HARVARD Kennedy School
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Critical and Emerging Technologies Index 2025: Germany Report

Executive Summary

Germany ranks 7th out of 26 in the CET index. The German legacy industrial base is dominated by precision engineering and traditionally focused on continuous incremental innovation. Mechanical and chemical engineering as well as biotechnology stand out in particular. Even though Germany's research institutions produce competitive fundamental research across various fields, German industry struggles to transform that into more disruptive applications. As a result, Germany lacks high-tech disruptors. The most notable systemic challenges include slow regulatory adaptation, an aging workforce, talent drain and attraction, a high bureaucratic burden, and high energy prices. Venture capital is limited due to a traditionally risk-averse financial culture and legacy industries that historically had a limited need for growth capital. Major industrial strategies are successfully starting to address these issues.[1]

Cross-Sector Recommendations

- **Secure long-term public funding** for Germany's strong foundational research ecosystem.
- **Ease high bureaucratic burdens**, such as lengthy market approval processes, data privacy protocols, and bureaucratic visa procedures for foreign talent.
- **Address the talent development, retention, and attraction crisis**: Expand public STEM education funding, ease tech immigration pathways, lower language requirements, emphasize low cost-of-living in international recruiting (to counter relatively low salaries).
- **Foster industry-academia collaboration**: Strengthen technology transfer offices at universities, expand public-private innovation ventures (SPRIN-D), and fund tech start-up accelerators at public universities.

1 This piece has been informed by off-the-record exchanges with industry experts, policymakers, and researchers in Germany.

- **Strengthen startup support**: Attract venture capital through tax incentives and grants, building on the success of the German Future Fund. Improve effectiveness of scaling capital through mechanisms like accelerated depreciation and loss carryovers.
- **Create investor confidence in long-term energy prices** by accelerating the energy transition.

General Overview

Overall, Germany ranks 7th out of the 26 nations and regional blocs analyzed in the CET index. As Europe's largest economy, Germany is a leading innovation hub in Europe, investing 3.13% of its GDP in R&D in 2022 and is on track to 3.5% in 2025.[2] Germany's relative investment is among the highest worldwide, compared to 3.59% in the U.S., 3.41% in Japan, 2.91% in the UK, and 2.23% in France in 2022.[3]

Germany's economic and technological strengths are rooted in precision engineering and a culture of continuous optimization. This approach of incremental, rather than disruptive, innovation has brought about strong legacy industries in mechanical and chemical engineering, as well as biotechnology. A long-standing, well-funded public university system underpins Germany's excellence in fundamental research. However, the past three decades of particularly disruptive innovations globally, mainly in the digital and computing domains, have been challenging for Germany.

While its industry is beginning to catch up, significant systemic challenges remain, such as slow regulatory adaptation, an aging workforce, talent drain and attraction, a high bureaucratic burden, and high energy prices.[4] Startups face the additional challenge of comparatively limited availability of venture capital due to a risk-averse financial culture and legacy industries that historically had a limited need for growth capital.[5]

Major policy initiatives are starting to address these issues, such as the SPRIN-D agency for disruptive innovations[6], the €10 billion German Future Fund to mobilize venture capital,[7] and targeted industrial strategies for AI, quantum technology, space, and green tech—tied together under the High-Tech Strategy 2025.[8]

Germany performs relatively strongly across all technologies analyzed: artificial intelligence (4rd), biotechnology (6th), semiconductors (8th), space (8th), and quantum (5th). The following sections dive deeper into each of them.

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2 Germany – Country of Innovation," German Missions in the United States, accessed May 14, 2025, https://www.germany.info/us-en/2427156-2427156.

3 "Bulk Data Download Service," UNESCO Institute for Statistics, accessed April 5, 2025, https://apiportal.uis.unesco.org/bdds.

4 *Innovationsindikator 2023*, Bundesverband der Deutschen Industrie e.V. and Roland Berger, accessed April 5, 2025, https://www.innovationsindikator.de/fileadmin/innovationsindikator/downloads/Innovationsindikator-2023.pdf; *Artificial Intelligence in Germany: Status Quo, Opportunities and Options for Economic Policy Measures*, KfW Research, accessed April 4, 2025, https://www.kfw.de/PDF/Download-Center/Konzernthemen/Research/PDF-Dokumente-Fokus-Volkswirtschaft/Fokus-englische-Dateien/Fokus-2024-EN/Focus-No.-463-June-2024-AI.pdf.

5 "The Future of Venture Capital Funds in Germany," Beaumont Capital Markets, accessed May 6, 2025, https://beaumont-capitalmarkets.co.uk/the-future-of-venture-capital-funds-in-germany/; "Investment Activity in German Venture Capital Market Is Better Than Sentiment," KfW, accessed May 6, 2025, https://www.kfw.de/About-KfW/Newsroom/Latest-News/Pressemitteilungen-Details_796288.html; *Venture Capital Market Study 2023*, PwC, accessed May 6, 2025, https://www.pwc.de/en/deals/venture-capital-market-study.html.

6 *Evaluation der SPRIND GmbH – Executive Summary*, Fraunhofer-Institut für System- und Innovationsforschung ISI, accessed April 5, 2025, https://www.isi.fraunhofer.de/content/dam/isi/dokumente/p/2025/2024_01_28_SPRIND_Executive_Summary.pdf.

7 "The Future of Venture Capital Funds in Germany," Beaumont Capital Markets, accessed May 6, 2025, https://beaumont-capitalmarkets.co.uk/the-future-of-venture-capital-funds-in-germany/.

8 *Federal Government Report on the High-Tech Strategy 2025*, Federal Ministry of Education and Research (BMBF), accessed April 5, 2025, https://www.bmbf.de/SharedDocs/Publikationen/DE/FS/657232_Bericht_zur_Hightech-Strategie_2025_en.pdf; *Artificial Intelligence Strategy of the German Federal Government – Update 2020*, Federal Government of Germany, accessed April 4, 2025, https://www.ki-strategie-deutschland.de/files/downloads/Fortschreibung_KI-Strategie_engl.pdf; "Germany – Quantum Computing," International Trade Administration, accessed April 4, 2025, https://www.trade.gov/market-intelligence/germany-quantum-computing.

Artificial Intelligence

Status Quo

Germany's strengths in AI lie in industrial application, autonomous systems, and data privacy as well as a strong foundational research system with deep historical roots. The country has yet to see major success in commercial AI development and is failing to attract investments from global players. The comprehensive regulatory environment may offer opportunities for innovation.

Strengths: Germany's Saarland played a pivotal role in the early days of foundational AI research, driven by the German Research Center for AI, the Max Planck Institute for Informatics, and the Fraunhofer AI center. Thus, it exceeds the rest of Europe in the number of AI patents. Other strengths include industrial application of AI, autonomous systems (esp. vehicles), and data privacy.[9] Comprehensive EU and national legislation with an emphasis on privacy, security, and trust provide regulatory clarity and the most consumer-friendly AI policy framework globally.

The federal government has declared AI a major industrial policy priority as a cross-industry accelerator, marked a €5 billion ($5.5 billion) National AI Strategy, the AI Observatory, and expansion of Fraunhofer AI Centers.[10]

Challenges: Germany has no major players in consumer-facing AI or global AI startups. In the face of insufficient venture and growth capital, this is unlikely to change. The talent drain is particularly prevalent in the industry due to uncompetitive salaries. Domestic AI development lags far behind global players and is dependent on foreign computing infrastructure. Major US AI companies focus their European investments on Paris and London. While forward-looking, the regulatory environment is viewed as burdensome in the industry.[11]

Recommendations

- **Double down on the European regulatory framework** by making human-centered, trustworthy, and private AI Germany's/Europe's comparative advantage. Iterate the framework by identifying points of friction for industry and innovation while maintaining the emphasis on transparency, robustness, and data governance.
- **Solidify leadership in AI industry application** by identifying best practices and facilitating cross-industry exchanges. Accelerating AI diffusion into Germany's industrial base, esp. SMEs, allows the economy to profit from AI more broadly, stirring inclusive growth.
- **Expand AI startup funding via tax incentives and targeted growth capital subsidies**. Tailored fiscal instruments, such as loss carryovers, would help promising firms overcome scaling bottlenecks

9 *Artificial Intelligence in Germany: Status Quo, Opportunities and Options for Economic Policy Measures*, KfW Research, accessed April 4, 2025, https://www.kfw.de/PDF/Download-Center/Konzernthemen/Research/PDF-Dokumente-Fokus-Volkswirtschaft/Fokus-englische-Dateien/Fokus-2024-EN/Focus-No.-463-June-2024-AI.pdf; *OECD Artificial Intelligence Review of Germany*, OECD Publishing, accessed April 4, 2025, https://www.oecd.org/en/publications/oecd-artificial-intelligence-review-of-germany_609808d6-en.html.

10 *Artificial Intelligence Strategy of the German Federal Government – Update 2020*, Federal Government of Germany, accessed April 4, 2025, https://www.ki-strategie-deutschland.de/files/downloads/Fortschreibung_KI-Strategie_engl.pdf.

11 *Artificial Intelligence in Germany: Status Quo, Opportunities and Options for Economic Policy Measures*, KfW Research, accessed April 4, 2025, https://www.kfw.de/PDF/Download-Center/Konzernthemen/Research/PDF-Dokumente-Fokus-Volkswirtschaft/Fokus-englische-Dateien/Fokus-2024-EN/Focus-No.-463-June-2024-AI.pdf; *OECD Artificial Intelligence Review of Germany*, OECD Publishing, accessed April 4, 2025, https://www.oecd.org/en/publications/oecd-artificial-intelligence-review-of-germany_609808d6-en.html.

and retain IP within Germany. Leverage the German Future Fund to boost capital mobilization.

- **Invest in AI supercomputing infrastructure in a joint European effort**, including sovereign cloud environments and scaled model training capacity. This would reduce reliance on US hyperscalers and enable sovereign training and operation of large models.
- **Reduce bureaucratic friction for foreign talent to join the workforce** by simplifying visa processes, prioritized visa categories, and industry-specific allocations.

Biotechnologies

Status Quo

Germany has a long tradition of biomedical research and development, characterized by a mix of large legacy companies and disruptive innovators.

Strengths: Germany's biotechnology sector is dominated by drug development marked by a combination of global industry giants, like Bayer, Merck, and Boehringer Ingelheim, and innovators, such as BioNTech, that have put the country at a world-leading position in mRNA. Additional strengths include cancer immunotherapies and advanced diagnostics.[12] This is underpinned by a world-leading foundational research ecosystem, made up of Max Planck and Fraunhofer Institutes as well as public universities, sustained through public funding.

Challenges: Growth capital for startups is limited due to a risk-averse financial culture and a limited need for it historically[13], leading to early acquisitions by industry giants before major market disruption.[14] A heavy bureaucratic burden slows down clinical trial approvals—particularly compared to France and the UK—and difficulties attracting foreign talent. The foundational research output could be leveraged more effectively for private sector innovation.

Recommendations

- **Increase R&D tax incentives to improve startups' liquidity**, lowering the need for growth capital. Enhanced tax credits and loss carryovers would make early-stage biotech ventures more resilient and attract private investment at critical phases.
- **Streamline clinical trial approvals**, especially for early-stage and high-impact therapies. Accelerated timelines would erase the competitive disadvantage from prolonged delays until commercial market entry.
- **Sustain funding for the foundational research ecosystem, while establishing technology**

12 "Medical Biotechnology Industry," Germany Trade & Invest (GTAI), accessed April 5, 2025, https://www.gtai.de/en/invest/industries/healthcare-market-germany/medical-biotechnology.

13 "The Future of Venture Capital Funds in Germany," Beaumont Capital Markets, accessed May 6, 2025, https://beaumont-capitalmarkets.co.uk/the-future-of-venture-capital-funds-in-germany/; *Venture Capital Market Study 2023*, PwC, accessed May 6, 2025, https://www.pwc.de/en/deals/venture-capital-market-study.html.

14 "BioNTech's Covid-19 Vaccine Success Sparks Investments in German Biotech," *Wall Street Journal*, May 10, 2021, https://www.wsj.com/articles/biontechs-covid-19-vaccine-success-sparks-investments-in-german-biotech-11620644401.

transfer offices and expanding biotech incubators at universities. This would smoothen the commercialization pipeline for Germany's existing research excellence.

- **Reduce bureaucratic friction for foreign talent to join the workforce** by simplifying visa processes, broader recognition of international qualifications, and prioritized visa categories.

Semiconductors

Status Quo

Germany's semiconductor industry has fallen behind the rapid innovations of the past decades. Recent developments created momentum for manufacturing expansion but there is still no clear pathway for domestic cutting-edge chips.

Strengths: "Silicon Saxony" is Europe's largest microelectronics hub with 3,600 companies and 76,000 employees,[15] expanding rapidly through major recent investments in new plants by Intel (€30 billion / $33 billion) and TSMC (€10 billion / $11 billion) or Infineon's €5 billion ($5.5 billion) expansion. This strengthens Europe's capacity and independence in mass semiconductor production.

Challenges: Germany's semiconductor industry is focused largely on the manufacturing of "mid-tech" chips with a complete lack of sub-10nm fabrication. The economies of scale needed to be competitive in the industry make market entries challenging. Thus, there is a lack of domestic companies focused on cutting-edge chip development. The chip production itself is heavily reliant on subsidies and strained by high energy prices and talent shortages.[16]

Recommendations

- **Offer a clear roadmap for the long-term future of semiconductor subsidies**, ensuring predictability for firms and investors. A multi-year framework with transparent criteria and post-2027 funding clarity would safeguard planned investments and avoid project delays amid shifting budgetary conditions.
- **Pursue a joint European effort to attract cutting-edge semiconductor manufacturing**, particularly sub-10nm nodes. Coordinated incentive packages, shared infrastructure investment, and strategic alignment with critical partners like France, the Netherlands, and Italy would reduce intra-EU subsidy races, while strengthening European high-tech autonomy.
- **Provide targeted support for public universities to strengthen teaching and expertise in the field**, including specialized degree programs and professorships as well as lab partnerships with industry. Expanding microelectronics education would address severe talent shortages and stir a domestic ecosystem and innovation.

15 "Semiconductor Industry in Germany," Germany Trade & Invest (GTAI), accessed April 5, 2025, https://www.gtai.de/en/invest/industries/industrial-production/semiconductors; "Top Investments of the Year: Saxony Is Becoming a Global Venue for the Semiconductor Industry," Germany Trade & Invest (GTAI), accessed April 5, 2025, https://www.gtai.de/en/invest/business-location-germany/fdi/top-investments-of-the-year-saxony-is-becoming-a-global-venue-for-the-semiconductor-industry-1075990.

16 "No Subsidies? No TSMC," *fDi Intelligence*, August 29, 2024, https://www.fdiintelligence.com/content/54330be8-0a4c-5bdf-b83a-0ddcf8274c16.

Space Technologies

Status Quo

Germany is building new momentum in space marked by achievements such as the first Isar Aerospace launch in March 2025, the ongoing construction of the German Offshore Spaceport, and increased government interest in space independence.

Strengths: Germany's strengths in space stem from a strong legacy aerospace sector, particularly satellite systems and manufacturing, space situational awareness, and launch innovations. These are driven by major industry players like Airbus Defence and Space and OHB SE as well as a scientific research core led by the German Aerospace Center (DLR). A new wave of startups, most notably Isar Aerospace and Rocket Factory Augsburg, drive innovations such as small launch vehicles and lead the push toward European launch independence.

Challenges: Few industries are as closely linked and dependent on government programs and objectives as space. Thus, insufficient coordination between the German National Programme for Space and Innovation (NPWI) and the European Space Agency (ESA) as well as the EU Space Program lead to redundancies and a lack of clear priorities—providing an uncertain environment for long-term private investors. This is exacerbated by the absence of a German National Space Law that would clarify operational and regulatory frameworks, such as liability or launch requirements, unlike in France or the UK.[17] While limited space defense capabilities create risk for operators of space assets, their future development also presents business opportunities.

In 2023, the federal government released a National Space Strategy, emphasizing commercialization, ESA cooperation, space security, and space sustainability.[18]

Recommendations

- **Pass a national Space Law**, offering regulatory and operational clarity. This would streamline licensing, liability, and insurance requirements for private space activities, reducing uncertainty for startups and investors.
- **Expand public-private partnerships for startups and guarantee long-term public contracts**. Stable demand from public procurement would de-risk private investment and enable firms to scale domestically.
- **Push German leadership in ESA projects and integrate industrial space policy with key European partners** by taking lead roles in flagship missions and coordinating industrial emphases with France, the UK, and Italy. Closer coordination would reduce duplication, strengthen joint supply chains, and boost European autonomy.
- **Foster talent pipelines through increased public funding for aerospace engineering** at public

17 *Global Outer Space Guide: Germany*, Norton Rose Fulbright, February 2024, https://www.nortonrosefulbright.com/en/knowledge/publications/582a6d62/global-outer-space-guide-germany.

18 *The German Federal Government's Space Strategy*, Federal Ministry for Economic Affairs and Climate Action (BMWK), accessed April 5, 2025, https://www.bmwk.de/Redaktion/EN/Publikationen/Technologie/the-german-federal-governments-space-strategy.html.

universities and academic partnerships with industry clusters. This would help address long-term workforce gaps and accelerate applied research.

Quantum Technologies

Status Quo

In quantum technologies, Germany is leveraging its precision engineering capabilities to provide crucial components and industrial machinery, while being held back by the talent drain, a lack of capital, and limited interest by legacy industries in quantum technologies.

Strengths: Precision engineering excellence helped Germany to lead globally in quantum sensors and photonics as well as supplying industrial machinery for the production of specialized quantum technologies—with a startup scene focused on these topics. Quantum-secured communication is another strength. Strategic public private partnerships are bringing cutting-edge quantum computing to Germany, most notably Fraunhofer Institute's partnership with IBM (Quantum System One, Europe's first superconducting quantum computer) and an Infineon/eleQtron collaboration developing quantum processor units. This is complemented by a strong foundational research ecosystem.[19]

Germany's federal government views quantum as a cross-industry accelerator, similar to AI. The €3 billion Quantum Action Plan offers research grants and industry subsidies across the field.[20]

Challenges: Despite progress, Germany is lagging behind the US and China in scaling usable quantum computers. Public private partnerships cannot fill the gap left by a lack of venture capital. Uncompetitive salaries fuel the talent drain in quantum as well. Further challenges include the translation of foundational research into practical applications and limited interest/creativity within the legacy industries to apply quantum technologies.

Recommendations

- **Extend Quantum Action Plan funding beyond 2026**, ensuring continuity for long-horizon R&D and hardware development. Stable support would avoid project fragmentation and signal long-term commitment to public and private actors alike.
- **Foster quantum talent pipelines through stronger quantum clusters at public universities**, including specialized degree programs and professorships as well as partnerships with industry.
- **Offer quantum training to experienced engineers to encourage new quantum applications in the legacy industries**. Upskilling programs in collaboration with industry associations would expand near-term use cases and bridge Germany's industrial base with emerging quantum capabilities.
- **Reduce bureaucratic friction for foreign talent to join the workforce** by simplifying visa processes, prioritized visa categories, and industry-specific allocations.

19 "A Brief Overview of Quantum Computing in Germany," *The Quantum Insider*, April 11, 2023, https://thequantuminsider.com/2023/04/11/a-brief-overview-of-quantum-computing-in-germany/; "Germany – Quantum Computing," International Trade Administration, accessed April 5, 2025, https://www.trade.gov/market-intelligence/germany-quantum-computing.

20 *Handlungskonzept Quantentechnologien*, Bundesministerium für Bildung und Forschung (BMBF), April 2023, https://www.bmbf.de/SharedDocs/Publikationen/DE/5/31822_Handlungskonzept_Quantentechnolgien.pdf.

Governance Structure

Responsibilities for emerging technologies are spread across several ministries and agencies, with no centralized executive body. The Federal Ministry of Education and Research and the Federal Ministry for Economic Affairs and Climate Action lead public R&D and industrial innovation policy, respectively. They are independent bodies but coordinate planning. In 2019, Germany established a Federal Agency for Disruptive Innovation (SPRIN-D), focused on supporting specific high-potential ideas through public-private partnerships. Initial evaluations have found its impact to be effective and promising.[21]

The federal government has launched large programs aimed at accelerating the modernization and diversification of Germany's technological industrial base, prioritizing AI (€5 billion AI strategy), quantum technology (€3 billion quantum action plan), space (National Space Strategy), and green tech—tied together under the High-Tech Strategy 2025.[22] The German Future Fund is proving successful in closing the venture capital gap to its peers.[23]

Some governance gaps remain. Germany lacks a national innovation council or cabinet-level coordination mechanism, such as Japan's CSTI or Korea's PACST, to set strategic priorities across sectors. Thus, limited alignment of cross-sector goals, strategic frameworks, and funding reduces the system's responsiveness.

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21 *Evaluation der SPRIND GmbH – Executive Summary*, Fraunhofer-Institut für System- und Innovationsforschung ISI, accessed April 5, 2025, https://www.isi.fraunhofer.de/content/dam/isi/dokumente/p/2025/2024_01_28_SPRIND_Executive_Summary.pdf

22 *Federal Government Report on the High-Tech Strategy 2025*, Federal Ministry of Education and Research (BMBF), accessed April 5, 2025, https://www.bmbf.de/SharedDocs/Publikationen/DE/FS/657232_Bericht_zur_Hightech-Strategie_2025_en.pdf;
Artificial Intelligence Strategy of the German Federal Government – Update 2020, Federal Government of Germany, accessed April 4, 2025, https://www.ki-strategie-deutschland.de/files/downloads/Fortschreibung_KI-Strategie_engl.pdf; "Germany – Quantum Computing," International Trade Administration, accessed April 5, 2025, https://www.trade.gov/market-intelligence/germany-quantum-computing.

23 The Future of Venture Capital Funds in Germany," Beaumont Capital Markets, accessed May 6, 2025, https://beaumont-capitalmarkets.co.uk/the-future-of-venture-capital-funds-in-germany/.