Reclaiming Europe's Edge: Competitiveness *through* STEM Talent

ane ASSOCIATION OF NORDIC ENGINEERS

Content

Foreword

The Association of Nordic Engineers (ANE) represents trade unions of engineers and STEM (Science, Technology, Engineering and Mathematics) professionals who possess critical know-how and competencies essential for driving innovation, technological development, and the sustainable transition of our societies. This critical role is not sufficiently acknowledged, because, today, we face persistent shortages of STEM talents, which poses a significant threat to Europe's ability to remain competitive in the global economy. Therefore, ANE actively urges policymakers at both the Nordic and EU levels to recognize and address the STEM skills gap across diverse industry sectors.

To overcome the lack of dynamism in Europe, as rightly pointed out by Mario Draghi in the report: The Future of European Competitiveness, politicians need to dare to go beyond the soft forms of coordination in the EU policies related to STEM skills. Politicians can't use national competence as an excuse to hinder the political commitment to bridging the current STEM skills gap. We reject this notion and believe it is crucial to challenge it.

In response, we commissioned this report to demonstrate that STEM skills shortages are not merely an education issue but a cross-sectoral one. The report also underscores that this challenge transcends national borders. The Nordic countries offer attractive job markets that draw STEM talents from across Europe. However, if the EU allows certain regions to lag, we risk weakening the Single Market and failing to meet our green and digital ambitions.

This report: Reclaiming Europe's Edge: Competitiveness through STEM Talent, positions STEM professionals as a cornerstone of Europe's competitiveness, highlighting their role in innovation, economic growth, and strategic autonomy.

The report comprehensively analyses the current state of STEM talent mobility within Europe. It emphasises the urgent need for cohesive strategies to address the skills shortages that threaten our global competitiveness. The report outlines the necessary steps for the European Union to enhance its attractiveness as a destination for skilled STEM professionals while addressing barriers to mobility and integration. Based on the report's findings, we have developed recommendations for the EU.

These emphasise the importance of prioritising STEM competencies on the EU political agenda, significantly increasing research and development (R&D) funding to drive technological advancements, and creating a supportive ecosystem for scaling up innovations. Finally, we provide concrete recommendations for an EU STEM Strategy.

You can download the recommendations here:
Recommendations

Acknowledgements

We extend our heartfelt gratitude to Hanne Shapiro from HANNE SHAPIRO futures for producing this report. Hanne works at the intersection of education, the labour market, and the business world, collaborating with Danish and international clients to leverage new technology for social cohesion, sustainability, and competitiveness.

We also thank ANE's policy group for their inspiring input and contributions to this report.

Introduction

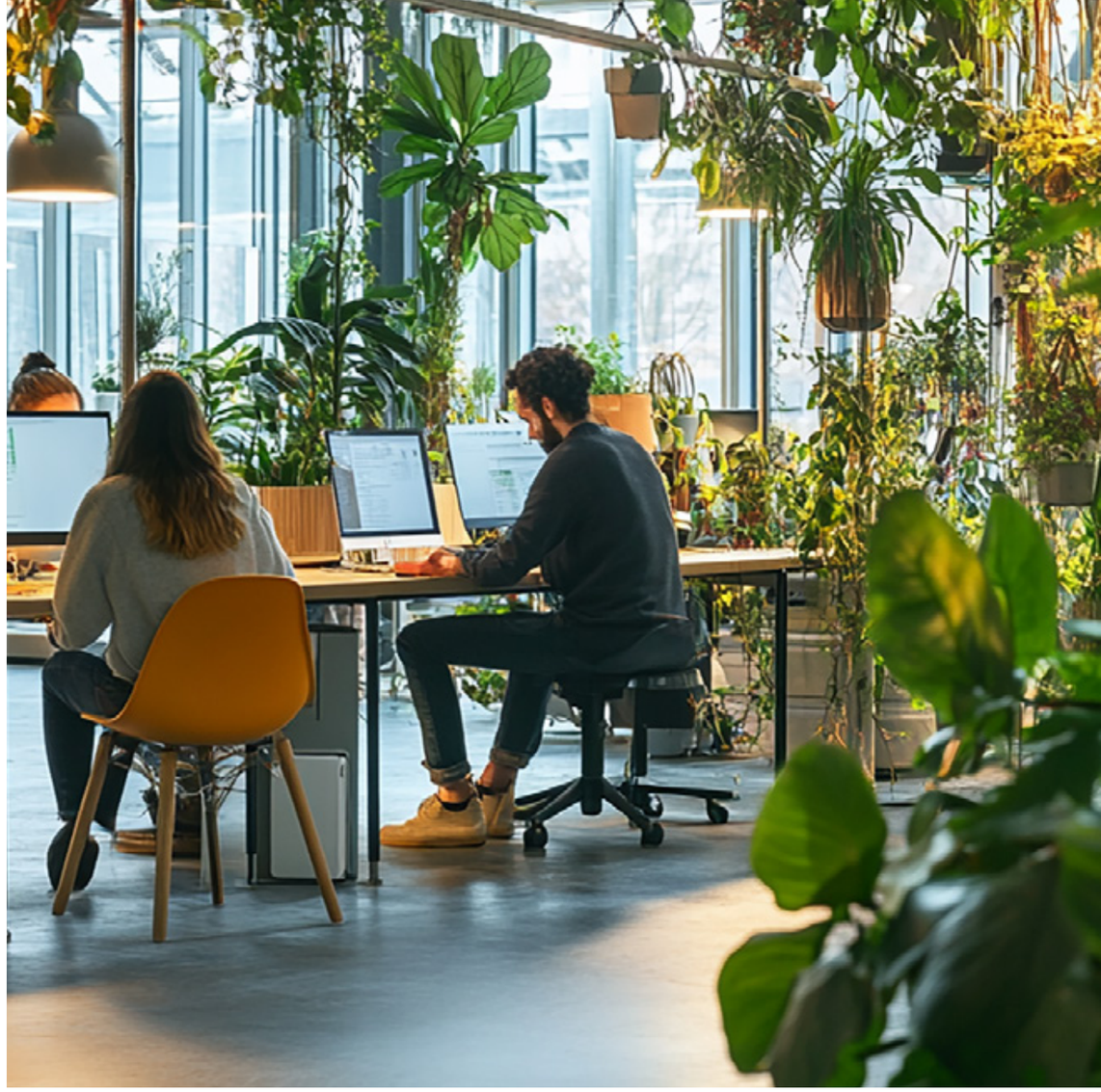
In the 2024 State of the Union speech[1], the EU Commission president, Ursula von der Leyen, announced the European ambition to do "whatever it takes" to keep its competitive edge. One immediate action was to entrust the former Italian prime minister, Mario Draghi, to produce a report with an assessment of the EU's competitiveness and suggestions for ways forward. Keeping the EU's competitive edge and strategic autonomy will be the priority of the EU Commission (2024-2029), and it will be challenging to achieve the ambitious goals without the strategic development of STEM skills as a basis for the EU's competitive edge.

The lack of STEM skills poses a significant threat to Europe's ability to remain competitive in the increasingly technology-driven global economy. It not only hinders research and innovation, but it also poses substantial barriers to European advancement in areas such as artificial intelligence, sustainable energy, and medical research. Following the publication of the Science, Research and Innovation Performance of the EU (SRIP) report, the Association of Nordic Engineers (ANE) commissioned a study to examine and provide strategic recommendations on the nexus between Europe's global competitiveness and STEM talent to the incoming Commission, 2024-2029.

[1]State of the Union Address by President von der Leyen (europa.eu)

Methodology

This report is based on a comprehensive literature review analysing the intricate and interrelated challenges currently hindering Europe's global technological competitiveness. It explores the strategic policy measures needed to enhance Europe's technological leadership, with a particular focus on the critical role of STEM talent in driving this agenda forward. The review has drawn on a diverse range of sources, including European Union policy documents, reports from international organizations like the OECD, leading think tank publications, policy publications from outside the EU, and key academic research.



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> It explores the strategic policy measures needed to enhance Europe's technological leadership, with a particular focus on the critical role of STEM talent in driving this agenda forward.

The report is structured as follows:

Chapter 1 presents an overall assessment of the challenges posed to European global competitiveness.

Chapter 2 further unfolds, how the EU has become stuck in what has been characterised as a middle technology trap. For Europe to regain global competitiveness, the EU must prioritize investments in advanced key technologies, and that hinges on STEM skills.

Chapter 3 situates STEM talent as a key enabling force in regaining a competitive edge globally. It makes a compelling case for a European STEM strategy, emphasising the need for a comprehensive, horizontal policy approach supported by robust metrics.

Chapter 4 highlights the limitations of current skills anticipation methods and emphasises the need for granular approaches considering developments at the occupational level, at the sectoral level, and within value chains to develop responsive and coherent continuing training measures at the European level. Additionally, it calls for a more coordinated use of European funding schemes for continuing training to avoid investment overlaps and to ensure that these funds contribute to sustainable and scalable business models.

Chapter 5 discusses the importance of advanced research infrastructures in Europe as key to regaining technological competitiveness. These infrastructures are also crucial for attracting and retaining STEM professionals in R&D and innovation careers.

Chapter 6 emphasises the importance of creating enabling conditions to help tech startups scale and compete globally. This includes a supportive regulatory frame-work, access to capital, and a strong STEM skills base throughout the R&D cycle.

Chapter 7 concludes by stressing the urgent need for the EU to regain its leadership in high-end technologies. To achieve this, it calls for a comprehensive, cross-sector STEM strategy, supported by clear metrics and effective governance structures.

1.
Reclaiming Europe's Edge:

The introductory chapter sets the stage for this paper by examining key factors, which have contributed to Europe's decline in global competitiveness over the past two decades, while the US and China have positioned themselves in the race for technological leadership.

Over the past two decades, Europe has seen a decline in its global competitiveness. To regain competitiveness, the EU must prioritise coherent approaches to competitiveness taking fully into account that human capital, and in particular STEM talent, is the key resource to sustainable global competitiveness. Global competitiveness is, at present, played out between the two dominant powers, China and the United States, engaged in a race for dominance, increasingly marked by a winner-takes-all dynamic. China is intently focused on capturing and internalising all segments of the advanced technology supply chain, while the US is implementing large-scale industrial policies to restore high-value domestic manufacturing and using protectionist measures to exclude competitors and reorient supply chains.

The ongoing transformations are mirrored in the composition of the global list of Fortune 500 companies. The list is dominated by Chinese and US firms; moreover, the list of firms mirrors how STEM talent is a cornerstone of competitiveness.[2] [3] In the last 15 years, the number of European firms forming part of the global list of Fortune 500 companies has roughly halved.[4] For Europe to compete in this global reality, it will require technological leadership and a holistic strategy across Directorate-Generals (DGs), with ambitious targets and rigorous execution to overcome the current fragmentation in policy efforts.

New technologies are reshaping our world by accelerating the flow of information and transforming industries at an unprecedented rate. Knowledge is spreading more quickly than ever, and innovations are creating new sectors while disrupting old ones. Advanced economies continue to enhance their technological capabilities, while emerging economies are rapidly catching up and even leading in certain areas. The geopolitical turbulence brought about by the war in Ukraine has led to instability in global value chains.[5] The challenges in trade relations are evident in the significant increase in trade and foreign direct investment (FDI) restrictions affecting EU countries, which nearly tripled between 2012 and 2022 (ibid). A notable example is China, responsible for 80% of the global graphite supply, a crucial component in electric vehicle batteries. In December 2023, China imposed export restrictions on this material.[6]

These developments have emphasised that Europe must take action to strengthen open strategic autonomy and reinforce global leadership as spelt out in Resilient EU 2030.[7]

However, Europe's competitiveness cannot be bolstered without addressing the foundations for technological innovation and leadership, which hinge on a strong base of STEM talent.

> **The global list of Fortune 500 companies is dominated by Chinese and US firms; moreover, the list of firms mirrors how STEM talent is a cornerstone of competitiveness.**

[2] https://interactives.fortune.com/global_500_2023/dashboard/index.html
[3] https://www.fortune.com/ranking/global500/
[4] https://ert.eu/documents/2022bmr/
[5] Strategic Foresight Report 2023 https://commission.europa.eu/system/files/2023-07/SFR-23-beautified-version_en_0.pdf
[6] McKinsey Global Institute (2024) Accelerating Europe. Competitiveness for a New Ara. https://www.mckinsey.com/mgi/our-research/accelerating-europe-competitiveness-for-a-new-era
[7] Spanish Presidency (2023) Resilient EU 2030. https://futuros.gob.es/sites/default/files/2023-09/RESILIENTEU2030.pdf

1.
Reclaiming Europe's Edge:

Europe grapples with several interconnected issues that place it at a disadvantage[8]:

An ageing STEM workforce and an insufficient STEM talent pipeline. In 2023, from the 71.8 million people employed in science and technology in the EU, more than 32.5 million were between 45 and 64 years old, corresponding to 45.2% of persons engaged in Science and Technology (S&T) occupations in the EU. In comparison, the S&T workforce aged 25-34 numbered 18.8 million in 2023, corresponding to 26.2% of persons employed in S&T occupations in the EU.[9] The situation is furthermore aggravated by differences in the STEM talent pipeline compared to competitor economies. In 2021, the EU had about 20% fewer STEM graduates per thousand inhabitants than the United States, and 45% fewer than South Korea.[10]

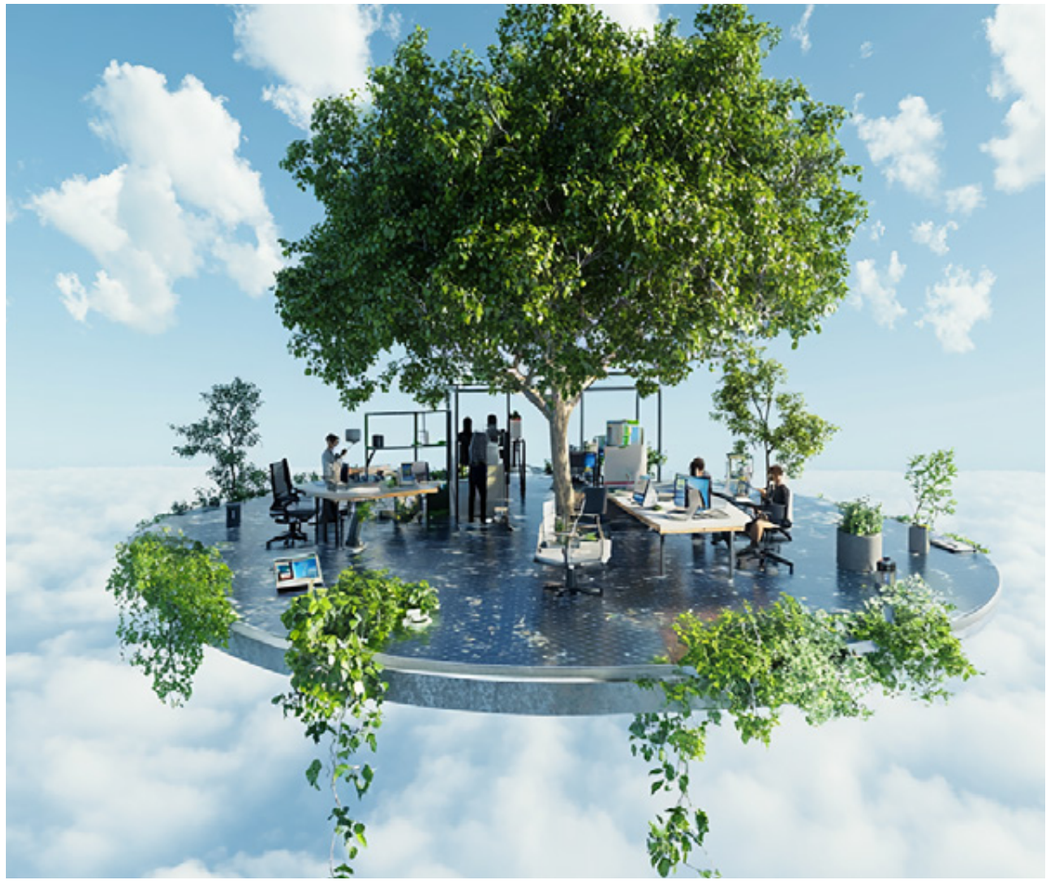
Absence of strong technology ecosystems: Compared to leading regions, Europe lacks robust technology ecosystems that can drive and sustain innovation.

Underdeveloped risk-capital funding: The availability of venture capital in Europe is insufficient to support high-risk, high-reward innovative ventures.

Regulatory complexity is perceived as a major obstacle to competitiveness, and inconsistency in the regulatory environment is referred to as a key issue undermining the competitiveness of companies.[11]

Fragmentation and lack of scale: Europe's fragmented market structure hinders the ability to achieve the necessary scale for competitive innovation.

High energy prices in Europe pose a significant barrier to the EU's global technological competitiveness, as they drive up operational costs for businesses in ways that ultimately hamper investments in innovation. It should, however, be noted that those Member State countries that have invested in clean energy technologies, in general, are less affected by high energy prices.[12]



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[8]Bauer Matthias (2023) What is Wrong with Europe's Shattered Single Market? – Lessons from Policy Fragmentation and Misdirected Approaches to EU Competition Policy https://ecipe.org/publications/europes-shattered-single-market-eu-competition-policy/
[9]Eurostat(2023) Human Resources in Science and Technology. https://ec.europa.eu/eurostat/statistics-explained/SEPDF/cache/2193.pdf
[10]https://cset.georgetown.edu/article/the-global-distribution-of-stem-graduates-which-countries-lead-the-way/
[11]https://ert.eu/wp-content/uploads/2024/03/ERT-Competitiveness-and-Industry-Benchmarking-Report-2024.pdf
[12]Compass Lexon (2024) Energy and Climate transition. How to strengthen Europe's competitiveness. Business Europe. https://rebooteurope.eu/energy-climate-transition-how-to-strengthen-eu-competitiveness/

1.
Reclaiming Europe's Edge:

European competitiveness fundamentally depends on the capacity of companies to spearhead groundbreaking innovations, which are increasingly underpinned by advanced technologies, with artificial intelligence (AI) playing a pivotal role. Therefore, there is an urgent need for coherent policy measures that place the cultivation of STEM talent at the core of Europe's competitiveness agenda.[13] This approach must encompass not only AI but also a wider range of advanced technologies, including biotechnology, nano-technology, and quantum computing. These technologies, central to driving transformative businessinnovations, rely on a robust pipeline of STEM talent to develop, implement, and scale them effectively across industries. Fostering such talent is essential for ensuring that Europe remains at the forefront of technological progress and continues to compete successfully on a global scale. STEM talent is thus pivotal in an integrated sustainable competitiveness strategy which can enable Europe to position itself in global value chains in frontier technologies.[14] While the political guidelines for the next European Commission acknowledge the need to strengthen the educational foundation for STEM talent, it is crucial to recognise that this alone will not be sufficient to harness the full potential of STEM investments in Europe. To ensure that Europe is globally competitive looking ahead, a comprehensive STEM strategy must be implemented, which must be broader in scope than concerned with education and lifelong learning policies. This includes enhancing the attractiveness of research infrastructures, creating clear and rewarding career pathways for STEM researchers, and providing access to sufficient capital to enable successful tech start-ups to scale and thrive within the European market. Without such complementary measures, Europe risks losing out on the benefits of increased STEM investments, as talent and innovation may migrate to more conducive environments elsewhere, thereby undermining the EU's ambition to be a leader in science, technology, and innovation on the global stage.[15] While the EU has created several major policy initiatives to drive green and digital transformation such as the Chips Act and the Net-Zero Industry Act, there is now a need to bring the specific policy measures together in an overarching competitiveness framework, situating STEM as the motor of future competitiveness. A European STEM strategy is urgently needed to enable the realisation and impact on European competitiveness.[16]

> **STEM talent is thus pivotal in an integrated sustainable competitiveness strategy which can enable Europe to position itself in global value chains in frontier technologies.**

[13] Accelerating Europe: Competitiveness for a new era
[14] https://goingdigital.oecd.org/en
[15] Europe's Choice (2024) Political Guidelines for the Next European Commission 2024-2029 https://commission.europa.eu/document/download/e6cd4328-673c-4e7a-8683-f63ffb2cf648_en?filename=Political%20Guidelines%202024-2029_EN.pdf
[16] Europe needs to make its STEM strategy a reality now. https://ceemet.org/wp-content/uploads/2024/03/STEM-Strategy-Joint-Statement-EN-ceemet-eceg-iAE-Ceemet.pdf

2.
The dynamics of Global Technology leadership

This chapter further unfolds, how the EU has become stuck in what has been characterised as a middle technology trap.

As global value chains evolve, there are increasing concerns that Europe is caught in a middle-technology trap. To regain its global competitiveness, the EU must prioritise investments in advanced key technologies. Additionally, addressing STEM skills shortages is essential for European firms to strategically position themselves within high-tech global value chains. Historically, the United States has led the technology wave centred around the internet and software, while Southeast Asia has rapidly advanced its position in the high-tech sector.[17] In contrast, Europe continues to lag in establishing a strong foothold in emerging high-tech industries.[18] European industry remains predominantly concentrated in mid-tech sectors that have been entrenched for decades, unlike the United States and Southeast Asia, where the industrial landscape has undergone substantial transformation towards more advanced technological capabilities. In a global comparison, Europe's capacity to secure a leading position in research, development, and innovation remains a challenge particularly in technologies critical to driving digital and green transitions such as:

- **5G and internet of things**
- **Next-level automation and process virtualisation**
- **Cloud technologies and edge computing**
- **Quantum computing and neuromorphic software**
- **Software 2.0 - low code, no code software**
- **Trust architecture such as blockchain and zero trust computing**
- **Machine learning and generative AI**
- **Material technologies**

These technologies are increasingly permeating all sectors of the economy, enabling product added value and servitisation, with the blending of hardware, software, sensors, and new materials, disrupting business models and value chains; what they have in common is that they all hinge on STEM capabilities. Failure to be globally positioned in these technology fields does not merely impact growth sectors such as sustainable energy, health tech, and Information and communications technology (ICT). These technologies are also critical to the transformation of sectors of the economy where Europe, traditionally, has had a stronghold such as automotive, where ICT technologies are critical to the future of mobility and intelligent and sustainable transport infrastructures. This involves the development and deployment of electric vehicles (EVs), advancing battery technology, improving charging infrastructures, and optimising transportation logistics.
The European Environment Agency notes that innovation in transportation technology, driven by engineers and scientists, is key to reducing the sector's carbon footprint and achieving the Green Deal's objectives (EEA, 2020). The transition to renewable energy sources is a cornerstone of the European Green Deal. Achieving significant reductions in greenhouse gas emissions requires advances in solar, wind, and other renewable technologies. Energy efficiency improvements are crucial for reducing emissions and achieving sustainability goals. Engineers and scientists are essential for designing energy efficient buildings, developing smart grid technologies, and creating more efficient industrial processes.

[17]Fuest C., Gros D. Mengel P.L.; Tirole J (2024) EU Innovation Policy. How to escape the Middle Technology Trap. A report by the European Policy Analysis Group. https://iep.unibocconi.eu/sites/default/files/media/attach/Report_EU%20Innovation%20Policy.pdf?VersionId=MsKNtaKhnJ2OQ0m2Vq8bs0BOHx8e1CwJ

[18]Dietrich A., Florian D., Fuest C., Groes D., Presidente G., Mengel P.L., Tirole J. (2024) Europe's Middle-Technology Trap. Economy Policy and its Impact https://www.econpol.eu/sites/default/files/2024-07/econpol-forum-2024-4-dorn-fuest-etal-innovation.pdf

2.
The dynamics of Global Technology leadership

A report by the International Energy Agency highlights advancements in energy efficiency technologies, many of which are developed by STEM professionals, that could account for over 40% of the emissions reductions needed to meet global climate goals.[19] Transitioning to a circular economy is another pillar of the Green Deal, aiming to minimise waste and make the most of resources. This requires innovation in materials science to develop recyclable and biodegradable materials, as well as engineering solutions for waste management and recycling processes.[20] It will call for closer policy coordination with STEM as an overarching, horizontal priority.

It must, furthermore, be underpinned by a comprehensive governance framework with well-defined targets, robust metrics, and reporting processes.[22] [23]
Lessons emerging from Southeast Asia demonstrate the effectiveness of coordinated policy strategies that closely align and prioritise research and development, R&D and innovation infra-structures within a regulatory environment supportive of digital advancement. These strategies are complemented by substantial investments in developing and attracting worldclass STEM professionals, which serve as integral components of their broader competitiveness frameworks. The experiences from this region show that companies with a robust foundation in STEM talent not only drive innovation and resilience but also become significantly more attractive to investors seeking high-return opportunities, thereby reinforcing their potential for sustained growth.[24] To fully harness the productivity benefits of AI technologies, Europe will need to reskill 12 million workers, which represents approximately 6.5% of its current workforce, according to McKinsey.[25]
At present, European firms on average have slower growth, lower returns, and are marked by lower investments in research and development compared to major competitors such as the United States and China; to reverse these trends, advanced STEM skills are needed to achieve the productivity and innovation effects of AI technologies, where the EU lags behind the US and China.[26]
This trend exposes a critical gap in Europe's innovation ecosystem, which, if left unaddressed, could severely hinder the region's competitiveness and long-term economic vitality. In an area like AI applications, Europe has several AI unicorns, such as DeepL, Synthesia, and Wayve, and the EU is also home to global software companies such as Dassault Systèmes, Hexagon, and SAP, which have increased their efforts to integrate generative AI in their products and services. In 2023, SAP invested more than $1 billion investments in generative AI companies, according to McKinsey. However, compared to the US, Europe has only captured a limited share of the global equity and venture capital funding for AI software services companies in 2023. Moreover, some of Europe's highly successful AI startups and scale-ups, such as Hugging Face (valued at $4.5 billion) and Dataiku (valued at $3.7 billion), have relocated their headquarters to the US, due to the enabling framework conditions they can offer, including venture capital.[27]
Recent research from the European Investment Bank and the European Commission's Innovation Scoreboard emphasizes the urgent need for strategic interventions to strengthen Europe's position in global high-tech industries and to ensure that R&D and STEM talent development remain at the forefront of policy initiatives.[28] [29]

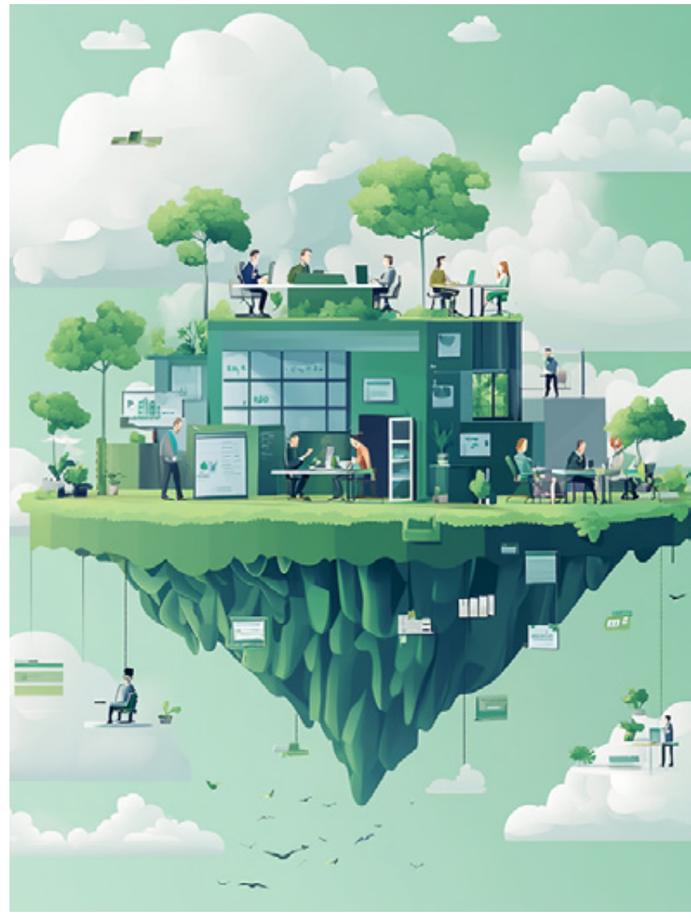
There is a need to prioritise future investments with a dual focus on:

- technologies where Europe aims to develop global leadership
- technologies where minimum capacity is a precondition to security and resilience.[21]

[19]Energy Efficiency 2021 https://www.iea.org/reports/energy-efficiency-2021 [20]Ellen Mc Arthur Foundation (2019) Completing the Picture. How the Circular Economy Tackles Climate Change https://circulareconomy.europa.eu/platform/sites/default/files/emf_completing_the_picture.pdf [21]Swieboda Pavel(2024) Funding Europe's Technology Revival. European Investment Bank [22]Draghi M. (2024) The Future of European Competitiveness https://commission.europa.eu/document/download/97e481fd-2dc3-412d-be4c-f152a8232961_en?filename=The%20future%20of%20European%20competitiveness%20_%20A%20competitiveness%20strategy%20for%20Europe.pdf [23]https://research-and-innovation.ec.europa.eu/knowledge-publications-tools-and-data/publications/all-publications/science-research-and-innovation-performance-eu-2024-report_en [24]Berger Roland (2024) The Rise of Southeast Asia https://www.rolandberger.com/en/Insights/Publications/The-rise-of-Southeast-Asia.html [25]McKinsey (2024) Time to place our bets: Europe's AI opportunity. https://www.cyprus-ceo.com/70515/time-to-place-our-bets-europes-ai-opportunity/ [26]McKinsey (2024) The state of AI in early 2024: Gen AI adoption spikes and starts to generate value. https://www.mckinsey.com/capabilities/quantumblack/our-insights/the-state-of-ai [27]McKinsey (2024) 1. Oct. 2024 ibid [28]https://www.google.com/url?sa=t&source=web&rct=j&opi=89978449&url=https://research-and-innovation.ec.europa.eu/statistics/performance-indicators/european-innovation-scoreboard_en&ved=2ahUKEwju9aiY8t6IAxVBQ_EDHadNAtoQFnoECBEQAQ&usg=AOvVaw1Q0w6gUDgD6gjvVUxBMuC- [29]EIB Investment Report 2022/2023. https://www.google.com/url?sa=t&source=web&rct=j&opi=89978449&url=https://www.eib.org/en/publications/20220211-investment-report-2022&ved=2ahUKEwitsb-D8t6IAxVBBNsEHc8wGxIQFnoECBUQAQ&usg=AOvVaw19kv5gGkBzzyRgOWxiSPCN

2.
The dynamics of Global Technology leadership

European competitiveness challenges are further compounded by the fact that 85% of companies across the EU identify a shortage of skilled professionals as a major barrier to making long-term investment decisions— a challenge that is equally prevalent in the five Member States with the highest GDP.[30] This skills deficit not only limits the capacity of European companies to innovate and expand but also constrains their ability to attract the investment needed for scaling operations, driving technological advancements, and maintaining a competitive edge in an increasingly knowledge-based global economy.
Addressing this challenge requires urgent and coordinated action to develop a robust pipeline of STEM talent, ensuring that European businesses are equipped to meet the demands of the future and remain at the forefront of global innovation. STEM skills shortages have a profound ripple effect on technological competitiveness within the EU.
The pandemic further exposed the scarcity of qualified specialists in key areas of the EU economy. Without a reliable talent pool, companies are less likely to invest in new technologies or expand their operations in the EU, fearing that they will not be able to find the qualified professionals to drive innovation, giving competitor regions further advance.[31]
The skills shortage prompted the EU Commission to propose measures such as the "Talent Pool.[32] [33] While concerns have been raised about the potential negative effect of the proposed talent pool, policies that involve talent migration can offer substantial mutual benefits for both sending and recipient countries.
For receiving countries, the influx of STEM talent enhances innovation, research capacity, and technological development, thereby boosting productivity and economic growth. Skilled STEM professionals contribute to advancing cutting-edge research, filling critical skill gaps, and fostering a culture of innovation, which is crucial for maintaining competitiveness in an increasingly knowledge-driven global economy.
Sending countries, on the other hand, benefit through the transfer of knowledge, skills, and networks, when their expatriate professionals return or engage in collaborative projects with institutions in their home countries. These returning professionals often bring back advanced expertise, international experience, and connections to global research networks. Through the cross-border cooperation of STEM professionals, countries or regions may become engaged in global innovation ecosystems, where expertise and technologies flow more freely, driving collective progress due to the social capital that has been built at an earlier stage.[34] [35] [36] [37]



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[30] ERT 2024 Competitiveness and Industry Benchmarking Report. 2024 p. 22 https://ert.eu/flagships-focus-areas/?category=131 [31] A COMPETITIVE EUROPE FOR A SUSTAINABLE FUTURE – WHAT SRIP 2024 TELLS US ABOUT KEY CHALLENGES FOR EU R&I https://research-and-innovation.ec.europa.eu/knowledge-publications-tools-and-data/publications/all-publications/science-research-and-innovation-performance-eu-2024-report_en [32] https://www.cgdev.org/blog/eus-talent-pool-live-will-it-attract-skilled-non-eu-migrants [33] European Commission, Directorate-General for Research and Innovation. The PSF supports national policy-makers in designing major R&I reforms, Publications Office of the European nion,2023, https://data.europa.eu/doi/10.2777/766987 [34] PMA Consult (2024) Global Talent Mobility Trends: Key Insights from the Decoding Global Talent 2024 Report https://people-mobility.org/global-talent-mobility-trends-key-insights-from-the-decoding-global-talent-2024-report/ [35] Sousa B., Ferreira J.J.M., Jayantilal S. Dabic M (2024) Global talent management – talents, mobility and global experiences – a systematic literature review https://www.emerald.com/insight/content/doi/10.1108/JGM-03-2023-0018/full/html [36] World Bank (2019). Leveraging Migration for Development: A Briefing for the World Bank Group. [37] For a wider discussion on brain circulation as supposed to brain drain see: Kenney M.; Breznitz D. Murpphree M. (2013) Coming back home after the sun rises: Returnee entrepreneurs and growth of high tech industries. Research Policy Volume 42, Issue 2, March 2013, Pages 391-407

3.
Strengthening STEM human capital related *policies*

The chapter situates STEM talent as a key enabling force in regaining a competitive edge globally. It makes a compelling case for a European STEM strategy, emphasising the need for a comprehensive, horizontal policy approach supported by robust metrics.

Addressing Europe's persistent skills shortages requires a unified effort at the EU level. The European Commission has proposed policy measures to enhance mobility, simplify recruitment, and make the EU a more attractive employment destination. However, the success of these measures depends on robust data to ensure the effective implementation of the comprehensive Skills and Talent Mobility package.

The Competitiveness and Industry benchmarking report, from the European Roundtable for Industry, presents a compelling set of arguments for why the European Commission 2020-2024 may have set the bar high with the policies proposed, but that the pace of transformation is slow and exacerbated by fragmented approaches to implementation at national levels, and in a context where skills shortages have rippling negative effects on SME investments in advanced technologies.[38] [39] This shortfall could result in Europe becoming a follower rather than a leader in key technological areas essential for green and digital transformation, and for European competitiveness in the medium term.

A renewed coordinated effort is essential to strengthen human capital in STEM fields across the entire education and lifelong learning value chain.[40]

STEM talent is a critical enabling factor needed for EU companies to compete in a global context and must be supported by creating incentives for innovation. This calls for a strong base of STEM talent at all qualification levels, as Europe's future industrial competitiveness depends on advancing high technologies as both innovators and producers. To achieve "Innovation Made in Europe", policymakers and industry must prioritize technological leadership and significantly improve support for R&D. Low investment in R&D threatens Europe's global competitiveness, highlighting the need for a stronger platform to support experimental R&D and deep tech innovation. Additionally, Europe must attract more scientific talent to drive technological progress in academia and industry, while also recognizing the value of defence R&D and dual-use innovation, particularly considering evolving security challenges.

The global knowledge frontier is expanding rapidly, as evidenced by the fast growth in high-quality scientific output from countries like China and India, particularly in STEM fields. In that respect, future European competitiveness does not merely hinge on sufficient funding for R&D and Innovation. Sustainable European competitiveness must also be underpinned by a coherent strategy for investing in and coordinating STEM-related policies and data on the STEM workforce and talent pipeline. While Europe has world-class universities and research institutions, it often struggles to retain top talent. The lure of higher salaries, better funding opportunities, and a more vibrant entrepreneurial culture in the USA and China can lead to the migration of S&T specialists. The EU needs to create a more attractive environment for STEM researchers and innovators by offering competitive remuneration, cutting-edge research facilities, and a supportive ecosystem that encourages risk-taking and entrepreneurship.

The recent council agreement aimed at attracting and retaining research, innovation, and entrepreneurial talents in Europe highlights significant barriers to effective policymaking at the EU level.[41]

[38] Eurobarometer (2024 March) - SMEs and skill shortages https://single-market-economy.ec.europa.eu/news/eurobarometer-smes-and-skill-shortages-2024-03-14_en
[39] European Roundtable for Industry (2024) Rebuilding Europe's business case, working against the clock. https://ert.eu/bmr2024/ [40] Cedefop (2021) The Green Employment and Skills Transformation. Insights from a European Green Deal Skills Forecast Scenario. https://www.giz.de/fachexpertise/downloads/24_The%20green%20employment%20and%20skills%20transformation%20-%20Publications%20Office%20of%20the%20EU.pdf [41] https://www.consilium.europa.eu/en/press/press-releases/2023/12/08/council-approves-conclusions-on-strengthening-the-role-and-impact-of-research-and-innovation-in-the-policymaking-process-in-the-union/Council approves conclusions on strengthening the role and impact of research and innovation in the policymaking process in the Union

3.
Strengthening STEM human capital related *policies*

While the agreement underscores the complex interplay between European competitiveness and the availability of STEM talent, it may have a limited impact as the agreement is not legally binding. This may result in disparities in how effectively countries adopt these measures, potentially worsening existing inequalities between nations with strong research and innovation systems and those without. Ultimately, this could further fragment the European Research Area (ERA) due to differing levels of commitment and implementation across Member States, and in a context where the recommendations do not include financial commitments, leaving it to the Member States to provide the necessary resources.

Moreover, effective implementation of these recommendations requires robust monitoring and evaluation mechanisms. In July 2023, the European Commission announced the creation of ReICO, an observatory established through an agreement with the OECD. ReICO aims to develop an information repository to monitor trends in research and innovation talent development. It will track jobs, working conditions (including contracts), and the mobility of skilled workers in research and innovation. Additionally, it will provide institutional data on research career paths, disaggregated by gender, covering the EU, OECD countries, and major economies.[42] While the initiative has been welcomed, several shortcomings have been identified.[43] To overcome these, it is in particular recommended early career researchers play an active role in co-defining goals, indicators and modes of outreach so that the observatory can serve its purposes and be an enabling force in improving working conditions and labour market opportunities for young scientists and researchers in their early career.

The Letta report: Much More Than a Market, correctly highlights the necessity for a coordinated effort beyond individual national policies to bolster the EU's industrial and technological competitiveness.[44]

However, although the report briefly refers to challenges concerning the migration of the EU science and technology workforce to countries outside the EU, it lacks detail. In the USA the Institute for Defence Analysis was commissioned to undertake a comprehensive study to understand why STEM talent leaves the United States or chooses to go to other countries. The study comprises the entire innovation pipeline to estimate the magnitude of native American and international STEM talent flows in and out of the United States. The study concludes that a notable challenge lies in the inconsistent categorisation of STEM disciplines and occupations across Federal agencies, leading to discrepancies that hamper a consistent analysis across datasets. As also noted in the European context, the US study concludes that limitations in data quality are caused by a lack of clear distinctions between STEM and non-STEM occupations, and in other cases due to that, STEM is referred to as one single category. This restricts the ability to accurately map and analyse recruitment and retention patterns, and the robustness of the data and their use in policy-making.[45]

The report from the Defence Institute was followed by a report in September 2024, published by the National Academies for Science, Engineering and Medicine, titled: "International Talent Programs in the Changing Global Environment". The report comprises an analysis of international STEM talent programs, including the analysis of initiatives in countries that the US considers could pose a threat to homeland security—namely Russia, China, and Iran.[46] In the US, the Department of Homeland Security has implemented measures to expedite visa processing for professionals in AI and emerging technologies. However, it is still too early to determine how effective these efforts will be in attracting top talent.

[42]ERA Talent Platform - Research and Innovation Careers Observatory (ReICO) (europa.eu) [43]Initiative for Science in Europe (2023) Statement on the planned ReICO Observatory. https://initiative-se.eu/2023/07/17/statement-on-the-planned-reico-observatory/ [44]Letta Enrico (2024) Much More than a Markethttps://www.consilium.europa.eu/media/ny3j24sm/much-more-than-a-market-report-by-enrico-letta.pdf [45]Olszewski T.D., Sabatini J.E., Kirk H.L., Hazan G.G., Liu I. (2024) Characterizing the Loss of Talent From the US STEM Ecosystem. https://www.ida.org/-/media/feature/publications/C/Ch/Characterizing-the-Loss-of-Talent-From-the-US-STEM-Ecosystem/Product-3001891.pdf [46]National Academies of Sciences, Engineering, and Medicine. 2024. International Talent Programs in the Changing Global Environment. Washington, DC: The National Academies Press. https://doi.org/10.17226/27787

3.
Strengthening STEM human capital related *policies*

In contrast, European tech startups are likely to continue facing significant challenges when recruiting talent from outside the EU.
Visa procedures differ widely across member states, and proposed EU-level actions are unlikely to fully address these barriers. Despite some structural initiatives, the lack of a unified visa system in the EU may limit startups' ability to recruit skilled workers from third countries.
In addition to the challenges brought on by the lack of a unified visa system at the EU level, the lack of granular and comparable data on the migration patterns of STEM professionals could hamper the added value and the quality of the implementation of the Skills and Talent Mobility package.[47] The limitations in data encompass the inward migration of STEM talent from countries outside the EU, and the outward migration of STEM professionals to countries outside the EU. Without accurate and comprehensive data, it is difficult to understand the full scope of the problem and to develop effective policies to address it. The absence of reliable data hampers the ability to identify trends such as which coutries are attracting EU-trained STEM talent, which non-EU countries are the primary sources of incoming STEM professionals, and what are the effects in terms of brain drain. This gap in information makes it challenging to assess the effectiveness of current policies aimed at attracting and retaining STEM talent, and any global efforts to develop a governance framework for global talent mobility in a context where talent competition has become increasingly fierce.[48] Additionally, the inability to track the migration of STEM talent accurately undermines the EU's competitiveness in the global market.
It is for example notable that there are no easily available data on migration of European STEM graduates and professionals to countries outside the EU, and data on labour market integration of third-country STEM nationals are limited.[49]

There is a need for better data on STEM talent flows to and from different countries to fully understand the magnitude and motivations of STEM talent flows in and out of the EU and within the EU, and in a context where the US is investing more research on STEM talent flows to shape US policies. High-skilled STEM specialists are increasingly mobile, and advanced economies are eager to attract STEM scientists and professionals who can contribute to their national economic, social, and scientific capacity. The competition for international STEM expertise is intensifying, not only from the USA and China but also from other economies such as Canada, Singapore, and the United Arab Emirates. Understanding the mobility patterns of STEM professionals and what motivates their moves at different stages of their careers is thus a precondition so that Europe can develop unified and mutually beneficial brain circulation policies within the EU and with third-party countries. The absence of comparable data makes it challenging to design targeted initiatives for retaining STEM professionals.
A detailed, occupation-specfic European STEM labour market dash-board could provide a solid foundation for informed STEM policy decisions at both the EU and national levels.
The labour market outlook dashboard, developed by the Think Tank Bruegel, offers an example of the features such a tool should include, especially as the demand for AI, green jobs, and reskilling within the European work-force—particularly among STEM professionals—continues to grow.[50] [51]

[47] https://www.google.com/url?sa=t&source=web&rct=j&opi=89978449&url=https://year-of-skills.europa.eu/news/introduction-skills-and-talent-mobility-package-2023-12-19_en&ved=2ahUKEwiL2JGb5bOJAxW9Z_EDHejKA2kQFnoECBIQAQ&usg=AOvVaw0pOHHem1Jhkw2vuvCjxkZa [48] Miao Lu (2021) Global talent Mobility. Trends, Challenges, and proposed Global Governance Solutions https://www.researchgate.net/publication/354916235_Global_Talent_Mobility_Trends_Challenges_and_Proposed_Global_Governance_Solutions [49] Kogan Irena, Schabinger Jule (2023) Successful due to STEM? Labour market returns to STEM qualifications among skilled immigrants in Germany https://www.mzes.uni-mannheim.de/d7/en/publications/journal-article/successful-due-to-stem-labour-market-returns-to-stem-qualifications-among-skilled-immigrants-in-germany [50] Stephany Fabian (2024) Reskilling and mobility: a round-up of project research. Bruegel. https://www.bruegel.org/analysis/reskilling-and-mobility-round-project-research [51] Labour market outlook dashboard (bruegel.org)

4.
The evolving STEM Skills Ecosystem

The chapter highlights the limitations of current skills anticipation methods and emphasises the need for granular approaches considering developments at the occupational level, at the sectoral level and within value chains to develop responsive and coherent continuing training measures at the European level.

At the technological frontier of European businesses, STEM skills are rapidly evolving. Robust anticipation methods are therefore a critical component in the dynamic STEM skills ecosystem and a tool that can assist continuing education and training providers in the provision of training, which is responsive to the evolving needs of tech companies. To support the mobility and employability of the STEM workforce, the EU must reinforce that initiatives or projects funded by the EU systematically deploy skills anticipation methods.
The contribution of skills anticipation methods to policymaking and implementation in EU countries has expanded in recent years. Partnership approaches are developing across the EU, likely linked to increased engagement in tackling the skill challenges stemming from the twin transition, demographic changes, and a growing recognition of the interlinkage between competitiveness, innovation, and human capital investments.
Sectoral convergence and dynamics within global value chains challenge national sectoral approaches to skills anticipation, as does the half-life of skills in many technology fields. Even when comprehensive skills anticipation approaches are in place, there are risks of a disconnect between the quality of skills intelligence available and the extent to which it is deployed by different stakeholders.[52] [53] Moreover, generative AI will likely dramatically accelerate the evolution of skill sets within STEM fields, thereby transforming and reshaping the essence of STEM professions. As tasks for example in software coding, product design, and medical diagnostics become increasingly augmented and automated, there is an urgent need for actions at the EU level to fully exploit opportunities afforded by AI in real-time data analysis of occupational changes and transformations.
McKinsey estimates that with the full adoption of generative AI, European STEM professionals could see 13% to 27% of their working hours automated by 2030. Meanwhile, the demand for STEM professionals, including those in healthcare, could increase by 13% to 30% over the same period.[54] These forecasts indicate the complexity of the STEM skills demands with risks of major shortages of STEM professionals, and risks of STEM skills mismatch due to the speed of obsolescence of skills impacted by AI technologies. This is why granular skills intelligence is crucial. It must deploy consistent methods to support labour mobility and employability. This is the only way we will achieve a robust foundation for flexible, scalable, and personalized continuing training solutions, aligned with the European approach to micro-credentials.[55]

AI generated image

[52]Cedefop (2019) Online job vacancies and skills analysis https://www.cedefop.europa.eu/files/4172_en.pdf [53]Carmichael T., Stamper J., Carney J. (2022) Developing a Continuous, Rather Than Binary, Classification for Measuring STEM Jobshttps://www.google.com/url?sa=t&source=web&rct=j&opi=89978449&url=https://proceedings.open.tudelft.nl/cte-stem2022/article/view/473&ved=2ahUKEwjxx52B2fSHAxUDVPEDHT_7KI8QFnoECBIQAQ&usg=AOvVaw3MjiQcpbm_1ovZQENt3qvY [54]McKinsey (2023) A new future of work: The race to deploy AI and raise skills in Europe and beyond p. 13. P. 19-2o [55]Shapiro H., Andersen, T. and Nedergaard Larsen, K. (2020), A European approach to micro-credentials – Output of the micro-credentials higher education consultation group – Final report, Publications Office of the European Union, 2020, https://data.europa.eu/doi/10.2766/30863 [56]https://ec.europa.eu/eurostat/statistics-explained/index.php?title=R%26D_personnel&oldid=641520

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The evolving STEM Skills Ecosystem

There are three key shortcomings commonly found in the literature and statistical data about STEM:

1. The literature often treats these components as a single entity rather than examining each one individually.

2. There is a lack of effective methods to monitor changes in STEM-related jobs over time and across different locations in a sufficiently granular way.

3. In terms of study fields there are no common agreements as to what constitutes core STEM disciplines—e.g. whether STEM includes architecture or not.

The above limitations partly arise from the simplistic way in which STEM jobs are classified as STEM or non-STEM. Moreover, the use of traditional forecasting methods, especially in tech-intensive sectors, has limitations. For one, they ignore that technological developments and diffusion do not occur linearly.[57] Secondly, in tech-intensive sectors emerging skills demands are often shaped by the dynamics of global value chains,[58] and traditionally, skills anticipation tends to be based on national statistical data and qualitative data, and they will thus miss out on the impact of global value chain dynamics.[59] However, the use of real-time labour market data offers new opportunities to identify the required STEM knowledge, skills, and competencies for specific occupations by drawing on and mining job postings and CVs within an economy, regardless of the size of the country or across economies.[60]
Real-time labour market data can thus be an important data source for continuing education and training providers, as they for example can be used in a systematic way to capture emerging skills demands and changes in this in leading tech firms within a particular technology field. It can, therefore, allow for developing responsive and tailored skills strategies that meet the diverse needs of companies in STEM-intensive sectors. Secondly, real-time labour market data have the potential to improve official occupational and skill taxonomies. This is particularly important in the context of STEM policies due to the speed of technological advances concurrently resulting in new skills beyond existing taxonomies, such as ESCO (the European taxonomy for classification of skills and competencies). Data-enabled skills taxonomies can for example assist in providing a continuous lens on the transformation of STEM jobs and the wider EU labour markets associated with the green and digital transformation including the impact of AI.[60 61 62 63 64]
The European Commission could enhance skills anticipation by providing monitoring services that leverage real-time analysis of standardized job vacancy data within STEM occupations. This would provide a detailed view of the skills required for specific STEM roles, building on the services already provided by its agency, Cedefop, and it could contribute to overcoming the fragmentation in skills anticipation methods deployed in the sectoral partnerships under the Pact for Skills, in the University micro credential initiatives in the European University Alliances, and the European Institute of Technology.[65]
While realtime labour market data is useful for monitoring labour dynamics over shorter time frames and as the basis for the provision of micro-credentials, scenario and foresight exercises play a crucial complementary role. They can increase awareness of trends and critical uncertainties that could have a transformative impact on the supply and demand of skills.[65 66 67 68 69]

[57]Ciarli T. Kenney M; Massini S; ; Piscitello L (2021) BRIE Working Paper2021-2 #2, Berkeley University. https://brie.berkeley.edu/sites/default/files/publications/special_issue_introduction_digital_technologies.pdf Technologies, Innovation, and Skills: Emerging Trajectories and Challenges [58]OECD (2017) OECD Skills Outlook. Skills and Global Value Chains https://www.oecd-ilibrary.org/education/oecd-skills-outlook-2017_9789264273351-en [59]OECD (2017) OECD Skills Outlook 2017 Skills and Global Value Chains. https://www.oecd-ilibrary.org/education/oecd-skills-outlook-2017_9789264273351-en [60]The Study America's tech Hubs are multiplying illustrates how skills studies can be undertaken in an efficient manner over large geographies. Burning Glass Institute has built an extensive data repository of jobs adds and CVs from across economies, and data are mined on an ongoing basis and feed into policy making for example in collaboration with the OECD. L, Levanon G. Sigelman M. (2024) America's Tech Hubs Are Multiplying How Tech Powerhouses' Diaspora Are Fuelling the Rise of New Cities on the Talent Frontier. Burning Glass Institute. USA https://www.burningglassinstitute.org/research/americas-tech-hubs-are-multiplying [61]Stephany Fabian, Teutloff Ole (2024 What is the price of a skill? The value of complementarity. Research Policy. (53 2024) [62]https://ec.europa.eu/eurostat/statistics-explained/index.php?title=ICT_specialists_-_statistics_on_hard-to-fill_vacancies_in_enterprises&oldid=534531#Employment_and_recruitment_of_ICT_specialists [63]https://www.cyberseek.org/ [64]For a granular illustration of skills pathways that could lay the foundation for development of micro-credentials, see also https://www.cyberseek.org/pathway.html [65]https://www.cedefop.europa.eu/en/tools/skills-intelligence/trend-focus/skills-online-job-advertisements?country=DE&year=2021#30

4.
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The relevance and the impact of recent large-scale policy measures such as the European Pact for Skills and the European University Alliances are ultimately shaped by the coherence and dynamics of the wider skills ecosystem. Inconsistent and insufficiently rigorous methodologies for assessing future skills needs hinder the effective development of skills frame-works that align with labour market demands. This creates a risk that current investments in micro-credentials and other forms of training may be driven by supply rather than demand.[70] There is no doubt that the European Institute for Innovation & Technology (EIT) with its Deep Tech Talent Initiative, which aims to train one million professionals in deep tech fields by 2025, intends to send a positive signal, stating that 513,539 individuals have already been trained. This effort comes at a time when the EIT has faced criticism for its operational costs by the Fraunhofer Institute and has even been proposed for closure by the Danish government.[71]

While the number seems impressive, it is unclear what counts as "having been trained", and what the added value is from the perspective of learners and participating companies. It is also unclear whether the training initiative builds on robust skills intelligence, and whether any external and independent evaluation is panned, and if so, based on what metrics.[72]
As highlighted in Draghi's report on competitiveness, there is a need to restructure the EU's training and lifelong learning programs to address the current fragmentation of upskilling and reskilling initiatives. This restructuring should ensure that allocated funding is scalable and sustainable, especially considering that pilot projects often do not focus on the long-term viability of business models beyond the funding period.[73] To allow for this, the evaluation criteria of pilot projects need to be revised. Secondly, they must be underpinned by monitoring instruments and indicators that systematically track outputs, outcomes, and impacts, which is not the case at present. Therefore, new measures, such as the Deep Tech Initiative, risk furthering fragmentation and supply-driven approaches to addressing STEM skills shortages and mismatches.[74] Moreover, whereas Draghi's report addresses the fragmentation in European skills initiatives, it does not consider demand-side factors which ultimately shape company skills strategies.
A restructuring of European skills initiatives will need to consider factors relating to effective skills utilistion practices, which are furthermore conducive to the quality of jobs, labour market mobility, and company innovation performance.[75] Measures such as the European Institute of Technology and the European University Alliances Initiative were created to spur a globally more attractive R&D and innovation environment with stronger synergies between research, innovation, education, and lifelong learning. However, several factors negatively impact their development.
Their development and funding models are marked by an insufficient focus on building sustainable business models, which could be critical to scaling and mainstreaming in the medium term. Moreover, the way funding instruments are implemented, University Alliances are in general developing without explicit strategies to tap into innovation clusters, and the same is the case for the European Institute of Technologies and their Knowledge and Innovation Communities. This is likely to hamper the innovation impact of these two European Flagship Initiatives.[76]
This issue is further exacerbated by a monitoring and reporting system based on a project model and a lack of focus on digital infrastructures and services, which are paramount to scaling, out-reach and flexibility in services that match diversified needs.

[66]ETF, CEDEFOP, ILO (2016) Developing Skills Foresights, scenarios and forecasts. Guide to anticipating and matching skills and jobs. Volume 2. https://www.ilo.org/sites/default/files/wcmsp5/groups/public/@ed_emp/@ifp_skills/documents/publication/wcms_534328.pdf [67]Tonurist P., Hanson A.(2017) OECD Working Paper on Public Governance. Anticipatory Innovation Governance. Shaping the future through proactive policy making. https://www.sdg16hub.org/system/files/2021-01/cce14d80-en.pdf [68]See for example OECD Chapter 5: OECD (2023), Getting Skills Right Assessing and Anticipating Skills for the Green Transition UNLOCKING TALENT FOR A SUSTAINABLE FUTURE [69]ETF, Cedefop, ILO (2016) Developing Skills Foresights, Scenarios, and Forecasts https://www.ilo.org/sites/default/files/wcmsp5/groups/public/@ed_emp/@ifp_skills/documents/publication/wcms_534328.pdf [70]Cedefop (2023) Microcredentials for labour market education and training: the added value for end users https://www.cedefop.europa.eu/en/publications/5603 https://www.eitdeeptechtalent.eu/?gad_source=1 s://www.eitdeeptechtalent.eu/calls-and-opportunities/eit-deep-tech-talent-initiative-call-for-training-proposals/ [71]https://sciencebusiness.net/news/european-institute-innovation-and-technology/calls-scrap-eit-mount-fraunhofer-slams-eu [73]Draghi M. (2024) The future of European competitiveness Part A | A competitiveness strategy for Europe. EC (p. 33) https://commission.europa.eu/document/download/97e481fd-2dc3-412d-be4c-f152a8232961 en?filename=The%20future%20of%20European%20competitiveness%20_%20A%20competitiveness%20strategy%20for%20Europe.pdf [75]OECD (2020) Laggard firms, technology diffusion and its structural and policy determinants. Policy paper. https://www.oecd.org/en/publications/laggard-firms-technology-diffusion-and-its-structural-and-policy-determinants_281bd7a9-en.html [76]Draghi M. (2024) The future of European competitiveness. https://commission.europa.eu/document/download/97e481fd-2dc3-412d-be4c-f152a8232961_en?filename=The%20future%20of%20European%20competitiveness%20_%20A%20competitiveness%20strategy%20for%20Europe.pdf

5.
European Research Infrastructures *Geared for* the Future

This chapter emphasises the critical role of improving Europe's research infrastructure to enhance competitiveness, attract STEM talent, and drive innovation. It highlights the need for investment in advanced research facilities, better coordination across Member States, and fostering collaboration between academia and industry to support high-tech development. Strengthening research infrastructure will help Europe retain its competitive edge, promote technological leadership, and ensure long-term economic growth.

> In conclusion, enhancing European research infrastructures is a strategic priority for building a competitive, knowledge-driven economy.

Improving Europe's research infrastructure is crucial for enhancing competitiveness, especially in the context of cultivating and retaining top STEM talent. The quality and availability of research infrastructures significantly influence the ability of countries to attract and retain researchers, foster innovation, and develop high-tech industries that contribute to long-term economic growth. According to the European Investment Bank, the EU lags behind key global competitors, such as the United States and China, in terms of investment in innovation, and technology adoption, highlighting the need for more robust research infrastructures to support the development and commercialisation of new technologies.[77]

Advanced research infrastructures provide the necessary environment for STEM professionals to engage in cutting-edge research, facilitate knowledge transfer, and promote collaboration between academia and industry, which are vital components for driving innovation and competitiveness. The European Strategy Forum on Research Infrastructures (ESFRI, 2018) emphasized that state-of-the-art research facilities are indispensable for addressing complex societal challenges and ensuring that Europe remains at the forefront of scientific discovery. However, many European research infrastructures suffer from underfunding, outdated equipment, and a lack of integration across Member States, which limits their potential to contribute effectively to European competitiveness.[78]

Furthermore, well-developed research infrastructures play a crucial role in nurturing STEM talent by providing training opportunities, access to advanced technologies, and collaboration networks that enhance the skills and expertise of researchers. This is particularly important as Europe faces a shortage of highly skilled STEM professionals, a factor that hinders innovation and productivity in high-tech sectors.[79]

The World Economic Forum's Global Competitiveness Reports underscore that countries with well-funded and coordinated research ecosystems are better equipped to foster an environment conducive to technological advancement, which is fundamental to maintaining a competitive edge in the global economy.

Moreover, improving research infrastructures can help bridge the gap between academia and industry, facilitating the commercialization of research outcomes and encouraging the development of start-ups and scale-ups in high-tech sectors.

[77] Investment Report 2022/2023: Resilience and renewal in Europe. https://www.eib.org/en/publications/online/all/investment-report-2022-2023

[78] Feurer t. (2024) Viewpoint: Why Europe must invest in research infrastructures now https://sciencebusiness.net/news/fp10/viewpoint-why-europe-must-invest-research-infrastructures-now

[79] Rosetta Federica (2023) The growing importance of research infrastructures. Elsevier. https://www.elsevier.com/connect/the-growing-importance-of-research-infrastructures

5.
European Research Infrastructures *Geared for* the Future

This connection is vital for translating research into marketable products and services, thereby driving economic growth and job creation. According to the European Research Area (ERA) policy agenda, strengthening the infrastructure and innovation ecosystem is essential to support the development of frontier technologies and the rapid uptake of emerging technologies across industries, which can significantly enhance Europe's competitiveness.
In addition, investment in research infrastructures would address the fragmentation issue that currently impedes the EU's ability to capitalize on its full potential. Harmonizing efforts across Member States can create a more interconnected and efficient research ecosystem, enabling the pooling of resources, sharing of expertise, and fostering cross-border collaborations. This approach aligns with the goals outlined in the Horizon Europe program, which calls for the establishment of a European Research Infrastructure Consortium (ERIC) to facilitate world-class research across disciplines and strengthen the global standing of European research.
In conclusion, enhancing European research infrastructures is a strategic priority for building a competitive, knowledge-driven economy. By investing in cutting-edge facilities, fostering collaboration between academia and industry, and nurturing STEM talent, the EU can position itself as a global leader in innovation and technological advancement, ultimately ensuring sustainable economic growth and competitiveness in the international arena.

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6.
Framework conditions *conducive to the creation of* tech scale-ups

This chapter highlights the need for supportive framework conditions to help tech startups scale globally. It emphasises the importance of a favourable regulatory environment, access to capital, and a strong STEM skills base to foster innovation and enhance Europe's competitiveness.

Looking forward, European inventors require a much better platform for experimental R&D and deep tech innovation. The future of Europe's industrial business case lies in driving forward high technologies as innovators and producers. For 'Innovation Made in Europe" to keep succeeding, policymakers at all levels and industries must embrace technological leadership as a shared goal. Looking forward, European inventors need a much better platform for experimental R&D and deep tech innovation. In addition to more funding, the increasingly complex landscape means the next EU framework programme for research and innovation must prioritise areas in which Europe has the potential to excel and support excellence across the whole knowledge value chain. While Europe excels in the creation of startups, surpassing even the US with a stable share of repeat founders, challenges remain in scaling up these ventures as a precondition to future competitiveness. Breakthrough technological innovation is a lengthy and complex process that necessitates "patient" capital throughout the entire innovation cycle. In the US, companies receive substantially more private funding in late-stage financing compared to their European counterparts. EU funding policies must enable every phase of technology development, from its scientific foundations to market diffusion, ensuring breakthroughs in fundamental research reach the market efficiently, and that likely requires a new funding instrument. The standalone venture capital fund backed by 24 NATO allies, deploying €1 billion+ in deep tech investments, could serve as a model.[80] Pension funds could potentially have an interest in contributing to such a fund in combination with other funding sources. A shift towards a greater adoption of transformative policies is needed to allow for strategic prioritisation and a higher degree of risk-taking in the allocation of funding, to stimulate the opportunities afforded by disruptive technological innovation through ambitious projects that create synergies and scale of the kind that cannot be created by individual countries. This needs to be accompanied by policy measures that further support industrial involvement, and which focus on generating commercial outputs of R&D investments. Europe must demonstrate its capability to fully embrace new technologies with industry-wide global impact, which requires maintaining a dynamic, innovative, and diverse industrial ecosystem. A dynamic industrial ecosystem can be positively impacted by the policy framework for intellectual property rights (IPR). Clear and enforceable IPR policies can facilitate collaboration between academia, industry, and startups, and can accelerate technological advancements and the commercialisation of research, which is particularly important for innovation in STEM fields. Moreover, SMEs and startups often drive innovation. By simplifying the process for obtaining and enforcing IP rights, the framework can support value creation through commercial innovations in small high-tech firms. A renewed IPR policy framework should be flexible enough to adapt to rapid technological changes while also considering the advantage of data sharing, especially in publicly funded research to the benefit of the STEM ecosystem. Emerging fields such as artificial intelligence, biotechnology, and quantum computing present unique challenges and opportunities for IPR. By staying ahead of these trends, Europe can ensure its policies are conducive to favourable working and innovation environments for European STEM professionals.

[80] https://www.nif.fund/about/

6.
Framework conditions *conducive to the creation of* tech scale-ups

The European Commission has launched several measures such as the European Chips Act, the Green Deal, and the Net-Zero Industry Act, which have laid the foundation for enhancing economic resilience and industrial capacity in green and technological sectors, but the EU still lacks a truly comprehensive and effective industrial strategy. To establish such a policy, the European Union must capitalize on its greatest asset: the Single Market. The EU's unified and globally interconnected market provides a unique advantage, offering the potential to reach a scale comparable to the vast domestic markets of the United States and China. Achieving this scale is crucial for catalysing substantial private investments in clean technology ecosystems, which are essential for Europe to position itself as a globally competitive and resilient leader in the cleantech sector.
Despite existing efforts, there remains a significant shortfall in addressing the challenges that European startups encounter within the fragmented regulatory landscape of the Single Market. Although European tech startups theoretically have access to a market comparable in size to that of the continental United States, the incomplete integration of the Single Market, marked by divergent regulatory frameworks across Member States, presents substantial obstacles to scaling and achieving global competitiveness. The EU's policymaking process has historically resulted in a proliferation of Directives, which permit considerable national discretion in their implementation and enforcement. As a result, the Single Market continues to be a patchwork of inconsistent regulations, creating layers of complexity, legal uncertainty, and additional costs for businesses. This fragmentation not only hampers startups' ability to operate efficiently across borders but also undermines the potential for innovation and economic growth within the EU, limiting the ability of European enterprises to fully capitalize on the advantages of a unified market. Companies face numerous challenges navigating across EU markets. These include differences in national labour market regulations, tax policies, digital policies, and sector-specific rules, all of which contribute to the regulatory fragmentation across Member States. As a result, companies attempting to scale up consistently cite the lack of regulatory harmonisation as a significant barrier to growth. This fragmentation not only hampers the ability of businesses to fully leverage the potential of the Single Market but also leads to missed opportunities for economies of scale and market specialisation.[81]
Developments in Foreign Direct Investment (FDI) inflows to Europe illustrate the negative effects of the structural barriers to competitiveness. In 2022, Europe saw a net negative FDI inflow, which indicates that foreign investors withdrew more capital than they injected into the European market during this period. This development suggests that the EU has become less attractive to global private investors.[82] The reduced attractiveness of the EU for global investors could have significant implications for research, development, and innovation, as well as negatively impacting the potential effects of the EU Talent Pool Package.[83] The EU's attractiveness to STEM specialists is closely linked to the availability of opportunities, funding, and state-of-the-art research facilities.

> **Despite existing efforts, there remains a significant shortfall in addressing the challenges that European startups encounter within the fragmented regulatory landscape of the Single Market.**

[81] Bauer Matthias (2023) What is Wrong with Europe's Shattered Single Market? Lessons from Policy Fragmentation and Misdirected Approaches to EU Competition Policy. OCCASIONAL PAPER – No. 02/202 ECIPE
[82] https://ert.eu/wp-content/uploads/2024/02/ERT-Single-Market-Obstacles_Technical-Study_WEB.pdf
[83] https://year-of-skills.europa.eu/news/introduction-skills-and-talent-mobility-package-2023-12-19_en

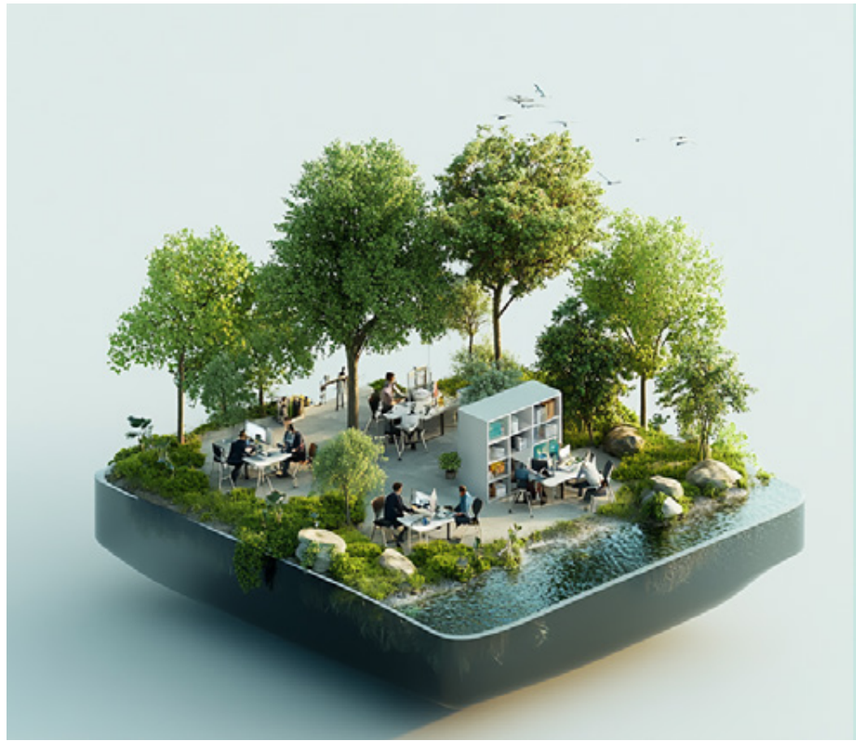
6.
Framework conditions *conducive to the creation of* tech scale-ups

A decline in investments could make the EU a less attractive destination for top talent, prompting scientists and researchers to move to regions that offer better funding, facilities, and career opportunities. This, in turn, would further diminish the EU's ability to innovate and further undermine European competitiveness in the global market. Moreover, the drop in foreign direct investments could lead to a stifled innovation ecosystem as it relies on a continuous influx of capital. If the EU becomes less attractive to global investors, there may be fewer opportunities for collaboration, fewer resources for scaling up innovative ideas, and overall, less dynamism in the innovation landscape.[84]

European business leaders have raised concerns about the European business environment. One of the primary factors cited by CEOs for Europe's declining competitiveness is its complex and fragmented regulatory landscape, which hampers business growth and investment.[85] A truly integrated Single Market would empower European businesses to achieve economies of scale, fostering an environment that encourages innovation and the mobility of STEM talent.

In the digital domain, adopting a global perspective is essential. To effectively compete with major non-EU tech companies, Europe must consolidate efforts to achieve enabling framework conditions that will create an environment conducive to scaling for European tech startups. Scaleups—tech companies that have raised over $1 million in funding—play a crucial role in driving Europe's prosperity. These businesses are not just engines of innovation; they also contribute significantly by creating quality jobs for STEM professionals and enhancing Europe's productivity. Scaleups are not only Europe's best opportunity to cultivate home-grown tech giants but also a strategic move for ensuring sustained economic prosperity. A survey conducted among European scale-ups by Digital Europe provides recommendations, which could improve framework conditions in ways that could enable the growth of European global champions. In addition to investment frameworks, which can provide patient capital, recommendations include a flexible legal framework that keeps pace with technological advancement, for example by establishing regulatory sandboxes.[86]

Supportive EU-level framework conditions are essential for tech startups to scale, as they require significant investment in research, talent acquisition and market access, which will often surpass what member states can offer.



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[84] https://www.oecd.org/en/data/indicators/fdi-flows.html

[85] ERT (2023) Complex and Incoherent Regulation Puts Pressure on Europe's Competitiveness And Green Transition Efforts. The Conference Board https://ert.eu/wp-content/uploads/2023/11/The-Conference-Board-Measure-of-CEO-Confidence-for-Europe-by-ERT-H2-2023.pdf

[86] Digital Europe (2021) Scaling in Europe report. https://cdn.digitaleurope.org/uploads/2021/02/DIGITAL-EUROPE-SCALING-IN-EUROPE-REPORT.pdf

6.
Framework conditions *conducive to the creation of* tech scale-ups

A robust EU-level investment framework can bridge this gap by offering more substantial and flexible funding options, allowing startups to grow without the constraints of limited capital. Additionally, a cohesive regulatory environment helps reduce market fragmentation, enabling startups to operate seamlessly across borders, access larger markets, and comply with unified standards for issues such as taxation, data protection, and intellectual property. This harmonisation lowers operational costs and complexity.

Interconnectedness not only enhances the attractiveness of the market for investors but also significantly amplifies the potential to scale successful technologies and business models across the EU. This is also the case for European cleantech startups, where the EU could be positioned as a global leader in sustainable industrial practices. According to Net Zero's State of Climate Tech report, the US raised $43.9 billion in 2022 compared to $35.6 billion raised in Europe representing a 33% year-over-year increase in Europe, compared to only 7% in the US —meaning that in Europe this vertical is growing 26% faster.[87]

> **The EU could be positioned as a global leader in sustainable industrial practices**

By fully harnessing the capabilities of the Single Market, the EU could establish a robust framework that can support the scaling of cleantech companies increasing their capabilities to engage in global markets and reinforcing Europe's position as a global leader in sustainable industrial practices. Moreover, a coordinated European approach is essential to overcome the current lack of common definitions for green sectors, jobs, and skills across Member States, which is crucial for achieving efficiency and scaling green skills initiatives. Thus, the realisation of the EU's Single Market is not only advantageous but conducive to an effective implementation of a green industrial policy. Through a cohesive approach, the EU can foster a thriving cleantech ecosystem that competes effectively on the global stage and makes a substantial contribution to combating climate change.

While the European Commission has launched numerous initiatives to enhance European competitiveness amidst growing vulnerabilities, the key question remains whether these initiatives are sufficiently coordinated and supported by a comprehensive and coordinated implementation framework that can match or exceed the scale and ambition of efforts launched by leading competitor regions.

> **A coordinated European approach is essential to overcome the current lack of common definitions for green sectors, jobs, and skills across Member States.**

[87] https://netzeroinsights.com/state-of-climate-tech-2022/

7.
Europe at *a crossroads*

This chapter concludes by highlighting the urgent need for Europe to reclaim its position in high-end technologies by fostering sustainable competitiveness through agile and anticipatory governance. It emphasises the importance of a coordinated European STEM strategy to rebuild Europe's competitiveness based on technological leadership.

It is time for Europe to reclaim and enhance its global position in high-end technologies, resting on sustainable competitiveness in the medium term. The involvement of different stakeholders and multi-level agile and anticipatory governance will be essential to achieving these goals. Agile and anticipatory governance at the European Union level is crucial for achieving economies of scale that enable EU companies to compete globally. This approach can enhance STEM skills and intelligence and improve our understanding of the complex relationships between technology development and diffusion, firm innovation routines, and skills formation and transformation. The EU's ability to maintain competitiveness hinges on its capacity to adapt swiftly and predictively to these changes through agile and anticipatory governance which can allow for the rapid adaptation of policies to reflect technological advancements, changes in market dynamics, and geopolitical volatilities. This adaptability is furthermore essential to ensure that regulatory frameworks remain relevant and supportive of innovation, and it is beneficial to competitiveness in sectors and value chains characterised by rapid innovation cycles such as digital technology, renewable energy, and biotech. The ability to predict and prepare for future developments ensures that the EU can maintain a competitive edge in these critical industries and can contribute to reducing operational complexities and costs in ways that can further the integration of the Single Market.

Furthermore, the integration of agile and anticipatory governance frameworks supports the development of a robust STEM talent pool. Policies that prioritise STEM education and training, coupled with incentives for retaining and attracting talent, are crucial for maintaining a competitive edge in high-tech industries. Empirical evidence supports the notion that regions with robust, forward-thinking governance have increased capabilities to proactively identify and mitigate potential risks and opportunities. By forecasting future trends and challenges, policymakers can create a more stable and predictable environment for businesses, which in turn are critical to success in attracting investment and fostering high-growth industries, and which furthermore are conducive to nurturing and retaining a vibrant STEM economy.

> **Empirical evidence supports the notion that regions with robust, forward-thinking governance have increased capabilities to proactively identify and mitigate potential risks and opportunities.**

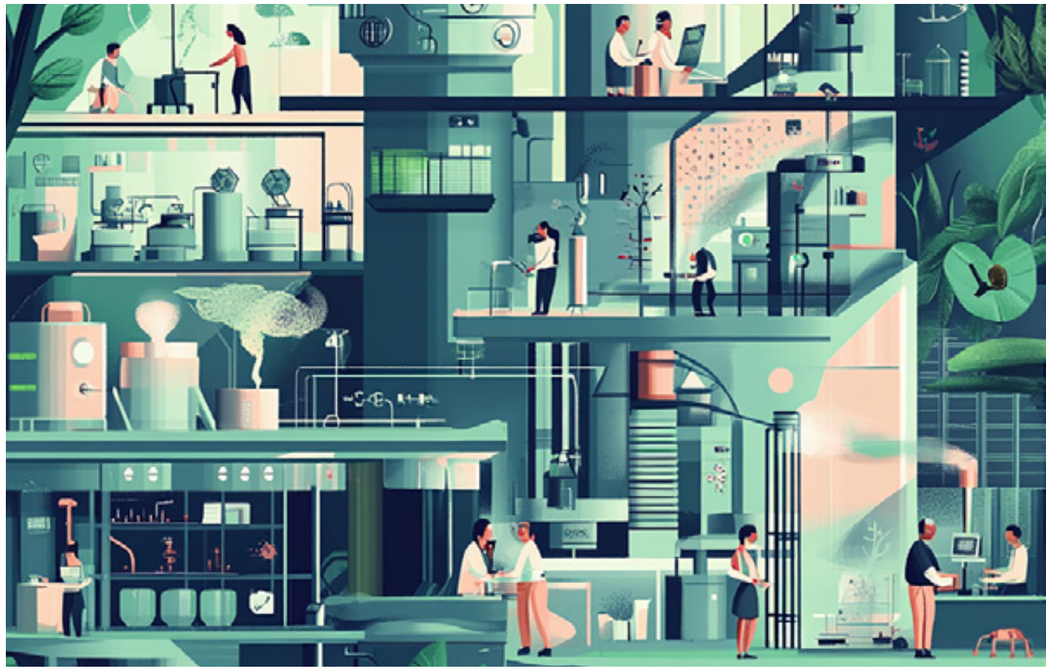
[88] Europe needs to make its STEM strategy a reality now https://news.industriall-europe.eu/documents/upload/2024/3/638465270633407604_STEM_Stratregy_Joint_Statement_EN_cee-met_eceg_iAE_Ceemet-_Final_signed.pdf

7.
Europe at *a crossroads*

Recognising that education is a Member State competence, the increased scale and pace of change across sectors of the economy has nevertheless led industry workers to call for a European STEM strategy.[88]
A European strategy could frame a coordinated approach to STEM-related policies, which is critical to driving effective policy implementation at the EU level, nationally, and regionally. Such a framework would enable the monitoring and evaluation of the impact of STEM policies within European reporting processes, ensuring that STEM policies contribute to the intended targets and allowing for adjustments as needed.
Europe stands at a pivotal moment in its history marked by decreasing productivity and shaped by a confluence of economic, technological, and societal challenges that necessitate urgent and strategic responses.[89] Several factors underscore why Europe is at this critical juncture, emphasising the need for a robust STEM strategy to secure future competitiveness and sustainability.

The global economic landscape is becoming increasingly competitive, with the United States and China, producing significant advances in technology and innovation. These countries are investing heavily in research and development and are rapidly advancing in areas like artificial intelligence, biotechnology, and renewable energy. Europe must respond by enhancing its innovation capacity to remain a key player on the global stage.
A well-developed STEM strategy is essential for fostering the talent needed to harness emerging technologies and secure Europe's strategic autonomy and homeland security. The European Green Deal is an ambitious strategy to make Europe the first climate-neutral continent by 2050. This will require significant advancements in green technologies and sustainable practices, which in turn hinge on STEM talent.
Geopolitical tensions and uncertainties have significant implications for Europe's economic and political stability. These dynamics necessitate a resilient and self-sufficient approach to technology and innovation. By cultivating a robust STEM talent pool, Europe can reduce dependency on external technological capabilities and strengthen its strategic autonomy.
Based on the report's findings, we have formulated a comprehensive set of recommendations for the EU.

You can download the recommendations here:
Recommendations



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[89] Draghi m. (2024) The Future of European Competitiveness. EC https://commission.europa.eu/document/download/97e481fd-2dc3-412d-be4c-f152a8232961_en?filename=The%20future%20of%20European%20competitiveness%20_%20A%20competitiveness%20strategy%20for%20Europe.pdf

Glossary

Innovation Hubs are dynamic ecosystems that bring together diverse stakeholders, including startups, established companies, research institutions, universities, investors, and government entities, to foster collaboration, creativity, and the development of new ideas, technologies, and solutions. These hubs provide a supportive environment with access to resources such as funding, mentorship, networking opportunities, research facilities, and digital infrastructure, enabling innovators to accelerate the development and commercialization of their ideas.

Microcredential (EU definition) A micro-credential is the record of the learning outcomes that a learner has acquired following a small volume of learning. These learning outcomes have been assessed against transparent and clearly defined standards. Courses leading to micro-credentials are designed to provide the learner with specific knowledge, skills and competencies that respond to societal, personal, cultural or labour market needs. Micro-credentials are owned by the learner, can be shared and are portable. They may be standalone or combined into larger credentials. They are underpinned by quality assurance following agreed standards in the relevant sector or area of activity.

STEM refers to Science, Technology, Engineering and Mathematics. It is an interconnection of fields to solve real-world problems rather than studying them in isolation.

Skills Ecosystem refers to a network of inter-connected organizations, institutions, and stakeholders—including education and training providers, employers, industry bodies, social partners, and workers—that collaborate to develop, enhance, and sustain a region's or sector's skills base. This ecosystem is characterized by the continuous exchange of information, resources, and expertise to ensure that skills supply aligns with current and future labour market demands.

Glossary

Skills Lattice: A skills lattice is a concept that represents a more dynamic, flexible approach to career development, in contrast to the traditional "career ladder." While a career ladder emphasizes upward progression through a series of hierarchical steps, a skills lattice re-flects the idea that career growth can occur in multiple directions—upward, lateral (sideways), or even downward (to reskill or specialize in different areas). It allows for more varied career trajectories. The idea behind the skills lattice is to embrace a more holistic development process where individuals can move across sectors, roles, or industries by accumulating a diverse portfolio of skills.

STEM Skills Intelligence refers to the systematic collection, analysis, and interpretation of data related to skills demands, trends, and gaps within the fields of Science, Technology, Engineering, and Mathematics (STEM). It involves various methods such as real-time labour market data, forecasting methods, and stakeholder insights to understand current and future skills requirements.

STEM Talents refer to individuals with a formal qualification in Science, Technology, Engineering, and Mathematics (STEM) fields, regardless of qualification levels. These talents are equipped with a strong foundation in analytical thinking, problem-solving, technical skills, and the ability to apply scientific and mathematical concepts to real-world challenges. They often excel in areas such as data analysis, coding, engineering design, research, and technology development.

STEM Technology Clusters are geographically concentrated networks of interconnected companies, research institutions, universities, and other organizations that specialize in fields related to Science, Technology, Engineering, and Mathematics (STEM). These clusters facilitate collaboration, innovation, and knowledge sharing, often resulting in accelerated technological development, enhanced productivity, and increased competitiveness.

The Association of Nordic Engineers, ANE, consists of engineering trade union associations from the Nordic countries:

The Swedish Association of Graduate Engineers (Sveriges Ingenjörer)
The Danish Society of Engineers (IDA)
The Norwegian Society of Engineers and Technologists (NITO)
The Association of Chartered Engineers in Iceland (VFÍ)
Engineers Finland representing the Finnish organisations:
the Academic Engineers and Architects in Finland (TEK), the Technical Association in Finland (TFiF),
the Union of Professional Engineers in Finland (ILRY) and the Engineers in Finland (DIFF)

For more information, please visit www.nordicengineers.org

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