commensurate investment returns are critical. This may require an approach that facilitates rather than limits not only cross-border but also in-country consolidation to drive the scale and profitability levels needed to accelerate investments. This could cover the critical technologies outlined above, but also infrastructure such as in advanced connectivity, as well as other industries such as banking and insurance. This may benefit from competition authorities prioritizing the anticipated impact of M&A on investments more than other metrics.

Simplifying the regulatory and permitting environment to make Europe investible and more attractive to start-ups, scale-ups and large innovative firms and investors. Addressing this swiftly could include:

3. **Speeding up: EU-wide, digital, time-bound approvals.** Delays and complexity in permitting can be a major impediment to innovation. Implementing a fully digital, time-bound, single EU-wide permission process could help overcome such obstacles. Examples that emerged from discussions with business leaders include mandating that environmental assessment reviews for building permits (for such projects as semiconductor manufacturing sites or data centres) be processed within a set number of weeks. Another idea floated was to develop an EU-wide certification programme that could simplify healthcare regulatory approvals, helping to encourage cross-border collaboration and perhaps even stimulate competition, for instance, in clinical trials.[40]

4. **Simplifying: Opportunity cost-based stance in regulation.** Certainly, there are many unknowns and risks that new technologies – from AI to bioengineering – might bring, that call for careful oversight and have led to the precautionary principle in the EU. But amid accelerating global technological advancements and heightened geopolitical tensions, the risk of missing out is growing, too. Policy-makers could consider mandates for cost-benefit analyses that estimate and weigh the opportunity cost when devising new rules such as AI or data regulations as high as the risk of unintended consequences; institute time limits so rules eventually sunset if not renewed; and commit to one set of EU-wide regulations rather than directives entailing additional national layers of rules.[41]

Increasing innovation capital and investment. Long-term goals like attracting risk capital and implementing the Savings and Investment Union, as per Letta,[42] remain crucial. But shifting existing capital at scale into innovation could provide a much-needed boost to Europe fast. The EU exported €450 billion in surplus savings in 2024, underscoring the opportunity to direct current European overseas investments towards EU innovation.[43] Europe's immediate focus could include the following initiative explored in previous reports:

5. **Funding risks: Pension booster.** Adjusting the allocation rules related to pensions would enable institutional investors to direct a larger portion of their assets into venture capital (VC) and private equity (PE) investments. This could potentially increase the pool of readily available capital for investments ("dry powder") or total assets under management (AuM), which are currently four times higher in the US than in Europe.[44] There will be concerns about the heightened risk to pension assets, and this risk would need to be calculated and managed. But such a shift could ultimately result in higher returns and higher retirement replacement rates over the investment horizons of such funds.

Driving commercialization. Procurement by the public sector and large private sector firms can create demand signals and remuneration potential for early-stage and sub-scale innovations, and thus much needed confidence in riskier innovation investments. In a discussion with more than 50 CEOs of scale-up firms and unicorns, this emerged as one of their biggest requests.

6. **Creating markets: Government as at-scale anchor customer.** Governments reallocating certain public spending to serve as first buyers of technology at scale could potentially create new markets and revenue streams. For instance, public payors could redirect a portion of European annual healthcare spending to become the first at-scale customer of AI-based diagnostic and treatment pathways. In defence, governments could procure quantum technology-based secure communication channels that still need to be developed.[45] To make a meaningful impact, levels of innovation procurement funding may need to be comparable to private sector investment budgets – in AI, that could mean double- or triple-digit billions.

   Concerns may arise about Europe's limited fiscal room to manoeuvre. But in the long run, Europe may not be able to afford to not make such investments, since they may ultimately save rather than add cost. To that end, Europe may want to consider adjustments to public accounting rules so that some portion of such outlays can be depreciated over time rather than treated as one-off expenses.

Strengthening research and talent. Increasing tech skills can help create a positive feedback loop, where greater innovation and productivity lead to higher returns on investment in skills development, which in turn encourages further demand for skilled workers. This could help Europe address some of its significant talent gaps. One-third of top AI researchers[46] are leaving Europe and tech professionals in the EU earn less than half of what their US counterparts do for similar roles.[47] Moreover, 37% of those in the workforce lack basic digitals skills.[48]

7. **Building talent magnets: Developing tech "CERNs" for all priority technology areas.** Pan-European research hubs funded at the EU level could provide attractive co-investment incentive mechanisms for companies via tax reductions and strengthened IP protection (somewhat similar in concept to CERN, the European Organization for Nuclear Research). These hubs could offer competitive packages for global top researchers to win back talent; provide leading infrastructure like high-performance computing; and offer streamlined IP rights treatment and technology transfers for faster commercialization in prioritized technology arenas. State-of-the-art facilities and equipment and a strong talent ecosystem could additionally recruit and nurture STEM talent who could eventually move into the industry through close ties with leading tech companies.

8. **Securing skills: Reskilling 1 million Europeans in priority tech.** Extending on-the-job reskilling, diplomas and postgraduate courses in fields such as AI, cybersecurity, automation and big data with the goal to train more than 1 million Europeans in skills related to priority tech by 2030[49] could begin to close the skills gap and create the required baseline of tech talent. Europe could win back talent with talent attraction and visa programmes in sectors such as banking and "industrials".[50] Incentives for businesses to upskill, cross-skill and reskill employees and a robust career support system, including internships and job placement services, could begin to bridge the tech skills gap in critical value chain segments.

Cultivating ecosystems and global leaders. Europe has largely missed the software wave and the consumer internet wave in tech. It focused instead on expanding its leadership in areas like industrial machinery and automotives. As a result, Europe does not have innovation clusters to rival Silicon Valley, and fewer leading technology firms that can serve as a nucleus of innovation for start-ups, a customer for new products, a potential funder or later buyer, or a source of well-trained employees and founders. Taking a page from the playbook of emerging economies could help address this.

9. **Securing know-how: Global capability transfer:** Europe can learn from emerging economies that have a long history of technology and capability transfer. Now it may be time for Europe to act where it has fallen behind, specifically incentivizing hyper-scalers to expand R&D presence and footprint in Europe and creating incentives or rules for them to build out European ecosystems and capabilities. More can be done to encourage within-Europe exchange of leading practice and capabilities, too.

To ensure that the nine *grands projets* gain the required traction and momentum to deliver impact fast, a final overarching 10th *grand projet* is proposed with the purpose of coordinating efforts and tracking progress.

10. **Driving action: Deploying a nerve centre and ensuring governance.** Leadership, clear governance and accountability will be needed to move the other nine *grands projets* – as well as Europe's overall competitiveness agenda – to action. Could a "nerve centre" across EU corporate and public leaders, large technology firms, start-up leaders, academics and civil society be established that coordinates and accelerates action? It would need to be sponsored at the highest level, reporting directly to EU leaders and CEOs, to set the right priorities. It could also continuously track progress, and course-correct where needed. One simple metric to track could be: How much in actual investment is being announced and made – in aggregate and per technology arena – in Europe?

Though it's incumbent upon the public sector to initiate and drive the policies it ultimately decides to propose, the private sector does not need to wait and has its own part to play in parallel across the same six key themes (see Box 2).

BOX 2

Europe's private sector has to take its own steps to improve the investment environment and drive productivity and innovation

Industry leaders typically point first to policy and regulatory shifts as essential enablers of raising Europe's global technology competitiveness. Those public sector steps may well be critical, but there are a number of corresponding actions the private sector can take across the same six priority areas to help reduce the continent's innovation and funding gap. Corporate leaders can recommit to bold strategic and productivity agendas to regain lost ground no matter what the environment around them.

- **Building scale.** A complete single market should help – but so would consortiums, alliances and programmatic M&As.
- **Simplifying the regulatory and permitting environment.** Simplification of the regulatory environment should help – but so would private companies joining forces to provide a platform for regulatory services that helps firms navigate public processes and procedures.
- **Increasing innovation capital and investment.** A capital markets union and healthier venture capital and private equity environment should help – but so would more growth-oriented strategies, equity stories and corporate venture units.
- **Driving commercialization.** Government procurement and market creation should help – but so would (cross-)industry partnerships to scale rollouts of new services.
- **Strengthening research and talent.** Better public education should help – but so would corporate on-the-job and formal trainings as well as increased industry collaboration with academia.
- **Cultivating ecosystems and global leaders.** Cluster development and industrial policies should help – but so would particularly large multinational enterprises paying more attention to nurturing ecosystems of innovators around them.

4 Case studies: Exploring the potential across four technologies

An in-depth look at four key technologies and their value chains shows how Europe can use different strategic postures to strengthen its competitive positions.

This research includes an in-depth exploration of advanced connectivity, quantum, AI and semiconductor markets, offering one example technology area for each strategic posture previously highlighted in the maturity-innovation matrix. Each summary provides an overview of the market, including the strategic posture and the current starting point, as well as potential supporting initiatives by the public sector, based on recommendations in the reports by Draghi, Letta and McKinsey Global Institute, as well as World Economic Forum dialogues.[51] These are organized according to the six priority areas for spurring innovation and investment previously highlighted in the paper. Finally, it shares value chain priorities based on the research.[52]

4.1 Advanced connectivity

Europe's starting point: Scaled technology, various well-established leadership positions

Strategic posture: Cement global leaders

Advances in connectivity like 5G (and eventually 6G) and low-power wireless networks don't just make connections faster. They lay the groundwork for critical capabilities, such as smart factories, autonomous driving and precision farming, which will advance Europe's way of life. With the global market expected to reach $3.8 trillion by 2040,[53] this sector has immense opportunity.

Europe's starting point and potential unlocking actions

Europe has a strong ability to compete globally within certain parts of the technology innovation value chain such as 3GPP (the Third-Generation Partnership Project for standards organizations for mobile telecommunications), but its fragmented operator landscape, profit pools sitting outside of Europe, and regulated marketplace mean that significant shifts may be required for Europe to speed up technology adoption.

- **Building scale.** Europe has not grown infrastructure as quickly as other regions, and faces high spectrum costs and fragmented spectrum processes, directly impacting telecom operators' ability to increase network coverage and creating complexity for business-to-business (B2B) companies to invest in wireless technology solutions. Exploring reforms to the EU's regulation and competition stance to support M&A could contribute to a unified, scalable market landscape. Moves could include making mergers conditional on deployment commitments rather than imposing punitive remedies, shifting telecom market definitions to the EU as opposed to individual country level, and favouring post-merger competition enforcement with strong legal means, instead of strict country-level regulation that effectively limits consolidation.
- **Simplifying the regulatory and permitting environment.** The current regulatory environment and competition stance limit consolidation among telecom operators and completion of the Digital Single Market, as evidenced by the fact that the EU has 34 mobile network operators (MNOs) versus three in the US and four in China.[54] Fragmentation created by lack of harmonization restricts cross-border solutions. Introducing cross-border regulatory entities for the advanced connectivity services sector – through for example simplified EU digital approvals – could increase demand for

and deployment of fibre and 5G coverage. The development of 6G infrastructure could depend on regional carriers working together to implement radio access network (RAN)-sharing agreements. To help support such efforts, public sector leaders may consider revising regulations around 6G infrastructure investments.

- **Increasing innovation capital and investment.** Europe benefits from strong private funding, capturing 34% of global private- and public-market investments (excluding corporate investments) in advanced connectivity across the value chain, second only to the US.[55] Yet Europe accounts for a small share of global venture capital investments. Deregulating financial investments in fibre, 5G standalone and IoT networks could potentially accelerate modernization and attract private capital crucial for scale.

- **Driving commercialization.** Historically, Europe has been a laggard on advanced connectivity technology adoption and commercialization. Notable examples include many European countries still trailing the US on mobile 5G penetration. Several strategic initiatives have been launched to bolster its position in advanced connectivity adoption, including the 5G PPP for securing 5G leadership, Horizon Europe for research and Gaia-X for a federated cloud dataspace, but these have so far had limited impact on shifting market leadership. Yet telecom infrastructure build-out remains structurally challenged. To unlock a new level of investment, policy-makers could consider incentivizing industrial companies to invest in digital infrastructure projects, by, for example, becoming early adopters through B2B and public procurement of private wireless and smart cities.

- **Strengthening research and talent.** Europe has a large base and strong talent bench to build on. It hosts two of the largest telecom equipment and services leaders in RAN and publishes nearly three times as much research as the US in this field.[56] While Europe has been at the forefront of R&D and design for connectivity networks, the competition on research and commercialization is growing, most recently from China, despite the US-imposed trade restrictions. Europe could benefit from establishing itself as an early adopter and bolstering R&D investments in high-growth areas such as open, cloud-based and virtualized communication platforms, edge cloud, AI-RAN and 6G development.

- **Cultivating ecosystems and global leaders.** Europe-based global leaders are already investing heavily in 6G research and leading wireless and next-gen tech development. But with underdeveloped standards for shared connectivity, the potential of cross-border advanced connectivity ecosystems remains largely untapped. Harmonizing rules across member states could foster the creation of ecosystems to help fuel the growth of regional services, networks and other digital infrastructure.

Value chain priorities

Within the advanced connectivity value chain, there are three areas leaders may want to explore[57] (Figure 7):

- **Equipment manufacturing.** Europe should consider focusing investments in its already significant stronghold in R&D and equipment manufacturing. Developing cloud-native 5G equipment and AI-RAN, for instance, is a prime growth opportunity, as European manufacturers already are among the leaders in this market and, with focused investment, could supply critical components worldwide.

- **Software.** The software market is currently split between RAN vendors, which have a strong foothold and include the leading European equipment manufacturers, and specialized software companies that typically sit outside of Europe. European OEMs are investing in next-generation ORAN (open radio access network) technology but are facing severe cost pressure from operators due to their diminishing returns on investment (RoI). Synergies at component level in ORAN would occur mostly outside of Europe (given that some large US players are better positioned to capture potential standardization opportunities in security operation centres (SOCs)). One possible way to turn the tide could be to develop an application programming interface (API) ecosystem on top of ORAN architecture, in which European RAN vendors could – together with the European start-up and developer ecosystem, particularly in industrial segments – leverage their experience, capabilities and innovation capacity to champion this segment early on.

- **Connectivity services.** Europe should also consider identifying mechanisms to improve profitability in connectivity services, which underpin advanced digital applications and drive global industrial scale in a wide range of sectors. It could, for example, tackle the challenge of stricter building regulations that drive up costs and lower average customer revenues compared to the US. To help close Europe's fibre and 5G coverage gap – at around 81% coverage, Europe trails the US's roughly 98% and China's approximately 95% coverage[58] – leaders could consider creating cross-company alliances to share the cost and risk of network deployments and eventually leapfrog to piloting early 6G roll-out and become pioneers in the next standard.

FIGURE 7 | **Europe's position in the advanced connectivity value chain**

Key value chain steps[1]

Components	Equipment manufacturing	Software	Infrastructure management and maintenance	Connectivity services
Description				
Sourcing required physical hardware (e.g. chipsets such as specialized system-on-a-chip (SOC) and application-specific integrated circuit (ASIC), antennas and connectors) Players range from chipset manufacturers to infrastructure cloud ecosystem providers	Manufacturing radio access network (RAN) and fibre equipment to be integrated within the network infrastructure Mainly three categories of players: RAN vendors, Open RAN vendors and fibre vendors	Develop supporting software to be used in association with the technologies as well as operations support systems and business support systems Split of market between RAN vendors and software specialists	Infrastructure deployment of 5G networks and fibre roll-out and maintenance Players include telecom operators, tower companies, RAN vendors and systems integrators	Interconnecting new technology into existing networks Offers connectivity (e.g. internet or mobile network access) and value-added services (e.g. security and entertainment) to end users
Europe's competitiveness				
Europe has limited presence in materials, chipsets (including SOC and ASIC), and other components – has significant dependency on Asia (including China) and the US	**Two out of three world leaders for telecommunications equipment and services are based in Europe** (the two largest European companies had ~45% of global RAN market in 2023)[2] **Cloud-native 5G is an area where Europe leads,** has the potential to supply critical components globally	**Leading European players are mainly equipment manufacturers** **Specialized software players typically sit outside of Europe**	**Generally limited innovation in this space** **Largely represented by local or regional players** **Mainly done by telecommunications operators or tower players** selling infrastructure management and maintenance as a service	**EU has 34 mobile network operators (MNOs) as against three in the US and four in China) –** regulation prevents economies of scale **Gaps in 5G coverage and fibre;** 5G coverage is at 81%, lagging the US and China (both at >95%) **MNOs in Europe face lower return on invested capital (ROIC) than those in the US, limiting their ability to invest** in infrastructure and innovate (Europe's capex in connectivity per capita is 40-45% of US and Japan levels in 2022)

Europe's starting point Leading ●●●●● Lagging ■ Strategic focus area

1. Equipment manufacturing also includes development and standardization of connectivity technologies and software includes R&D in software development to be used with connectivity technologies **2.** In these figures, RAN includes software and hardware for macro base stations and smaller cells. Services and solutions belonging to other network domains (e.g. transport and core networks) are not included

Source: The Future of European Competitiveness,[59] DigitalEurope: The EU's critical tech gap,[60] McKinsey Technology Trends Outlook 2024,[61] expert interviews

4.2 Quantum technologies

Europe's starting point: Nascent technology, well positioned to lead

Strategic posture: Create future global leaders

With an estimated market size of ~$0.1-0.5 trillion by 2040,[62] there is a significant untapped potential across all three areas of quantum technology.[63] Quantum computers will enable industries to solve complex statistical problems[64] that are

currently unsolvable, enabling breakthroughs in drug discovery, personalized medicine and many other industries. Quantum communication will shape the future of encryption and data security,[65] while quantum sensors will enable more precise measurements, collecting data at the atomic level, for innovations in medical imaging, navigation and environmental tracking.[66] Researchers still have some major challenges to solve to reap the technology's full benefit, but its market potential and strategic importance make it a top priority.

Europe's starting point and potential unlocking actions

It is still relatively early days for quantum technology, but becoming a leader in the field will require Europe to consider a wide range of moves without much delay.

- **Building scale.** While quantum technology is still nascent, Europe's capabilities position it well to be among the first regions to scale it effectively. Proactively aligning regulatory standards, such as tax policies and fiscal measures, can support the growth and retention of quantum tech companies across member states as the technology matures.

- **Simplifying the regulatory and permitting environment.** Regulations for the nascent quantum technology are still evolving, but the market is already showing signs of fragmentation. Harmonizing national quantum sandbox frameworks with a common set of rules across all member states could enable experimentation and the development of quantum applications by European start-ups, offering a much-needed boost that typically is provided through private investment.

- **Increasing innovation capital and investment.** Five of the top 10 tech companies globally ranked in terms of investment in quantum technologies are based in the US and four in China, while none are based in the EU, according to the Draghi report. While private funds make up about 80% of quantum technology investments, only 9% of these funds have flowed to Europe.[67] Creating a long-term EU quantum chips plan that coordinates funding and architectural choices across the European Investment Fund and European Investment Bank could help concentrate existing funding more efficiently.

- **Driving commercialization.** Quantum tech start-ups in Europe benefit from accelerators, tech transfer organizations and country-based programmes to develop and commercialize innovations, while projects like Project Petrus aim to deploy a secure quantum communication infrastructure across the EU.[68] However, the region struggles with weaker coordination between research start-ups, venture capital and leading industries. Creating a CERN-like organization for quantum technologies could foster extensive collaboration among academia and industry and enable rapid scaling of commercial opportunities to shorten time-to-value for innovation.

- **Strengthening research and talent.** The EU has the highest number and concentration of quantum technology talent,[69] yet retaining skilled employees in European industry and improving technology transfers still present challenges. To address these, Europe should continue building quantum technology programmes at universities and up-skilling programmes in industry to give graduates more relevant knowledge in adjacent areas.

- **Cultivating ecosystems and global leaders.** Member states are announcing large investments to create local quantum capabilities, and many ecosystems and hubs have already been established across the region, including in Munich, Delft, Paris, Basel, Zurich, Oxford and Stuttgart. Focusing on scaling up ecosystems similar to regional initiatives such as the Munich Quantum Valley, with industry collaboration at the core, can strengthen the transfer of innovation to industry.

Value chain priorities

With the opportunity to drive early adoption and establish global leadership, Europe may want to consider building on its current strengths in several areas of the quantum value chain, including the following (Figure 8):

- **Quantum communication technology.** Given the strategic importance of quantum communication capabilities overall, Europe could benefit from establishing a stronger position across the entire value chain. Defence projects, for example, could enable early development and testing of ultra-secure communication channels to protect sensitive national security information, capabilities that could later be adapted for broader governmental and civilian applications.

- **Hardware.** A primary focus for Europe could be significant investments in hardware manufacturing across the quantum value chain. Europe has experience and expertise in the delivery of photonic networks and superconducting circuits – two essential building blocks for quantum infrastructure – but it faces new competition from large US tech firms that have greater access to private capital. As a result, many quantum computing hardware start-ups have relocated away from Europe. In quantum sensing, where large European incumbents currently partner with smaller players, moving rapidly from prototype to commercialization will be crucial to remain competitive.

– **Systems and application software.** Since off-the-shelf products do not yet exist, most business models are still based on exploratory research projects. Efforts to develop capabilities as the technology matures can include investments in quantum neural networks for AI and machine learning applications as well as in superconductors for high-quality cubits with long coherence times, crucial for reducing application error rates. To scale industry solutions, such as quantum communication applications for defence and financial transactions, Europe could focus on forming cross-sector coalitions for companies that share a common technical backbone, which could increase their chances of getting funding for pilot programmes with industry participants, such as automotive players.

FIGURE 8 **Europe's position in the advanced connectivity value chain**

Key value chain steps

Equipment/ components	Hardware	Systems software	Applications software	Services
Description				
Providers of hardware components e.g. electrical components, dilution refrigerators and semiconductors	Manufacture of full-scale quantum computers and simulators	Software development that interacts with the quantum processing unit (e.g. low-level programming)	Development of algorithms that run on quantum equipment, interacting with the systems layer	Consulting and education services around strategic and technological aspects of quantum technologies
Europe's competitiveness				
1) Quantum computing (QC)				
Most mature segment – in value chain with Europe as leader (e.g. detector tech and control components) Tech improvement needed to enable scaling of fault-tolerant QC	**Mature value chain segment (e.g. superconducting circuits) dominated by tech giants,** but Europe competes well and has presence	**Low presence of European players, still in prototype phase** for system software players (e.g. logical programming languages and error-correction software for quantum technology)	**Europe excels in algorithms for applications,** but is outpaced by US/China with large and at-scale hardware and software players with leading full-stack solutions	**Growth expected, but still in early-stage development** (e.g. cloud services) where Europe lags. Mix of upward integrating hardware and dedicated cloud players offering access to third-party hardware
2) Communications				
Europe leads in quantum key distribution (QKD), and has presence of both general and specialized quantum tech component manufacturing	**Europe is strong in QKD systems. Global giants have entered hardware,** but start-ups are more technologically advanced	**European research is competitive** as software development follows progress in hardware	**Europe is well-positioned** in an immature value chain segment; telecom companies have started to invest to fill the role as quantum network operator	**Low maturity with few consulting services players in the market –** existing players focus on security or general quantum technology
3) Quantum sensing (QS)				
Most mature segment in the sensing value chain **Fragmented landscape in Europe,** which has some commercial products but limited standardization	**Europe competes moderately in QS hardware manufacturing,** and we see **European incumbents partnering with smaller players** to commercialize	**Europe is strong in the innovation and research of this emerging domain,** though it still has low maturity with few players on the market	**Europe is strong in research and number of start-ups in this less mature domain** with few players As the hardware segment matures, Europe is likely to be threatened by global hardware/software giants Application themes are focused on different use cases (e.g. bio imaging, navigation and infrastructure monitoring)	

Europe's starting point Leading ●●●●● Lagging ■ Strategic focus area

Source: The Future of European Competitiveness,[70] DigitalEurope: The EU's critical tech gap,[71] McKinsey Technology Trends Outlook 2024,[72] expert interviews

4.3 Artificial intelligence (AI)

Europe's starting point: Scaling technology, starting to fall behind

Strategic posture: Pick your battles, leapfrog

The AI market is set to be one of the largest among emerging technologies, projected to reach $3.1 trillion globally by 2040.[73] Generative AI (GenAI) alone could inject over $575 billion into the European economy by 2030 through productivity gains.[74]

However, AI's importance extends beyond its economic growth potential; the geopolitical landscape is evolving, and it is unclear whether adversaries or even allies might place restrictions on the technology, raising strategic implications for Europe's AI ambitions and sovereignty.

Europe's starting point and potential unlocking actions

Europe has strong potential to compete in AI (comprising applied AI, GenAI and machine learning operations), which could help address its current labour shortage and reinforce its economic resilience. Yet it could have a hard time staying relevant if its own companies don't create greater demand for the burgeoning technology. So far, European organizations have been notably slow to adopt AI in their own operations; they trail their US counterparts in that critical metric by 45% to 70%.[75] Bridging Europe's AI gap with both the US and China, whether for adoption, funding or other areas, is not an easy task given Europe's data sharing and privacy safeguards, high energy costs and fragmentation. Some possible solutions include:

- **Building scale.** Europe currently lacks the local computing and cloud hosting capacity to develop and scale AI across the continent. With data centre demand projected to grow 22% per year by 2030,[76] European policy-makers may want to consider facilitating increased investments in data centres and cloud-hosting facilities, through targeted incentives and access to reliable and affordable (green) energy. Creating an EU-wide framework for providing "computing capital" to innovative small and medium-sized enterprises in the EU could be explored, as could opening the Euro High Performance Computing Joint Undertaking (Euro HPC JU) to a federated AI model favouring public-private cooperation to develop the relevant infrastructure.

- **Simplifying the regulatory and permitting environment.** The EU AI Act has taken a step towards modernizing regulations specific to AI, yet 70% of European companies report they find the obligations too complex.[77] Policy-makers may want to consider harmonizing national AI sandbox frameworks across all member states to facilitate the development of innovative AI applications in selected industrial sectors, while also ensuring streamlined and consistent implementation of AI regulations and the General Data Protection Regulation (GDPR).

- **Increasing innovation capital and investment.** Europe is significantly underinvested in AI. The US funnels six times as much private capital into the technology, and European public sector funding also significantly lags both the US and China.[78] To begin to bridge the gap, Europe could explore loosening pension private equity/venture capital (PE/VC) allocation rules and setting an aspiration for member states to invest 0.1% of European GDP in GenAI infrastructure, such as data centres along several AI verticals.[79] This could be supported through the allocation of public budgets for procurement of AI applications for sectors such as healthcare, defence and automotives, with potential guardrails to allocate a defined share to European innovators.

- **Driving commercialization.** Despite some significant advancements in AI, particularly in healthcare and banking, Europe still trails the US in commercialization due to lower penetration and corporate adoption. The integrated use of open-source AI models with proprietary ones can be a way to trickle down innovation and support commercialization. Gaps in growth funding, and less sector collaboration, especially between new players and incumbents, only add to the challenges. Simplifying business regulations with measures such as a "28th tech regime" could be beneficial in addressing disparities in European companies' scale and resources.

- **Strengthening research and talent.** Though Europe has slightly more AI professionals than the US and produces 22% of the world's leading AI researchers, only 14% stay in the region.[80] This is driven by a large compensation gap of two to four times between the US and Europe.[81] Incentives such as premiums or tax breaks for talent win-back initiatives, and support for research institutions could enhance Europe's appeal to top-tier talent.

- **Cultivating ecosystems and global leaders.** The scale of investment required to be globally competitive in AI is too large for any single European company or even country to manage. Building an AI start-up ecosystem in Europe could enable future development of globally relevant, scalable solutions for priority AI application verticals, such as mobility, manufacturing and defence.

Value chain priorities

Europe's AI challenge is daunting. It holds less than 15% global market shares across all four segments of the GenAI value chain,[82] with less than 5% in cloud infrastructure (Figure 9). Making up ground will depend on its ability to spur the creation of AI technologies across the value chain including:

- **Infrastructure and supercomputing.** Europe lags in computing power. It has only half the supercomputing capacity in flop/s,[83] which is increasingly necessary in basic and applied research. Establishing sufficient computing power, at a sustainable operating cost, is essential for maintaining its competitiveness in AI services.
- **Foundation models and AI applications.** A few European specialized language models and AI applications are increasingly competitive. Europe is home to several emerging AI unicorns, and leading global software companies are incorporating AI into their products. Yet companies in both parts of the AI value chain remain underfunded compared to their US peers. To maintain relevance and even expand those strengths, Europe should consider prioritizing actions to create a more attractive environment for global investors, building on ideas postulated by Draghi.[84]
- **AI services.** Europe already has a strong presence in this part of the value chain, as home to major players focused on integrating AI into various business processes and industries. By focusing on specialized offerings for sectors where Europe has existing industrial strengths, such as automotives, defence and manufacturing, European service providers could accelerate adoption and drive demand.

FIGURE 9 **Europe's position in the generative AI value chain**

Key value chain steps

Semiconductor raw materials, equipment, design and manufacture	Cloud infrastructure and supercomputer	Foundation models	AI applications	AI services
Description				
Covered in the semiconductor section	Infrastructure offering computing power and data hosting, including basic software layer	Design and training of foundation models	AI-based software using AI to perform specific tasks across various industries	Services to support with design and deployment of AI use cases
Europe's competitiveness				
Covered in the semiconductor section	Europe cloud infrastructure leader has **<$1 billion** in revenue as opposed to **~$90 billion** for the US market leader	**~$6 billion** valuation for European market leader vs **~$80 billion** for US market leader – European players increasing its global market share	**~12%** of global VC and PE funding for software-as-a-service[2] AI companies raised by European companies, with European players increasing global market share	**~ $80 billion** total revenue for Europe market leaders vs **~$90 billion** for similar US companies, with European players increasing global market share

Europe's starting point Leading ●●●●● Lagging ■ Strategic focus area

Source: The Future of European Competitiveness,[85] DigitalEurope: The EU's critical tech gap,[86] McKinsey Technology Trends Outlook 2024,[87] expert interviews

4.4 Semiconductors

Europe's starting point: Scaled technology, leading in select segments, needs to catch up in others

Strategic posture: Secure access, capacity and adoption in segments where Europe falls behind; strengthen and double-down in segments where Europe leads

As the backbone of nearly all electronic devices and next-generation technologies, semiconductors are critical to Europe's economic and strategic independence. However, this sector is in many segments dominated by the US and China, for example, with Europe's front-end manufacturing just 9% of total global semiconductor capacity.[88] Strengthening access, building domestic production and driving adoption in these segments of semiconductors may reduce Europe's reliance on foreign supply chains and enhance its tech resilience. In addition, Europe is leading in various segments, such as early-stage R&D for the leading-edge nodes and new materials, semiconductor equipment, power electronics and semiconductors for automotive and industrial applications.

Europe's starting point and potential unlocking actions

Europe can draw on its leadership in early R&D, materials, equipment, CPU IP and automotive and industrial applications to compete in semiconductors. However, to ensure retention of its strategic autonomy, Europe needs to structurally strengthen its position in various segments and should consider actions that can overcome challenges in risk funding, energy costs, infrastructure support and talent, including:

- **Building scale.** Europe is home to some of the leading equipment manufacturers in certain areas of the sector (such as lithography or advanced packaging). But in a global value chain, it has limited scale across high-value segments, such as chip design for leading-edge nodes, and front-end and back-end manufacturing. Defining minimum viable, local back-end and front-end manufacturing capacity in Europe could serve as a pillar of the EU initiative to attract foreign, leading-edge designers and manufacturers to the region and to ensure sufficient independence in challenging times.

- **Simplifying the regulatory and permitting environment.** The EU has supported its semiconductor industry through a combination of policy measures, funding programmes and stringent regulations regarding environmental standards, cybersecurity and data protection. European players face higher compliance costs compared to less tightly regulated regions.[89] Adopting a simplified permitting process for chips across member states, including streamlined environmental requirements where relevant, may simplify construction processes to attract manufacturers.

- **Increasing innovation capital and investment.** Despite committing large investments through the EU Chips Act, Europe is trailing both China and the US in private funding and public support of the semiconductor industry.[90] An EU semiconductor strategy could coordinate funding and architectural choices, addressing the availability of grants, subsidies or R&D tax incentives for leading-edge design centres active in chip design and foundries in selected strategic segments. Exploring avenues to competitively price stable and green energy within strategic domains, such as by providing energy tax reductions, state subsidies and price caps, could create a more favourable operating environment for attracting and retaining manufacturers.

- **Driving commercialization.** Though it has attracted foreign private investments with joint ventures for the construction of new semiconductor fabs, Europe remains challenged by heavily subsidized industries in the US and East Asia and a lack of innovative and scalable back-end manufacturing capabilities. To drive commercialization, Europe could consider defining chip procurement preferences for EU products and a new "EU chips" certification for public and private procurement tenders, e.g. semiconductors for AI data centres or defence. Of course, this only works if these semiconductors are competitive and state-of-the-art – hence the need to do this smartly (e.g. by requiring a minimum amount of European content in the aggregate value-chain steps, where the minimum amount scales with the build-up of Europe's capabilities).

- **Strengthening research and talent.** Despite being world-leading in early-stage pre-competitive R&D, Europe is experiencing a shortage of specialized engineering talent. A targeted technology skills acquisition programme could attract, develop and retain the talent critical for advancing semiconductor technology in front- and back-end manufacturing, AI chip design and new materials development. Such a programme could include a special visa for graduates and researchers in advanced electronics, enhanced subsidies for high-demand skills like electronic engineering, new EU-wide scholarships for top graduate and PhD students, and early internships and temporary contracts in public and private research centres.

– **Cultivating ecosystems and global leaders.** Given the global interdependencies of the semiconductor value chain, ecosystems tend to be transcontinental, but high operating costs render Europe less attractive for joint ventures and co-investments. A new fast-tracking "important project of common European interest" programme could be introduced to support European consolidation and leadership in semiconductor manufacturing equipment for lithography, depositions and other priority capabilities. Europe could also consider incentives for foreign hyper-scalers to expand their presence in Europe or pursue joint ventures with local firms in leading edge manufacturing, advanced packaging facilities and advanced substrates.

Value chain priorities

No region is self-sufficient all through the semiconductor value chain, but Europe can effectively compete by creating a robust foundation for technological leadership in certain promising areas, including (Figure 10):

– **Early-stage R&D and materials.** Europe can double down on its global leadership in early-stage R&D in new materials, such as leading-edge logic, power, optical as well as process technologies and leading-edge equipment. There is also an opportunity to strengthen business models to better monetize market strengths.

– **Strongholds for automotive, industrial and power electronics.** With its strong industrial domain expertise, the EU is well-positioned to combine specialized chips, operating systems and software stacks for specific industry applications, such as advanced driver-assistance systems (ADAS), connectivity modules and extensive sensor networks.

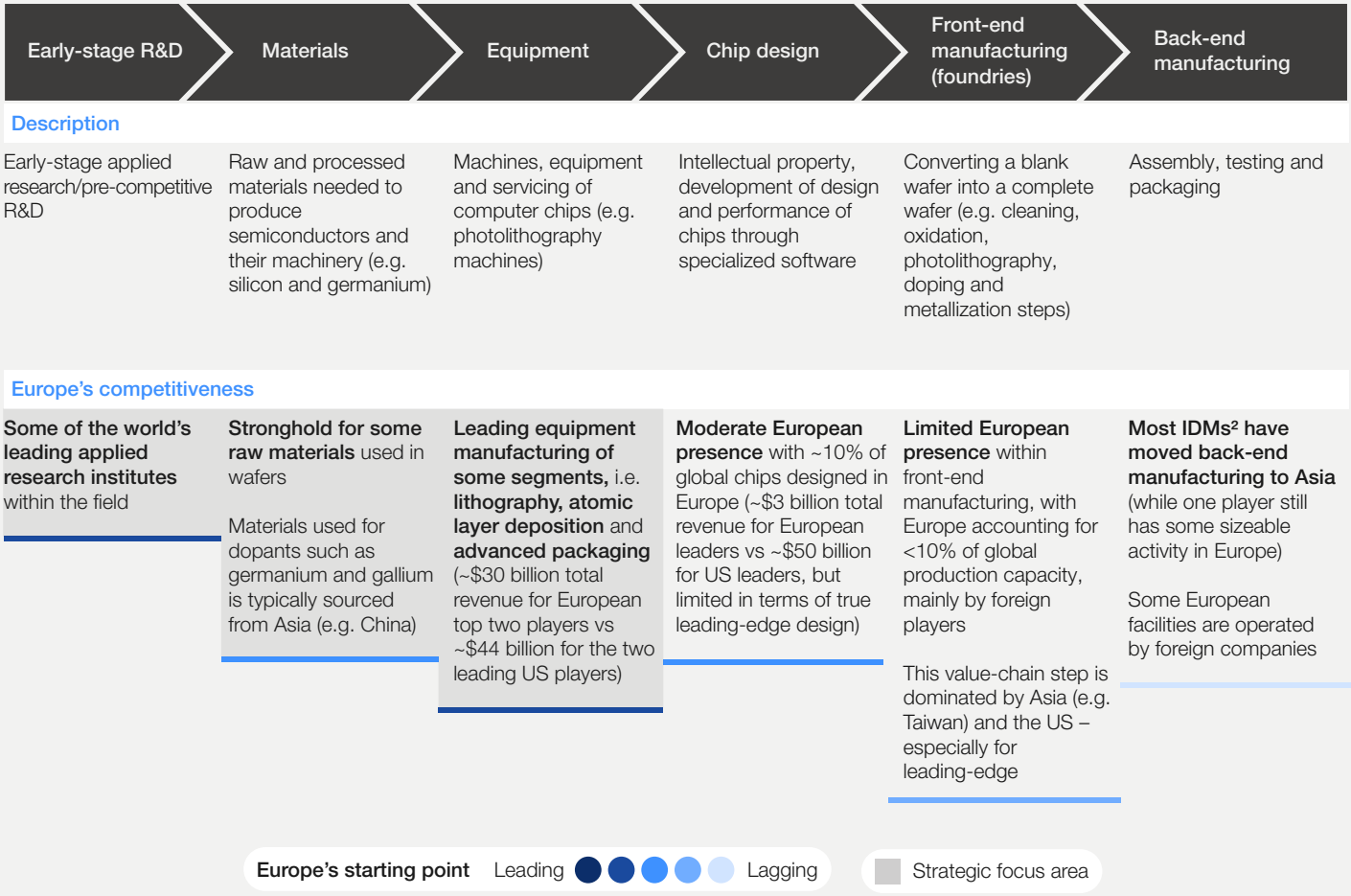
– **Chip design.** Europe's strengths in areas such as CPU IP could be leveraged to build and scale true centres of excellence for leading-edge semiconductor design, e.g. for automotive and industrial AI chips. To remain competitive, Europe will need to build a highly-skilled talent pool, which it can leverage to leapfrog in next-generation chip innovation – especially for quantum and neuromorphic computing, crucial for real-time processing in robotics, IoT and AI. With some of the world's top applied research institutes, Europe is well-positioned to drive these breakthroughs.

– **Front-end manufacturing.** Europe could consider actively driving critical scale in front-end manufacturing, in mature (where there is an ongoing conversion from legacy 200 millimeter (mm) to more efficient 300 mm fabs), advanced (where European players can pool and team up with global leaders in foundry) and leading edge (where Europe should stay the course and ensure presence above a critical threshold).

– **Back-end manufacturing.** Europe could consider building up an innovative back-end manufacturing capability with an ambition of around 5-10% market share. This may reduce reliance on foreign supply chains to safeguard against global disruptions. Joint ventures could help build these capabilities quickly, particularly if regions can be identified with a competitive cost base and access to renewable energy.

FIGURE 10 | **Europe's position in the semiconductors value chain**

Key value chain steps



1. By company mapping across value chain **2.** Integrated device manufacturers

Source: The Future of European Competitiveness, DigitalEurope: The EU's critical tech gap, McKinsey Technology Trends Outlook 2024, expert interviews

Conclusion

Europe has to strengthen its competitiveness to remain relevant in the Intelligent Age. The issues and broad answers are well known. Now is the time to follow through on priority initiatives that can catapult the “old continent” into this age of innovation. This research argues for razor-sharp strategies, lighthouse initiatives that need to be resourced with scale and stamina, and priority public-sector catalysts.

This is also the time for bold visionary leadership and decisions setting the guardrails and aspirations needed to refocus energy from analysing difficulties to turning vision into reality. Too much is at stake: it is time for Europe to move from ideas to action.

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