OECD Artificial Intelligence Review of Germany

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Federal Ministry of Education and Research

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Please cite this publication as:
OECD (2024), *OECD Artificial Intelligence Review of Germany*, OECD Publishing, Paris, https://doi.org/10.1787/609808d6-en.

ISBN 978-92-64-88673-5 (print)
ISBN 978-92-64-62650-8 (PDF)
ISBN 978-92-64-64620-9 (HTML)
ISBN 978-92-64-40455-7 (epub)

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Foreword

The *OECD Artificial Intelligence Review of Germany* provides an international benchmarking of Germany's artificial intelligence (AI) ecosystem and discusses progress in implementing its national AI strategy. The report draws on quantitative and qualitative data and insights from the OECD.AI Policy Observatory and from the OECD Programme on AI in Work, Innovation, Productivity and Skills (AI-WIPS) – an OECD research programme financed by the German Federal Government – and results from a series of interviews with a wide range of stakeholders in Germany carried out in 2023. The review discusses Germany's strengths, weaknesses, opportunities, and challenges in AI, and provides recommendations to steer AI policy in Germany in the coming years.

Acknowledgements

The review was undertaken following an invitation by the Federal Ministries of Labour and Social Affairs (*Bundesministerium für Arbeit und Soziales,* BMAS), of Education and Research (*Bundesministerium für Bildung und Forschung*, BMBF), and of Economic Affairs and Climate Action (*Bundesministerium für Wirtschaft und Klimaschutz*, BMWK). The BMAS also provided financial support for this review.

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Lead authors for individual chapters were Noah Oder and Lucia Russo (Chapters 2, 3, 6 and 7), Lucia Russo, Celine Caira, and Noah Oder (Chapter 4), Sandrine Cazes and Anja Meierkord, with contributions from Glenda Quintini and Stijn Broecke (Chapter 5), Jamie Berryhill and Moritz von Knebel (consultant to the OECD) (Chapter 8), Johannes Kirnberger (consultant to the OECD) and Celine Caira (Chapter 9), and Eric Sutherland (Chapter 10). Sophia Klumpp (consultant to the OECD) provided research and organisational support.

Luis Aranda led the data gathering from the OECD.AI Policy Observatory with Besher Massri and Jakob Jelencic (Jožef Stefan Institute), Fabio Curi Paixao and Jacqueline Lessoff (consultants to the OECD). Lucy Russell (consultant to the OECD) assisted with data visualisation.

John Tarver, Misha Pinkhasov, Walter Pasquarelli, Eleonore Morena (consultants to the OECD), as well as Angela Gosmann and Nikolas Schmidt edited this report. Andreia Furtado provided editorial and publishing support. The report benefited significantly from their engagement.

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Abbreviations and acronyms

ABHen	*Ausländerbehörden* (German immigration authorities)
ABOS	*Algorithmenbewertungsstelle für Behörden und Organisationen mit Sicherheitsaufgaben* (Algorithm Assessment Centre for Authorities and Organizations with Security Tasks)
ADViCE	Artificial Intelligence for Decarbonisation's Virtual Centre of Excellence
AI	Artificial intelligence
AIAMO	Artificial Intelligence and Mobility
AISEC	*Fraunhofer-Institut für Angewandte und Integrierte Sicherheit* (Fraunhofer Institute for Applied and Integrated Security)
AI-WIPS	OECD programme on AI in Work Innovation Productivity and Skills
ANR	*Agence nationale de la recherche* (French National Agency for Research)
AVen	*Auslandsvertretungen* (German foreign diplomatic representations)
BAdW	*Bayerische Akademie der Wissenschaften* (Bavarian Academy of Science and Humanities)
BAKS	*Bundesakademie für Sicherheitspolitik* (Federal Academy for Security Policy)
BAMF	*Bundesamt für Migration und Flüchtlinge* (Federal Office for Migration and Refugees)
BeKI	*Beratungszentrum für Künstliche Intelligenz in der Öffentlichen Verwaltung* (Centre for Artificial Intelligence in Public Administration)
BetrVG	*Betriebsverfassungsgesetz* (German Works Constitution Act)
BfDI	*Bundesbeauftragter für den Datenschutz und die Informationsfreiheit* (Federal Commissioner for Data Protection and Freedom of Information)
BIBB	*Bundesinstitut für Berufsbildung* (Federal Institute for Vocational Education and Training)
BIFOLD	Berlin Institute for the Foundations of Learning and Data
BMAS	*Bundesministerium für Arbeit und Soziales* (Federal Ministry of Labour and Social Affairs)
BMBF	*Bundesministerium für Bildung und Forschung* (Federal Ministry of Education and Research)
BMDV	*Bundesministerium für Digitales und Verkehr* (Federal Ministry for Digital and Transport)
BMEL	*Bundesministerium für Ernährung und Landwirtschaft* (Federal Ministry of Food and Agriculture)
BMFSFJ	*Bundesministerium für Familie, Senioren, Frauen und Jugend* (Federal Ministry for Family Affairs, Senior Citizens, Women and Youth)
BMG	*Bundesministerium für Gesundheit* (Federal Ministry of Health)
BMI	*Bundesministerium des Innern und für Heimat* (Federal Ministry of the Interior and Community)
BMUV	*Bundesministerium für Umwelt, Naturschutz, nukleare Sicherheit und Verbraucherschutz* (Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection)
BMWK	*Bundesministerium für Wirtschaft und Klimaschutz* (Federal Ministry for Economic Affairs and Climate Action)
BMZ	*Bundesministerium für wirtschaftliche Zusammenarbeit und Entwicklung* (Federal Ministry for Economic Co-operation and Development)
BPI	*Banque publique d'investissement* (French Public Investment Bank)
BSI	*Bundesamt für Sicherheit in der Informationstechnik* (Federal Office for Information Security)
CAD	Canadian dollar
CAIOs	Chief Artificial Intelligence Officers
CEN	European Committee for Standardization
CENELEC	European Committee for Electrotechnical Standardization
CERTAIN	Centre for European Research in Trusted AI
CIP	Civic Innovation Platform
CO_2	Carbon dioxide
COVID-19	*Coronavirus* disease 2019
CPU	Central processing unit
DAAD	*Deutscher Akademischer Austauschdienst* (German Academic Exchange Service)
DENA	*Deutsche Energie-Agentur* (German Energy Agency)

DFKI	*Deutsches Forschungszentrum für Künstliche Intelligenz* (German Research Centre for Artificial Intelligence)
DIHK	*Deutsche Industrie- und Handelskammer* (German Chamber of Industry and Commerce)
DLT	Distributed ledger technology
ECDF	Einstein Centre Digital Future
EHDS	European Health Data Space
EMR	Electronic medical record
EnEfG	*Energieeffizienzgesetz* (Energy Efficiency Act)
ePA	*Elektronische Patientenakte* (Electronic patient record)
ESF	European Social Fund
EU	European Union
EUR	Euro
EuroHPC	*European High Performance Computing Joint Undertaking*
FCA	Financial Conduct Authority
FEG	*Fachkräfteeinwanderungsgesetz* (Skilled Immigration Act)
FITKO	*Föderale IT-Kooperation* (Federal IT Co-operation)
FMD	*Forschungsfabrik Mikroelektronik Deutschland* (Research Fab Microelectronics Germany)
FOKUS	*Fraunhofer-Institut für Offene Kommunikationssysteme* (Fraunhofer Institute for Open Communication Systems)
GAO	United States Government Accountability Office
GDNG	*Gesundheitsdatennutzungsgesetz* (Act on Health Data Use)
GDPR	General Data Protection Regulation
GHG	Greenhouse gas
GIZ	*Deutsche Gesellschaft für Internationale Zusammenarbeit* (German Agency for International Co-operation)
GPAI	General-purpose AI
GPU	Graphics processing unit
GWS	*Gesellschaft für wirtschaftliche Strukturforschung* (Institute for Economic Structure Research)
GXFS	Gaia-X Federation Services
HAI	Stanford Institute for Human-Centred AI
HLRS	*Höchstleistungsrechenzentrum Stuttgart* (High-Performance Computing Centre Stuttgart)
HPI	*Hasso-Plattner-Institut* (Hasso Plattner Institute)
IAB	*Institut für Arbeitsmarkt- und Berufsforschung* (Institute for Employment Research)
IAIS	*Fraunhofer-Institut für Intelligente Analyse- und Informationssysteme* (Fraunhofer Institute for Intelligent Analysis and Information Systems)
IAO	*Fraunhofer-Institut für Arbeitswirtschaft und Organisation* (Fraunhofer Institute for Industrial Engineering)
ICO	United Kingdom Information Commissioner's Office
ICT	Information and communication technology
IDMT	*Fraunhofer-Institut für Digitale Medientechnologie* (Fraunhofer Institute for Digital Media Technology)
IEA	International Energy Agency
INQA	*Initiative Neue Qualität der Arbeit* (New Quality of Work Initiative)
IÖW	*Institut für ökologische Wirtschaftsforschung* (Institute for Ecological Economic Research)
IPA	*Fraunhofer-Institut für Produktionstechnik und Automatisierung* (Fraunhofer Institute for Manufacturing Engineering and Automation)
IT	Information technology
ITU	International Telecommunication Union
JSC	Jülich Supercomputing Centre
K.I.E.Z.	*Künstliche Intelligenz Entrepreneurship Zentrum* (AI Entrepreneurship Centre)
KiKoN	*KI-Kompetenzzentrum für die niedersächsische Verwaltung* (Lower Saxony's Competence Centre for AI in Public Administration)
KISSKI	*KI-Servicezentrum für sensible und kritische Infrastrukturen* (AI Service Centre for Sensitive and Critical Infrastructures)
KOINNO	*Kompetenzzentrum innovative Beschaffung* (Competence Centre for Innovative Procurement)
KPI	Key performance indicator
kWh	Kilowatt-hour
LAC	Latin America and the Caribbean
LAMARR	Lamarr Institute for Machine Learning and Artificial Intelligence North Rhine-Westphalia
LLM	Large language model
LMs	Language models
LRZ	Leibniz Supercomputing Centre
MCML	Munich Centre for Machine Learning
NAIIO	National Artificial Intelligence Initiative Office

NCA	Netherlands Court of Auditors
NLP	Natural language processing
OECD	Organisation for Economic Co-operation and Development
ÖFIT	*Kompetenzzentrum Öffentliche IT* (Competence Centre for Public IT)
OGD	Open government data
OURdata	Open, Useful, and Re-usable data
PES	Public Employment Services
R&D	Research and development
RAIOs	Responsible Artificial Intelligence Officers
ROI	Return on investment
S4CS	Speech Assistance for Citizen Services
ScaDS.AI	Centre for Scalable Data Analytics and Artificial Intelligence Dresden/Leipzig
SDGs	United Nations Sustainable Development Goals
SMEs	Small and medium-sized enterprises
SPRIND	*Bundesagentur für Sprunginnovationen* (Federal Agency for Disruptive Innovation)
STEM	Science, technology, engineering and mathematics
SWOT	Strengths, weaknesses, opportunities and threats
TAB	*Büro für Technikfolgen-Abschätzung beim Deutschen Bundestag* (Office of Technology Assessment at the German Bundestag)
TUE.AI	Tübingen AI Centre
UK	United Kingdom
US	United States
USD	United States dollar
VC	Venture capital
VDE	*Verband der Elektrotechnik Elektronik Informationstechnik* (Association for Electrical, Electronic & Information Technologies)
VET	Vocational education and training
WBGU	*Wissenschaftlicher Beirat der Bundesregierung Globale Umweltveränderungen* (German Advisory Council on Global Change)
ZITiS	*Zentrale Stelle für Informationstechnik im Sicherheitsbereich* (Central Office for Information Technology in the Security Sector)
ZVKI	*Zentrum für vertrauenswürdige Künstliche Intelligenz* (Centre for Trustworthy Artificial Intelligence)

Executive summary

Germany demonstrated vision and leadership by being one of the first countries to establish a national strategy for artificial intelligence (AI) in 2018. Since then, the Federal Government has steered AI development to strengthen both national and European competitiveness in AI, prioritising human-centred AI for the benefits of workers and society.

Six years later, the geopolitical and economic context has changed drastically. Challenges include supply chain disruptions due to the COVID-19 pandemic and an energy crisis triggered by Russia's war of aggression against Ukraine, which has fuelled inflation and threatened German firms' competitiveness. Domestically, demographic shifts have resulted in healthcare costs and exacerbated labour shortages.

At the same time, the AI landscape has been evolving very rapidly. The rise of general-purpose AI systems took the world by storm in late 2022 due to their significant potential to transform entire industries and boost productivity. These promises ignited an international "AI race", with countries competing to secure economic and political advantages and assert leadership in the technology and its applications. Rapid advancements also heightened concerns about AI development, deployment, and governance.

As Germany grapples with establishing a "new era" (*Zeitenwende*) of economic and political trajectory, AI should be considered an important lever for preserving its international position as an economic powerhouse. Tackling persistent challenges and unlocking AI's full potential across sectors requires a strategic shift.

Initiatives implemented as part of the national AI strategy laid the foundation for Germany to emerge as a global leader in AI research. Germany has made significant strides in impactful AI research, with both public and private institutions featuring among global leaders in AI research publications.

Germany's efforts to attract skilled AI professionals have also been successful, but more needs to be done to broaden the AI talent pool and to prepare the workforce. Stronger participation of women in AI research and leadership is crucial to expand the talent pool, and to narrow the gender gap. Preparing the workforce for the AI era also requires more AI programmes at German universities. Furthermore, proactive measures such as conducting in-depth skill anticipation on AI, promoting lifelong training opportunities and incentivising companies to provide on-the-job training on AI will be essential.

AI can improve physical safety, enjoyment at work and productivity. **However, it also carries risks, including concerns about automation, data privacy, bias, accountability, transparency and increased work intensity.** Social dialogue and training are vital for a trustworthy use of AI in the workplace. Involving workers in the adoption of AI tools can improve working conditions and performance. Yet, social partners face expertise and resource limitation. As seen in Germany's Works Council Modernization Act, training and expert consulting are instrumental for informed decision making on AI in workplaces.

Infrastructure for AI is critical to AI advances and is expected to continue to be a driver of AI capabilities over time. While Germany has solid AI compute capacity, particularly in the research sector, a comprehensive assessment of its capacities and needs can identify gaps and help guide future investments.

Data are needed for AI applications but remain a significant bottleneck due to uncertainty about personal data protection and limited availability of industrial and open government data. Data quality and availability to train AI could be increased by requiring government agencies to publish non-sensitive data in open formats, reinforcing frameworks for responsible sharing of industry-specific data, and by providing regulatory guidance on using personal data.

German firms increasingly use and are interested in AI solutions, possibly due to developments in generative AI and to labour shortages. Sustaining this momentum requires targeted financial support to help enterprises understand business cases and strengthen key complementary assets, namely skills, digital infrastructure, and broader digitalisation. Start-ups are developing and bringing to the market innovative AI solutions. To fuel AI development, Germany should more actively nurture its AI entrepreneurial ecosystem and support start-up growth.

AI can enhance the public sector's efficiency and decision making and improve public services. Germany is seizing this opportunity in various government levels, but initiatives are often standalone, and the low level of digitalisation in the public sector limits the potential for AI use. Improving co-ordination, clarifying responsibilities, upskilling civil servants, and updating the roadmap for public sector initiatives could accelerate the transition towards a more innovative and agile public sector.

Germany is taking action to build a robust policy and legal foundation for AI's use in healthcare. AI can accelerate diagnostics and drug discovery, freeing time for health professionals to focus on patient care. However, developing and scaling AI healthcare applications faces challenges related to data access and interoperability, securing stakeholder buy-in, and human and AI compute capacity. Updated guidance on practices could help to create value from secondary use of data, with strong measures to protect citizens' rights including privacy.

Germany is poised to be a global leader in AI and environmental sustainability, given its well-funded initiatives, world-leading researchers, and innovative companies. AI can help accelerate decarbonisation in energy, transport, industry, and agriculture. Yet strengthening Germany's leadership position requires inter-ministerial and interdisciplinary co-operation, knowledge-sharing and widening the focus of what constitutes sustainability beyond energy and resource efficiency, while measuring and mitigating the negative environmental impacts of developing and using AI itself.

German public perception of AI is fairly positive among the general population, specialised users and workers. However, vigilance is needed in the face of rapidly evolving societal risks, including threats to human rights and democratic values. Germany could also involve a broader set of stakeholders in AI policy discussions, and regularly monitor public perceptions to understand how citizens' views evolve as AI increasingly becomes part of everyday life.

Germany should adjust its national AI strategy's vision and approach to navigate today's new realities effectively. Germany should leverage AI to meet its most pressing challenges, including the green transition, administrative and industrial efficiency, and healthcare quality. This requires strategic vision and co-ordination at the highest political level, alongside a solid technology, data and infrastructure foundation, a skilled workforce to diffuse AI across sectors, and societal trust.

1 Key findings

This chapter provides a summary of the key findings from the international benchmarking of Germany's AI ecosystem and from the analysis of achievements of its national AI strategy. It discusses Germany's strengths, weaknesses, opportunities and challenges regarding AI development and use. The chapter concludes with recommendations to help steer AI policy in Germany to maximise opportunities and mitigate risks moving forward.

Context

Germany's 2018 national AI strategy, updated in 2020, aims for responsible growth and competitiveness in AI

In 2018, Germany was among the first countries to adopt a national strategy for AI. The strategy's objective is to foster growth and competitiveness and ensure the responsible and trustworthy development of AI. Three federal ministries are responsible for the strategy's development and implementation: the Federal Ministries of Education and Research (*Bundesministerium für Bildung und Forschung*, BMBF), of Economic Affairs and Climate Action (*Bundesministerium für Wirtschaft und Klimaschutz*, BMWK) and of Labour and Social Affairs (*Bundesministerium für Arbeit und Soziales*, BMAS).

The main goals of Germany's AI strategy are: i) to secure Germany's future competitiveness while making Germany and Europe leading locations for the development and application of AI technologies; ii) to ensure that AI use and development are responsible and focused on the common good; and iii) to embed AI in society ethically, legally, culturally, and institutionally through broad societal dialogue and active political efforts.

In November 2019, the German Federal Government published an interim report with results after the first year of implementation. In December 2020, Germany updated the national AI strategy in response to developments. In particular, the COVID-19 pandemic, environmental sustainability, and climate protection were brought to the fore, alongside the importance of European and international collaboration on AI. The EUR 3 billion budget originally allocated to the strategy was later announced to be increased to EUR 5 billion. The three leading ministries evaluated the national AI strategy in 2023-24. In this context, they invited the OECD to support their analysis through an international benchmarking of the German AI ecosystem.

The geopolitical, technological, and economic context changed significantly since 2020

As Germany seemed to be recovering from the COVID-19 pandemic, Russia's war of aggression against Ukraine began and Germany's dependence on energy imports turned into an energy-security threat. Energy prices increased substantially, fuelling inflation, and affecting firms' competitiveness. Several bottlenecks caused first by the pandemic then by the war disrupted global value chains and brought to light Germany's energy security vulnerability. Domestically, Germany faced the challenge of a demographic change, resulting in high healthcare costs, and contributing to labour shortages.

At the same time, AI technologies continue to evolve rapidly. AI is widely considered the next general-purpose technology, given its potential to transform entire sectors and enable the discovery of innovative new business models and products. The worldwide number of scientific publications on AI nearly quadrupled over the past five years, and venture capital (VC) investment in AI more than doubled over the same period. In November 2022, the release of the conversational AI language model ChatGPT-3 brought generative AI to the attention of the broader public, raising awareness of the technology's potential and its risks.

Against this background, assessing Germany's international AI performance and evaluate the achievements to date of its national AI strategy is timely to recognise its strengths, identify weaknesses and ultimately shape its AI vision for the years ahead to both maximise opportunities and mitigate risks.

This report draws on data and on insights from interviews with key German stakeholders in the field of AI to provide an international benchmarking of Germany's AI ecosystem and progress in implementing its national AI strategy. It discusses Germany's strengths, weaknesses, opportunities and challenges in AI development and use, and recommends approaches to help steer AI policy in Germany moving forward.

This review is organised according to six pillars: minds, research, transfer and applications, the world of work, policy and regulatory frameworks, and society. The review also includes three sector spotlights on AI in the public sector, healthcare, and environmental sustainability.

Overview of strengths and weaknesses, opportunities, and threats

Figure 1.1 summarises the key findings stemming from the analysis, while the next section provides overall recommendations. Chapters in the report discuss in detail the findings by each area of the analysis.

Strengths

In the unfolding AI race, Germany is equipped with unique competitive assets: research excellence coupled with a priority to develop AI in a human-centred way, as well as Germany's international clout, create fertile ground for AI development and adoption.

- **German research pioneers AI development in all key AI sub-disciplines, positioning the country as a leader in global AI trends and standards**. A robust network of public and private research institutions characterises Germany's AI research landscape. Institutions like the Max Planck Society, Fraunhofer Society, and leading universities are renowned for their rigorous scientific output, ranking highly in international comparisons. German institutions focus on both fundamental and applied research. This research excellence has become a magnet for talent, contributing to global AI knowledge. German researchers' academic outputs, as measured in AI research publications, consistently rank among the top worldwide. This prolific output demonstrates Germany's importance in advancing AI knowledge and applications.
- **Germany's solid compute capacity underpins the research sector's ability to research AI models**. With the emergence of generative AI and foundation models, AI research is increasingly computationally intensive. Germany has numerous supercomputers that can be used for training AI models and meet growing demand for AI compute from the research and private sector. Though the broad accessibility of compute resources still needs to be assessed, compute capacity represents a major competitive advantage. A majority of other European countries have insufficient AI compute.
- **Germany has adopted a human-centred approach to AI**. The German Federal Government, through its AI strategy and policies, emphasises the development and use of AI for social good. It invests in projects that promise to benefit society, such as healthcare and environmental sustainability. These policy priorities align AI advancements with societal objectives, ensuring that technology serves the public interest broadly. AI developments should prioritise ethical considerations, societal needs, and individual rights. To do so Germany emphasises AI applications that enhance human capabilities, respect privacy, and ensure fairness. In line with the European Union (EU) AI Act, German policies and research initiatives reflect this human-centred ethos and help set a global benchmark for responsible AI development.
- **Keeping humans at the centre of AI development has translated into a generally positive attitude towards AI in the workplace**. Germany has actively consulted with workers on AI adoption in the workplace. By addressing concerns and incorporating feedback, German stakeholders ensure that AI adoption is aligned with employers and workers' needs and values and enhance the effectiveness and acceptance of AI solutions.
- **Beyond making AI ethically sound, Germany is uniquely positioned to make it environmentally sustainable**. As the world faces a climate crisis, driving AI as part of the green and digital "twin transition" has become crucial. With recent reports highlighting both the significant

ecological footprint of developing AI systems and the large potential of leveraging AI for rapid decarbonisation, Germany features AI and sustainability ecosystems that could drive the sustainability of its AI models and applications. Beyond reducing carbon emissions, this approach may spearhead the development of environmentally sustainable AI and prove to be a competitive advantage.

- **Germany is breaking grounds on AI policy initiatives, both domestically and internationally and it is exporting its vision for the future of AI abroad**. Germany is carving out space for policy experimentation. To better support the regulatory management of AI, Germany initiated a series of measures aimed at enhancing regulatory experimentation. These include the Spaces for Learning and Experimentation (*Lern-und Experimentierräume*) and the creation of regulatory sandboxes, as outlined in its national AI strategy. Germany is expected to enact a federal regulatory sandbox law by 2025. Germany is taking deliberate steps to lead AI regulation and standardisation, to foster the twin-objectives of trustworthiness and competitiveness. Initiatives such as the establishment of a national AI standardisation roadmap, engagement in international standardisation organisations, the introduction of an "AI trust label", illustrate the country's proactive approach to ethical AI development. These measures are symbolic of Germany's dedication to shaping a competitive AI industry within the European framework, in line with the EU's regulatory ambitions.

Weaknesses

While AI hype is peaking globally, Germany's economy shows reserved enthusiasm: although AI is widely considered to be the next general-purpose technology that will provide major competitive advantages to businesses, limited availability of VC and of other AI enablers, alongside weariness for innovation have resulted in only modest adoption.

- **German companies that fail to adopt AI risk losing global competitiveness and remaining vulnerable to supply chain disruptions**. Despite its solid foundation in AI research and development, Germany's AI adoption across key industries is more fragmented. While public and private research institutes have made significant strides in AI development, the overall pace of industry adoption remains relatively low compared to European frontrunners. In particular, the manufacturing sector, which plays a key role in the German economy, is slower than other sectors in taking up AI applications. This slow adoption can be attributed to various factors that range from industry-specific challenges to broader economic and policy environments. Like many other countries, Germany faces an AI skills bottleneck. Although its educational institutions excel in producing high-quality graduates, the demand for AI expertise far outstrips the supply.
- **AI roles remain predominantly male dominated**. Mirroring a global issue, there is a wide gender gap in AI roles, particularly in leadership positions within Germany. This disparity restricts Germany's ability to meet labour market demands and to ensure that AI solutions cater to diverse populations and to avoid perpetrating biases.
- **While employers complain about talent bottlenecks, the scale of the issue is largely unknown**. National skills assessment studies lack a specific examination of available AI skills, generating an opaque picture with regards to skills demand and perceived shortages. This highlights a need for a bespoke and precise evaluation of AI skill requirements needed for designing educational policy responses and on-the-job re-skilling programmes. Germany's flagship vocational programme (*Ausbildungsmodell*) needs an AI update. In the absence of a precise AI skills assessment, updating vocational training regulations to incorporate AI content is advancing slowly. Yet, the flexibility of Germany's vocational programmes and employers' ability

to proactively integrate AI-related skills into their programmes make vocational training a uniquely agile vehicle to address the AI skills gap.

- **Following a decade of economic growth, Germany may be a victim of its own success as economic actors become increasingly weary towards innovation**. Across several sectors, there is a low understanding of AI's potential applications, coupled with a mindset that past economic success pre-empted a need for innovation. This lack of awareness impedes the adoption of AI, as businesses and public-sector entities fail to recognise how AI can help address critical business challenges or enhance operational efficiency. A limited appetite for risk hampers the growth of German AI champions. Germany's conservative investment mindset, characterised by a reluctance to engage in high-risk ventures, significantly impacts the AI landscape. The limited availability of VC for AI startups stifles innovation and slows down the commercialisation and diffusion of AI technologies. This risk aversion manifests itself both in the world of VC, but also within civil service when procuring AI solutions. Faced with a lack of funding, high potential start-ups may choose to relocate abroad.
- **Policy and governance mechanisms remain partly fragmented but are crucial to steer beneficial AI adoption**. Leadership at a high political level could signal widely that AI is a national priority. In the public sector, there is a lack of clarity on roles and oversight regarding AI implementation. Government ministries each manage initiatives with their own set of AI usage rules, but a centralised approach is missing. This absence of a cohesive strategy and co-ordination function results in lack of AI leadership in government and potential duplication of efforts across different ministries. Germany's federated governance creates bottlenecks, hindering uniform AI adoption across states. The centralisation of AI expertise within national ministries results in expertise bottlenecks at the state level, and this may impact implementation of regulatory sandboxes due to the limited know-how of Germany's federal states (*Länder*). Further complicating matters is a fragmentation of authority across states (such as in healthcare or data protection), each developing their own initiatives at varying paces. This disjointed approach not only slows AI integration but also makes it challenging to adopt AI nationwide uniformly.
- **Civil society needs a bigger seat at the table**. While the German Federal Government engages stakeholders in AI policy design, such as during the 2018 national AI strategy formulation, representation is limited. Seats at the policy-making table are typically occupied by social partners (*Sozialpartner:innen*), leaving other stakeholder groups, including civil society, minority and environmental protection groups on the fringes. This imbalance in participation does not sufficiently capture the full spectrum of perspectives needed to ensure that AI policy is designed inclusively.
- **But the challenges are technical as much as they are structural**. Open data accessibility and digital infrastructure are limited. Developing and training AI applications requires access to large, high-quality, and detailed datasets while ensuring the security of these data. Yet, government datasets, crucial for training and refining AI algorithms, remain predominantly closed. Industrial data are similarly largely underutilised. Similarly efficient and widespread connectivity is a prerequisite for smooth data transfer and availability, while Germany's patchy digital infrastructure, especially in rural areas, limits AI penetration. Within the healthcare sector strict adherence to data protection laws and an overly cautious stance towards innovation limit progress, despite the sector's desire to enhance access to health data for research. The lack of standardised data protocols and interoperability creates significant barriers to integrating AI, with researchers facing considerable administrative challenges in accessing health data.

Opportunities

A number of opportunities could help navigate these new global realities.

- **Current hype may be the perfect storm for promoting AI adoption in Germany**. The current momentum and surge in AI interest can support driving actionable strategies across key sectors including manufacturing, public services, healthcare, and green initiatives. AI adoption could be driven through incentives, awareness drives, and supportive policies.
- **This may help re-design industries for the age of AI**. Crafting targeted policies for AI to transform critical industries could support AI penetration across sectors. By focusing on sector-specific AI strategies, funding transformative projects, and supporting R&D in key sectors, industries could be made ready for a global economy shaped by AI.
- **Expanding the circle of consultation could create a more inclusive policy design process**. Germany's strong social partnership tradition creates fertile ground for an inclusive AI policy environment. By creating platforms and processes for diverse stakeholder engagement, including citizens, Germany is well placed to ensure wider representation in AI policy development.
- **Germany is strongly positioned to be a frontrunner in AI policy**: Germany can support and fund initiatives that promote standards for trustworthy AI internationally.
- **From sustainable AI to AI for sustainability**: Mapping and measuring the environmental footprint of AI and leveraging Germany's AI and environmental sustainability ecosystem can help decarbonise energy, transport, industry, and agriculture. Through the formulation of policies that back AI research for sustainability and offer industry incentives for eco-friendly AI adoption.

Threats

As global AI competition heats up, vigilance is needed in the face of rapidly evolving societal risks. In trying to lead a future shaped by AI, governments worldwide are investing heavily in AI capabilities. But as AI development accelerates, it risks sparking disinformation, economic inequality, or bias perpetration, threatening public trust.

- **The global frontrunners have positioned themselves**. German industry may lose competitiveness at the global level if it does not adopt trustworthy AI timely. Widely regarded as the next general-purpose technology, AI has the potential for contributing to large scale economic growth and social innovation and could reduce the impact of labour shortages on the economy. Failure to adopt AI could result in German industry losing its competitiveness edge, as rivals harness AI to improve operations, cut costs, and innovate.
- **Germany must leverage the EU to keep pace in the global AI race**. As the competition for AI dominance intensifies, global superpowers are marking their territories, with the People's Republic of China (hereafter "China"), the United States and an increasingly ambitious India making a firm stance on the global stage. To remain globally competitive, Germany must harness the collective scale of the EU to bolster its technological capabilities, innovation potential, and avoid trailing behind.
- **Thus far AI has been viewed favourably. But its rapid advancement and ensuing threats may put this trust to the test, triggering public resistance to wider adoption**. In a year filled with high profile elections, deepfakes and AI-generated disinformation will bring emerging threats to the centre stage. In 2024, an unprecedented number of voters will go to the polls across 68 nations. Previous cases of deepfakes and disinformation have dominated news headlines. In what has been coined the "Year of Elections" the risk of AI being used to create and spread

misinformation and disinformation is particularly high. This misuse could undermine the integrity of democratic processes and weaken public trust in AI.

- **Anxiety about automation and economic disparities are increasingly prevalent as topics of public concern**. AI's benefits risk accruing disproportionately to higher-income groups, intensifying economic inequality. Such a scenario could contribute to the erosion of the German middle class, posing threats to societal cohesion and overall prosperity.
- **AI systems, if not carefully designed and monitored, can perpetuate existing biases**. To date, Germany has not faced a case of large-scale bias perpetration compared to other countries, but such a high-profile case could turn the tide against public perception on AI. Securing vigilance and countering these risks will be imperative.
- **The use of AI systems in the workplace can raise risks for the safety of workers and their rights**. Germany needs to implement measures to monitor and manage these risks.
- **The massive use of computational resources for AI systems raises sustainability concerns.** While AI only represents a fraction of overall environmental impacts from digital technologies, the proliferation of AI applications and the exponential dynamic of AI compute requirements call for implementing measurement standards and expanding measurement efforts to assess and mitigate the energy, water, and resource impacts of AI compute infrastructure.

Figure 1.1. Strengths, weaknesses, opportunities, and threats (SWOT) analysis

STRENGTHS

+ Capacity to attract international AI talent in business and academia.
+ Strong research base in publications in all key AI disciplines, and by both public and private sectors.
+ Solid AI compute capacity, particularly in the research sector.
+ Generally positive attitudes of workers towards AI.
+ Workers more likely to be consulted about adoption of new technologies than in most other countries.
+ Human-centred AI as a government priority.
+ Strong legal framework for regulatory experimentation.
+ Involvement in international AI policy making and standardisation bodies.
+ Government support for developing AI projects for the common good.
+ Outstanding AI and environmental sustainability ecosystem.
+ Ongoing policy and legislative action to build a foundation for AI use in healthcare.

WEAKNESSES

- Low proportion of women in AI research, particularly in leadership positions.
- Shortage of AI skills and low understanding of potential use cases among key barriers to wider diffusion of AI in firms.
- Siloed industrial and government data, uncertainty about personal data protection rules.
- Limited availability of risk capital and under-developed VC mentality.
- Slow progress updating vocational training regulations to include AI.
- Lack of an oversight and co-ordination function at higher political level to implement AI and related digitalisation strategies.
- Limited competences at *Länder* level for regulatory experimentation.
- Limited involvement of civil society and citizens in AI policy debates and design.
- Lack of clarity about roles and responsibility in AI governance for the public sector.
- Lack of coherent strategy to harness AI for environmental sustainability.
- Poor interoperability and cautious interpretation of legislation regarding health data.

OPPORTUNITIES

+ Increased interest in AI solutions ("turning point in AI adoption").
+ Potential for AI to transform entire sectors, including manufacturing, public sector and health care, and support the green transition.
+ Overall positive public perception of AI.
+ Strong social partnership tradition to build upon and involve a broader range of stakeholders in AI policy design.
+ Potential of AI to support rapid decarbonisation in key sectors such as energy, transport, industry and agriculture.

THREATS

- China and the United States are the worldwide AI powerhouses and India is quickly catching up on AI research, requiring stronger leveraging of the European Union's scale.
- Risk of insufficiently exploiting AI's potential for Germany's international competitiveness, prosperity and social cohesion.
- Heightened types of ethical concerns related to AI, risks of misuse of AI applications, with the potential to threaten people's trust in AI, risks to the safety and rights of workers.
- Fragmented health systems may slow down AI adoption, requiring harmonisation across regions to create a scalable environment for AI.
- AI as part of the larger digital compute infrastructure has considerable environmental impacts, such as energy consumption and water use, that are not yet systematically measured in Germany.

Key recommendations

Germany is well-positioned overall to keep pace in the AI global competition, but to meet its AI ambitions it could leverage its international clout and economic weight to implement reforms

While vision and strategic co-ordination at the highest level of Government are key, it is crucial to have a robust technological, data and infrastructure foundation, a competitive and technically savvy workforce to diffuse AI across sectors, and society's trust. To meet existing and upcoming challenges, Germany could focus its attention on:

- **Keeping sight of the bigger picture**. Germany's national AI strategy could be updated to target sectors where AI is expected to have the strongest impact. This involves identifying and channelling efforts towards specific challenges and creating a roadmap for integrating AI solutions in these sectors.
- **Securing buy-in at the highest political level and harmonising policy efforts in adjacent areas**. Germany lags in key enablers of digital transformation and AI uptake, such as connectivity infrastructure and open-data availability. While the Government issued strategies to advance these fields, they are managed by separate entities lacking co-ordination authority. Given the interdependence of digitalisation, data and AI, commitment at the top political level (i.e. the Federal Chancellery) to orchestrate these policies is required to unlock opportunities, ensure policy effectiveness, and avoid conflicting or duplicating efforts.
- **Leveraging AI to cut red tape in the public sector, reach healthcare and environmental objectives, and secure industrial competitiveness**. AI can transform entire sectors, including manufacturing, which are key for the German economy. AI solutions can also accelerate the green transition, increase public-administration efficiency, and mitigate challenges of an ageing population – key issues for Germany.
- **Involve and inform citizens and workers**. Germany's approach to AI, including for AI adoption in the workplace, is human-centred and transparent. Continued acceptance of the technology will hinge on stakeholders' capacity to engage in meaningful dialogue, with a nuanced picture of the technology itself and the impact of its adoption, including in the workplace. Labour-market resilience will need to be cultivated, including enhancing AI expertise and awareness among workers and employers.

Attention should focus on three strategic enablers:

- **Widening access to data**. Data are the raw material for developing AI systems, but in Germany their availability and use are limited, due to cautious interpretation of data protection legislation, and public and industrial data remaining siloed. Data-protection authorities should proactively develop data-sharing protocols for personal data use in sectors, such as healthcare. Furthermore, the Federal Government could mandate government agencies at all levels to publish non-sensitive data in open registries. Frameworks that facilitate the responsible sharing of industry-specific data for AI development should be reinforced. The EU and national policy frameworks recently enacted go in the right direction in fostering data as a key enabler for AI innovation. Implementation of these policies will be key.
- **Nurture the next generation of AI entrepreneurs**. While government financing to start-ups is available in pre-seed and seed rounds, AI start-ups face challenges accessing domestic or European capital to scale up. More risk capital could be made available by revisiting the legal framework for capital-collecting institutions, while targeted government financing could enhance AI start-ups in their growth phase. Finally, the Federal Government should revisit its procurement guidelines to allow AI start-ups to more easily sell to the public sector.

- **Build and scale a globally competitive computing infrastructure**. Germany should assess its current AI compute infrastructure to gauge existing capacity and potential gaps for matching stakeholder demands. This assessment would help ensure that capacity is available to implement Germany's AI strategy, produce world-class frontier AI research and develop sector-specific solutions. To ensure that national AI infrastructure is inclusive and accessible to all stakeholders, a portion should be made accessible for use by AI start-ups and SMEs.

Methodology

The review draws on qualitative and quantitative data collected in two phases. The first phase (November 2022-February 2023) gathered data on the five pillars of the 2020 national AI strategy (Minds, Research, Transfer and applications, Regulatory Framework, and Society) and an additional pillar: The world of work. Data were sourced from the OECD.AI Policy Observatory and from the OECD's AI Work Innovation Productivity and Skills (AI-WIPS) project, supported by the BMAS, complemented by data from third parties and *ad hoc* data collection for specific areas and indicators. Upon completion of the first phase, preliminary results and recommendations were presented to the three federal ministries responsible for implementing the AI strategy.

The second phase of the study (July-October 2023) delved deeper into specific areas: transfer from research to commercial applications, and the use of AI in the public sector, healthcare, and environmental sustainability. The discussions pertaining to these sector "spotlights" (and the 'Transfer and applications' pillar) are thus more extensive than other sections. For the second phase of the review, over 90 individual interviewees provided their perspectives on the advancement of AI in several German sectors (Annex B). These discussions took place through a combination of in-person and remote interviews, supplemented by desk research and four site visits to Germany. The review combines results from both phases and discusses the status of AI in each of the pillars, policies, and challenges to address.

2 Minds

This chapter explores Germany's initiatives to address challenges in developing, attracting, and retaining artificial intelligence (AI) talent. Notable achievements include a positive AI skills migration gain, thriving tech hubs in Berlin, Munich and Stuttgart, and the successful establishment of 150 additional AI professorships since the launch of the national AI strategy. The chapter discusses the amended Skilled Immigration Act (*Fachkräfteeinwanderungsgesetz*, FEG) potential in easing visa processes for non-European Union (EU) skilled professionals. It also looks at the offer of AI-related courses in German universities. Recommendations include continued efforts to streamline visa processes for AI professionals, a higher number of shorter AI courses and AI programmes in English, and mandatory ethical/human-centric AI courses to ensure responsible AI development.

The Minds section of Germany's national AI strategy recognises that German companies, universities, and research institutions face challenges securing AI talent in a highly competitive global labour market. Since 2018, Germany has launched several initiatives to attract skilled workers through higher education and training, and to create an attractive working and research environment for scientists (German Federal Government, 2020[1]).

Box 2.1. Minds: Findings and recommendations

Findings

- In recent years, German companies have attracted and retained international workers with AI skills. However, competition for AI talent from foreign companies is still present, and intricate visa processes hamper recruiting talent from non-EU countries.
- An additional 150 AI professorships were established between 2018 and 2023, signalling a strong commitment by German universities and the Federal Ministry of Education and Research (*Bundesministerium für Bildung und Forschung*, BMBF) to promote academic excellence in the field of AI.
- Compared to six other European countries (Austria, France, Italy, the Netherlands, Switzerland and the United Kingdom), Germany ranks second-to-last in terms of AI degree programmes per capita. Furthermore, most AI-related degrees are in German, which is a barrier to attracting foreign students.
- AI education at universities consists mostly of full-degree AI programmes, whereas other countries have a large availability of shorter programmes for certificates or one-year masters.
- There are many compulsory human-centred AI courses, but no full degree for human-centred AI. That said, an increasing number of AI courses are offered outside of computer science departments at universities.

Recommendations

- Continue efforts to facilitate visa processes and immigration for AI professionals through the FEG.
- Increase AI course offerings in English and in ethical/human-centred AI across degree programmes and disciplines.

AI talent attraction

Germany's national AI strategy has achieved its goal by funding 150 AI professorships ahead of the 2025 target. German tech hubs like Berlin and Munich are attracting AI talent, leading to a net skills migration gain. However, AI job vacancies remain open longer than in other sectors, indicating an AI skills shortage.

Germany's national AI strategy emphasises attracting and retaining AI talent

The national AI strategy aimed to attract academic talent for at least 100 additional AI professorships by 2025. This target was achieved in 2022, and 150 additional professorships on AI were funded by 2023 through measures supported by the BMBF: i) the Alexander von Humboldt Professorship for AI (18 new AI professorships); ii) the establishment of five AI competence centres at universities (24 new AI professorships); iii) the tenure-track programme (85 new AI professorships); iv) programmes by the German Research Foundation (*Deutsche Forschungsgesellschaft*, DFG) (8 additional AI professorships);

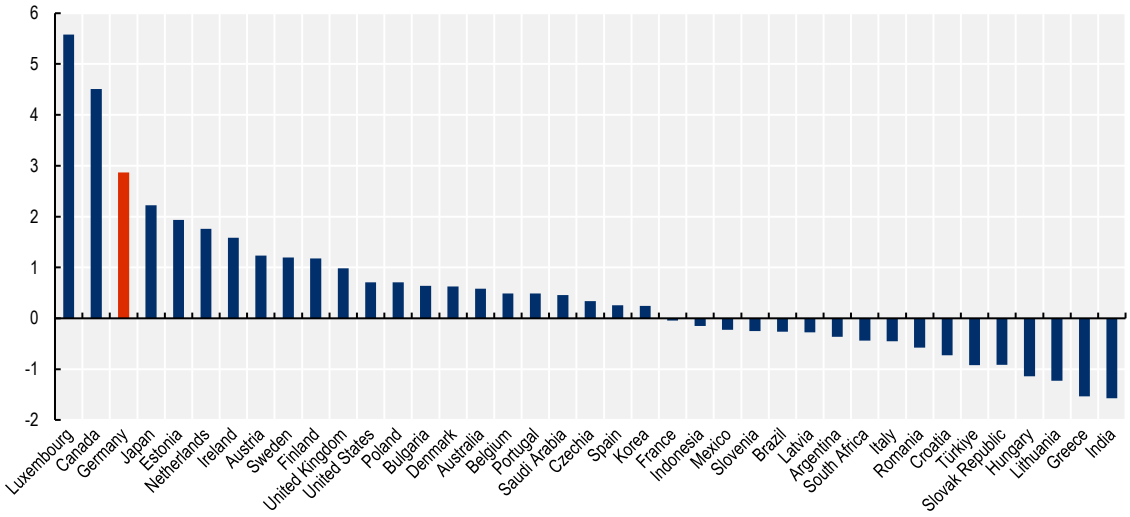
and v) collaborations between non-university research institutions and universities (15 additional AI professorships) (BMBF, 2022[2]). Stakeholders recognised the success of the additional 100 professorships initiative and advocated for its continuation (Humboldt Foundation, 2023[3]). The programme's initial success was due to initial funding and longer-term funding to the German AI excellence centres is considered crucial to sustain the initiative and allow for hiring more AI professors.

Additionally, the BMBF-funded Konrad Zuse Schools for Excellence in AI (funded by the German Academic Exchange Service, *Deutscher Akademischer Austauschdienst*, DAAD) welcome international AI talents at the master's and PhD level. They offer teaching and research programmes in English and bring together a consortium of renowned scientists from universities and non-university research institutions with an interest in innovative teaching as well as representatives of research and development departments in business and industry as fellows.

German companies have been able to attract and retain workers with AI skills internationally in recent years. This is reflected in Germany's positive AI skills migration gain: according to LinkedIn data more AI-skilled workers are coming into the country than are leaving it (OECD.AI, 2023[4]). Moreover, the German cities of Berlin, Munich and Stuttgart are among Europe's largest tech hubs, with approximately 47 200, 40 300 and 31 000 engineers working in each city, respectively (Sequoia, 2023[5]).

Figure 2.1. Germany attracts international AI talent

AI skills migration per 10 000 LinkedIn users, 2022



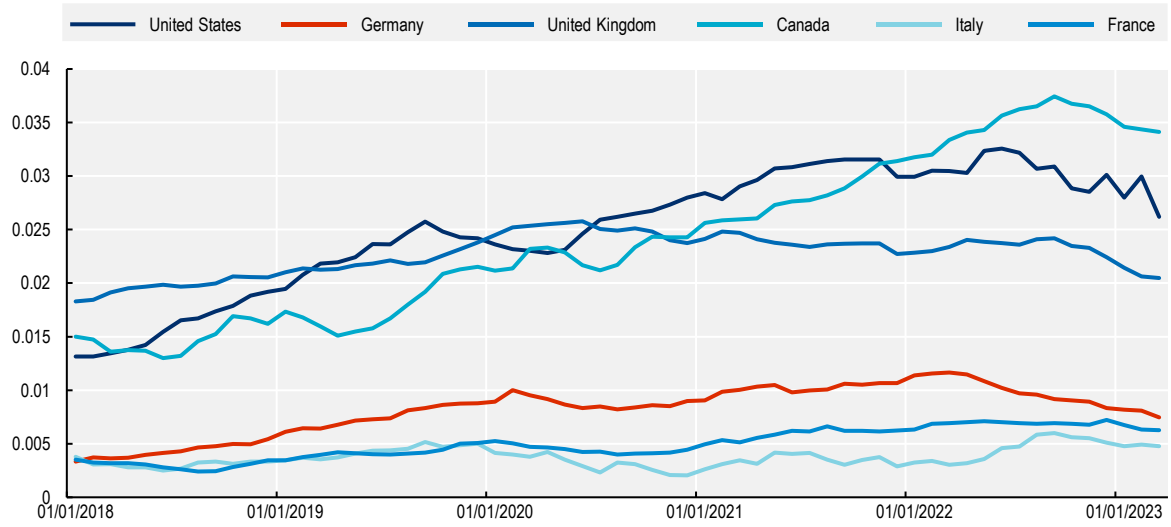
Notes: This chart displays the net migration flows of LinkedIn members with AI skills from 2019 to 2022. The height of the dark bars indicates the magnitude of a country's AI talent gains/losses, respectively. Average from 2019 to 2022 for a selection of countries with 100 000 LinkedIn members or more. Migration flows are normalised according to LinkedIn membership in the country of interest.
Source: OECD.AI (2023[4]), *Between-country AI Skills Migration*, https://oecd.ai/en/data?selectedArea=ai-jobs-and-skills&selectedVisualisation=between-country-ai-skills-migration (accessed on 11 October 2023).

Demand for AI skills in Germany has been growing in recent years. AI-related online vacancies in Germany were 0.4% of all job postings in 2022, in an increasing trend and above most EU countries considered in the study, but below the United States (0.8%), Canada (0.54%) and the United Kingdom (0.51%) (Borgonovi et al., 2023[6]) (Figure 5.2). According to data from Adzuna, a search engine for job advertisements, the demand for AI skills within information technology (IT) job postings increased since 2018 and was at 1.5% in 2023 (Figure 2.2). This is above other EU countries such as France and Italy but again below the level of Canada, the United States and the United Kingdom (all above 2%, with Canada

at 3%). Data from the same platform show that IT jobs, particularly those requiring AI skills, in Germany stay vacant online for a longer period than those in other sectors, such as healthcare, engineering, and manufacturing (Figure A A.4). After three months of being posted online, the proportion of IT jobs in Germany that require AI skills is almost 20% higher than at the beginning of the period, signalling a persistent shortage of workers with AI skills to fill the advertised positions in this category (Figure A A.5). Employers also report a shortage of AI skilled professionals as one of the key obstacles to implementing AI solutions (see Chapters 4 and 5).

Figure 2.2. Demand for AI skills in IT job postings has been growing in recent years in Germany

Relative international AI skill demand



Note: The line chart shows the probability that an AI skill appears in an IT-related job posting within the selected countries.
Source: OECD.AI (2023[7]), *Relative International AI Skill Demand*, https://oecd.ai/en/data?selectedArea=ai-jobs-and-skills&selectedVisualisation=relative-international-ai-skill-demand (accessed on 5 November 2023).

Stakeholders pointed out that lengthy and intricate visa application processes have made it challenging for universities and research centres to employ academics from non-EU countries. However, they have also acknowledged that the amended FEG (Box 2.2) is expected to help alleviate this situation.

AI education at universities

Germany offers 50 AI degree programmes, with a balanced supply between Bachelor's and Master's levels. Introducing shorter programmes could be helpful. AI courses are increasingly being offered at German universities across departments. Overall, Germany's AI educational offerings remain less accessible to non-German speakers.

German universities increasingly offer AI-related courses, in and out of computer-science departments

As of December 2022, German universities offered 50 full AI degree programmes,[1] 20 bachelor's and 30 master's degrees. In absolute numbers, compared to six other countries in Europe (Austria, France, Italy, the Netherlands, Switzerland and the United Kingdom), Germany stands out as ranking second in terms of full AI degree programmes offered. However, the offer is relatively lower in per capita terms

(Figure A A.1). This indicator only offers a partial view, though, since it does not consider the number of students enrolled in the respective programmes, for which information is not available. The supply of AI courses in Germany is more balanced between Bachelor's and Master's courses than in neighbouring countries that tend to offer AI degrees as certificate courses (non-German-speaking part of Switzerland) or as one-year master's programmes (France) (Figure A A.2). Offering shorter AI courses, including AI bootcamps or intensive courses, alongside full AI degree programmes would provide a flexible and efficient way for individuals to acquire essential AI skills in a shorter timeframe and enable professionals from diverse backgrounds to integrate AI into their expertise more quickly. This would help address growing demand for AI specialists and ensure that professionals integrate AI advancements across sectors.

Box 2.2. The Skilled Immigration Act (*Fachkräfteeinwanderungsgesetz*)

The amended FEG, with its initial part taking effect in November 2023 and subsequent parts in March and June 2024, broadens opportunities for foreign skilled workers with higher education qualifications to work in Germany, lowers salary thresholds to live in Germany, and expands eligibility. For example, immigrants with a qualified vocational qualification or a university degree are no longer restricted to applying for jobs only related to their training and qualification. The amended act also broadens the list of recognised professions and facilitates family reunification for family members of EU Blue Card holders who have already lived with their family in another EU member state. IT specialists can also qualify for an EU Blue Card without a formal qualification but based only on relevant professional experience.

Since March 2024, participants in initiatives to improve skills and qualifications (*Qualifizierungsmaßnahmen*) can enter Germany and stay up to three years. *Qualifizierungsmaßnahmen* are measures targeted at immigrants who strive to attain complete equivalence between their foreign professional qualifications and those recognised in Germany. Furthermore, a new recognition partnership of skilled employment (*Anerkennungspartnerschaft*) allows individuals from non-EU member states to enter Germany, complete the entire recognition process, and engage in training, with an initial one-year residence permit extendable to three years. In June 2024, the act also introduced an opportunity card for job searching. Those with full professional recognition receive this card without additional requirements, while others must demonstrate recognised professional or higher education qualifications. Although not AI specific, this is expected have significant impact on Germany's ability to attract and retain talent in the AI ecosystem, thanks to foreign credential recognition and labour market mobility.

Source: Anerkennung in Deutschland (2023[8]), "Einwanderung wird erleichtert", https://www.anerkennung-in-deutschland.de/html/de/aktuelles-neues-fachkraefteeinwanderungsgesetz.php (accessed on 11 October 2023).

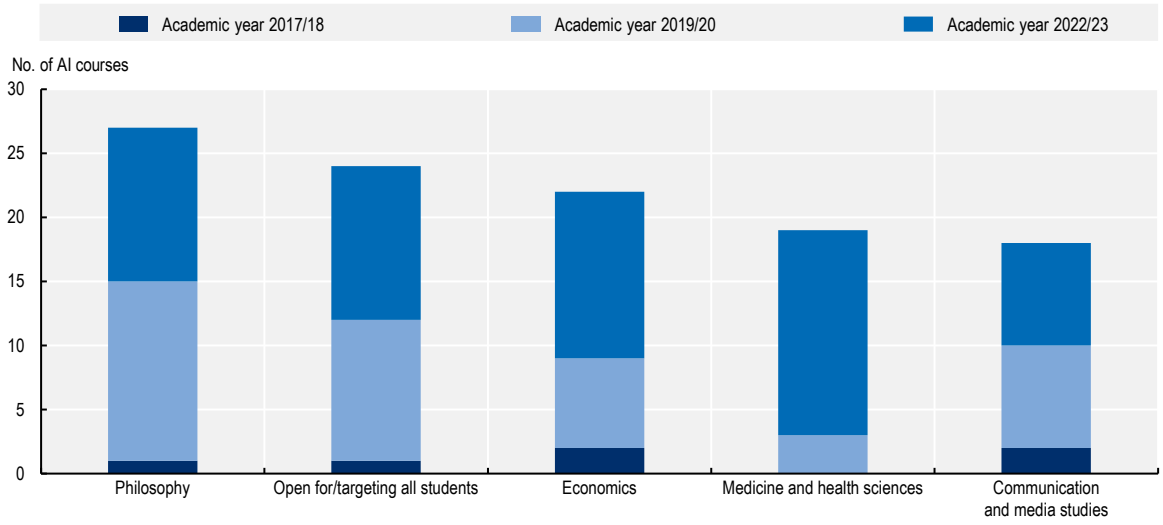
Germany is already focusing on interdisciplinarity in AI by including AI courses in curricula across disciplines. The number of AI courses outside of computer science departments has seen a fivefold increase between 2017 and 2022, with 109 such courses taught across departments (Figure A A.2). AI courses are increasingly offered outside computer science departments at German universities, in particular in philosophy, economics, medicine and health sciences, communication and media studies, and law. Many courses are also open to all students, regardless of their department affiliation (Figure 2.3). AI courses in these disciplines and in education have substantially increased over the years. While there was a drop in the number of AI courses in political sciences in 2022-23 (Figure A A.3), this may be due to coverage of AI topics embedded in broader technology governance courses or degree programmes (e.g. Technical University of Munich's Master's in "Politics and Technology" or Hertie School's Master's in

"Data Science for Public Policy"). Furthermore, courses in non-computer science departments are open to all students, increasing exposure to the topic.

More than two-thirds of Germany's full AI degree programmes are in German, which makes the country an attractive destination for prospective students from German-speaking countries, but possibly less attractive to non-German speaking students, thus reducing the ability to attract internationally mobile students and reach a larger pool of potential AI talent. Smaller EU countries, such as Cyprus, the Netherlands and Scandinavian countries, offer more AI courses in English per capita than Germany (OECD.AI, 2023[9]).

The national AI strategy places a substantial emphasis on ethical/human-centred AI. However, completing an ethical/human-centred AI course or module is compulsory in less than one-third of the degree programmes offered. Human-centred AI courses or modules could be required in AI educational programmes to ensure the development of trustworthy and responsible AI.

Figure 2.3. AI courses at German universities are mainly offered in five departments outside computer science



Notes: This graph shows the number of AI courses offered outside computer science departments at German universities for three different time periods. It includes data from the general course registries of the 50 largest German universities in terms of students registered on AI courses for three different time periods: academic years 2017/18, 2019/20 and 2022/23. For academic years 2017/18 and 2019/20, no data were available for LMU München, Friedrich-Alexander Universität Erlangen-Nürnberg, Universität Leipzig, Justus-Liebig-Universität Gießen, Rheinland-Pfälzische Technische Universität Kaiserslautern-Landau, Universität Augsburg, Hochschule für angewandte Wissenschaften München, Technische Hochschule Mittelhessen – THM, and Hochschule Darmstadt. No data were available for academic year 2019/20 for Heinrich-Heine-Universität Düsseldorf. No data were available for winter term 2017/18 for Julius-Maximilians-Universität Würzburg, and Karlsruher Institut für Technologie. When combining the data for all three periods, the courses offered at these 13 universities were removed from each period.
Source: Based on HRK (2023[10]), *Statistik - Hochschulen in Zahlen - 2022*, https://www.hrk.de/themen/hochschulsystem/statistik/ (accessed on 11 October 2023).

Recommendations

Continue efforts to facilitate visa processes and immigration for AI-professionals through the amended FEG

The amendment of the FEG is a positive step for Germany's competitiveness in the race for skilled workers, especially AI talent. It is essential to communicate these intentions abroad, actively recruit skilled workers, and support interested individuals accordingly. Germany already has numerous initiatives to this end. For example, "Make it in Germany" was created as a central information portal for interested foreign professionals (German Federal Government, 2023[11]). In addition, the "ProRecognition" project provides onsite advice on recognition for skilled workers in German Chambers of Commerce Abroad and German business delegations in ten countries (Algeria, Bosnia and Herzegovina/Western Balkans, Brazil, Colombia, Egypt, India, Iran, Italy, Poland and Viet Nam) (Anerkennung in Deutschland, 2023[12]). Germany could expand this successful programme to other countries, in particular those with a high AI talent concentration, such as Bulgaria, Chile, Mexico or Norway (OECD.AI, 2023[13]).

The amended FEG is expected to simplify and accelerate visa application processes, rendering Germany more attractive to AI professionals. In practice, however, the low level of digitisation of the responsible authorities often hinders the rapid processing of applications. One reason is the postal dispatch of paper files (especially documents proving non-academic professional qualifications) between immigration authorities (*Ausländerbehörden*, ABHen) in Germany and applications and authorisations between *ABHen* and German foreign diplomatic representations *Auslandsvertretungen*, AVen). According to a study by the Federal Office for Migration and Refugees (*Bundesamt für Migration und Flüchtlinge*, BAMF), few authorities have digitised their documents and transferred them to e-files (BAMF, 2023[14]). It is imperative that Germany strengthen the digitisation of these to ensure a streamlined process that reinforces Germany as a jurisdiction of choice for global AI talent.

Increase course offerings in English and in ethical/human-centred AI across degree programmes and disciplines

First, Germany should increase the number of full AI degree programmes offered in English to boost their attractiveness for internationally mobile students. As discussed in the first recommendation of this chapter, facilitating visa processes and immigration through the amended FEG is crucial for attracting foreign AI professionals. At the same time, Germany can take a more proactive approach by seeking to attract pre-trained international talent and nurturing foreign students interested in pursuing AI degrees within the country. To achieve this, enhancing the availability of AI education in English would be crucial, allowing Germany to access a more extensive pool of international AI talent.

Second, expanding the availability of ethical and human-centric AI courses and full-degree programmes can advance Germany's strategic commitment to prioritising human-centric AI. Today's students are tomorrow's AI developers. It is, therefore, essential that they do not regard AI ethics simply as a "nice to have" but actively incorporate fundamental AI principles such as those reflected in the 2019 OECD Recommendation on AI into their AI models and AI-enabled products and services, including fairness, transparency, safety, and accountability, among others. The foundation for this could be laid by introducing a mandatory, ethical/human-centred AI course in every AI degree programme.

Third, the offer of full AI master's degree programmes could be increased to allow people specialised in different fields to further specialise in AI and to complement higher education in other domains (e.g. biology or law) with AI-specific skills. Combining domain expertise with understanding and management of AI will be increasingly crucial for adopting AI across sectors.

Fourth, introducing AI bootcamps or intensive course in AI would facilitate upskilling and possible career transitions of individuals holding master's degrees in other domains. These programmes could also facilitate developing interdisciplinary skills by bridging the gap between domain-specific expertise and AI.

References

Anerkennung in Deutschland (2023), "Einwanderung wird erleichtert", https://www.anerkennung-in-deutschland.de/html/de/aktuelles-neues-fachkraefteeinwanderungsgesetz.php (accessed on 11 October 2023). [8]

Anerkennung in Deutschland (2023), *ProRecognition*, https://www.anerkennung-in-deutschland.de/html/de/pro/prorecognition.php (accessed on 8 December 2023). [12]

BAMF (2023), *Entwicklung der Fachkräftemigration und Auswirkungen des beschleunigten Fachkräfteverfahrens*, Bundesamt für Migration und Flüchtlinge, https://www.bamf.de/SharedDocs/Anlagen/DE/Forschung/Forschungsberichte/fb45-feg.html (accessed on 8 December 2023). [14]

BMBF (2022), "Stark-Watzinger: 100. zusätzliche KI-Professur wurde besetzt", Bundesministerium für Bildung und Forschung, https://www.bmbf.de/bmbf/shareddocs/pressemitteilungen/de/2022/05/030522-KI-Professoren.html (accessed on 11 October 2023). [2]

Borgonovi, F. et al. (2023), "Emerging trends in AI skill demand across 14 OECD countries", *OECD Artificial Intelligence Papers*, No. 2, OECD Publishing, Paris, https://doi.org/10.1787/7c691b9a-en. [6]

German Federal Government (2023), *Make It In Germany*, https://www.make-it-in-germany.com/en/ (accessed on 8 December 2023). [11]

German Federal Government (2020), *Strategie Künstliche Intelligenz der Bundesregierung - Fortschreibung 2020*, https://www.ki-strategie-deutschland.de/files/downloads/201201_Fortschreibung_KI-Strategie.pdf (accessed on 11 October 2023). [1]

HRK (2023), *Statistik - Hochschulen in Zahlen - 2022 [Statistics - Universities in Numbers - 2022]*, Hochschulrektorenkonferenz, https://www.hrk.de/themen/hochschulsystem/statistik/ (accessed on 11 October 2023). [10]

Humboldt Foundation (2023), *Sieben Empfehlungen zur Künstlichen Intelligenz (KI) an die Deutsche Bundesregierung*, https://www.humboldt-foundation.de/fileadmin/Bewerben/Programme/Alexander-von-Humboldt-Professur/Positionspapier_zur_Kuenstlichen_Intelligenz_Recommendations_on_AI.pdf (accessed on 20 October 2023). [3]

OECD.AI (2023), *AI Courses in English by Country*, OECD, Paris, https://oecd.ai/en/data?selectedArea=ai-education&selectedVisualization=ai-courses-by-country-in-time (accessed on 6 December 2023). [9]

OECD.AI (2023), *AI Talent Concentration by Country*, OECD, Paris, https://oecd.ai/en/data?selectedArea=ai-jobs-and-skills&selectedVisualization=ai-talent-concentration-by-country (accessed on 8 December 2023). [13]

OECD.AI (2023), *Between-country AI Skills Migration*, OECD, Paris, https://oecd.ai/en/data?selectedArea=ai-jobs-and-skills&selectedVisualization=between-country-ai-skills-migration (accessed on 11 October 2023). [4]

OECD.AI (2023), *Relative International AI Skill Demand*, OECD, Paris, https://oecd.ai/en/data?selectedArea=ai-jobs-and-skills&selectedVisualization=relative-international-ai-skill-demand (accessed on 5 November 2023). [7]

Sequoia (2023), *Atlas - Sequoia's Guide to Europe's Technical Talent*, https://www.sequoiacap.com/wp-content/uploads/sites/6/2023/06/Sequoia-Atlas-Final.pdf (accessed on 11 October 2023). [5]

Note

[1] "Full AI degree programmes" are defined as degree programmes containing in their title "Artificial Intelligence", "AI", "Machine Learning", or "ML" in English or in their national language.

3 Research

Research serves as the foundation for advancements in artificial intelligence (AI). This chapter explores Germany's position in the global landscape of AI research. With its national AI strategy emphasising the importance of reinforcing and expanding its research excellence in AI, Germany aims to remain at pace with rapid international progress. Germany ranks highly worldwide, excelling in robotics, automation, and in AI research in energy and manufacturing. German research institutions like the Max Planck Society and Siemens rank among the top globally, and a network of six AI excellence centres aim to enhance Germany's standing in AI technologies. While funding for AI research is available from various sources, mechanisms could be made more agile to align with the rapidly evolving technology landscape. The German AI research community is characterised by a strong gender disparity, underscoring the need for Germany to strengthen efforts to increase women’s representation in AI.

Research underpins progress in AI. Both the 2018 German national AI strategy and its 2020 update emphasise the need for Germany to reinforce and expand its research excellence in AI to keep up with rapid international developments (German Federal Government, 2020[1]). Accordingly, the national AI strategy foresees several measures in this regard.

Box 3.1. Research: Findings and recommendations

Findings

- Germany is well-positioned in research internationally, ranking fifth worldwide in number and quality of publications. However, countries such as India have quickly climbed the ranking in recent years, albeit not in terms of quality.
- Public and private German institutions both rank in top positions for the quality of their AI research (the Max Planck Society and Siemens).
- German institutions participate in many European Union (EU)-funded AI projects. However, German institutions collaborate more with institutions from the People's Republic of China (hereafter "China"), the United Kingdom (UK) and the United States (US) than European ones.
- In AI research topics, Germany ranks third in robotics and automation, fourth in computer vision and natural language processing, and fifth in artificial neural networks worldwide.
- Germany's funding system is uniquely positioned, as applicants can apply for joint funding programmes, EU funding, and federal and *Länder* funding. However, this diversity of funding often causes uncertainty in practice, and funding requirements are reported to be bureaucratic and cumbersome for applicants.
- Even though the gender gap in AI research has decreased in recent years, it is still larger than in peer countries. Several federal ministries and universities have launched initiatives to counteract this trend.

Recommendations

- Implement agile funding mechanisms that can adapt to the rapidly changing landscape of AI research.
- Double down on efforts to increase the involvement of women and under-represented communities in AI research and development (R&D) and collaborate between ministries to address structural issues underlying unequal opportunities for the participation of women in the labour market.

AI publications

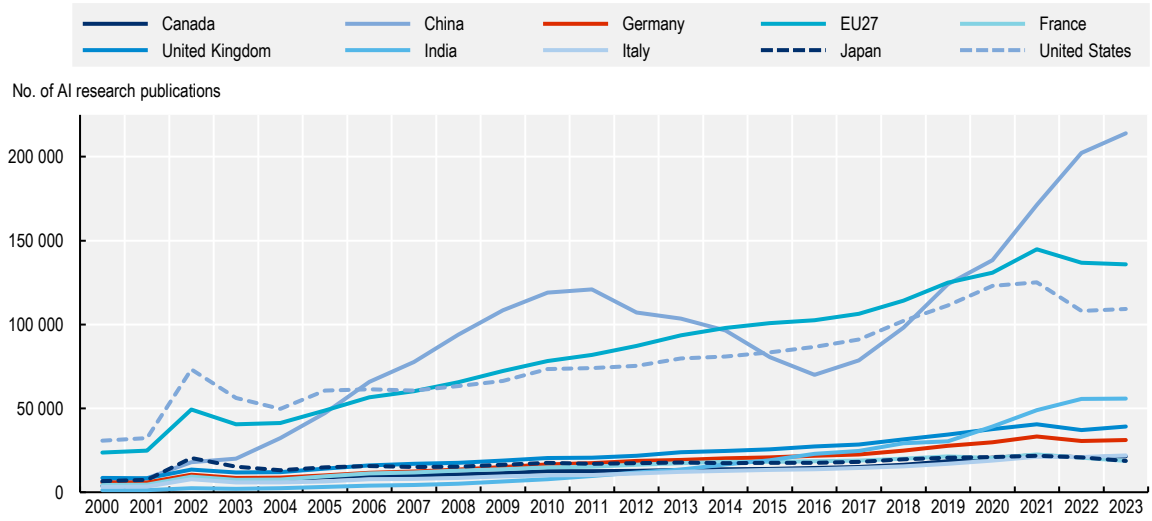
German institutions reported a notable increase in AI research publications since 2018, ranking fifth globally in number and fourth in quality, with strengths in computer vision and robotics.

In Germany's national AI ecosystem, its solid research base is a strength

German institutions published about 31 105 AI publications in 2023, representing a 26% increase since 2018. Germany ranks fifth internationally (Figure 3.1) in number of AI publications, following the US, China, the UK and India. It is fourth when considering publication quality, as measured by the number of times a publication has been cited. Public and private German institutions rank in top positions for the quality of

their AI research: the Max Planck Society ranks second worldwide alongside the University of California Berkeley, while Siemens ranks seventh among leading global companies producing AI research (OECD.AI, 2023[2]).

Figure 3.1. Germany ranks fifth worldwide in number of AI publications



Note: More than 600 000 AI scholarly publications were extracted from Elsevier's Scopus archives using core AI keywords such as back-propagation neural network, genetics-based machine learning, Cohen-Grossberg neural networks, back-propagation algorithm, and neural networks learning. Chapter 1 of Elsevier's "Artificial Intelligence: How knowledge is created, transferred, and used" report provides more details on the methodology used to identify AI publications.
Source: OECD.AI (2023[3]),*AI Research Publications Time Series by Country*, https://oecd.ai/en/data?selectedArea=ai-research&selectedVisualisation=ai-publications-time-series-by-country (accessed on 12 October 2023).

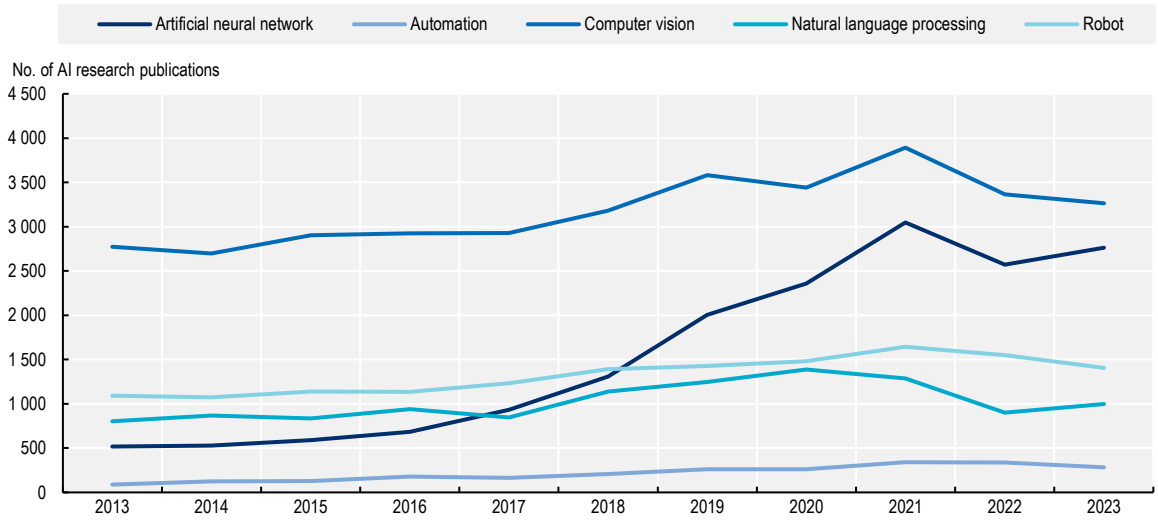
In line with current research trends in other countries, German institutions publish the most on computer vision, a field of AI enabling computers to interpret and understand the visual world from images, videos, and other inputs (Figure 3.2). Computer vision applications can be used in many domains, including automotive, medicine, and manufacturing (e.g. quality anomaly detection). In this field, the country ranks fourth worldwide for the quality of publications (calculated in terms of citations).[1] Germany also has a competitive advantage in robotics and automation, ranking third worldwide in these fields of research (calculated in terms of citations). Germany also ranks fourth in natural language processing. Since 2016, AI publications in Artificial Neural Networks, the machine learning sub-domain which has enabled the rapid advancements of AI, including in generative AI, have dramatically increased, and Germany currently ranks fifth worldwide in this domain for the quality of its AI publications (OECD.AI, 2023[4]).

There are two more areas of AI specialisation where Germany and Europe are leading research. In energy, where they explore AI uses to improve the efficiency and reliability of generating and distributing energy. They also have an edge in manufacturing research, to optimise and automate production, inventory, and predictive maintenance (OECD.AI, 2023[5]). It is crucial for Germany to remain competitive in the future AI-heavy transportation industry, and in manufacturing, for example by further leveraging the use of AI in robotics.

While Germany compares well in AI research worldwide, the size of the leading global competitors – China, India and the US, which is growing rapidly – makes it essential for Germany to leverage co-operation with EU27 countries. Effectively, Germany is the country with the highest participation in AI-related projects funded by the EU research programmes, both in number of projects and in terms of funding. In 2023, German institutions were involved in over 290 projects, for a total funding of about EUR 310 million (OECD

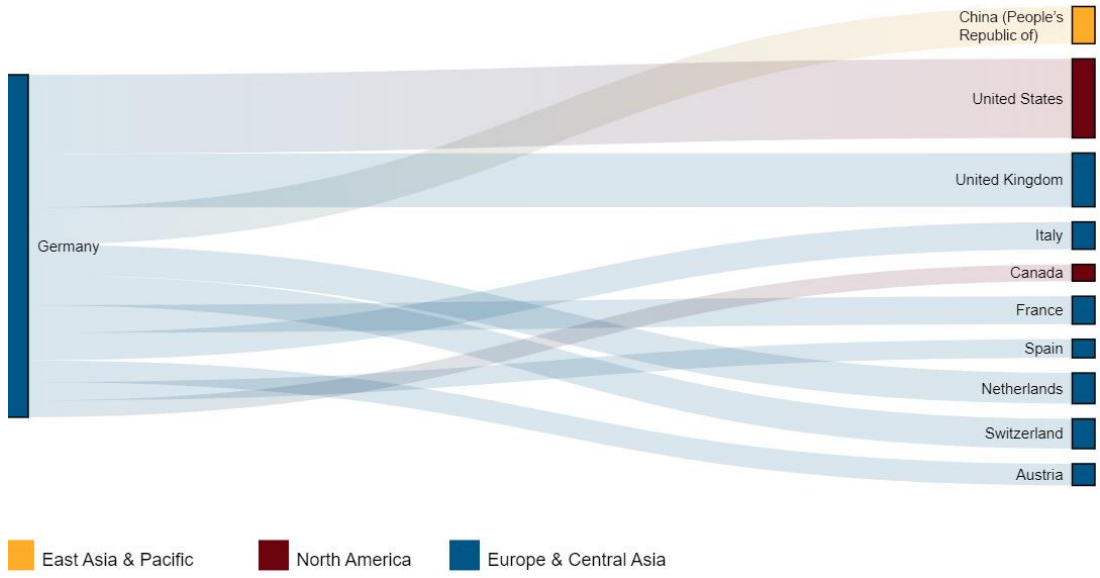
calculation based on Community Research and Development Information Service data). But Germany collaborates more with the US and the UK than with individual EU countries (Figure 3.3).

Figure 3.2. German institutions publish in all key AI topics



Source: OECD.AI (2023[4]), *Trends in AI Application Areas by Country*, https://oecd.ai/en/data?selectedArea=ai-research&selectedVisualisation=trends-in-ai-application-areas-by-country (accessed on 12 October 2023).

Figure 3.3. German institutions mainly collaborate with partners in the United States and the United Kingdom



Source: OECD.AI (2023[6]), *Domestic and International Collaboration in AI Research Publications*, https://oecd.ai/en/data?selectedArea=ai-research&selectedVisualisation=domestic-and-international-collaboration-in-ai-publications (accessed on 5 November 2023).

To support research collaboration nationally, the Federal Ministry of Education and Research (*Bundesministerium für Bildung und Forschung*, BMBF) helped to create the Network of German Centres of Excellence for AI Research (*Netzwerk der Deutschen Kompetenzzentren für Forschung zu Künstlicher Intelligenz*), six leading AI research institutions funded by federal and state budgets: i) Berlin Institute for the Foundations of Learning and Data (BIFOLD); ii) German Research Centre for Artificial Intelligence (*Deutsches Forschungszentrum für Künstliche Intelligenz*, DFKI); iii) Munich Centre for Machine Learning (MCML); iv) Lamarr Institute for Machine Learning and Artificial Intelligence North Rhine-Westphalia (LAMARR); v) Centre for Scalable Data Analytics and Artificial Intelligence Dresden/Leipzig (ScaDS.AI); and vi) Tübingen AI Centre (TUE.AI). While the objective is for these institutions work together to strengthen Germany as a top location for AI technologies and increase German AI research's national and international visibility (DFKI, 2023[7]), stakeholders say it has yet to act as a network. While the BMBF actively promotes stronger collaboration in the German AI research community, e.g. via the All-Hands-Meeting of the competence centres and the "AI Grid", there could be considerations to introduce incentives to deepen co-operation, for instance through funding for joint projects.

Funding for AI research in Germany comes from different sources. These include European (e.g. Horizon Europe), federal and state programmes, as well as joint programmes between universities and industry. The BMBF funds AI research, development, and application work of 50 ongoing measures that focus on research, skills development, infrastructure development and transfer to application. As part of the BMBF AI Action Plan published in November 2023, these are supplemented by at least 20 further initiatives. Moreover, BMBF's AI budget has increased annually since 2017, most significantly between 2021, 2022, and 2023 (Table 3.1).

On its Federal Funding Advisory Service (*Förderberatung des Bundes*) website (Förderberatung des Bundes, 2024[8]), the federal government provides an overview of funding opportunities for applicants by consolidating access to initiatives on a centralised platform, including personalised advice. However, many interviewed experts were unaware of its availability and expressed a need for a specific centralised database. Promotion efforts are needed to reach a broader audience of potential users. Given the pace of AI development, researchers need to receive financial support more rapidly and with minimal bureaucracy. The research community (Humboldt Foundation, 2023[9]) suggests relying on the EU's evaluation process for projects, which can be considered a "seal of excellence". Proposals for projects evaluated above threshold by the EU panels but not funded for budgetary reasons could be considered for financial support from national sources, provided German institutions implement them.

Table 3.1. Funding for AI research in Germany

Year	2017	2018	2019	2020	2021	2022	2023 (planned)	2024 (planned)
EUR million	17.4	20.5	41.9	85.7	120.2	280.4	427.2	483.3

Source: Based on BMBF (2023[10]), *BMBF-Aktionsplan "Künstliche Intelligenz"*, https://www.bmbf.de/bmbf/de/forschung/digitale-wirtschaft-und-gesellschaft/kuenstliche-intelligenz/ki-aktionsplan.html (accessed on 30 November 2023).

Gender representation in AI research

Despite some progress, women remain underrepresented in German AI research and AI leadership positions. Enhancing diversity in AI development through increased female participation can lead to fairer and more ethical outcomes of AI systems.

Women are under-represented in AI research

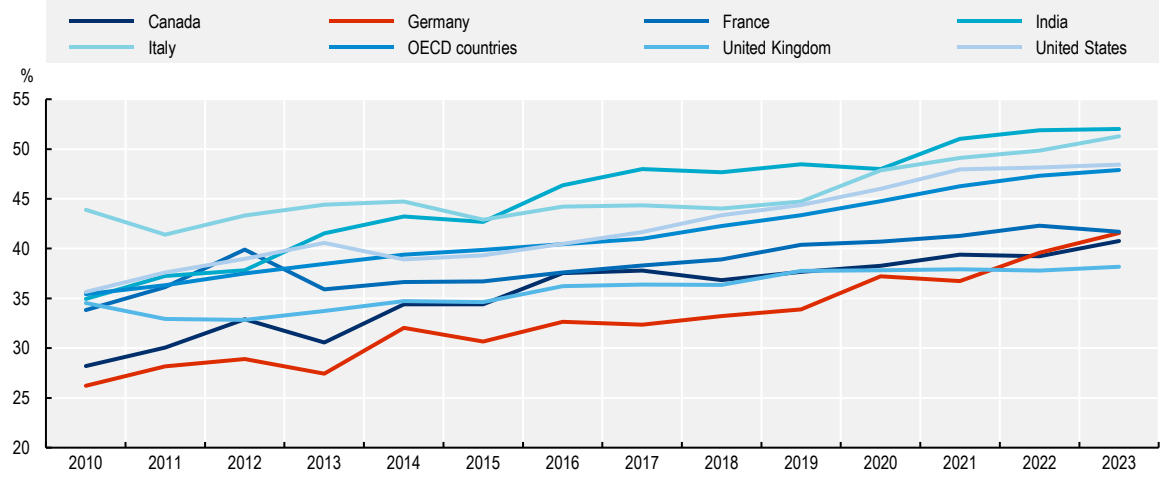
The increasing deployment of AI systems has raised the importance of ensuring fairness, lack of bias and non-discrimination of AI systems. An overrepresentation of male AI developers can lead to gender bias in AI through biased training data, subjective design choices overlooking considerations important to underrepresented groups, the introduction of unintentional biases and stereotypes, and a lack of diverse perspectives in addressing user needs. This imbalance may result in AI systems that perpetuate societal stereotypes and inadequately cater to the preferences and requirements of diverse user groups, including women (Leavy, 2018[11]; Nadeem, Abedin and Marjanovic, 2020[12]).

Increasing women and minorities representation in the design of AI systems can enhance AI systems by providing diverse perspectives and experiences during development, leading to more comprehensive and inclusive outcomes. Female developers, who might be more attuned to biases affecting women, play a crucial role in identifying and effectively addressing these biases. Diverse teams contribute to balanced decision making, fostering fair, ethical, and user-aligned AI systems. This inclusivity results in AI applications that better understand and cater to the diverse needs of users, ultimately improving user experience and satisfaction across various demographic groups (Gallego et al., 2019[13]).

Gender and other divides in the AI research ecosystem limit inclusion of women in AI development and reduce the number of skilled AI workers available in the country. In Germany, the gender gap in AI research has been narrowing in recent years: in 2023, 41% of AI publications had at least one female author, compared to 33% in 2018 (Figure 3.4). However, only 7% of publications were authored by women exclusively in 2023 (slightly up from 5% in 2018), while 58% were written by men only (significantly down from 67% in 2018). The gender gap in AI research remains broader than in peer countries (such as France and the US). The gap is also present in leadership positions: as of January 2023, none of the six German Centres of Excellence for AI Research is led by a woman, and only 14% of the researchers or principal investigators in these centres were women (Figure 3.5).

Figure 3.4. The gender gap in AI research is broader in Germany than in peer countries

Share of AI publications authored by at least one woman

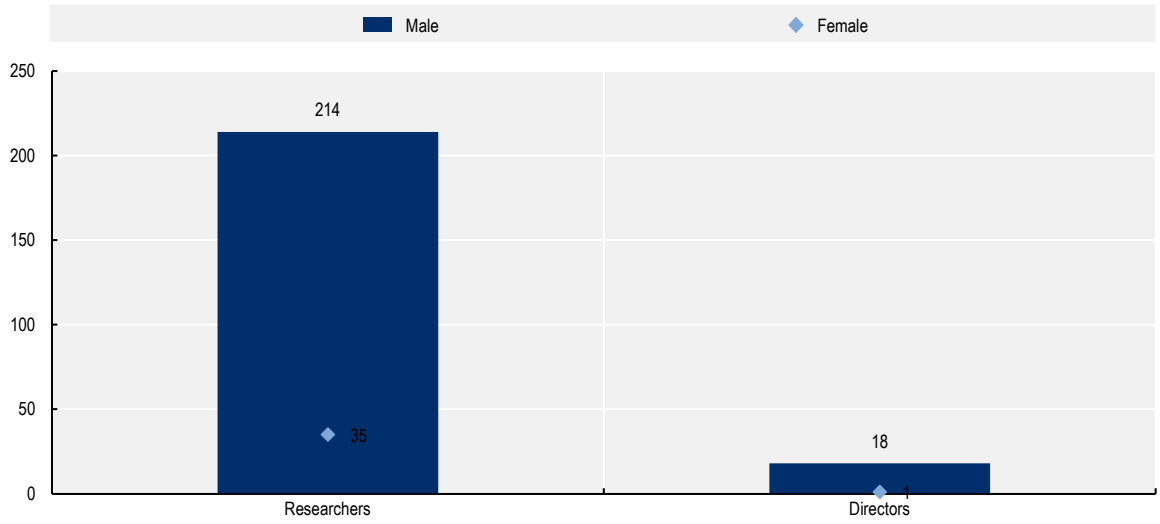


Notes: This chart shows the percentage of AI publications in Scopus with at least one female author by country and over time. For this experimental indicator, Elsevier assigned a gender value only to those authors in the Scopus dataset for whom the algorithm used returned a gender probability of 85% or higher. Due to a lag in reporting, figures for the latest quarter may appear slightly lower than they actually are. This is automatically corrected in subsequent updates.
Source: OECD.AI (2023[14]), *Share of Women in AI Scientific Publications by Country,* https://oecd.ai/en/data?selectedArea=ai-research&selectedVisualisation=share-of-women-in-scientific-publications-by-country-2 (accessed on 5 November 2023).

Differences in men's and women's careers start early, when making choices about education (OECD, 2017[15]). For example, on average only 0.5% of 15-year-old girls across OECD countries aim to become information and communication technology (ICT) professionals, compared to 5% of boys. This difference in career expectations is carried into tertiary education. Across OECD countries, young men dominate ICT studies, constituting 79% of new entrants on average. In 2021, the proportion of women among first-year students in the science, technology, engineering and mathematics (STEM) field and in Germany reached 34.5%. This is a record high but still shows women opt for STEM studies less frequently than men, and among different STEM fields there are significant variations. For instance, in computer science, the percentage of female first-year students in 2021 was only 21.8% (OECD, 2023[16]).

Figure 3.5. Representation of women in the German AI Excellence Centres is low

Number of women researchers/principal investigators and directors of German Centres of Excellence for AI Research, 2022



Source: Analysis based on information from the six German Centres of Excellence for AI Research's websites (https://www.dfki.de/web; https://www.bifold.berlin/; https://mcml.ai/; https://lamarr-institute.org/; https://scads.ai/; https://tuebingen.ai/).

Federal programmes in place to put more women in tech

Recently, the German Federal Government launched several initiatives to close the gender gap in AI research and in technology. They include leveraging interactions with young women to assist them in making career choices, targeted support at universities, and programmes funding women-led AI research teams.

"MissionMINT" aims to put more women in STEM (MINT) by supporting and inspiring young women transitioning from school to university and from university to the job market. Through joint projects, role models, network activities and workshops, the programme exposes women to opportunities in the STEM sector to break down prejudices and create opportunities to experiment (BMBF, 2023[17]). Influencing career choices through representatives from the AI field is certainly one of the key policy levers to increase the number of women in AI. While the programme goes in the right direction, it should be expanded to include a focus area on AI.

The number of women in AI and science declines as careers advance. Barriers, such as cultural norms (i.e. gender-assigned roles), implicit biases, and the unique impact of parenthood on women's careers, are more likely to reduce participation in science at higher levels than a lack of talented women at the early career stage (Statistisches Bundesamt, 2023[18]; EC, 2021[19]; Stadler et al., 2023[20]).

Since 2020, the BMBF has supported female-led junior research groups in AI through its funding measure "Female AI junior scientists" (*KI-Nachwuchswissenschaftlerinnen*). The programme aims to increase the proportion of qualified women in leadership positions in German AI research, and to strengthen the influence of female scientists sustainably. While the focus is placed on AI research on novel and innovative topics, family-work balance conditions at the applicants' respective universities are also considered as an allocation criterion. In 2023, the BMBF published a new call for junior female AI scientists.

The Federal Ministry for Family Affairs, Senior Citizens, Women and Youth's (*Bundesministerium für Familie, Senioren, Frauen und Jugend*, BMFSFJ) "Third Equality Report" focused on digital gender equality (BMFSFJ, 2021[21]). The report highlighted potential for gender-based discrimination in AI, such as biased human resources tools, and provided recommendations for ways the federal government can address these issues. Examples include promoting gender-sensitive and inclusive technology development and risk assessments of algorithmic human resource systems.

German computer science departments have targeted support for women. Nearly all of the 20 largest German universities have networks, coding initiatives, mentoring programmes, project funding or equal opportunity councils for women in computer science (*Informatik*). Most of these measures are not AI-specific; only two universities have targeted programmes for women in AI.

Beyond these programmes, it is essential to acknowledge the more extensive, systemic issues affecting the number of women in AI R&D, STEM, and the workplace in general. Existing income taxation rules for couples reduce labour supply incentives, particularly for women (OECD, 2023[22]). Cultural factors still place childcare responsibilities in predominantly on women. In places where external childcare facilities are limited, women are likely to be more affected than men, and to be required to make corresponding adjustments to their employment. For instance, in Tübingen, where the CyberValley is located, the operating hours of kindergartens have recently been reduced (Süddeutsche Zeitung, 2023[23]). This indicates the need to look at broader issues when devising policies related to AI, such as the distribution of domestic labour and care responsibilities between men and women.

In the future, Germany should double down on efforts to increase women in AI through larger programmes that focus on AI. Germany should continue encouraging education initiatives targeted at young women to raise awareness about roles and paths in the AI field, recognising that a degree in computer science is not a prerequisite. Increasing the visibility and showcasing female leaders in AI would contribute to overcoming societal stereotypes, expose them to career options and encourage girls to pursue AI careers. Early engagement through extracurricular AI programmes such as bootcamps or practical projects can foster interest, confidence, and competence. To support women who chose careers in AI, it is crucial to develop mentorship programmes and ensure equal workplace opportunities, including through better work-life balance support.

Recommendations

Implement agile funding mechanisms that can adapt to the rapidly changing landscape of AI research

Funding programmes for AI research are highly decentralised and often rely on a lengthy process to select projects for awarding grants. Given the pace of AI developments, researchers need to receive financial support fast and with minimal bureaucracy. German programmes could rely on the EU's project evaluation

process, which can be considered a “seal of excellence”. Projects rated above threshold but not funded for budgetary reasons could be considered for financial support from national sources, provided they are implemented by German institutions.

Double down on programmes aimed at involving women in AI R&D, and collaborate between ministries to address structural issues of unequal opportunities for women’s participation in the labour market

Increasing the number of women in AI development is necessary to reduce the risks of bias and discrimination in AI algorithms. To increase the AI-skilled labour force there needs to be more women. While the gender gap in AI research in Germany has narrowed in recent years, women are still under-represented in the AI ecosystem, including in leadership positions. Current efforts to increase women’s participation in AI go in the right direction and should continue and be expanded. At the same time, inter-ministerial efforts should address broader structural factors that reduce women’s participation in the labour market such as the availability of childcare facilities.

References

BMBF (2023), *BMBF-Aktionsplan “Künstliche Intelligenz”*, Bundesministerium für Bildung und Forschung, https://www.bmbf.de/bmbf/de/forschung/digitale-wirtschaft-und-gesellschaft/kuenstliche-intelligenz/ki-aktionsplan.html (accessed on 30 November 2023). [10]

BMBF (2023), “MissionMINT – Wir stärken die Innovationskraft von Frauen im akademischen MINT-Bereich”, Bundesministerium für Bildung und Forschung, https://www.bmbf.de/bmbf/de/forschung/gleichstellung-und-vielfalt-im-wissenschaftssystem/mint-pakt/mint-pakt_node.html#:~:text=F%C3%B6rderrichtlinie%20%E2%80%9EMissionMINT%20%E2%80%93%20Frauen%20gestalten%20Zukunft%E2%80%9C&text=In%20den%20sensiblen%20Pha (accessed on 11 October 2023). [17]

BMFSFJ (2021), *Dritter Gleichstellungsbericht - Digitalisierung geschlechtergerecht gestalten*, Bundesministerium für Familie, Senioren, Frauen und Jugend, https://www.bmfsfj.de/bmfsfj/service/publikationen/dritter-gleichstellungsbericht-184546 (accessed on 11 October 2023). [21]

DFKI (2023), *Netzwerk der Deutschen Kompetenzzentren für Forschung zu Künstlicher Intelligenz*, Deutsches Forschungszentrum für Künstliche Intelligenz GmbH, https://www.dfki.de/web/qualifizierung-vernetzung/netzwerke-initiativen/ki-kompetenzzentren (accessed on 12 October 2023). [7]

EC (2021), *She Figures 2021: Gender in Research and Innovation - Statistics and Indicators*, Directorate-General for Research and Innovation, European Commission, https://doi.org/10.2777/06090. [19]

Förderberatung des Bundes (2024), *Förderfinder des Bundes*, Federal Funding Advisory Service, https://www.foerderinfo.bund.de/SiteGlobals/Forms/foerderinfo/bekanntmachungen/Bekanntmachungen_Formular.html?cl2Categories_Foerderer=bund (accessed on 29 January 2024). [8]

Gallego, A. et al. (2019), "How AI could help - or hinder - women in the workforce", https://www.bcg.com/publications/2019/artificial-intelligence-ai-help-hinder-women-workforce (accessed on 5 December 2023). [13]

German Federal Government (2020), *Strategie Künstliche Intelligenz der Bundesregierung - Fortschreibung 2020*, https://www.ki-strategie-deutschland.de/files/downloads/201201_Fortschreibung_KI-Strategie.pdf (accessed on 11 October 2023). [1]

Humboldt Foundation (2023), *Sieben Empfehlungen zur Künstlichen Intelligenz (KI) an die Deutsche Bundesregierung*, https://www.humboldt-foundation.de/fileadmin/Bewerben/Programme/Alexander-von-Humboldt-Professur/Positionspapier_zur_Kuenstlichen_Intelligenz_Recommendations_on_AI.pdf (accessed on 2023 October 2023). [9]

Leavy, S. (2018), "Gender bias in artificial intelligence: The need for diversity and gender theory in machine learning", Conference paper, https://www.researchgate.net/profile/Susan-Leavy-4/publication/326048883_Gender_bias_in_artificial_intelligence_the_need_for_diversity_and_gender_theory_in_machine_learning/links/5bce138aa6fdcc204a001d87/Gender-bias-in-artificial-intelligence-the-need-for. [11]

Nadeem, A., B. Abedin and O. Marjanovic (2020), "Gender bias in AI: A review of contributing factors and mitigating strategies", *ACIS 2020 Proceedings*, https://aisel.aisnet.org/acis2020/27. [12]

OECD (2023), *Education at a Glance 2023: OECD Indicators*, OECD Publishing, Paris, https://doi.org/10.1787/e13bef63-en. [16]

OECD (2023), *OECD Economic Surveys: Germany 2023*, OECD Publishing, Paris, https://doi.org/10.1787/9642a3f5-en. [22]

OECD (2017), *The Pursuit of Gender Equality: An Uphill Battle*, OECD Publishing, Paris, https://doi.org/10.1787/9789264281318-en. [15]

OECD.AI (2023), *AI Research Publication Time Series by Institution*, OECD, Paris, https://oecd.ai/en/data?selectedArea=ai-research&selectedVisualization=ai-publication-time-series-by-institution (accessed on 12 October 2023). [2]

OECD.AI (2023), *AI Research Publications Time Series by Country*, OECD, Paris, https://oecd.ai/en/data?selectedArea=ai-research&selectedVisualization=ai-publications-time-series-by-country (accessed on 11 December 2023). [3]

OECD.AI (2023), *Domestic and International Collaboration in AI Research Publications*, OECD, Paris, https://oecd.ai/en/data?selectedArea=ai-research&selectedVisualization=domestic-and-international-collaboration-in-ai-publications (accessed on 5 November 2023). [6]

OECD.AI (2023), *Share of Women in AI Scientific Publications by Country*, OECD, Paris, https://oecd.ai/en/data?selectedArea=ai-research&selectedVisualisation=share-of-women-in-scientific-publications-by-country-2 (accessed on 5 December 2023). [14]

OECD.AI (2023), *Top Policy Areas in AI Publications by Country*, OECD, Paris, https://oecd.ai/en/data?selectedArea=ai-research&selectedVisualization=top-policy-areas-in-ai-publications-by-country (accessed on 11 December 2023). [5]

OECD.AI (2023), *Trends in AI Application Areas by Country*, OECD, Paris, https://oecd.ai/en/data?selectedArea=ai-research&selectedVisualisation=trends-in-ai-application-areas-by-country (accessed on 12 October 2023). [4]

Stadler, B. et al. (2023), *The "PARENT" Initiative: PArents in REsearch aNd Technology*, https://doi.org/10.34726/4822. [20]

Statistisches Bundesamt (2023), "6,5 % weniger Studienanfängerinnen und -anfänger in MINT-Fächern im Studienjahr 2021", https://www.destatis.de/DE/Presse/Pressemitteilungen/2023/01/PD23_N004_213.html#:~:text=Frauen%20entscheiden%20sich%20nach%20wie,2021%20bereits%2034%2C5%20%25. (accessed on 2023 November 2023). [18]

Süddeutsche Zeitung (2023), "Eltern nach Kürzungen der Kita-Öffnungszeiten besorgt", https://www.sueddeutsche.de/leben/kindergaerten-tuebingen-eltern-nach-kuerzungen-der-kita-oeffnungszeiten-besorgt-dpa.urn-newsml-dpa-com-20090101-230211-99-559092 (accessed on 19 October 2023). [23]

Note

[1] Global rankings are calculated on the basis of cumulative number of citations of AI research publications in the topic of application from 2000 to 2023, based on data from the OECD.AI Policy Observatory (OECD.AI, 2023[4]).

4 AI transfer, applications and computing infrastructure

This chapter discusses the use of artificial intelligence (AI) in the German economy, barriers to further diffusion, and AI compute infrastructure. Germany is advancing AI capabilities by modernising its AI infrastructure, and German firms with a strong foundation in academic research are flourishing. However, AI adoption by German firms has been slow, yet increasing, facing challenges including skills shortages, limited awareness of potential AI use cases, regulatory uncertainties, and lagging digitalisation. Several actions could support AI diffusion in Germany, including building confidence to implement AI solutions through clear regulatory guidance, increasing access to open and industrial datasets, leveraging various channels to increase venture capital (VC) availability, and simplifying procurement procedures. Assessing Germany's current and future AI compute supply and needs, while making current capacity more accessible to AI start-ups and small and medium-sized enterprises (SMEs), would help to inform investment decisions and promote inclusive infrastructure to serve Germany's AI ecosystem.

The effective and widespread utilisation of AI hinges on the seamless transfer, development, and commercialisation from academia to the private sector of research findings and applications with real-world potential. This points out to the critical need to bridge the gap between academic insights and commercial implementations for the benefit of the broader economy. The diffusion of AI in companies is challenged by the complexity of integrating new technologies into existing workflows and adapting organisational structures to leverage its full potential. In its 2018 National AI Strategy and its 2020 update, the German Federal Government is taking targeted measures to strengthen transfer, to maintain the competitiveness of the German and European economies and expand them through widespread application of innovative technologies (German Federal Government, 2020[1]).

Box 4.1. Transfer and applications: Findings and recommendations

Transfer to small and medium-sized enterprises and start-ups

Findings

- While use of AI in Germany proceeded at a relatively moderate pace to date, factors such as rising labour shortages and rapid technological progress (namely generative AI and its potential productivity gains) have triggered increased interest in AI. Recent data suggest that Germany might be at a turning point in AI adoption.
- Wider diffusion of AI in firms is hindered by delayed digitalisation, weak connectivity and low understanding of the benefits AI could bring. Firms do not have the data streams to train, test and implement AI applications. Uncertainty over regulatory compliance for personal data and concerns about trade secrets also prevent firms from investing in AI solutions. Another obstacle is a lack of trained personnel to identify, develop, and maintain AI solutions. Little awareness of successful cases makes it hard for SMEs to estimate their return on investment in AI.
- Germany supports the diffusion of AI in firms through several programmes and a mix of instruments, including grants, collaboration with research institutes, advisory and consulting services, awareness-raising events and training.
- The number of active AI start-ups in Germany has increased significantly over the past 15 years. The large share of AI start-ups originating from universities underscores the strong relationship between AI start-ups and the scientific community. However, transfer units at universities are understaffed, and publications are still the main key performance indicators (KPIs).
- The amount of VC invested in German AI start-ups has increased since 2018 but remains smaller than in the United States (US), the People's Republic of China (hereafter "China"), the United Kingdom (UK), India and Israel. While public support is available at early stages – namely through the EXIST programme – AI start-ups do not have access to financing for subsequent growth stages, also called the "valley of death".

Recommendations

- Improve the visibility of programmes supporting AI application by SMEs.
- Develop regulatory guidance on data protection regulation and on provisions applicable to data identified as trade secrets.
- Help SMEs access quality data by increasing the availability of open government data, supporting firms in improving their data maturity.
- Revise tax incentives, strengthen research and development (R&D) grants and consider additional financial support (e.g. small vouchers to implement generative AI solutions) to support AI uptake in SMEs.

- Improve access to financing for AI start-ups.
- Revise and simplify procurement procedures to ensure that start-ups and established companies have equal access to opportunities.

AI infrastructure

Findings

- Germany holds a leading position in computing infrastructure for research and academia, anchored by the Gauss Centre for Supercomputing's three national centres.
- While it is possible for private-sector partners (start-ups, SMEs, large companies) to use the Gauss Centre's systems alone or as part of research consortia for some projects, the systems are used primarily for pre-commercial research purposes.
- The vision for Gaia-X is to establish a decentralised and interoperable data exchange for business and research partners to share data and access services at scale.
- While the federal government funds relevant AI projects as part of Gaia-X, and the German Gaia-X Hub is active, it has low awareness and few links with the German AI ecosystem. Information on the types of datasets and users related to AI are not tracked, pointing to a gap in KPIs that could help to inform AI policy.
- Many interviewees pointed to a specialised talent gap for operating AI infrastructure efficiently and effectively. Some suggested the need for access to skilled labour in tandem with access to computing time.
- An AI strategy update could include an AI compute plan to address the AI needs and readiness of different actors in Germany such as the private sector, public sector, SMEs, start-ups, researchers and others.

Recommendations

- Assess the current and future AI compute infrastructure landscape to gauge existing capacity and potential gaps in meeting demand from stakeholders.
- Designate a portion of AI compute infrastructure for start-ups and SMEs, with a streamlined application process and fewer administrative barriers.
- Expand support services to include time for compute resources, technical assistance and advice on using AI compute infrastructure effectively and efficiently.
- Develop a dedicated programme offering expertise and training in the effective and efficient use of AI compute infrastructure.
- Engage in activities to increase awareness about Gaia-X in the AI ecosystem.
- Conduct an assessment of Gaia-X datasets that are of particularly high value for AI, and label them accordingly.

AI diffusion in firms

While larger companies are ahead in AI integration, SMEs' interest and usage are cautiously growing, as indicated by recent surveys. This is driven in part by factors like labour shortages and generative AI. Key sectors like information and communication technology (ICT) and knowledge-intensive services show significant AI adoption. Challenges for firms include skill shortages, data protection concerns, low digitalisation, and limited awareness of AI use cases. The German government promotes AI adoption

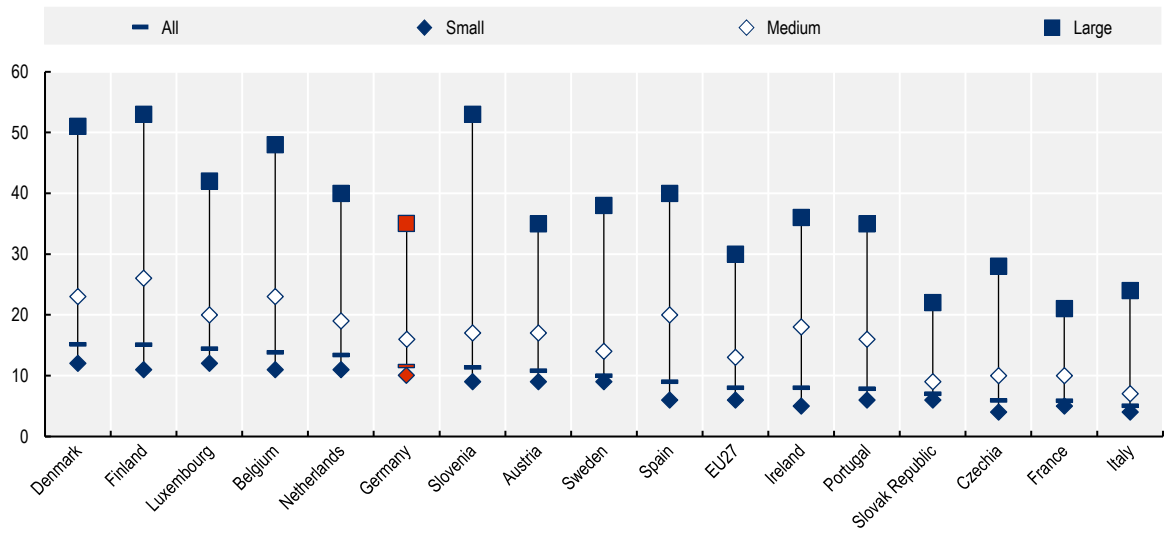
through financial support targeting both research transfer and practical implementation in SMEs, educational initiatives, and platforms for data exchange.

German firms take a cautious approach to adopting AI solutions, with some leading in their sectors

According to the latest comparable data at the European Union (EU) level, 12% of German firms used at least one AI system in 2023 (Figure 4.1). This figure showed an increase compared to the 2021 level (10.6%) and was higher than the EU average (8%). Over one-third of German large companies used AI, with adoption rates at 10% for small and 16% for medium-sized companies. These aligned favourably with the EU average, but they fell below those of EU countries at the forefront in AI adoption, including for large firms. German firms were above the EU average in all sectors, although with notable differences in rates of AI adoption (Figure 4.2).

Figure 4.1. AI uptake by German firms is above EU average, but below EU frontrunners

As a percentage of firms with ten or more employees, 2023

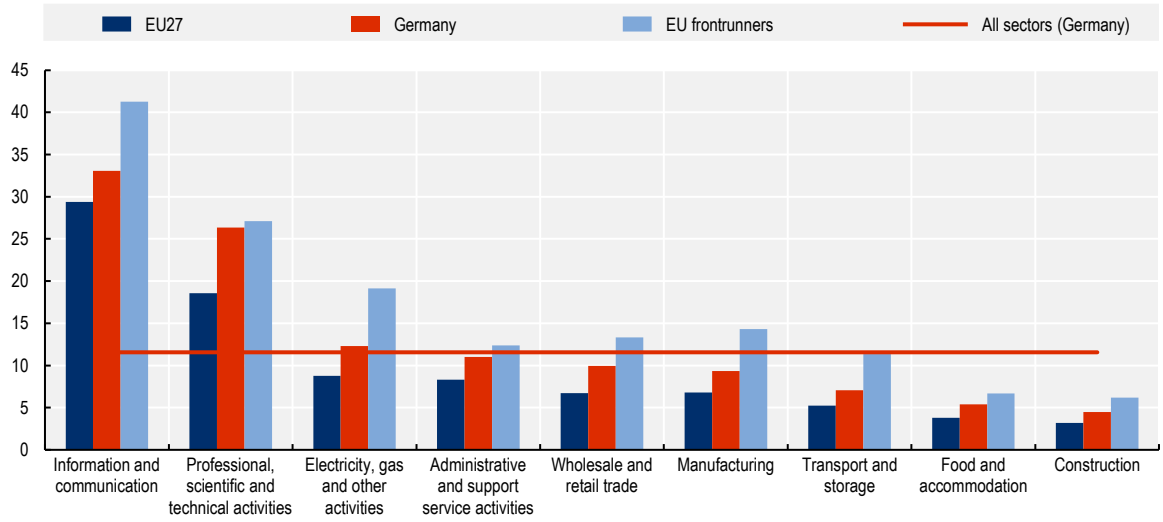


Note: EU frontrunners are the top five countries with the highest AI use by firms, simple average.
Source: Eurostat (2023[2]), *Digital Economy and Society Database*, https://ec.europa.eu/eurostat/databrowser/explore/all/science?lang=en&subtheme=isoc&display=list&sort=category (accessed on 16 October 2023).

Recent data from national surveys also show increased adoption and interest in AI solutions in Germany. As of June 2023, 13.3% of the companies surveyed were already using AI, while 9.2% had intentions to do so (ifo Institute, 2023[3]). Additionally, 36.7% were engaged in conversations about potential AI use cases (Figure 4.3, Panel A). A second national survey found a similar overall adoption rate of AI applications across firms, standing at 14%, while 23% indicated plans for future adoption (Figure 4.3, Panel B) (DIHK, 2023[4]). A third national survey found that 15% of German companies use AI, an increase of 6 percentage points from the previous year (bitkom, 2023[5]). Rates of adoption by sector differed from the EU survey, particularly concerning the relative use in the manufacturing sector. However, it is important to stress that the two national surveys cited here lack detailed information at the firm level, such as whether AI is applied to enhance internal processes, improve customer relations, or develop new products and services. Neither is there a breakdown of AI usage by company size.

Figure 4.2. Firms in ICT and knowledge-intensive sectors lead in AI use

As a percentage of firms with ten or more employees, 2023



Note: EU frontrunners are the top five countries with the highest AI use by firms, simple average.
Source: Eurostat (2023[2]), *Digital Economy and Society Database*, https://ec.europa.eu/eurostat/databrowser/explore/all/science?lang=en&subtheme=isoc&display=list&sort=category (accessed on 16 October 2023).

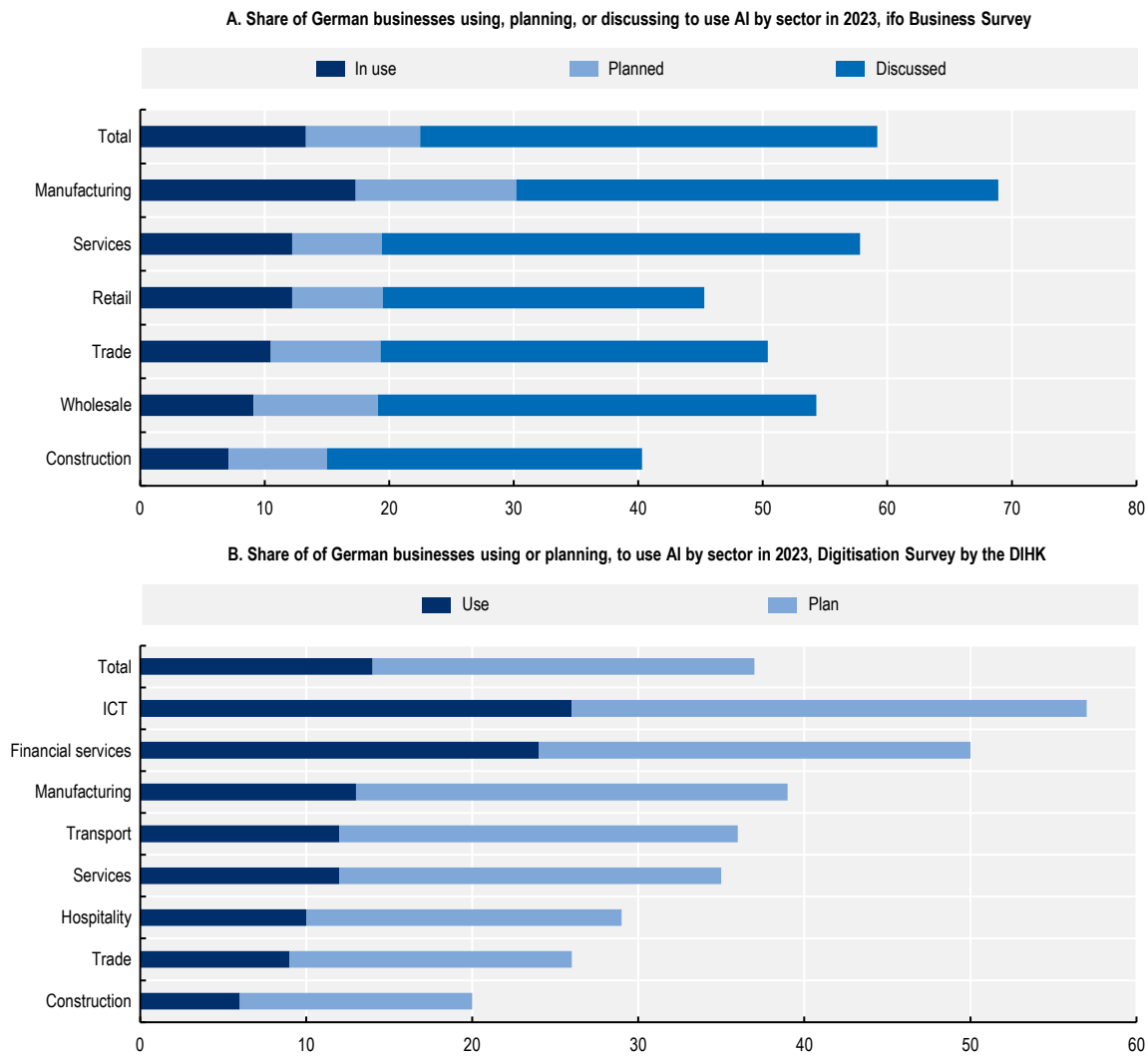
While comparisons with non-EU countries pose challenges due to differences in survey questions and coverage (Montagnier and Ek, 2021[6]), recent findings from the Business Trends and Outlook Survey provide some insights for the US. In 2023, only 3.9% of US firms used AI to produce goods and services. The information sector used AI the most, at 13.8%. Notably, an additional 6.5% and 22% of firms reported plans for adoption within the next six months (US Census Bureau, 2023[7]). These data refer to the use of AI to *develop* new products and goods, while recent data on broader *use* and by economic sectors is lacking. McElheran et al. (2023[8]) found a low average diffusion among US firms (6%), although with higher concentration among specific sectors and a smaller number of very large firms (over 5 000 employees). Weighted by employment, average adoption in US firms was slightly over 18%. However, the analysis is based on 2018 data from the Annual Business Survey and current rates are likely to be higher, particularly in view of recent developments in AI.

Adoption of AI across sectors is illustrated by the AI-related activities of large German companies. In 2017, Siemens established an AI-lab that currently has 250 researchers. In 2022, AI was one of Siemens' eleven core technological research and development focuses (Siemens, 2023[9]). Furthermore, in 2023 the company announced an increase in around EUR 0.5 billion in R&D in AI and the industrial metaverse (Siemens, 2023[10]). Bosch also set up an AI centre (the Bosch Centre for Artificial Intelligence, BCAI) in 2017 to develop innovative AI technologies. Likewise, SAP established an AI central team in 2016. Some of Siemens, Bosch and BMW's manufacturing plants figure in the World Economic Forum's Global Lighthouse Network of the most advanced Industry 4.0 production facilities worldwide (WEF, 2023[11]).

German companies ranked third in the automotive sector in 2019 among peer countries regarding AI deployment at scale (Capgemini, 2019[12]). AI is mainly leveraged in this sector for: i) design and customisation purposes to expedite idea implementation and reduce innovation cycles; ii) optimising autonomous vehicle development; and iii) developing driving and costumer assistants (Capgemini, 2023[13]).

Mercedes-Benz became the first car manufacturer to receive US government approval for a Society of Automotive Engineers (SAE) Level3 autonomous driving feature. The company self-certified its Drive Pilot feature in Nevada, allowing the car to handle all driving tasks while requiring the driver to be ready to take control at any moment (The Verge, 2023[14]). In its subsidiary brand Audi, Volkswagen Group also uses the FelGAN software for design inspiration. This in-house development by corporate information technology (IT) and Audi Design suggests photorealistic designs or recombines existing designs in a targeted manner. In production, AI is being used to detect anomalies via sound or specific patterns and to detect out faulty parts. Machine learning and digital copies of models, called digital twins, help to make production more energy and cost-efficient.

Figure 4.3. Recent national surveys show increased use and interest for AI by German firms



Notes: Panel A: The ifo Institute asked about attitudes towards AI on behalf of the Hanseatic Blockchain Institute e.V. as part of the ifo Business Survey for June 2023. The ifo Business Survey is based on approx. 9 000 monthly responses from businesses in manufacturing, the service sector, trade, and construction (ifo Institute, 2023[3]). Panel B: The German Chamber of Commerce and Industry (*Deutsche Industrie und Handelskammer*, DIHK) asked the question about the application of AI by sector as part of their Digitisation Survey 2022/2023. The analysis is based on the responses of 4 073 companies from 8 different economic sectors.

Sources: Panel A: ifo Institute (2023[3]), "Artificial intelligence in use at 13.3% of companies in Germany", https://www.ifo.de/en/facts/2023-08-02/artificial-intelligence-use-companies-germany (accessed on 16 October 2023); Panel B: DIHK (2023[4]) , *Digitale Innovationen, Technologien und Produkte*, https://www.dihk.de/de/themen-und-positionen/wirtschaft-digital/digitalisierung/digitalisierungsumfrage-2023 (accessed on 24 October 2023).

Generative AI can increase the competitiveness of German firms

Increased use and interest in AI solutions appears to be influenced by the advent of generative AI (ifo Institute, 2023[3]). Labour shortages have also compelled companies to explore solutions to reduce costs and enhance process efficiency. This is in line with findings showing that employers in Germany are more likely to cite skills shortages as a reason to adopt AI in the manufacturing and finance sectors than employers in other OECD countries (Austria, Canada, France, Ireland, the UK and the US), and that improving workers performance and cost efficiencies are even more prevalent reasons for AI adoption among German employers (Lane, Williams and Broecke, 2023[15]).

The link between AI use and firm productivity is still being investigated as existing literature remains inconclusive (Calvino and Fontanelli, 2023[16]). Nevertheless, empirical evidence suggests positive and significant productivity impacts for Germany. One study found that AI use among German firms contributed to approximately 6% of total annual cost savings for the German business sector in 2019 (Rammer, Fernandez and Czarnitzki, 2022[17]). The study also found that AI adoption increases annual worker productivity growth within-firm. Calvino and Fontanelli (2023[16]) also identified positive and significant effects of AI on productivity in a sample of German AI adopters with online presence.

Recent research suggests that adopting generative AI could lead to substantial productivity gains across diverse sectors. Estimates range from 0.1% to 0.6% annually over the next ten to twenty years (McKinsey Global Institute, 2023[18]), and up to 1.4% over a ten-year period (Briggs and Kodnani, 2023[19]). Workers' exposure to ChatGPT was also associated with increased firm value (Eisfeldt et al., 2023[20]) and revenue growth in SMEs (Soni, 2023[21]).

Various studies have investigated the productivity effects of generative AI tools in experimental settings. Dell'Acqua et al. (2023[22]) found that the use of generative AI can significantly improve the performance of highly skilled workers, particularly consultants, by up to 40% compared to those who do not utilise it. However, for tasks beyond the current capabilities of AI, consultants using AI were 19% less likely to produce correct solutions. In coding, developers using GitHub Copilot – an AI programming assistant that provides relevant code and functions – completed tasks 55.8% faster than those without the tool (Peng, Kalliamvakou and Cihon, 2023[23]). Less experienced programmers, older programmers, and those working long hours derived the most significant benefits from using the AI tool. Similarly, (Brynjolfsson, Li and Ray, 2023[24]) found that call centre agents with access to a conversational assistant experienced a 14% boost in productivity. In line with (Noy and Zhang, 2023[25]), the most significant gains were observed among new or low-skilled workers. However, research on the labour-market effects of generative AI is relatively recent and further peer-reviewed research is needed for more definitive conclusions to be drawn.

Generative AI has a wide range of possible applications at firm level. Potential use cases with the highest estimated value are software engineering, customer relations, marketing and sales, and R&D (McKinsey Global Institute, 2023[18]). In SMEs, usage can be diverse, spanning from content creation and automation of paperwork, to prototyping and customer support and interaction (Table 4.1).

Generative AI can also be used in robotics, where large language models (LLMs) can enhance robot intelligence, favour human-robot interaction, and increase autonomy (Zenga et al., 2023[26]). Robotics can also be combined with image, audio, and video generation models to produce advanced systems with multimodal capabilities combining these functions (Lorenz, Perset and Berryhill, 2023[27]). With 397 industrial robots per 10 000 employees in 2021, Germany's manufacturing industry has the highest robot to employee density in Europe (The Robot Report, 2022[28]). Germany is one of the top five adopters worldwide with 36% of the market share within the EU (IFR, 2023[29]). Germany is well positioned to seize the opportunities of LLMs to improve robots' capacity further and lead in intelligence robotics. The recent Action Plan on Robotics Research, launched by the Federal Ministry of Education and Research (*Bundesministerium für Bildung und Forschung*, BMBF) in November 2023 (BMBF, 2023[30]), aims at

strengthening Germany's position in AI-based robotics including through the creation of a Robotics Institute Germany.

Large German companies are increasingly exploring potential uses of generative AI in their products. Siemens recently partnered with Microsoft to speed up code generation for industry automation using ChatGPT (Siemens, 2023[10]). The enterprise software firm SAP has invested in three generative AI companies in Germany (Aleph Alpha) and abroad (Anthropic, in the US, and Cohere, a US/Canadian company). BMW partnered with Zapata and MIT's Centre for Quantum Engineering to address their plant scheduling optimisation challenge using generative AI techniques (Markets and Markets, 2023[31]). Mercedes-Benz is currently testing a GPT-based voice control system in its vehicles in the US. The assistant is supposed to provide information about destinations or answer knowledge-based questions. Based on the results of this beta test, Mercedes will assess whether to offer an LLM for "dialogical communication" in its vehicles in the future (Handelsblatt, 2023[32]).

Stakeholders consulted in the context of this study noted that, despite growing interest, companies have yet to fully comprehend the specific applications of generative AI within their operations. Furthermore, generative AI applications in an industrial setting (e.g. for predictive maintenance) are still being explored. However, it was widely acknowledged that the availability of standardised AI solutions, including generative AI, will ease integration into business operations. This could potentially result in significant adoption rates, especially among SMEs. Notably, sectors like retail and trade leverage AI to enhance marketing efforts, while the professional activities sector focuses on automating production processes (Eurostat, 2023[2]). Consequently, the potential use cases of generative AI are likely to its adoption for these specific purposes further.

Table 4.1. Uses of generative AI in SMEs

Use case	Description
Content creation	Marketing content: Generate text for ads, social media, and campaigns, blogging and search engine optimisation
Personalised customer communications	Generate personalised emails and content based on customer data
Customer support	Provide first level support through AI chatbots
Product design and development	Create new product designs or modify existing ones
Graphic design	Design logos, marketing materials, and other materials
Prototyping and 3D modelling	Assist in creating designs for rapid iteration and testing
Automation of paperwork and reports	Draft reports, generate invoices, and handle routine paperwork tasks
Language translation	Translate content into multiple languages

Source: Soni, V. (2023[21]), "Impact of generative AI on small and medium enterprises' revenue growth: The moderating role of human, technological, and market factors", https://researchberg.com/index.php/rcba/article/view/169.

Interviewees also pointed out that LLMs currently on the market have only been trained on small portions of German text, resulting in less accurate results. The restricted availability of open data for training German LLMs was identified as a current limitation, coupled with the need for significant computing capacity. Both academia and business sectors said that Germany urgently needs to develop its own LLM, both for higher accuracy and to ensure compliance with EU legal requirements, particularly regarding data protection (Löser et al., 2023[33]; AKI, 2023[34]).

Bottlenecks could hamper wider AI adoption

Notwithstanding the increased interest of German companies in AI, the experts interviewed pointed to challenges that may delay and even hamper AI diffusion in German firms, particularly in SMEs.

The main obstacle cited by employers for AI diffusion in firms is the shortage of AI skills. SMEs often cannot obtain the required AI talent to identify, develop, implement, and maintain AI applications.

Companies often do not see the advantage AI could bring to their business models. The experts described traditional German companies, and in particular SMEs, as “too successful to innovate”. These companies may have been highly successful in the past, but their success has led to complacency, making them resistant to investing in or adapting to new and potentially disruptive innovations, potentially limiting long-term competitiveness and growth. Moreover, estimating the return on investment (ROI) for AI applications is challenging, given that most require customisation to align with each firm’s unique work environments and processes. The interviewees noted that firms considering AI investments face decision-making challenges due to limited awareness of successful use cases.

Significant concerns arise from uncertainties regarding regulatory compliance. In this context, the primary challenge for companies actively using AI is the uncertainty related to regulatory compliance with data protection legislation for AI applications. In a survey conducted by the German Centre for European Economic Research (*Leibniz-Zentrum für Europäische Wirtschaftsforschung*, ZEW), 76% of the participating companies noted that this issue is very or somewhat important (Rammer, 2021[35]). The experts interviewed affirmed that German companies, especially SMEs and start-ups, encounter challenges with the General Data Protection Regulation (GDPR), since they often lack the human resources necessary to navigate the regulation and ensure legal compliance. Similarly, they expect the adoption of the European Union Regulation on Artificial Intelligence (the “EU AI Act”, see Chapter 6) (EU, 2024[36]) to be challenging for most SMEs and that compliance with the Act’s requirements will increase the costs of AI use.

There is a path dependency between the level of digitalisation and the use of AI. Germany lags in connectivity, with less fast Internet subscriptions and a very low share of high-speed fibre connectivity that is increasing but slowly (Figure A A.7). German mobile broadband subscribers also consume less data than the OECD average due to cost considerations. The German Federal Government’s Digitisation Index 2022 shows that digitalisation is least advanced in small German companies with 1 to 49 employees and is significantly below the EU average for all German company size classes. Even though medium-sized companies with 50 to 249 employees are making progress in digitisation, their index value is still below the baseline value of 2020 (German Federal Government, 2023[37]). According to Eurostat data on the digital intensity level in businesses, German SMEs are the seventh most advanced in the EU, lagging EU frontrunners, i.e. Finland, Denmark, Sweden, Ireland, Netherlands, and Malta (Eurostat, 2023[38]). This finding is also linked to German SMEs often lacking trust in AI solutions due to concerns about confidentiality. According to the experts interviewed, SMEs specialised in a particular niche product/market are afraid that competing companies will gain access to their expertise as a result of the use of new technologies, thereby losing their competitive edge in the market.

The low degree of digitalisation and data readiness in companies makes it challenging for firms to adopt AI solutions, as these complementary assets are significantly linked to AI use (Calvino and Fontanelli, 2023[16]). The development of AI systems hinges on each organisation and sector having a digital data strategy, since data are required for training, testing, validating and evaluating AI models. However, SMEs often lack sufficient quantity and quality data, in a structured format and do not have the competences to integrate data from different data sources. Accessing computing resources and cloud services, essential for computationally intensive tasks like deep learning, is also an obstacle.

AI adoption in the manufacturing sector

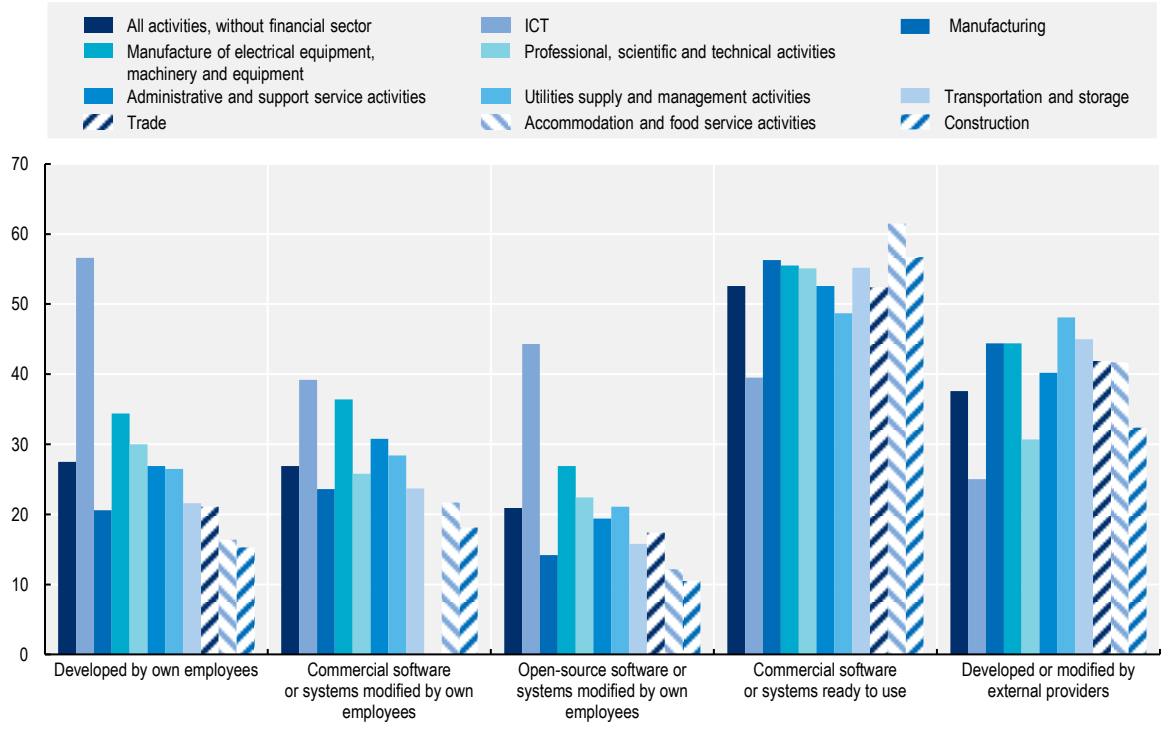
Adoption of AI in Germany’s manufacturing sector has been relatively slow to date, even though AI is one of the crucial enabling technologies of Industry 4.0, i.e. the paradigm shift in manufacturing processes conceptualised and promoted by Germany since 2011. Primary AI applications in industrial settings include predictive maintenance, quality control, process optimisation, and human-robot collaboration (Emerj,

2022[39]; Peres et al., 2020[40]). The diverse nature of industrial systems and applications makes it essential to have customised, firm-specific AI applications. In the EU, the majority of sectors rely on "AI as a service," aside from ICT, utilising commercial software or ready-to-use systems. Nevertheless, over one third of equipment manufacturers either develop their own AI systems or adapt commercially available ones (Figure 4.4).

Integrating AI into corporate structures and value chains requires substantial investment and organisational changes. However, due to insufficient evidence of successful industrial AI applications, many manufacturing firms fail to see any ROI. Interviews with a leading transfer institution indicated that most projects stall at the proof-of-concept level. Challenges such as a lack of skills to maintain solutions (e.g. for retraining and re-deployment), lack of clear ROI and a shortage of substantial evidence of industrial success impede progress in market uptake beyond this stage. A provider of AI solutions emphasised that the delayed adoption of industrial AI is also linked to cultural and competency issues at company level. The prevailing focus on engineering hampers broader organisational transformations.

Figure 4.4 Firms in most sectors are buyers of AI solutions, yet some need to develop their own

As a percentage of firms with ten or more employees in the EU27, using at least one AI technology, 2021



Source: Eurostat (2023[2]), *Digital Economy and Society Database*, https://ec.europa.eu/eurostat/databrowser/explore/all/science?lang=en&subtheme=isoc&display=list&sort=category (accessed on 16 October 2023).

Integrating AI into industrial business models and processes requires large volumes of quality data from various sources to train machine learning and deep learning models effectively. However, interviewees highlighted that both data availability and quality are significant bottlenecks. Obtaining substantial amounts of data proves challenging, especially in manufacturing environments with diverse data sources such as embedded machinery sensors and digitised processes like inventory management. Therefore, digitalising data is a prerequisite for SMEs to embrace industrial AI.

Implementing a data strategy and making organisational changes to align business models with industrial AI can enhance data collection, curation, and storage. Current research is look at ways to address initial data scarcity challenges by exploring the use of synthetic data, which entails creating data that resembles a real operational environment. It also looks at transfer learning or applying knowledge from one source domain to enhance learning in a new one with limited data (Peres et al., 2020[40]).

To increase availability of data for specific sectors, the EU and Germany have financed sectoral data spaces. "Data spaces" refers to secure and controlled virtual environments where data is stored, shared, and processed. These spaces are designed to facilitate seamless and trusted data exchange among stakeholders, fostering collaboration, innovation, and the development of new services and applications. In May 2023, the Federal Ministry for Economic Affairs and Climate Action of Germany (*Bundesministerium für Wirtschaft und Klimaschutz,* BMWK) published the funding concept for Manufacturing-X, with an allocation of EUR 152 million (Plattform Industrie 4.0, 2023[41]). Unlocking the untapped potential of industrial data is among the key objectives of the updated German data strategy released in 2023 (Box 4.2). The creation of sectoral data spaces, including Manufacturing-X, is part of the actions foreseen in the strategy. Manufacturing-X is planned to be an open, decentralised and collaborative data space for Industry 4.0 by financing application-oriented R&D projects implementing cross-industry use cases.

Box 4.2. The German National Data Strategy aligns with European and national laws

The German National Data Strategy aligns with European and national laws and encompasses various initiatives to promote responsible and effective data utilisation across sectors

The **European strategy for data**, introduced in February 2020, aims to establish a unified market for data to enhance Europe's global competitiveness and data sovereignty. It includes measures such as creating common European data spaces, making data more accessible across the EU, and investing in infrastructure and governance mechanisms. Two key legislative acts, the European Data Governance Act and the Data Act, are integral to achieving the strategy's goals by facilitating data sharing, increasing data availability, and clarifying conditions for data usage.

The **European Data Governance Act,** entered into force in June 2022 and applicable since September 2023, seeks to increase trust in data sharing, strengthen mechanisms to increase data availability and overcome technical obstacles to the reuse of data. The Act also supports the set-up and development of common European data spaces in strategic domains such as health, environment, energy, manufacturing, or public administration. The Act includes four sets of measures to: i) facilitate the reuse of certain public sector data; ii) ensure trustworthy data intermediaries; iii) promote citizen and business data sharing; and iv) facilitate cross-sector and cross-border data usage.

The Regulation on harmonised rules on fair access to and use of data – the **Data Act** – entered into force in January 2024, complementing the European Data Governance Act. While the Data Governance Act regulates processes and structures that facilitate voluntary data sharing, the Data Act clarifies who can create value from data and under which conditions. This legislation aims to enhance data availability for the benefit of companies, citizens, and public administrations by: i) establishing clear rules on data use and associated conditions for companies and consumers involved in data generation, particularly in the Internet-of-Things context; ii) addressing contractual imbalances to promote fair data sharing practices; iii) allowing public sector bodies to access and utilise private sector data for specific public interest purposes; and iv) introducing rules to enable customers to easily switch between different data processing service providers.

Based on European and national law and linked to various national initiatives, the German **National Data Strategy** (*Nationale Datenstrategie*), outlines a comprehensive approach to utilise data responsibly, effectively, and sustainably. It targets various sectors including the public sector, research, businesses, and individuals. Key points of the strategy include:

1. **Expanding data**: Initiatives to generate more data, facilitate access to government datasets, and promote data usage for the common good.
2. **Enhancing data quality**: Introduction of standardised data descriptions, labeling mechanisms, and quality assurance to ensure uniformity and trustworthiness of data.
3. **Promoting data usage and culture**: Encouragement of data-based government actions, support for the development of sectoral data spaces, and fostering of comprehensive data skills among the population to cultivate a responsible data culture.
4. **Roadmap**: A roadmap outlines the implementation plan until Q4/2024, considering EU legislation, federal legislation, relevant structures and networking initiatives.

Sources: EC (2020[42]), *A European Strategy for Data*, https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52020DC0066; EC (2022[43]), *European Data Governance Act*, https://digital-strategy.ec.europa.eu/en/policies/data-governance-act; EC (2024[44]), *Data Act*, https://digital-strategy.ec.europa.eu/en/policies/data-act; German Federal Government (2023[45]), *Fortschritt durch Datennutzung [Progress through Data Utilisation]*, https://www.bmi.bund.de/SharedDocs/downloads/DE/veroeffentlichungen/2023/datenstrategie.pdf.

Data spaces can make it easier for SMEs to implement AI by providing a platform to access and integrate data from various sources, including public databases, research institutions, and other businesses. SMEs can also monetise their data by sharing them on the platform and contributing to innovation along the supply chain. However, the low data maturity and lack of human resources may prevent some SMEs from participating in data spaces.

Germany's institutions have many programmes to promote the use of AI in firms, especially SMEs

In Germany, several programmes and institutions support transferring AI research results from academia to private sector commercial use (Figure 4.5). Notably, the national AI strategy allocated EUR 166 million to this area of action, i.e. 8% of the total allocated funding from the strategy to date.

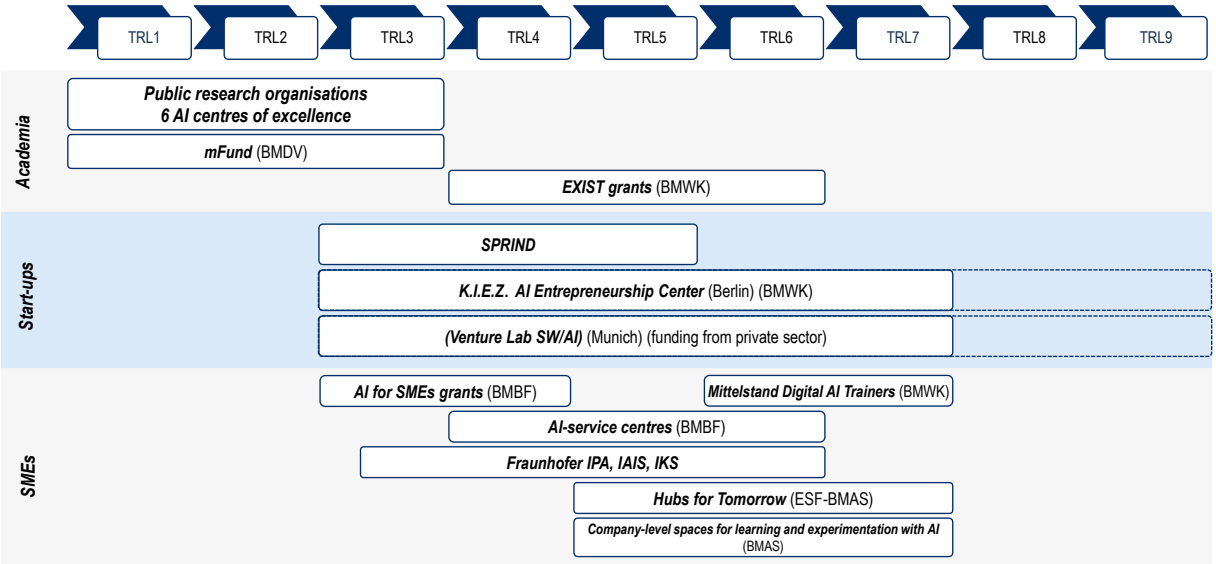
Established in 2020, the "AI for SMEs grants" (*Künstliche Intelligenz für KMU*, KI4KMU) is a funding programme managed by the BMBF. It specifically caters to SMEs with a maximum of 249 employees and an annual turnover of EUR 50 million or an annual balance sheet total of EUR 43 million (BMBF, 2020[46]). The programme co-finances innovative projects led and co-ordinated by SMEs in collaboration with entities such as universities and start-ups that serve as technology suppliers or test users. These projects are expected to demonstrate a substantial level of novelty compared to the prevailing international state of the art in AI-related science and technology.

The programme encompasses diverse topics, including automated information processing, digital assistants, computer vision/image comprehension, language and text comprehension, privacy-by-design approaches, data-driven systems, data engineering, traceability, and explainability of processes and systems for automated decision support and decision making. It also fosters new approaches to creating transparency in AI systems. Each project is encouraged to focus on a specific domain, such as renewable energies, ecology, environmental protection, logistics, mobility, automotive, production technologies, process control and automation, innovative user-oriented services, and the data and ICT economy.

With grants of a value up to EUR 1 million, covering around 50% of the costs, funding is awarded through a selection process, with applications accepted twice a year. The programme has already supported 61 projects involving 107 SMEs. The funding period typically spans over two to three years. The funding

period typically spans over two to three years. The programme has sparked significant interest among SMEs, with six to eight times more applications than the available funding capacity in each round. Since the initial projects started in 2020, only a few are finished, outcomes of most projects are still in progress, and results are not yet available.

Figure 4.5. Programmes and transfer institutions in Germany support AI research transfer from the lab to the firm



Note: The figure is for illustrative purpose only and it is not exhaustive.
Source: OECD elaboration based on information gathered in the context of the review.

In November 2022, the BMBF helped to create four AI Service Centres (*KI-Servicezentren*) across Germany. These centres are designed to enhance access to computing infrastructure, provide expertise in AI, and support the widespread transfer of AI through a catalogue of services, including hardware, software, data and models, solution development, customisation of AI models to specific requirements, consulting, and training (BMBF, 2022[47]). Endowed initially with a minimum of EUR 10 million each for a 60-month period, these centres offer computing and consulting services free of charge to SMEs and start-ups. They are expected to be self-sustaining once the initial funding concludes. The four centres are the following:

- WestAI (Dortmund/Bonn/Jülich/Aachen/Paderborn) combines the large computing capacities of the Jülich Super Computing Centre (JSC) and RWTH Aachen University with the AI expertise of the Lamarr Institute for Machine Learning and Artificial Intelligence (LAMARR) and the University of Paderborn.
- AI Service Centre for Sensitive and Critical Infrastructures (*KI-Servicezentrum für sensible und kritische Infrastrukturen*, KISSKI) (Hanover/Göttingen/Kassel) focuses on AI for sensitive and critical infrastructures, especially in the health and energy industries.
- Hessian AI Service Centre (Darmstadt) concentrates on the so-called third wave of AI, e.g. large generalisable models or data-intensive applications.
- AI Service Centre Berlin Brandenburg (Hasso Plattner Institute) is dedicated to the challenges and opportunities of AI in regions affected by structural change.

The BMWK's Digital Strategy 2025 aims to drive innovative digitalisation in the economy and society (BMWi, 2016[48]), establishing 26 regional hubs called Mittelstand[1] 4.0 Competence Centres, a total of

26 regional hubs for SMEs (BMWi, 2020[49]) to support SMEs with inter-business connections, knowledge transfer, and digital transformation. In 2019, the addition of AI trainers enhanced their role in educating SMEs about AI (BMWK, 2023[50]). Currently, 80 such AI trainers are active at a national level their number should increase in 2024. Funding for these centres ended in 2020, but the BMWK introduced support for Mittelstand-Digital Centres (*Mittelstand-Digital Zentren*) focused on the platform economy and AI. As of 2023, 30 such centres assist SMEs, with a shift towards AI in 2024 (BMWK, 2023[51]), Initially broadly dedicated to digitalisation enterprises, the network of Mittelstand Digital Centres shifted its focus to AI in 2024. This emphasis will concentrate on promoting the use of AI applications in SMEs and ensuring access to and preparation of high-quality data (Mittelstand-Digital, 2023[52]).

In co-operation with the German Chamber of Commerce and Industry (*Deutsche Industrie- und Handelskammer*, DIHK), the Mittelstand-Digital Centres host events to help businesses to incorporate AI. These events include individual consultation sessions and seminars on a range of AI topics, such as AI utilisation in office management and AI-based monitoring of office facilities (DIHK, 2023[4]).

Hubs for Tomorrow (*Zukunftszentren*) are a project funded in 2019 by the European Social Fund (ESF) and the Federal Ministry of Labour and Social Affairs (*Bundesministerium für Arbeit und Soziales,* BMAS), as well as partially by various *Länder*. The Hubs are essential for companies seeking guidance, mediation, and information regarding digitalisation and AI applications. They assist SMEs in accessing advice and training with minimal barriers. Currently, 12 regional Hubs are active in Germany. The programme has a funding pool of approximately EUR 125 million sourced from the ESF, federal funding, and supplementary state funding (BMAS, 2022[53]).

The “company level spaces for learning and experimentation with AI” (*KI Lern- und Experimentierräume*), part of the New Quality of Work Initiative (*Initiative Neue Qualität der Arbeit*, INQA) and financed by the BMAS, offer spaces for developing AI skills. The programme, running from September 2019 to September 2024, gives SMEs the opportunity to explore AI in an operational context. The results of the projects shed light on how AI can change the world of work and the opportunities and benefits of AI for SMEs (KOMKI, 2023[54]).

The Foundation Mittelstand – Society – Responsibility (*Stiftung Mittelstand – Gesellschaft – Verantwortung*) spearheads *en[AI]ble*, a project to promote the transfer from research to business and facilitate the widespread and profitable adoption of AI technology within the Mittelstand (Stiftung Mittelstand-Gesellschaft-Verantwortung, 2023[55]). The BMAS also funded it as part of the INQA and ran from September 2020 to September 2023. The initiative aimed to address the common challenges companies, particularly SMEs, face that struggle with the lack of competencies and resources needed to assess and implement AI solutions tailored to their specific needs. To help close the gap, *en[AI]*ble created a customised AI qualification programme, specifically designed to align with the Mittelstand’s requirements. This qualification aims to empower employees, staff associations, managers within SMEs, and consultants with the skills to evaluate AI applications effectively.

The Fraunhofer Society (*Fraunhofer-Gesellschaft*) represents a distinct German research transfer landscape feature. It focuses on crucial and future-relevant technologies for results in business and industry and plays a central role in the innovation process. It operates 76 institutes and research facilities in Germany and has an annual research volume of EUR 3 billion (Fraunhofer-Gesellschaft, 2023[56]). Three Fraunhofer Institutes are particularly relevant for the transfer of AI research: i) Fraunhofer Institute for Intelligent Analysis and Information Systems (IAIS); ii) Fraunhofer Institute for Manufacturing Engineering and Automation (IPA); and iii) Fraunhofer Institute for Industrial Engineering (IAO).

Notably, the Fraunhofer IPA and IAO offer three free of charge programmes in their jointly managed AI Innovation Centre Learning System and Robotics (*KI-Fortschrittszentrum Lernende System und Robotik*) to get companies closer to AI potential use in their businesses. First, the AI Explorer programme offers knowledge to companies exploring AI or robotics applications without a specific concept. In workshops, Fraunhofer employees assess the company's AI and robotics landscape, providing guidance on practical

implementation. Second, the Quick Checks programme enables companies to assess the feasibility of individual AI or robotics applications. Fraunhofer employees evaluate project feasibility based on the presented use case. Third, within the Exploring Projects programme, Fraunhofer staff can develop proofs-of-concept – standalone, fully operational systems not integrated with the firm's core processes. Fourth, the AI Innovation Seed format focuses on the consideration and development of innovative cross-company solutions in the field of AI. To date, about 250 companies have participated in the programmes, including large companies and SMEs from the manufacturing sector. Over 30% of these projects resulted in operational AI systems implemented by firms.

One of the main activities of the German Research Centre for Artificial Intelligence (*Deutsches Forschungszentrum für Künstliche Intelligenz*, DFKI), funded by the BMBF, is to transfer AI research findings into business applications. The centre engages in public-private research partnerships with software, automotive and manufacturing companies, with an annual project volume of EUR 82.6 million in 2022 (DFKI, 2023[57]).

The Platform Learning System (*Plattform Lernende Systeme*) is a network of experts on the topic of AI. Its aim is to act as an independent broker to promote interdisciplinary exchange and social dialogue on AI. Founded in 2017 by the BMBF, it relies on about 200 members from science, business and society to develop positions on opportunities and challenges in working groups and identify options for action for the responsible use of AI. One example of such guidance is the AI Roadmap for SMEs (Lernende Systeme, 2021[58]), which features use cases and practical implementation plans for AI in medium-sized businesses.

Despite numerous programmes available, SMEs and other businesses remain unaware

The platform also maps out the federal government's current programmes and activities related to AI (Lernende Systeme, 2023[59]). Despite the existence of the platform, interview participants believed that the landscape of financial and non-financial support to implement AI solutions in firms is too scattered and fragmented, explaining why they are often unaware of available initiatives and unable to find those best suited to their needs. The platform could be improved by transforming it into a more interactive tool where firms could self-assess their AI readiness, understand their specific needs, and find the most appropriate support for their needs. Business associations also have a role to play in increasing awareness about current initiatives related to AI transfer to firms.

Table 4.2. Selected transfer initiatives to increase diffusion of AI in firms

Initiative	Funded by	Year of launch/establishment	Year of termination	Key objectives
AI for SMEs grants	BMBF	2020	Ongoing	Co-finance innovative projects led and co-ordinated by SMEs in collaboration with entities such as universities and start-ups
Four AI Service Centres: i) WestAI; ii) KISSKI; iii) hessian AI Service Centre; iv) AI Service Centre Berlin Brandenburg	BMBF	2022	Ongoing	Enhance access to computing infrastructure, provide expertise in AI, and support the widespread transfer of AI through a catalogue of services
DFKI	BMBF	1988	Ongoing	Transfer research funding in business applications through public-private research partnerships with software, automotive and manufacturing companies
AI trainers	BMWK	2019	Ongoing	Strengthen Mittelstand 4.0 Competence Centres' and Mittelstand Digital Centres' ability to support SMEs in understanding challenges and opportunities of AI

Initiative	Funded by	Year of launch/establishment	Year of termination	Key objectives
Mittelstand Digital Centres	BMWK	2020	Ongoing	Currently 30 centres that help inform SMEs about innovation drivers, with a shift of focus to AI in 2024
Company level spaces for learning and experimentation with AI	BMAS	2019	2023	Consults SME on how AI can change the world of work and what opportunities and benefits AI can offer to SMEs
Hubs for tomorrow	BMAS	2019	Until 2026	Currently 12 regional Hubs that provide companies with guidance, mediation, training, and information regarding digitalisation and the introduction of AI applications
en[AI]ble	BMAS	2020	2023	Facilitate the widespread and profitable adoption of AI technology within SMEs through customised AI qualification
IPA	Industrial and service companies, federal and *Länder* governments	1959	Ongoing	Support companies with consulting, funding and implementation services such as feasibility studies, quick checks and workshops as well as the development of complex technical production modules based on machine learning
IAO	Industrial and service companies, federal and *Länder* governments	1981	Ongoing	Work with companies to create AI-based systems that operate according to ethical principles and implement the latest results from AI research to relieve employees of complex processes and create new types of service offerings for customers
IAIS	Industrial and service companies, federal and *Länder* governments	2006	Ongoing	Aid companies in the optimisation of products, services and processes and in the development of new digital business models in the fields of AI, machine learning and big data
AI Innovation Centre Learning System and Robotics	Fraunhofer IPA and IAO	2019	Ongoing	Help companies in exploring potential AI use in their businesses through three different programmes

AI start-ups

In Germany, AI startups have a strong foundation in academic research and are predominantly active in software and IT. They face funding challenges, relying more on cash flow and public grants than on VC, which is less available than in leading AI countries. Government programmes like EXIST support early-stage growth, fostering innovation and entrepreneurship.

AI start-ups are leading innovation in Germany, with many stemming from academic research

One way for AI research to reach the market is through innovative start-ups developing a concept into a solution to meet unmet demands. The number of actively operating AI start-ups in Germany has increased significantly over the past 15 years, rising from around 1 200 in 2007 to approximately 3 000 in 2021, even if a slight decline is expected for 2022 and 2023 (Figure 4.6). This decline can be attributed, in part, to several factors. Some start-ups exited the market during the economically challenging COVID-19 pandemic and the 2022 economic slowdown. On a more positive note, some strong start-ups reached the 12-year mark and are no longer considered AI start-ups. Interest in founding AI-related ventures resurged

in 2023, particularly in light of the rapid adoption of new AI applications based on analysing vast datasets, such as ChatGPT (Rammer, 2023[60]).

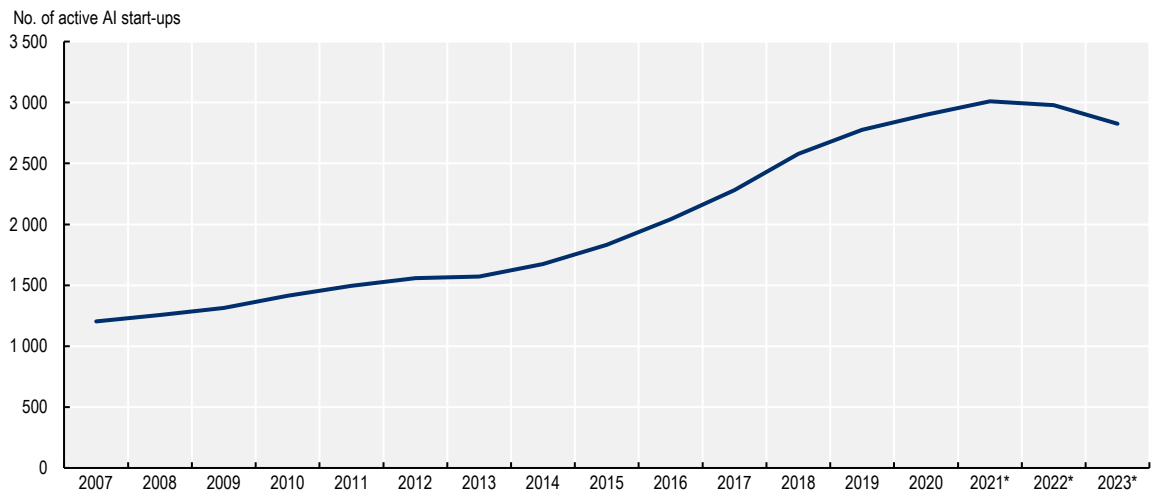
German AI start-ups are predominantly (57%) active in the field of software programming and IT services. This includes database and data analysis services, hosting, cloud computing services, IT infrastructure installation and maintenance, hardware design and software architecture. Consulting services (business, tax, legal, financial consulting, advertising) account for 19%, with the remaining AI start-ups distributed across various sectors (Rammer, 2023[60]).

Young and small companies are leading AI innovation. In a recent study on AI adopters with online presence, 40% of German AI companies identified as micro start-ups, founded after 2015 and featuring ten or fewer employees. Nearly half of AI companies in Canada shared similar characteristics, but only 28% in the UK and 27% in the US. Conversely, older and larger firms represented 2.3% of AI companies in Germany (Dernis et al., 2023[61]).

AI start-ups and the scientific community in Germany have a solid, interdependent relationship. This is obvious in the genesis of its AI start-ups: 41.5% of AI-related start-ups originate from academic research, whereas a mere 2.4% of all start-ups originate in scientific institutions (KI Bundesverband, 2023[62]). This underscores the strong and interdependent relationship between AI start-ups and the scientific community. However, interviews participants highlighted that transfer units at universities are often understaffed, and publications are still the main KPIs for universities, resulting in limited incentive for individual researchers to engage in knowledge transfer activities or transferring research findings to industry. Indeed, Germany has an untapped potential to expand its transfer structures within universities significantly.

Figure 4.6. The number of AI start-ups in Germany has increased in the past decade

Number of economically active AI start-ups in Germany



Note: The years marked with * are projected values.
Source: Rammer, C. (2023[60]), *Das Ökosystem für KIStartups. Vermarktung, Finanzierung, Fachkräfte und Vernetzung in Unternehmensgrün dungen im Bereich Künstliche Intelligenz*, https://www.zew.de/publikationen/das-oekosystem-fuer-ki-startups-in-deutschland-vermarktung-finanzierung-fachkraefte-und-vernetzung-in-unternehmensgruendungen-im-bereich-kuenstliche-intelligenz (accessed on 17 October 2023).

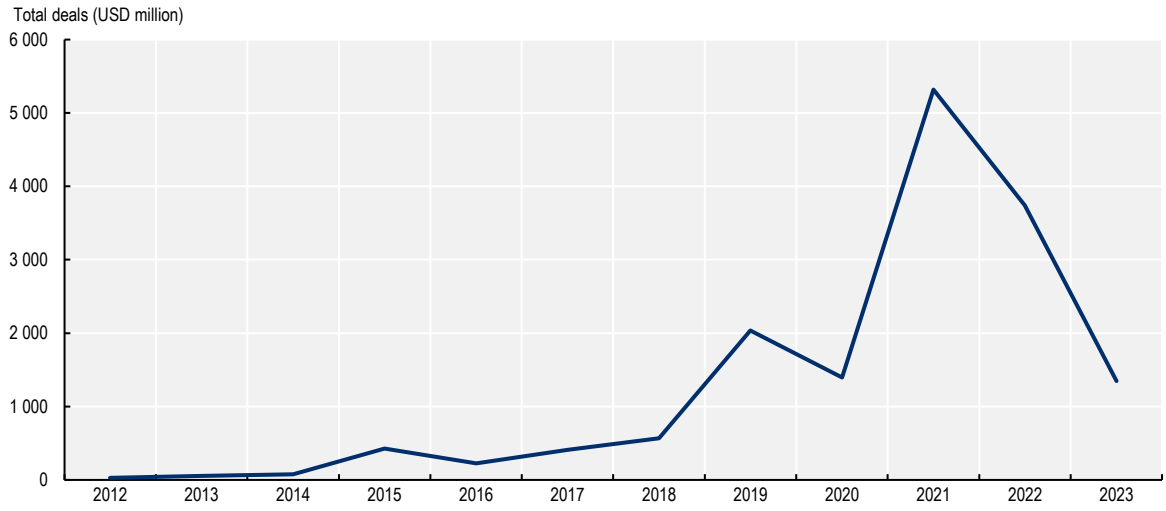
Funding for growth phases is limited

Start-ups' ability to stay dynamic and grow in the market depends considerably on the availability of risk capital. In Germany, VC investments in AI start-ups were particularly low in 2018 (at USD 758 million) but

have since grown to reach USD 3.7 billion in 2022 (Figure 4.7). This follows the global trend of increased investments in AI start-ups, particularly in generative AI. Globally, the annual value of VC investments in AI start-ups grew dramatically by over 300% between 2015 and 2022 (over USD 31 billion to nearly USD 125 billion) (OECD.AI, 2023[63]). The biggest increase happened between 2020 and 2021, when such investments jumped by more than 130% (from about USD 92 billion to USD 215 billion), with the vast majority flowing to AI firms in China and the US.

Figure 4.7. VC investments in German AI start-ups have increased since 2018

Sum of VC investments in AI in Germany



Note: The values for 2023 are estimated. Please see the methodological note available at www.oecd.ai/p/methodology for more information.
Source: OECD.AI (2023[64]), *VC Investments in AI by Country*, https://oecd.ai/en/data?selectedArea=investments-in-ai-and-data&selectedVisualization=vc-investments-in-ai-by-country (accessed on 13 March 2023).

VC investments in Germany mostly support start-ups developing AI solutions for business processes and support services, such as Celonis, an AI-based data processing platform, Wefox InsureTech, and Forto Logistics, digital freight forwarder and shipping management platform. Several promising sustainability start-ups that receive VC investments, such as Enpal and Twaice, have put AI at their core (see Chapter 8). Germany has also seen the emergence of very successful VC-backed start-ups in the field of LLMs (Aleph Alpha) and language translation (DeepL).

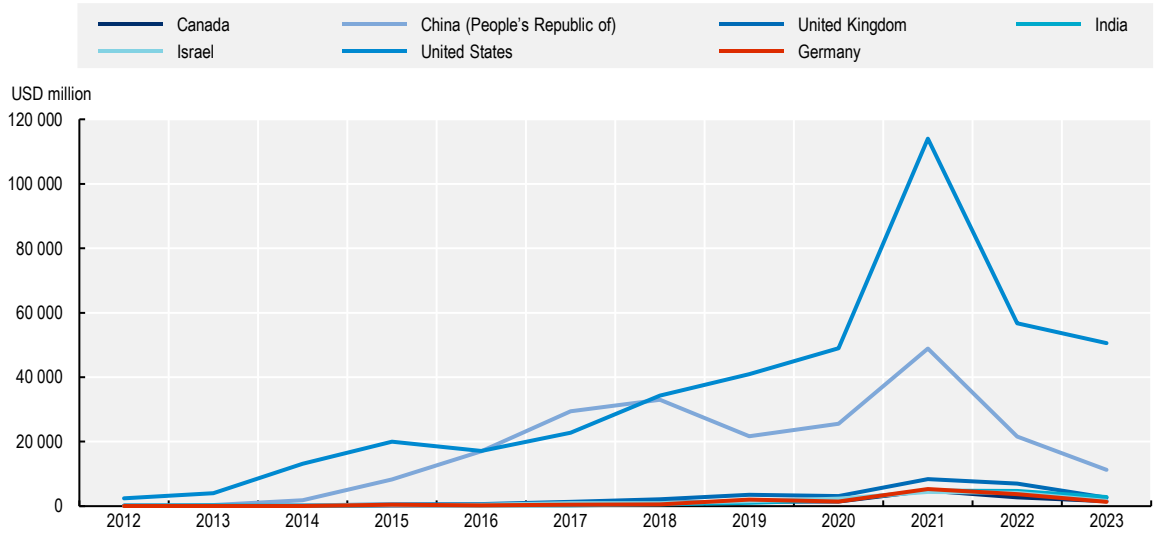
However, the availability of VC funding in Germany is still significantly lower than the amounts invested in AI start-ups in the US and China, where VC investment amounts are 14 and 5 times higher, respectively. It is also lower than VC funding in the UK, India and Israel (Figure 4.8). Most VC investors funding AI start-ups in Germany are foreign, highlighting German investors' aversion to risk.

While the supply of risk capital in Germany is limited, there may also be factors on the demand side that explain a lower reliance from AI start-ups on this source of funding. Around half of AI start-ups deliberately decide to refrain from VC funding (Rammer, 2023[60]), primarily because they want to keep complete control over strategic business decisions and have received adequate funding from alternative sources. In contrast to other external investors, venture capitalists may have a vested interest in exerting influence over strategic trajectory, encompassing factors such as the pace of expansion or the markets to be targeted. As a result, the primary funding source for AI start-ups in Germany is cash flow, i.e. revenue generated from ongoing operations (Figure 4.9). Compared to all start-ups in Germany, AI start-ups, including those operating in less pioneering sectors, demonstrate a heightened reliance on contributions from owners and

public funding, with VC coming third. Traditional bank financing is less prevalent. Given the substantial technological and market uncertainties associated with pioneering technological advances, conventional bank loans prove to be less suitable. In contrast, funding through public grants and VC emerges as more apt for supporting these high-risk investments (Rammer, 2023[60]).

Figure 4.8. Availability of VC funding in Germany is lower than in leading countries

Sum of VC investments in AI by country



Note: The values for 2023 are estimated. Please see methodological note available at www.oecd.ai/p/methodology for more information.
Source: OECD.AI (2023[63]), *Worldwide VC Investments in AI*, https://oecd.ai/en/data?selectedArea=investments-in-ai-and-data (accessed on 13 March 2023).

These findings emphasise the importance of diverse funding channels for AI start-ups in Germany. Even though approximately half of German AI start-ups choose not to seek VC funding in order to maintain complete control over their business decisions, this funding avenue is significant. However, compared to other countries, the comparatively limited availability of VC funding in Germany might prompt AI start-ups facing financial constraints to consider this funding option or relocate elsewhere. Specifically, with its substantial VC investments, the US stands out as an appealing destination for such a move (Rammer, 2021[35]). Recognising the pivotal role of public funding for German AI start-ups (Figure 4.9), it is imperative that Germany maintains financing programmes.

At the pre-seed and seed financing stages, Germany primarily backs AI start-ups through the EXIST Business Start-up Grant, a programme co-financed by the BMWK and the ESF. EXIST nurtures an entrepreneurial culture in academic institutions, fosters innovation-driven spin-offs, and helps university graduates, scientists, and students to establish technology-driven, knowledge-based start-ups. As part of the national AI strategy, Germany has established a new AI focus within the current EXIST funding programme for science start-ups with several individual measures.

Four prominent German AI regions (Berlin, Darmstadt, Munich and Hamburg) have initiated model projects funded by the EXIST programmes. The primary objective of these EXIST-AI model projects is to identify early-stage AI start-up concepts and provide them with the necessary resources for scaling. These projects also focus on networking within the start-up ecosystem, building connections between universities, start-up teams, and businesses, and prioritising scaling and internationalisation. One new pilot project AI Entrepreneurship Centre (*Künstliche Intelligenz Entrepreneurship Zentrum,* K.I.E.Z.) from the Berlin research association Science & Startups. K.I.E.Z. offers tailored opportunities for rapid and sustainable

growth to AI start-ups within a prominent European and global ecosystem. Its primary goal is to promote the success of science-based AI start-ups and advance technology transfer.

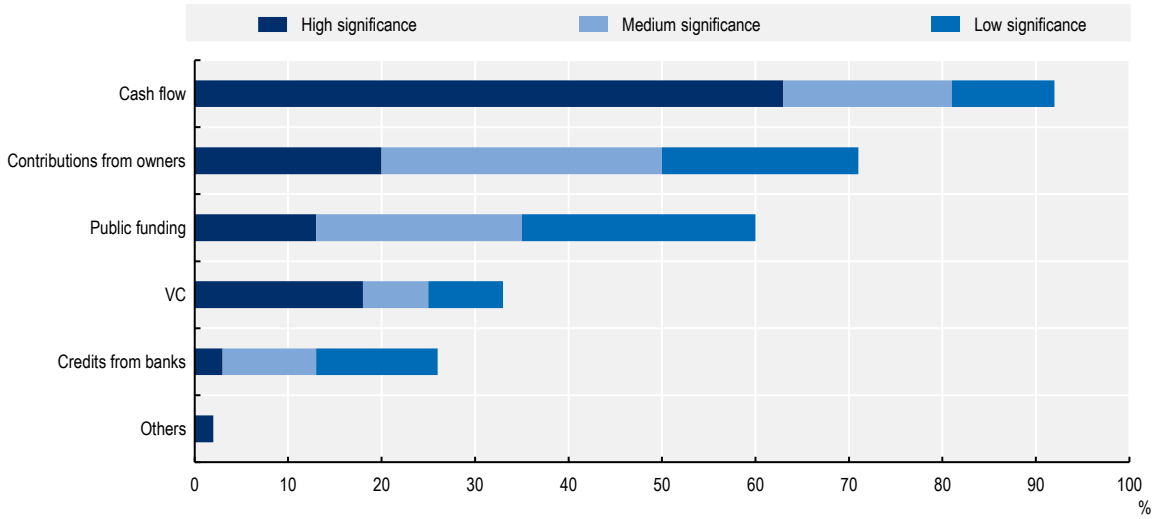
UnternehmerTUM is the Centre for Innovation and Entrepreneurship Support at the Technical University of Munich. It offers a wide range of programmes and resources to support entrepreneurs, start-ups, and innovation projects. This includes incubators, accelerator programmes, advisory services, and access to networks and resources for promoting innovation and entrepreneurship in the Munich region. It plays a significant role in the Bavarian start-up scene where it contributes to promoting technology, innovation, and entrepreneurship (UnternehmerTUM, 2023[65]).

EXIST is considered a successful programme, but the application process is regarded as long, cumbersome and too centralised. The programme has two application rounds per year (in January and July). Interviews participants advocated for a more decentralised approach, that would count on universities for the screening and evaluation of proposals. EXIST is also limited to the early stages of start-ups growth.

Like other countries, the most significant gaps for financial support pertain to later growth stages – the so-called "valley of death". This is due to limited development of risk capital market in Germany. Furthermore, interviewees highlighted that public procurement rules are unfavourable for start-ups, leading to lower exposure to innovative AI solutions for the public sector and preventing them from accessing a market which could support their growth.

Figure 4.9. German AI start-ups rely on cash flows and contributions from owners rather than VC

Importance of different funding sources for financing AI start-ups, share of all AI start-ups in percentages, 2023



Source: Rammer, C. (2023[60]), *Das Ökosystem für KIStartups. Vermarktung, Finanzierung, Fachkräfte und Vernetzung in Unternehmensgrün dungen im Bereich Künstliche Intelligenz*, https://www.zew.de/publikationen/das-oekosystem-fuer-ki-startups-in-deutschland-vermarktung-finanzierung-fachkraefte-und-vernetzung-in-unternehmensgruendungen-im-bereich-kuenstliche-intelligenz (accessed on 17 October 2023).

Although innovative start-ups are already providing solutions to the public sector (see Chapter 8), there is unexploited potential, as also recognised by the 2022 Start-up Strategy (BMWK, 2022[66]). The strategy highlights both the needs to make public procurers more aware of the existing opportunities for innovative procurements in the public procurement law, and to encourage start-ups to make greater use of these opportunities.

Germany has recognised the strategic importance of innovation procurement in the national policy frameworks for public procurement, innovation, and R&D (PwC, 2020[67]). In 2009, Germany implemented a legal change in its procurement framework to allow government agencies to specify innovative aspects of procured products as selection criteria in tender calls. However, innovation-promoting instruments are only partially known in public procurement organisations, and often, a lack of market knowledge makes it difficult to prepare tenders. Furthermore, requirements for suitability are often high in terms of turnover, references, number of employees and other criteria (BMWK, 2023[68]). The Competence Centre for Innovative Procurement (KOINNO) is the most crucial actor at the national level supporting innovation procurement policy implementation. KOINNO offers tools and specific consultancy services to public institutions for innovative management and innovative products. While providing guidance to public entities is a positive step to increase the public procurement of AI-driven innovations, there may room to analyse further which factors prevent start-ups from further participating in public calls and explore options for revising some requirements.

Germany could leverage a number of channels to increase VC funding availability in the country, as recommended in the 2022 OECD Review of Innovation Policy in Germany (Box 4.3). Additionally, to cater to AI start-ups' needs, the federal government could establish a dedicated fund to support science-based start-ups on the model of the Deep Tech plan in France. Launched in 2019 with a budget of EUR 3 billion spanning from 2019 to 2025 and overseen by the French Public Investment Bank (*Banque publique d'investissement*, BPI), the Deep Tech plan supports the creation and growth of deep tech start-ups, as well as the regional and sectoral innovation ecosystems. As of 2022, the plan facilitated the creation of 870 deeptech start-ups, for a total funding of EUR 2 billion. In 2022, resources allocated to the Deep Tech plan have been increased through the France 2030 programme, to add EUR 500 million. Another EUR 100 million fund dedicated to deep tech will provide equity support to start-ups at various stages of development (Bpifrance, 2023[69]; Ministre de l'Économie, des Finances et de la Souveraineté industrielle et numérique, 2023[70]).

Box 4.3. How to promote financial markets that are conducive to scaling up breakthrough innovations?

Recommendations from the 2022 OECD Review of Innovation Policy

- **Revisit the legal framework for German capital-collecting institutions to encourage investment in risky innovation.** The federal government should consider requiring institutional funds to allocate a percentage to VC or private equity funds for innovative firms. For example, German pension funds, insurance companies and public financing organisations provide very little risk capital, even though they are among the only sources that could provide the levels of funding (including investments in private companies through VC funds and investments in listed companies) that are necessary to scale the most promising innovations. Another approach might be to facilitate employee stock-ownership plans.
- **Expand tax incentives, especially those that allow private investors to offset capital losses against other income, or to exempt future profits when investing in the VC asset class**. Such incentives should apply to both the VC segment (pre-initial public offerings) and investment through the stock market (development and growth financing). France and the UK, for example, each have six different tax-incentives to improve the supply of private capital for VC markets.
- **The federal government should support the development of financial instruments at the EU level that would help scale and retain innovative firms**. The volume of finance necessary to scale some of the most promising firms is often available neither in Germany nor within the EU, meaning that firms regularly move to countries where finance is more easily available, such

as the UK or the US. The German government should advocate the establishment of EU-level private equity development for investment in pre-public technology and digital innovators. The Federal Agency for Disruptive Innovation (*Bundesagentur für Sprunginnovationen*, SPRIND) could play a more prominent role in developing a domestic VC market for higher-risk investments.

Source: OECD (2022[71]), *OECD Reviews of Innovation Policy: Germany 2022: Building Agility for Successful Transitions*, https://doi.org/10.1787/50b32331-en.

Recommendations for AI transfer to SMEs and start-ups

Improve the visibility of government programmes supporting AI application by SMEs

Germany is implementing many programmes to develop and integrate AI in business. However, targeted beneficiaries may not be aware of the programmes or find it challenging to navigate the opportunities. To increase awareness and user-friendliness, the platform that centralises government offers, *Lernende Systeme*, could be improved to offer a more interactive experience. For instance, it could include a self-assessment tool for firms to their level of AI readiness, define their needs, and be directed to the most fitting support initiative. The platform could also maintain an open and searchable catalogue of AI success stories, applications, and use cases with information on the economic impact of AI to help firms grasp what they can achieve.

Develop regulatory guidance to foster AI implementation

To give SMEs confidence in adopting AI, data protection authorities should provide clear regulatory guidelines and advice on technologies for the ethical and responsible use of data. In this regard, their mandate should include supporting innovative players towards compliance with GDPR. Regulatory guidance should also be provided with respects to provisions applicable to data identified as trade secrets. The federal government, in collaboration with business associations, should also implement programmes to provide guidance on the implementation of the EU AI Act.

Increase the availability of public open data, support firms in improving their data maturity, and promote data-sharing initiatives to help SMEs access quality data

Availability of and access to open and industrial data have emerged as bottlenecks for AI development. The federal government could introduce and enforce legislation that mandates government agencies at all levels to publish non-sensitive data in open formats. This will make a wide range of information available for training AI models on German content. Programmes supporting SMEs in transfer activities could strengthen their focus on improving data maturity in firms. Support could be accompanied by collaboration with research or government entities to assist SMEs in sharing, accessing and using data from sectoral data spaces. Establishing data quality standards could help SMEs ensure that shared data are reliable and accurate and comply with legislation.

Revise tax incentives, strengthen R&D grants and introduce vouchers to support AI uptake by SMEs

Germany is implementing programmes to foster the development and integration of AI within business. However, these initiatives, particularly those providing grants for AI R&D, face high demand and are unable to meet the needs of many SMEs. There is an opportunity to allocate additional resources to reinforce

support for SMEs engaged in AI research, development, and implementation in co-operation with research partners or start-ups. Financial support could be provided through tax policies. Germany could consider revising existing tax incentives, tailoring them specifically to businesses investing in AI technologies. This could include tax credits for AI research expenditures, training to enhance AI and data-related skills, or investment to improve data maturity. Furthermore, given generative AI's potential to enhance productivity, the federal government could consider establishing vouchers of modest amounts (e.g. EUR 5 000-10 000) to support SMEs' collaborations with advisors and consultants to tailor generative AI solutions to their businesses.

Improve access to financing for AI start-ups

While public support to new and small firms is available and effective in pre-seed and seed rounds, AI start-ups face challenges accessing capital to scale up. The availability of VC could be increased by revisiting the legal framework for capital-collecting institutions. For instance, institutional funds, like pension funds and insurance companies, could be required to allocate a percentage to VC or private equity for innovative firms. To mobilise corporate financing, the federal government could introduce and expand tax incentives, allowing private investors to offset capital losses against other income or providing exemptions for future profits when investing in the VC asset class. Moreover, public support could be enhanced by establishing a targeted funding programme to boost AI start-ups in their growth phase. Such a programme should prioritise science-based projects that demonstrate the potential to bring significant technological advancements and economic benefits.

Revise and simplify public procurement procedures to ensure that start-ups and established companies have equal access to opportunities

Access to public procurement contracts could provide AI start-ups with a market for their products and services. However, public procurement organisations only partially employ innovation-promoting instruments, and their requirements are often high in terms of turnover, references, number of employees, and other criteria. The federal government should provide guidelines to ensure that start-ups – particularly those with science-based innovations – have equal access to procurement opportunities alongside established companies. Furthermore, the federal government should analyse what factors prevent start-ups from participating in public calls and explore ways to revise some requirements.

AI infrastructure

As a key player in AI research and development, Germany is advancing its AI capabilities by investing in AI compute, which involves specialised hardware and software stacks. The country's strategic investment in modernising computing infrastructure and participating in the Gaia-X project reflects its commitment to enhancing AI applications and data sharing.

Germany's national AI strategy focuses on boosting compute infrastructure, especially for research and academia, and promoting data access

Along with data and algorithms, AI infrastructure, also known as "AI compute" is a substantial component of AI development. It is expected to drive and improve AI's capabilities over time. It is distinct from other AI inputs like data or algorithms because it is grounded in "stacks" or layers of physical infrastructure and hardware, along with AI-specific software (OECD, 2023[72]). Advancements in AI compute have enabled a transition from general-purpose processors, such as central processing units (CPUs), to specialised hardware requiring less energy for more computations per unit of time. Today, advanced AI is predominantly trained on specialised hardware optimised for certain types of operations, such as graphics

processing units (GPUs), Tensor Processing Units, and others. Advanced AI research is becoming more computationally intensive and expensive, and many countries do not have the AI compute capacity to implement their national AI strategies. The demand for AI compute has grown dramatically, especially for deep learning neural networks. Securing specialised hardware purpose-built for AI can be challenging due to complex supply chains, as illustrated by bottlenecks in the semiconductor industry (Khan, Mann and Peterson, 2021[73]).

The 2018 German national AI strategy and the 2020 update include significant investments in AI computing infrastructure. Namely, the strategies commit significant investments to develop advanced AI infrastructure to support national scientific, R&D, and academic applications, and to facilitate data sharing and use. The 2020 strategy update puts forward an AI Made in Europe approach, outlining various initiatives including modernising existing supercomputing infrastructure and increasing computing capacity through new ones. The strategy allocates EUR 512 million towards developing data infrastructure and supporting the Gaia-X project. These investments aim to provide more data from previously inaccessible data pools, to bolster Germany's AI centres of excellence and align them with regional AI application hubs (German Federal Government, 2020[1]).

According to the German Data Centre Association, the demand for AI infrastructure and services is growing in Germany, with many AI applications requiring infrastructure with high security and data protection requirements. Accordingly, the industry association notes in its 2023-24 German Datacentre Outlook that many companies plan to install related capacity in Germany in the years ahead (GDA, 2023[74]).

Germany's strategic approach to AI computing infrastructure focuses on building modern infrastructure to support research excellence. The commitment to modernising existing German AI infrastructure includes undertaking the accelerated expansion of the Gauss Centre for Supercomputing to exascale capability, along with investments in high-performance computing capacity jointly with relevant *Länder*, to support scientific, research, and academic applications. Germany's national computing capacity for AI is also bolstered by a significant country-wide network of universities and research institutes, that have invested in computing infrastructure for their students and researchers. Germany's strategic approach also includes cloud initiatives, namely the commitment to establish a high-performance and secure federated data infrastructure to support interoperable data sharing through the project Gaia-X (German Federal Government, 2020[1]).

Germany has world-class computing infrastructure for research and academia

Germany is starting from a leading position in computing infrastructure for research and academia, anchored by the Gauss Centre for Supercomputing (Box 4.4), in addition to infrastructure embedded within research institutes and universities. Although this infrastructure is not all AI-specific, much of its advanced capabilities are transferrable to AI applications. The Gauss Centre combines the three largest national supercomputing centres in Germany into a network of leading supercomputing infrastructure, comprised of the High-Performance Computing Centre Stuttgart (*Höchstleistungsrechenzentrum Stuttgart*, HLRS) in Stuttgart, the JSC in Jülich and the Leibniz Supercomputing Centre (LRZ) in Munich. They are supported by funding from the federal government, namely for infrastructure modernisation and expansion, and by the Länder for operating costs. The German AI strategy commits to upgrading the Gauss Centre to exascale capability, including the provision of GPUs, specialised hardware used to train AI systems.

While the Gauss Centre offers leading supercomputing capacity, such infrastructure is not solely dedicated for AI workloads. Users of the Gauss Centre include research consortia and students, in addition to private sector firms and industry partners that apply to use such infrastructure as a consortium, often requiring partnership with research institutions or universities who submit the project applications. While it is possible for private sector partners such as start-ups, SMEs, and large companies to use the Gauss Centre infrastructure alone or as part of a research consortia, the systems are used primarily for pre-commercial research purposes. Currently, research outcomes stemming from such partnerships cannot be used for

commercial purposes, pointing to challenges for transferring AI research findings into commercial applications. Accessing the Gauss Centre's infrastructure can also be challenging, with a high degree of documentation and review required to receive project approval, for example the requirement to form a consortium, often with users encountering long project approval wait times.

Box 4.4. The Gauss Centre for Supercomputing

Three supercomputing centres anchor Germany's excellence in computing infrastructure

The Gauss Centre for Supercomputing combines the three largest national supercomputing centres in Germany into the country's leading supercomputing institution: the HLRS, the JSC, and the LRZ.

The HLRS centre in Stuttgart is a research and service institution affiliated to the University of Stuttgart offering services to academic users and industry focusing on high-performance computing systems, teaching and training, and national and international research collaboration.

The JSC centre located in Jülich is one of the largest interdisciplinary research centres in Europe, providing high-performance capacity for scientists at national and international universities and research laboratories, as well as for industrial partners. The JSC centre offers services to assist with the operation of high-performance computing infrastructure, including data storage, visualisation systems, networks and software, and user support and training. Project applications to access JSC's infrastructure involve a scientific peer review process undertaken by the John von Neumann Institute for Computing. In 2024, one of the world's fastest supercomputers, JUPITER, is expected to become operational at JSC. It will be one of the most powerful supercomputers for AI applications and is expected to be made accessible to SMEs and start-ups as part of the new European High-Performance Computing initiative aiming to increase compute access across Europe's AI ecosystem.

The LRZ centre in Munich provides world-class high-performance computing infrastructure to the scientific community ranging from life sciences to astrophysics. Efforts are made to run the centre's operations in the most energy-efficient way. The LRZ focuses on developing capabilities for next-generation computing, including research on emerging technologies like quantum computing and integrating AI into large-scale high-performance computing systems. It offers education programmes for high-performance computing, including in machine learning. In addition to its role as national supercomputing centre, the LRZ is the IT service provider for all universities in Munich, as well as research organisations throughout Bavaria.

Source: GCS (2023[75]), *Our Centres*, Gauss Centre for Supercomputing, https://www.gauss-centre.eu/about-us/our-centres; EuroHPC (2023[76]), *Discover EuroHPC JU*, https://eurohpc-ju.europa.eu/about/discover-eurohpc-ju_en; JSC (2024[77]), *JUPITER - The Arrival of Exascale in Europe*, https://www.fz-juelich.de/en/ias/jsc/jupiter.

The Gauss Centre is also a key partner in the European High Performance Computing Joint Undertaking (EuroHPC), a EU initiative created in 2018 with a budget of about EUR 7 billion for 2021 27. While Germany participates as a key partner in the EuroHPC supercomputing network, the network also provides a means for German researchers, scientists, and academics to access greater computing capacity Europe-wide, contributing to Europe's excellence in research and academia. As with the Gauss Network, EuroHPC's infrastructure is traditionally used for scientific, research, and academic applications that are not of a commercial nature.

Traditionally, only some of EuroHPC's infrastructure is used for AI applications, despite growing demand for infrastructure to support AI-related projects in recent years. This has prompted a shift in EuroHPC's eligibility requirements. As of November 2023, the European Commission committed to widening access to EuroHPC's infrastructure for European AI start-ups, SMEs, and the broader AI community as part of the EU AI Start-Up Initiative. This aims to support the further development and scalability of AI models in Europe by facilitating access to powerful supercomputers for AI training and testing, with the aim of "reducing training time from months or years to a matter of weeks" (European Commission, 2023[78]). In January 2024, the European Commission also announced several policy changes targeting the facilitation of AI compute capacity to firms across Europe, including start-ups and SMEs. This includes an amendment to the EuroHPC Regulation to set up AI Factories, a new pillar for the program, in addition to other initiatives (European Commission, 2024[79]).

Widening infrastructure access requirements to the broader AI community could help ensure German AI start-ups and SMEs are able to leverage existing world-class infrastructure for AI research and commercial applications across Europe, including infrastructure suitable for AI workloads found at the Gauss Centre. EuroHPC has also launched a new Research and Innovation call to establish a European support centre to assist European AI users in finding supercomputing capacity. When implemented, such a support centre could also help to connect those in the German AI ecosystem looking for AI compute resources with relevant infrastructure, services, and support located across Europe (EuroHPC, 2023[80]).

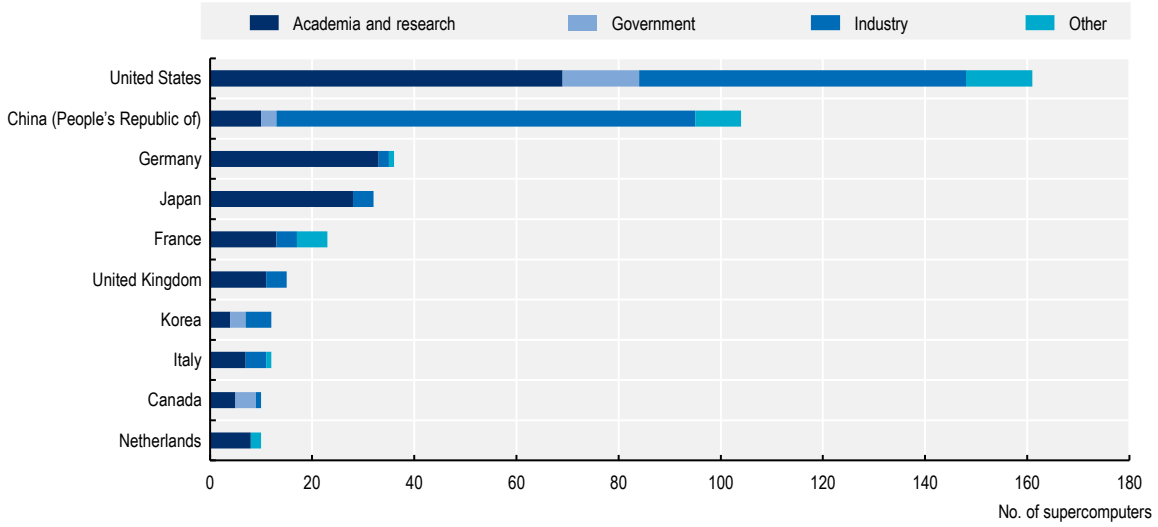
Germany's excellence in AI research is anchored in public sector institutions like leading universities and related research institutes. This contrasts to other jurisdictions, namely the US, where leading AI research is increasingly conducted through the private sector, or privately funded, led by large technology companies. This illustrates how compute divides within countries could emerge or worsen, namely between the public and private sectors, regarding which groups have access to the compute capacity and wider human and financial resources required to conduct advanced AI research (OECD, 2023[72]).

When benchmarked internationally, Germany ranks high in terms of national supercomputing capacity, namely for computing applications in science, research, and academia. According to the November 2023 Top500[2] list – a voluntary ranking of supercomputers globally – Germany ranks third of 35 countries for the highest number of top supercomputers (having 36 supercomputers, after the US at 161 and China at 104), with nearly all national computing capacity supporting academia and research applications (Figure 4.10). Although supercomputers are increasingly being updated with specialised infrastructure to enable the efficient execution of AI-specific workloads, the Top500 list does not distinguish supercomputers according to workload capacity specialised for AI. Thus, analysis of the Top500 list can only serve as a proxy measure for national compute capacity between countries, with the caveat that such infrastructure is not necessarily used solely for AI purposes and some countries have not consistently submitted results to the voluntary ranking in recent years.

A simple count of Top500 list does not reveal the full picture of which economies hold the greatest supercomputing capacity, as this treats different supercomputers as if they were the same despite significant variations in supercomputer speed and performance (OECD, 2023[72]). Germany's leadership position in computing infrastructure is notable for research and academic applications, in terms of the number of supercomputers, but also in terms of performance. For example, Germany ranks second in the number of supercomputers for academia and research (33), after the US (69) and followed by Japan (28), France (13), the UK (11), China (10), Italy (7), Canada (5), Australia (5), and Sweden (5) (Figure 4.11). When it comes to supercomputer performance for academia and research applications as measured by Rmax – a computer's maximum achieved performance – Germany still ranks high at fifth place (Figure 4.12), notably ahead of China and behind Finland (which houses the powerful LUMI supercomputer as part of the EuroHPC network) and the US. This indicates that Germany's supercomputers for research and academia have comparatively high performance (as measured by Rmax).

Figure 4.10. Germany has the third most supercomputers on the Top500 list, with nearly all national computing capacity supporting academia and research applications

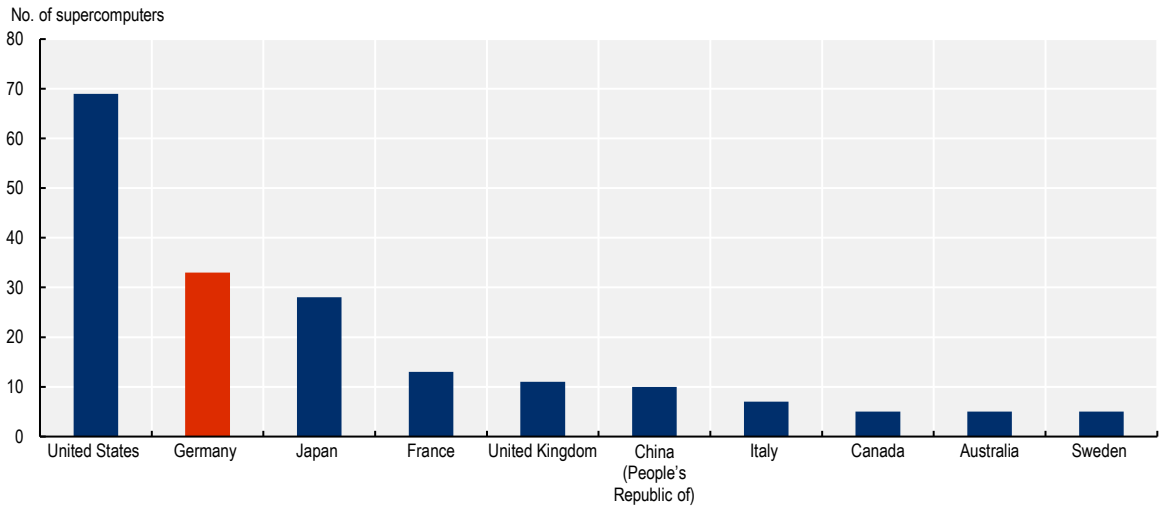
By economy and sector, top ten ranking economies, November 2023



Notes: Only the top ten economies are pictured out of 35 economies appearing on the November 2023 Top500. The Top500 is released twice a year authored by Jack Dongarra, Martin Meuer, Horst Simon, and Erich Strohmaier. Contributions to the list are voluntary, posing methodological challenges as some countries have not consistently submitted results in recent years. This figure should be taken only as a preliminary and directional proxy metric for national AI compute capacity and several caveats should be underlined. It does not distinguish supercomputers according to workload capacity specialised for AI. In addition, as workloads cannot be run across multiple supercomputers, this measure should be viewed with limitations (e.g. ten supercomputers that add up to the same sum of Rmax as a single supercomputer would not be equivalent).
Source: Figure produced using data from TOP500 (2023[81]), *The List*, https://www.top500.org/ (accessed on 15 November 2023).

Figure 4.11. Germany is in a leading position when it comes to the number of supercomputers for academia and research applications

Number of top supercomputers for academia and research by economy, November 2023



Note: Please see notes in Figure 4.10.
Source: Figure produced using data from TOP500 (2023[81]), *The List*, https://www.top500.org/ (accessed on 15 November 2023).

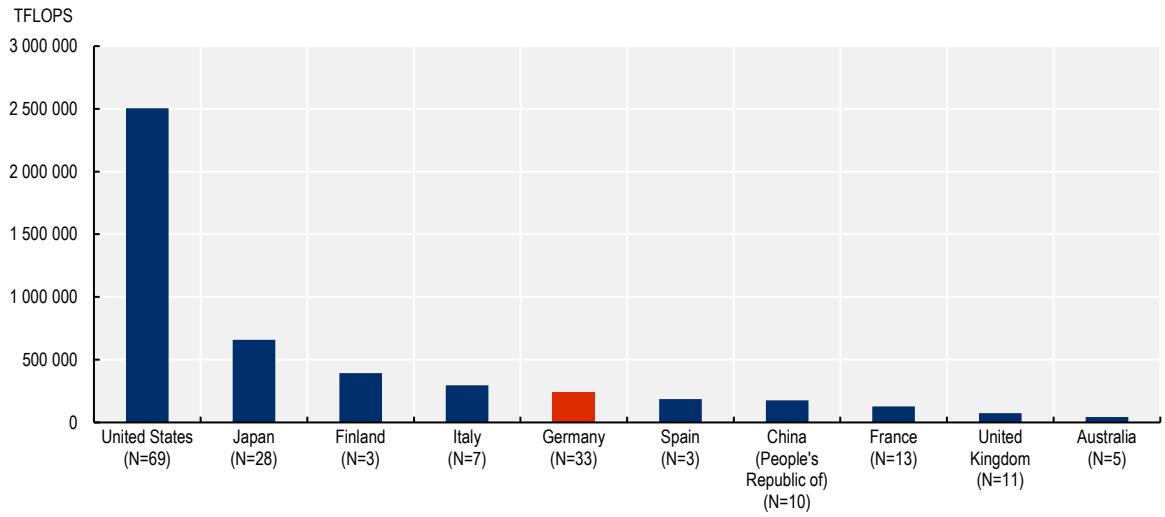
Analysis of the Top500 list conveys Germany's strong position in computing infrastructure for academic and research applications, while pointing to gaps in world-class computing infrastructure available in the government and in industry. For example, both China and the US have notable industry and government capacity contributing to their high ranking on the Top500, whereas Germany has nearly no industry supercomputers on the list, and no supercomputers from government on the ranking (Figure 4.10).

Analysis of global VC investments in German AI compute start-ups – as measured through VC transaction information available on Preqin, according to several keywords[3] – shows that VC investments in AI computing and hardware start-ups have increased in Germany over recent years, from about USD 11 million in 2017, peaking at USD 222 million in 2021, and amounting to approximately USD 138 million in 2023. As with the global VC market, overall VC investments in German AI compute start-ups experienced a significant drop since 2021, reflecting broader VC trends, with investors exercising caution after the technology boom of the COVID-19 pandemic, rising interest rates, and inflationary pressures.

While VC investment trends in AI compute start-ups reflect broader trends in the global VC industry, in 2022 levels of investment in Germany were lower than comparable economies such as Canada, Korea and the UK, but greater than economies like Japan and Spain. VC funding for German AI compute start-ups mostly comes from the German domestic market and the US, with smaller VC contributions also from investors in countries like Austria and the UK (OECD.AI, 2023[64]). This points to the significant role of investors from non-EU countries like the UK and the US in helping to fund and scale German hardware and infrastructure companies, pointing to the possible need to further develop domestic and EU VC markets.

Figure 4.12. Germany's supercomputers for academia and research applications rank fifth in terms of performance

Top500 supercomputers for academia and research by economy ranked by total Rmax, a computer's maximum achieved performance, November 2023



Notes: Please see notes in Figure 4.10. TFLOPS stands for teraFLOPS, a measure of a computer system capable of performing one trillion (10^{12}) floating-point operations per second. The N in brackets following the country name refers to the number of supercomputers dedicated to academia and research applications listed for that country on the Top500 November 2023 list.
Source: Figure produced using data from TOP500 (2023[81]), *The List*, https://www.top500.org/ (accessed on 15 November 2023).

Germany competes for specialised skills to use AI infrastructure efficiently and effectively

Specialised skills, often engineers or those with technical hardware expertise, are needed to use AI compute resources efficiently and effectively. However, with companies globally competing to attract the top AI talent, and considering the increasing compute demands of AI workloads and the evolving AI compute hardware stack, skilled labour specialised in AI infrastructure is a bottleneck globally (OECD, 2023[72]). Following global trends, analysis of the number of jobs postings in Germany containing AI compute related keywords has more than doubled, from about 12% of total IT jobs postings in 2019 to about 25% in 2023 (OECD.AI, 2024[82]). This indicates an increase in the demand for AI compute related skills in recent years. Such skills are currently acquired through university courses, at research institutes, and through on-the-job training. Interviews with those working in Germany's AI ecosystem pointed to a specialised talent gap for operating AI infrastructure efficiently and effectively. Some suggested the need for access to skilled labour in tandem with access to computing time.

Germany's AI strategy aims to support cloud and data infrastructure initiatives

While world-class infrastructure exists in Germany to support research and academia, businesses rely heavily on hyperscale cloud providers for their AI compute capacity – typically from companies based in the US. Analysis of the German AI start-up ecosystem shows that only 7% of AI start-ups use public compute infrastructure, while 84% of AI start-ups use cloud compute infrastructure from private providers (Rammer, 2023[60]). When it comes to sovereign cloud compute options in Germany, such options can be limited as they are often not available, not very user friendly, or not cost competitive compared to the capacity offered by large foreign companies. Reliance on foreign cloud providers, and lower levels of digital adoption in more traditional industrial sectors, as well as concerns about data protection and privacy, may play a role in the low level of cloud adoption by enterprises. For example, while Germany (10.3%) ranked around the EU27 average (9.8%) in 2021 for enterprises purchasing cloud computing to run their own software, they ranked lower than other leading cloud adopters (Sweden 32.2%, Denmark 28.1%, Norway 25.3%) (Eurostat, 2023[2]).

Gaia-X is highlighted in the 2020 update to the German AI Strategy and the platform has matured to include a German Gaia-X hub and various data listed in a federated catalogue (Gaia-X, 2021[83]). The vision for Gaia-X is to establish a decentralised and interoperable data exchange for business and research partners to share data and access services at scale. The BMWK funds several projects that feature AI as part of a Gaia-X Funding Competition, for example, Gaia-X 4 Future Mobility, Autowerkstatt 4.0, Cooperants, EuProGigant, Merlot and OpenGPT-X. Funding for the competition is approximately EUR 117 million between 2021 and 2024.

While the federal government funds relevant AI projects as part of Gaia-X, and the German Gaia-X Hub is active, it is largely not plugged into the German AI ecosystem, with awareness about this initiative remaining low. Information on the types of datasets and users related to AI are not tracked, pointing to a gap in KPIs that could help to inform Germany's AI policy.

Germany has numerous high-performance supercomputers that could be used for AI, though computing accessibility needs to be assessed

Many national AI policy initiatives do not include detailed measures of AI infrastructure corresponding to the needs of AI actors along the innovation continuum, focusing instead on general-purpose compute. Translating the AI ambitions contained in national AI strategies into more concrete considerations – such as reviewing current (and forecasting future) national AI infrastructure and the compute needs of public and private sector actors – would enable more efficient and targeted planning of AI infrastructure investments. Consideration should also be given to measuring whether national AI compute is owned

domestically or rented from providers abroad, such as through cloud compute providers. Based on national needs, data localisation requirements, and security priorities, attention to building out domestic or regionally owned on-premise and/or cloud compute capacity could be warranted (OECD, 2023[72]).

Some countries are undertaking initiatives to increase the AI infrastructure available for research and academia, in addition to taking stock of their national AI infrastructure needs. Canada's Pan-Canadian AI Strategy (2017, 2021) leverages a national network of AI research institutes and supports the acquisition of high-performance computing capacity for AI research. In 2020, the first Canadian Digital Research Infrastructure Needs Assessment was launched to identify future digital research infrastructure and service needs (Digital Research Alliance of Canada, 2020[84]). In 2022, the UK conducted the Future of Compute review to examine its digital research infrastructure needs, including for AI, calling for an integrated compute ecosystem and significant investment in public AI infrastructure (Alan Turing Institute, 2022[85]). The US aims to make world-class computing resources and datasets available to researchers through the proposed National AI Research Resource. Initiatives also exist further up the AI infrastructure supply chain, for example Korea's K-Cloud Project aims to manufacture and deploy world-class AI chips domestically, to provide improved national cloud computing infrastructure.

While substantial infrastructure exists for academia and research, a needs assessment would further help to identify gaps in the provision of AI infrastructure along the innovation continuum in Germany, mapping capacity across the public and private sectors. The AI needs and readiness of different sectors in Germany such as the private sector, public sector, SMEs, start-ups, researchers, and others, should be explicitly considered in an AI compute plan, with future forecasts included where possible.

Recommendations for AI infrastructure

Create a more inclusive, accessible, and expert-guided ecosystem for AI infrastructure in Germany

Germany's national AI strategy emphasises computing infrastructure, especially for research and academia, and promoting data access. Supported by these investments, Germany established world-class computing infrastructure for research and academia. Based on the above findings, Germany could undertake actions to create a more inclusive, accessible, and expert-guided ecosystem for its national AI infrastructure.

Map supply and demand for AI compute infrastructure

In line with international best practice, Germany should assess its current AI compute infrastructure landscape and needs to gauge existing capacity and potential gaps in meeting demand from stakeholders – including research institutions, businesses, SMEs, and start-ups – against the supply of AI-fit infrastructure, from both the public and private sector. This analysis should also forecast anticipated AI compute infrastructure needs to the extent possible. Expert-informed OECD work such as *A Blueprint for Building National Compute Capacity for Artificial Intelligence* (2023[72]) could guide such analysis.

Increase infrastructure access for start-ups and SMEs

Germany should designate a portion of its AI compute infrastructure to start-ups and SMEs, with a streamlined application process and reduced administrative barriers. Incentives could also be explored to promote partnerships to share AI compute infrastructure between large companies possessing AI infrastructure, and smaller start-ups and SMEs without such capacity.

Provide support beyond compute time

Germany should expand the scope of support services to encompass allocation of AI compute infrastructure resources (e.g. from public compute infrastructure) and include technical assistance and advice on the effective and efficient use of such infrastructure. This could be done through dedicated programmes offering expertise and training in the effective and efficient use of AI compute infrastructure, which could include university courses, workshops, seminars, a community of experts, and partnerships with the private sector.

Raise awareness about Gaia-X in the AI community and track key datasets for AI

The German government and Gaia-X Hub should increase awareness about Gaia-X in the AI ecosystem, such as by sharing information and organising presentations with German AI accelerators and incubators, universities, research institutes, and the private sector. An assessment should be conducted of Gaia-X datasets that are of particularly high value for AI, and these should be labelled so that those in the AI ecosystem can easily find them. Information on the types of Gaia-X datasets and users related to AI should also be tracked, to develop AI-related KPIs to inform future AI policy making.

References

AKI (2023), *Large European AI Models - Feasibility Study*, Akademie für Künstliche Intelligenz gGmbH, https://leam.ai/wp-content/uploads/2023/05/LEAM-Feasibility-STudy.pdf. [34]

Alan Turing Institute (2022), *UK AI Research Infrastructure Requirements Review*, https://www.turing.ac.uk/work-turing/uk-ai-research-infrastructure-requirements-review. [85]

bitkom (2023), "Deutsche Wirtschaft drückt bei Künstlicher Intelligenz aufs Tempo [German industry is pressing ahead with artificial intelligence]", https://www.bitkom.org/Presse/Presseinformation/Deutsche-Wirtschaft-drueckt-bei-Kuenstlicher-Intelligenz-aufs-Tempo. [5]

BMAS (2022), *ESF Plus-Programm "Zukunftszentren"*, Bundesministerium für Arbeit und Soziales, https://www.bmas.de/DE/Arbeit/Digitalisierung-der-Arbeitswelt/Austausch-mit-der-betrieblichen-Praxis/Zukunftszentren/zukunftszentren.html (accessed on 11 December 2023). [53]

BMBF (2023), *Action Plan on Robotics Research*, Bundesministerium für Bildung und Forschung, https://www.bmbf.de/bmbf/de/forschung/digitale-wirtschaft-und-gesellschaft/robotik/aktionsplan-robotik.html (accessed on 11 December 2023). [30]

BMBF (2022), "Förderung von vier KI-Servicezentren gestartet [Funding launched for four AI service centres]", Bundesministerium für Bildung und Forschung, https://www.bmbf.de/bmbf/shareddocs/kurzmeldungen/de/2022/11/foerderung-von-4-ki-zentren-gestartet.html (accessed on 4 December 2023). [47]

BMBF (2020), "Richtlinie zur Förderung von Projekten zum Thema „Erforschung, Entwicklung und Nutzung von Methoden der Künstlichen Intelligenz in KMU [Announcement of the guideline for the funding of projects on the topic of R&D and use of AI methods in SMEs]", Bundesministerium für Bildung und Forschung, https://www.bmbf.de/bmbf/shareddocs/bekanntmachungen/de/2020/03/2876_bekanntmachung.html (accessed on 11 December 2023). [46]

BMWi (2020), *Förderbekanntmachung für ein bundesweites „Netzwerk Mittelstand-Digital“*, Bundesministerium für Wirtschaft und Energie, https://www.mittelstand-digital.de/MD/Redaktion/DE/PDF-Anlagen/foerderbekanntmachung-m-d.pdf?__blob=publicationFile&v=2 (accessed on 24 October 2023). [49]

BMWi (2016), *Digitale Strategie 2025*, Bundesministerium für Wirtschaft und Energie, https://www.bmwk.de/Redaktion/DE/Publikationen/Digitale-Welt/digitale-strategie-2025.pdf?__blob=publicationFile&v=1 (accessed on 24 October 2023). [48]

BMWK (2023), “Die Zentren im Netzwerk Mittelstand-Digital unterstützen vor Or”, Bundesministerium für Wirtschaft und Klimaschutz, https://www.mittelstand-digital.de/MD/Redaktion/DE/Artikel/Mittelstand-4-0/mittelstand-40-kompetenzzentren.html (accessed on 24 October 2023). [51]

BMWK (2023), *KI Trainer*, Bundesministerium für Wirtschaft und Klimaschutz, https://www.mittelstand-digital.de/MD/Navigation/DE/Praxis/KI-Trainer/ki-trainer.html (accessed on 24 October 2023). [50]

BMWK (2023), *KOINNO and the Startup Strategy of the Federal Government*, Federal Ministry for Economic Affairs and Climate Action, https://www.koinno-bmwk.de/en/information/news/detail/koinno-und-die-startup-strategie-der-bundesregierung/ (accessed on 5 December 2023). [68]

BMWK (2022), *Start-up Strategy*, Bundesministerium für Wirtschaft und Klimaschutz, https://www.bmwk.de/Redaktion/DE/Publikationen/Existenzgruendung/start-up-strategie-der-bundesregierung.html (accessed on 11 December 2023). [66]

Bpifrance (2023), “Bilan du Plan Deeptech à 4 ans : doublement du nombre de startups deeptech créées entre 2018 et 2022 [Review of the 4-year Deeptech Plan: Doubling the number of deeptech startups created between 2018 and 2022]”, https://presse.bpifrance.fr/bilan-du-plan-deeptech-a-4-ans-doublement-du-nombre-de-startups-deeptech-creees-entre-2018-et-2022/ (accessed on 20 October 2023). [69]

Briggs, J. and D. Kodnani (2023), “The potentially large effects of artificial intelligence on economic growth”, Goldman Sachs, https://www.gspublishing.com/content/research/en/reports/2023/03/27/d64e052b-0f6e-45d7-967b-d7be35fabd16.html#. [19]

Brynjolfsson, E., D. Li and L. Ray (2023), “Generative AI at work”*, NBER Working Paper Series*, No. 31161, National Bureau of Economic Research, https://doi.org/10.3386/w31161. [24]

Calvino, F. and L. Fontanelli (2023), “A portrait of AI adopters across countries: Firm characteristics, assets’ complementarities and productivity”*, OECD Science, Technology and Industry Working Papers*, No. 2023/02, OECD Publishing, Paris, https://doi.org/10.1787/0fb79bb9-en. [16]

Capgemini (2023), *Harnessing the Value of Generative AI: Top Use Cases across Industries*, Capgemini Research Institute, https://prod.ucwe.capgemini.com/wp-content/uploads/2023/07/Final-Web-Version-Report-Harnessing-the-Value-of-Gen-AI.1.pdf. [13]

Capgemini (2019), *Accelerating Automotive’s AI Transformation: How Driving AI Enterprise-wide Can Turbo-charge Organizational Value*, https://www.capgemini.com/wp-content/uploads/2019/03/30-min-%E2%80%93-Report-3-11-1.pdf. [12]

Dell'Acqua, F. et al. (2023), "Navigating the jagged technological frontier: Field experimental evidence of the effects of AI on knowledge worker productivity and quality", *Harvard Business School Technology & Operations Mgt. Unit Working Paper*, No. 24-013, https://doi.org/10.2139/ssrn.4573321. [22]

Dernis, H. et al. (2023), "Identifying artificial intelligence actors using online data", *OECD Science, Technology and Industry Working Papers*, No. 2023/01, OECD Publishing, Paris, https://doi.org/10.1787/1f5307e7-en. [61]

DFKI (2023), *Company Profile*, German Research Center for Artificial Intelligence, https://www.dfki.de/fileadmin/user_upload/DFKI/Medienhttps://www.dfki.de/en/web/about-us/dfki-at-a-glance/company-profile (accessed on 11 December 2023). [57]

Digital Research Alliance of Canada (2020), *Canadian Digital Research Infrastructure Needs Assessment*, https://alliancecan.ca/en/initiatives/canadian-digital-research-infrastructure-needs-assessment (accessed on 11 December 2023). [84]

DIHK (2023), *Digitale Innovationen, Technologien und Produkte*, https://www.dihk.de/de/themen-und-positionen/wirtschaft-digital/digitalisierung/digitalisierungsumfrage-2023 (accessed on 24 October 2023). [4]

EC (2024), *Data Act*, European Commission, https://digital-strategy.ec.europa.eu/en/policies/data-act. [44]

EC (2022), *European Data Governance Act*, European Commission, https://digital-strategy.ec.europa.eu/en/policies/data-governance-act. [43]

EC (2020), *A European Strategy for Data*, European Commission, https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52020DC0066. [42]

Eisfeldt, A. et al. (2023), "Generative AI and firm values", https://doi.org/10.2139/ssrn.4436627. [20]

Emerj (2022), *Manufacturing AI Use Cases and Trends – An Executive Brief*, https://emerj.com/ai-sector-overviews/manufacturing-ai-use-cases-and-trends-an-executive-brief/ (accessed on 10 January 2023). [39]

EU (2024), *Regulation (EU) 2024/ ..... of the European Parliament and of the Council laying down harmonised rules on artificial intelligence (Artificial Intelligence Act)*, https://data.consilium.europa.eu/doc/document/PE-24-2024-INIT/en/pdf. [36]

EuroHPC (2023), *Discover EuroHPC JU*, European Union, https://eurohpc-ju.europa.eu/about/discover-eurohpc-ju_en (accessed on 11 December 2023). [76]

EuroHPC (2023), "Open call to support HPC-powered artificial intelligence (AI) applications", EuroHPC Joint Undertaking, https://eurohpc-ju.europa.eu/open-call-support-hpc-powered-artificial-intelligence-ai-applications-2023-11-28_en (accessed on 11 December 2023). [80]

European Commission (2024), "Commission launches AI innovation package to support Artificial Intelligence startups and SMEs", European Commission, https://ec.europa.eu/commission/presscorner/detail/en/ip_24_383 (accessed on 11 December 2023). [79]

European Commission (2023), "Commission opens access to EU supercomputers to speed up artificial intelligence development", European Commission, https://ec.europa.eu/commission/presscorner/detail/en/IP_23_5739 (accessed on 11 December 2023). [78]

Eurostat (2023), *Digital Economy and Society Database*, https://ec.europa.eu/eurostat/databrowser/explore/all/science?lang=en&subtheme=isoc&display=list&sort=category (accessed on 16 October 2023). [2]

Eurostat (2023), *Digitalisation in Europe - 2023 Edition*, https://ec.europa.eu/eurostat/web/interactive-publications/digitalisation-2023#technology-uptake-in-businesses (accessed on 6 October 2023). [38]

Fraunhofer-Gesellschaft (2023), *About Fraunhofer*, https://www.fraunhofer.de/en/about-fraunhofer.html (accessed on 17 October 2023). [56]

Gaia-X (2021), *Gaia-X Federation Services (GXFS): Gaia-X Ecosystem Kickstarter*, https://gaia-x.eu/wp-content/uploads/files/2022-01/Gaia-X_Federation_Services_White_Paper_1_December_2021.pdf. [83]

GCS (2023), *Our Centres*, Gauss Centre for Supercomputing, https://www.gauss-centre.eu/about-us/our-centres (accessed on 11 December 2023). [75]

GDA (2023), *Datacentre Outlook Germany 2023-24*, German Datacenter Association e.V., https://www.germandatacenters.com/fileadmin/documents/publications/GDA_Datacenter-Outlook-Germany_23-24.pdf. [74]

German Federal Government (2023), *Fortschritt durch Datennutzung [Progress through Data Utilisation]*, https://www.bmi.bund.de/SharedDocs/downloads/DE/veroeffentlichungen/2023/datenstrategie.pdf;jsessionid=40CF947A91E05F046F50EB305A75F333.live862?__blob=publicationFile&v=3. [45]

German Federal Government (2023), *Kernergebnisse des Digitalisierungsindex 2022*, https://www.de.digital/DIGITAL/Navigation/DE/Lagebild/Digitalisierungsindex/digitalisierungsindex.html (accessed on 16 October 2023). [37]

German Federal Government (2020), *Strategie Künstliche Intelligenz der Bundesregierung - Fortschreibung 2020*, https://www.ki-strategie-deutschland.de/files/downloads/201201_Fortschreibung_KI-Strategie.pdf (accessed on 11 October 2023). [1]

Handelsblatt (2023), "Mercedes holt ChatGPT ins Auto – und will Fehler der KI mit einem Kniff ausschließen [Mercedes brings ChatGPT into the car – and wants to rule out AI errors with a trick]", https://www.handelsblatt.com/technik/it-internet/kuenstliche-intelligenz-mercedes-holt-chatgpt-ins-auto-und-will-fehler-der-ki-mit-einem-kniff-ausschliessen/29209714.html (accessed on 11 December 2023). [32]

ifo Institute (2023), "Artificial intelligence in use at 13.3% of companies in Germany", https://www.ifo.de/en/facts/2023-08-02/artificial-intelligence-use-companies-germany (accessed on 16 October 2023). [3]

IFR (2023), "World Robotics 2023 Report: Asia ahead of Europe and the Americas", International Federation of Robotics, https://ifr.org/ifr-press-releases/news/world-robotics-2023-report-asia-ahead-of-europe-and-the-americas. [29]

JSC (2024), *JUPITER - The Arrival of Exascale in Europe*, Jülich Supercomputing Centre, Forschungszentrum Jülich, https://www.fz-juelich.de/en/ias/jsc/jupiter (accessed on 11 December 2023). [77]

Khan, S., A. Mann and D. Peterson (2021), *The Semiconductor Supply Chain: Assessing National Competititveness*, Center for Security and Emerging Technology, https://cset.georgetown.edu/wp-content/uploads/The-Semiconductor-Supply-Chain-Issue-Brief.pdf. [73]

KI Bundesverband (2023), *KI - Startups und Wissenschaft*, https://ki-verband.de/wp-content/uploads/2023/06/KI-Startups-Wissenschaft.pdf (accessed on 19 October 2023). [62]

KOMKI (2023), "KomKI entwickelt Qualifizierungsbausteine für KMU [KomKI develops qualification modules for SMEs]", https://projekt-komki.de/ (accessed on 11 December 2023). [54]

Lane, M., M. Williams and S. Broecke (2023), "The impact of AI on the workplace: Main findings from the OECD AI surveys of employers and workers", *OECD Social, Employment and Migration Working Papers*, No. 288, OECD Publishing, Paris, https://doi.org/10.1787/ea0a0fe1-en. [15]

Lernende Systeme (2023), *Künstliche Intelligenz in Deutschland [AI in Germany]*, https://www.plattform-lernende-systeme.de/ki-in-deutschland.html (accessed on 11 December 2023). [59]

Lernende Systeme (2021), "KI im Mittelstand [AI in Mittelstand]", https://www.plattform-lernende-systeme.de/aktuelles-newsreader/ki-im-mittelstand-roadmaps-und-praxisbeispiele-fuer-den-einstieg.html (accessed on 11 December 2023). [58]

Lorenz, P., K. Perset and J. Berryhill (2023), "Initial policy considerations for generative artificial intelligence", *OECD Artificial Intelligence Papers*, No. 1, OECD Publishing, Paris, https://doi.org/10.1787/fae2d1e6-en. [27]

Löser, A. et al. (2023), *Große Sprachmodelle entwickeln und anwenden - Ansätze für ein souveränes Vorgehen [Developing and Applying Large Language Models - Approaches for a Sovereign Approach]*, https://www.plattform-lernende-systeme.de/files/Downloads/Publikationen/AG1_WP_Grosse_Sprachmodelle_Anwendungen.pdf. [33]

Markets and Markets (2023), "Influence of generative AI on automotive industry: BMW, Toyota, General Motors leading with AI adoption", https://www.marketsandmarkets.com/industry-news/Influence-Of-Generative-AI-On-Automotive-Industry-BMW-Toyota-General-Motors-leading-With-AI-Adoption (accessed on 11 December 2023). [31]

McElheran, K. et al. (2023), "AI adoption in America: Who, what, and where", *NBER Working Paper Series*, National Bureau of Economic Research, https://doi.org/10.3386/w31788. [8]

McKinsey Global Institute (2023), *The Economic Potential of Generative AI: The Next Productivity Frontier*, McKinsey and Company, https://www.mckinsey.com/capabilities/mckinsey-digital/our-insights/the-economic-potential-of-generative-ai-the-next-productivity-frontier. [18]

Ministre de l'Économie, des Finances et de la Souveraineté industrielle et numérique (2023), "France 2030 : 500 millions d'euros pour donner un élan aux start-up issues de la recherche [France 2030: €500 million to boost research-led start-ups]", https://www.economie.gouv.fr/france-2030-500-millions-deuros-pour-donner-un-elan-aux-start-issues-de-la-recherche (accessed on 20 October 2023). [70]

Mittelstand-Digital (2023), "The network of medium-sized digital centers will focus on artificial intelligence from 2024", https://www.mittelstand-digital.de/MD/Redaktion/DE/Artikel/Themenbuehne/neuausrichtung-mittelstand-digital.html (accessed on 5 December 2023). [52]

Montagnier, P. and I. Ek (2021), "AI measurement in ICT usage surveys: A review", *OECD Digital Economy Papers*, No. 308, OECD Publishing, Paris, https://doi.org/10.1787/72cce754-en. [6]

Noy, S. and W. Zhang (2023), "Experimental evidence on the productivity effects of generative artificial intelligence", https://doi.org/10.2139/ssrn.4375283. [25]

OECD (2023), "A blueprint for building national compute capacity for artificial intelligence", *OECD Digital Economy Papers*, No. 350, OECD Publishing, Paris, https://doi.org/10.1787/876367e3-en. [72]

OECD (2022), *OECD Reviews of Innovation Policy: Germany 2022: Building Agility for Successful Transitions*, OECD Reviews of Innovation Policy, OECD Publishing, Paris, https://doi.org/10.1787/50b32331-en. [71]

OECD.AI (2024), *Demand for IT Skills Related to AI Compute by Country (Adzuna jobs postings)*, OECD, Paris, https://oecd.ai/en/site/compute-climate/data?selectedArea=compute-climate-data&selectedVisualization=demand-for-it-skills-related-to-ai-compute-by-country-2 (accessed on 11 December 2023). [82]

OECD.AI (2023), *VC Investments in AI by Country*, OECD, Paris, https://oecd.ai/en/data?selectedArea=investments-in-ai-and-data&selectedVisualization=vc-investments-in-ai-by-country (accessed on 13 March 2023). [64]

OECD.AI (2023), *Worldwide VC Investments in AI*, OECD, Paris, https://oecd.ai/en/data?selectedArea=investments-in-ai-and-data (accessed on 13 March 2023). [63]

Peng, S., E. Kalliamvakou and P. Cihon (2023), "The impact of AI on developer productivity: Evidence from GitHub Copilot", https://arxiv.org/abs/2302.06590. [23]

Peres, R. et al. (2020), "Industrial artificial intelligence in Industry 4.0 - Systematic review, challenges and outlook", *IEEE Access*, Vol. 8, pp. 220121-220139, https://doi.org/10.1109/ACCESS.2020.3042874. [40]

Plattform Industrie 4.0 (2023), *Manufacturing-X*, https://www.plattform-i40.de/IP/Navigation/EN/Manufacturing-X/Manufacturing-X.html (accessed on 11 December 2023). [41]

PwC (2020), *The Strategic Use of Innovation Procurement in the Digital Economy - Germany Country Report*, European Union, https://www.koinno-bmwk.de/fileadmin/user_upload/EU_Kontaktstelle/Download/de_country_report_12-10-2020_new_cover_v1.pdf. [67]

Rammer, C. (2023), *Das Ökosystem für KI-Startups. Vermarktung, Finanzierung, Fachkräfte und Vernetzung in Unternehmensgründungen im Bereich Künstliche Intelligenz*, https://www.zew.de/publikationen/das-oekosystem-fuer-ki-startups-in-deutschland-vermarktung-finanzierung-fachkraefte-und-vernetzung-in-unternehmensgruendungen-im-bereich-kuenstliche-intelligenz (accessed on 17 October 2023). [60]

Rammer, C. (2021), *Herausforderungen beim Einsatz von Künstlicher Intelligenz*, https://www.zew.de/publikationen/herausforderungen-beim-einsatz-von-kuenstlicher-intelligenz (accessed on 17 October 2023). [35]

Rammer, C., G. Fernandez and D. Czarnitzki (2022), "Artificial intelligence and industrial innovation: Evidence from German firm-level data", *Research Policy*, Vol. 51/104555, https://doi.org/10.1016/j.respol.2022.104555. [17]

Siemens (2023), *Annual Financial Report for Fiscal 2022*, https://assets.new.siemens.com/siemens/assets/api/uuid:19bbc110-8533-46e4-a27e-ec128d1d1434/Annual-Financial-Report-FY2022.pdf. [9]

Siemens (2023), "Siemens presents €2 billion investment strategy to boost future growth, innovation and resilience", https://assets.new.siemens.com/siemens/assets/api/uuid:2a7584b8-9407-401b-af71-5e6edc323baa/HQCOPR202306146727EN.pdf (accessed on 11 December 2023). [10]

Soni, V. (2023), "Impact of generative AI on small and medium enterprises' revenue growth: The moderating role of human, technological, and market factors", *Reviews of Contemporary Business Analytics*, Vol. 6/1, pp. 133-153, https://researchberg.com/index.php/rcba/article/view/169. [21]

Stiftung Mittelstand-Gesellschaft-Verantwortung (2023), "en[AI]ble – Künstliche Intelligenz in kleinen und mittleren Unternehmen präventiv und produktiv implementieren [en[AI]ble - Implementing artificial intelligence in small and medium-sized enterprises preventively and productively]", https://www.stiftung-m-g-v.de/unsere-projekte/enaible-kuenstliche-intelligenz-in-kleinen-und-mittleren-unternehmen-praeventiv-und-produktiv-implementieren (accessed on 11 December 2023). [55]

The Robot Report (2022), "IFR: China surpasses U.S. in robot density", https://www.therobotreport.com/ifr-china-surpasses-u-s-in-robot-density/ (accessed on 11 December 2023). [28]

The Verge (2023), "Mercedes-Benz is the first to bring Level 3 automated driving to the US", https://www.theverge.com/2023/1/27/23572942/mercedes-drive-pilot-level-3-approved-nevada (accessed on 11 December 2023). [14]

TOP500 (2023), *The List*, https://www.top500.org/ (accessed on 15 November 2023). [81]

UnternehmerTUM (2023), *Über uns*, https://www.unternehmertum.de/ueber (accessed on 17 October 2023). [65]

US Census Bureau (2023), "Only 3.8% of businesses use AI to produce goods and services, highest use in information sector", https://www.census.gov/library/stories/2023/11/businesses-use-ai.html (accessed on 6 December 2023). [7]

WEF (2023), *Global Lighthouse Network*, World Economic Forum, https://initiatives.weforum.org/global-lighthouse-network/home (accessed on 11 December 2023). [11]

Zenga, F. et al. (2023), "Large language models for robotics: A survey", https://arxiv.org/pdf/2311.07226.pdf. [26]

Notes

[1] The term "Mittelstand" is a distinctive feature in the German-speaking region, defined by the unity of ownership and management. The size of a company is not decisive for its classification as Mittelstand; rather, qualitative characteristics are key. This unity is characterised by the entrepreneur exerting significant personal influence, bearing entrepreneurial risk, and securing the company as their personal source of income and livelihood. In fact, the majority of SMEs meet the qualitative criteria of the Mittelstand concept, yet large enterprises can also be considered Mittelstand. While the terms Mittelstand, family business, owner-operated business, and family-run businesses are considered synonymous, it is important to note that the terms "Mittelstand" and "small and medium-sized enterprises (SMEs)" are technically not synonymous, even though they are oftentimes used interchangeably.

[2] The Top500 is released twice a year authored by Jack Dongarra, Martin Meuer, Horst Simon, and Erich Strohmaier. Contributions to the list are voluntary, posing methodological challenges as some countries have not consistently submitted results in recent years. Analysis of AI computing infrastructure using the Top500 should be taken only as a preliminary and directional proxy metric and several caveats should be underlined. Although supercomputers are increasingly being updated with specialised infrastructure to enable the efficient execution of AI-specific workloads, the Top500 list does not distinguish supercomputers according to workload capacity specialised for AI. Thus, analysis of the Top500 list can serve as a proxy measure for national compute capacity between countries, with the caveat that such infrastructure is not necessarily used solely for AI purposes. In addition, as workloads cannot be run across multiple supercomputers, this measure should be viewed with limitations (e.g. ten supercomputers that add up to the same sum of Rmax as a single supercomputer would not be equivalent). For further information, please see www.top500.org.

[3] AI start-ups can be focused on compute, and the keywords pertaining to this field include "compute", "data centre", "semiconductor", "GPU", "CPU", "high-performance compute", "core software system", "processor chip", "infrastructure-as-a-service", "neuromorphic computing", "full-stack", "integrated circuit", "FPGA" and "computing chips". For further information on this methodology, please see www.oecd.ai/en/preqin.

5 The world of work

This chapter discusses the impact of artificial intelligence (AI) on the world of work, affecting skill requirements, job roles, work organisation and employment relationships. As Germany moves to manage the transformative impact of AI on the labour market, several challenges emerge related to adopting AI in the workplace. These include a lack of comprehensive understanding of AI skill demand, slow progress in including AI skills in vocational training regulations, a lifelong learning system that needs updating and predominantly neutral career guidance. Social dialogue is pivotal in navigating AI transitions, but social partners often lack sufficient AI expertise. In response to these challenges, it is crucial for Germany to improve the anticipation of AI skill demand, actively promote education and training opportunities in AI, fostering flexibility in adult learning, incentivise employer-led AI training, enhance consultations and secure AI expertise at the workplace.

The 2018 AI strategy and its 2020 update focused on a holistic, human-centred approach that recognises the importance of preparing businesses and workers for the adoption and the responsible use of AI. The strategy highlights three policy levers to achieve these goals: i) actions to strengthen the anticipation and assessment of the skills needed for AI adoption, including the development of skilled-labour monitoring; ii) the development of tools to enable workers to build relevant skills in the context of the German National Skills Strategy; and iii) strengthening the voice of workers in the introduction of AI tools and applications in the workplace.

Box 5.1. The world of work: Findings and recommendations

Findings

- National assessment exercises in Germany lack focus on AI skills, hindering understanding of demand despite perceived shortages.
- Progress in updating vocational training regulations to include AI is slow, but in practice, employers and training providers can go beyond what is specified in these regulations.
- Germany faces challenges promoting lifelong learning for some groups, with implications for the effective upskilling and reskilling of adults for AI adoption.
- Public employment services are committed to providing “neutral” career guidance and services, limiting their active role in guiding education and training choices towards AI.
- Small initiatives such as futures centres and training consortia address localised gaps in AI skills development by targeting workplace training in AI skills.
- The lack of AI-related expertise among social partners and of resources to acquire it are the main challenges faced by social partners to support their members in the AI transition. Insufficient transparency and experiences to cover AI in co-determination are also noted as critical issues.
- Several projects have been launched by social partners and federal ministries to offer training and enhance AI-competences, but co-ordination between all these initiatives is an issue.
- The German Work Council Modernization Act is generally seen as positive by workers’ representatives but insufficient because it only applies to firms with a work council and falls short of what is needed in terms of co-determination when it comes to AI and algorithmic system.

Recommendations

- Collect information on the supply and demand of AI skills through a dedicated analysis in the context of the Skilled Labour Monitor or through an ad hoc study.
- Promote education and training opportunities in AI in the context of the Public Employment Services (PES)’ Lifelong Vocational Guidance programme and, more widely, ensure that information on opportunities in AI-occupations is readily available.
- Increase flexibility and modularity in adult learning, especially in continuous vocational education and training, by using elective qualifications to integrate AI content for adaptive up- and reskilling.
- Incentivise employers to provide AI-related training through capacity-building exercises and targeted subsidies.
- Encourage consultations and co-operation with social partners, work council members and employees on AI introduction.

- Foster AI-related knowledge in the workplace and facilitate access to external expertise. Create incentives to build AI competences and join forces with social partners to promote AI-related expertise to all stakeholders in the workplace.

Upskilling and reskilling adults for AI

Germany's adult upskilling and reskilling system must become more systematic and flexible to close the skills gap in AI effectively. Employers cite skill shortages as a primary barrier to AI adoption, higher than in several other countries, indicating a need for enhanced skills development. Adult learning system faces challenges, with wide gaps in participation rates across socio-economic groups, impacting AI skill acquisition. While vocational training in Germany slowly incorporates AI, public initiatives and regulation updates are not sufficiently AI-focused.

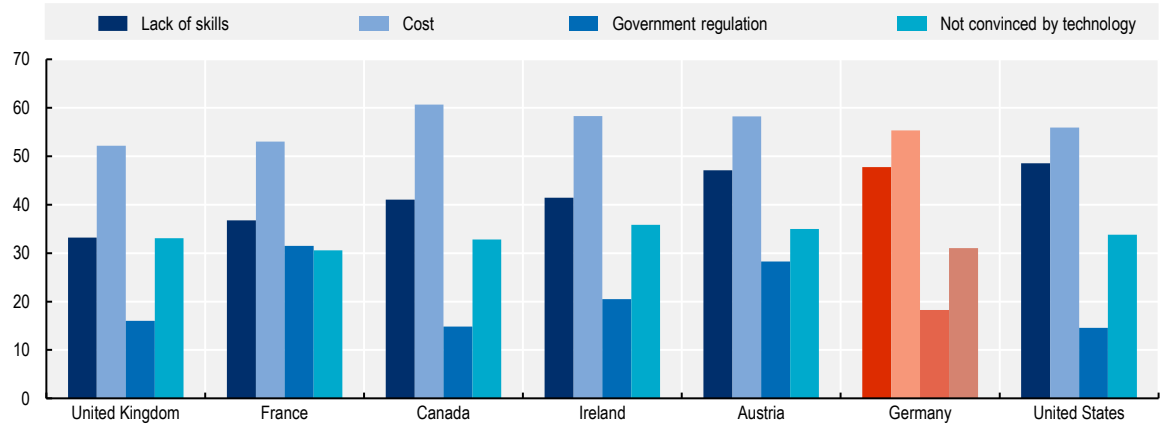
Skill shortages are a critical barrier to AI adoption

The share of workers with AI skills is small in Germany – as in other OECD countries – but has grown rapidly since 2011. Recent research shows that the average share of workers with AI skills in total employment across the OECD is just over 0.3%, ranging from 0.5% in the United Kingdom (UK) to 0.2% in Greece. The share in Germany is around the OECD average but has increased almost fivefold in the last decade. In all countries, the AI workforce is overwhelmingly highly educated and predominantly male. Women are underrepresented in the AI workforce, especially in Germany (Green and Lamby, 2023[1]).

Employers in Germany are more likely to cite lack of skills as a barrier to AI adoption than employers in other countries, notably in Austria, Canada, France, Ireland and the UK (Figure 5.1). 48% of employers in Germany cite a lack of skills as a barrier to adopting AI, a proportion second only to the United States (US), where 49% of employers say the same. Germany faces challenges in supporting adults to develop AI--relevant skills.

Figure 5.1. Lack of skills and cost are the main barriers to AI adoption in Germany

Share of employers who cite the following reasons as barriers to the adoption of AI, 2022



Note: All employers were asked: "I'm going to list a few potential barriers to the adoption of artificial intelligence. In each case, please tell me whether it has ever been a barrier to adopting artificial intelligence in your company: High costs/Lack of skills to adopt artificial intelligence/Government regulation/Not convinced by the technology/Any other barriers not previously mentioned".
Source: Lane, M., M. Williams and S. Broecke (2023[2]), "The impact of AI on the workplace: Main findings from the OECD AI surveys of employers and workers", https://doi.org/10.1787/ea0a0fe1-en.

The system for upskilling and reskilling adults faces challenges

While adult participation in upskilling and reskilling is slightly above the average of European OECD countries, it lags OECD countries with similar skill development systems, such as Austria, the Netherlands and Switzerland (OECD, 2021[3]). By international standards, Germany has wide disparities in learning participation across socio-economic groups, with low-skilled adults, the unemployed and those on low incomes lagging behind (OECD, 2021[3]). While the launch of the National Skills Strategy (*Nationale Weiterbildungsstrategie*) in 2019 signalled a commitment to promoting a culture of continuous skills development (BMAS et al., 2019[4]), a recent OECD report on continuing education and training in Germany highlights the continued need to undertake systematic reform of the system for upskilling and reskilling adults (OECD, 2021[3]). The report argues for a more systematic, flexible, and less complex adult learning system in Germany. These recommendations are directly relevant to upskilling and reskilling adults for the successful and reliable adoption of AI. Addressing the issues highlighted in the report is critical to creating an adaptive and effective system capable of meeting the demands of training individuals for AI-related skills in a rapidly evolving technological landscape.

Vocational training regulations tend to be technology-neutral

Training in vocational information technology (IT) skills accounts for a small proportion of all training provided by employers in Germany, but this proportion has increased between 2015 and 2020, according to data from the European Continuing Vocational Training Survey. Looking at the German vocational training system overall, while there are more than 300 vocational training profiles and regulations, there has been relatively little focus on creating specific vocational profiles for AI occupations. Similarly, the process of updating training profiles involving the social partners often takes one to two years, which limits regulations' ability to respond to sudden technological changes.

Training regulations for some IT occupations, such as information technology specialists, were updated in 2020 (BIBB, 2020[5]). Efforts to update continuous vocational training for IT professions are in progress. A pilot project in Baden-Württemberg – KI B3 – brings together government actors, universities and the Chamber of Commerce to develop continuing vocational training modules and qualifications in AI and machine learning (Vössing, 2023[6]). Yet, these are only relatively modest changes in the broader context of Germany's vocational education and training (VET) system. According to experts interviewed for this report, the slow pace of change is not necessarily problematic. Training regulations are generally worded in a technology-neutral way and intended to be minimum standards. This allows employers and education and training institutions to incorporate new developments related to AI into the curriculum if they wish.

Several smaller and more targeted public initiatives aim to address workplace training for AI skills, including the Federal Ministry of Labour and Social Affairs (*Bundesministerium für Arbeit und Soziales*, BMAS) projects Hubs for Tomorrow (*Zukunftszentren)* (BMAS, 2022[7]), which aims to support companies in the digital transition, and Continuing Education and Training Associations *(Weiterbildungsverbünde*) (BMAS, 2023[8]), in which several companies and stakeholders in the education landscape and regional labour market actors collaborate to efficiently organise and implement training measures across company boundaries, including in the field of AI.

Training choices are not typically steered towards AI

There is no discernible focus on AI skills when it comes to training supported by the PES, part of Germany's active labour market policy package. While they can provide information on AI job opportunities, the PES is committed to providing neutral career guidance and support to individuals and enterprises. The extent to which education and training choices are directed towards in-demand skills is extremely limited (OECD, 2017[9]). Maintaining a neutral stance while preserving individual autonomy may be insufficient to proactively address the urgency of acquiring AI skills in a rapidly evolving labour market.

Anticipating demand for AI skills

Germany's national skills assessment lacks focus on AI. While demand for AI skills is low but rising, no comprehensive data on AI skill needs exist, and existing forecasts overlook AI specifics.

National skill anticipation exercises have no specific focus on AI skills

Despite the commonly used narrative of an unmet demand for AI skills in Germany, notably from employers (Lane, Williams and Broecke, 2023[2]), surprisingly little attention is paid to the issue in national skills assessment and anticipation exercises. There is a lack of robust national data on the demand for AI skills from public sources.

The two most prominent national assessment and anticipation exercises for skilled labour are the Skilled Labour Monitor (*Fachkräftemonitoring*), commissioned by the BMAS (IAB/BIBB/GWS, 2023[10]), and the Bottleneck Analysis (*Engpassanalyse)* from the Federal Employment Agency (*Bundesagentur für Arbeit*) (Bundesagentur für Arbeit, 2023[11]). The Skilled Labour Monitor provides an annual medium- and bi-annual long-term overview of the likely development of labour supply and demand in Germany. It is conducted under the joint direction of the Federal Institute for Vocational Education and Training (*Bundesinstitut für Berufsbildung*, BIBB) and the Institute for Employment Research (*Institut für Arbeitsmarkt- und Berufsforschung*, IAB) and in co-operation with the Institute for Economic Structure Research (*Gesellschaft für Wirtschaftliche Strukturforschung*, GWS). The Bottleneck Analysis uses a set of standardised indicators to identify occupations or occupational groups where there are shortages and is carried out annually by the Federal Employment Agency (*Bundesagentur für Arbeit)*. There are several other sectoral or regional skills forecasting exercises (OECD, 2016[12]; 2021[3]).

None of the existing exercises provide a comprehensive picture of the demand for AI skills in Germany. According to interviewees, there are several factors that explain this shortcoming, including a strong focus on forecasting occupational rather than skill demand, methodological difficulties in defining AI skills, and scepticism towards new data sources such as online job vacancy data for skill forecasting exercises. There is also a widely held view amongst interviewed experts that specialised AI skills are still only required by a small share of jobs in the labour market.

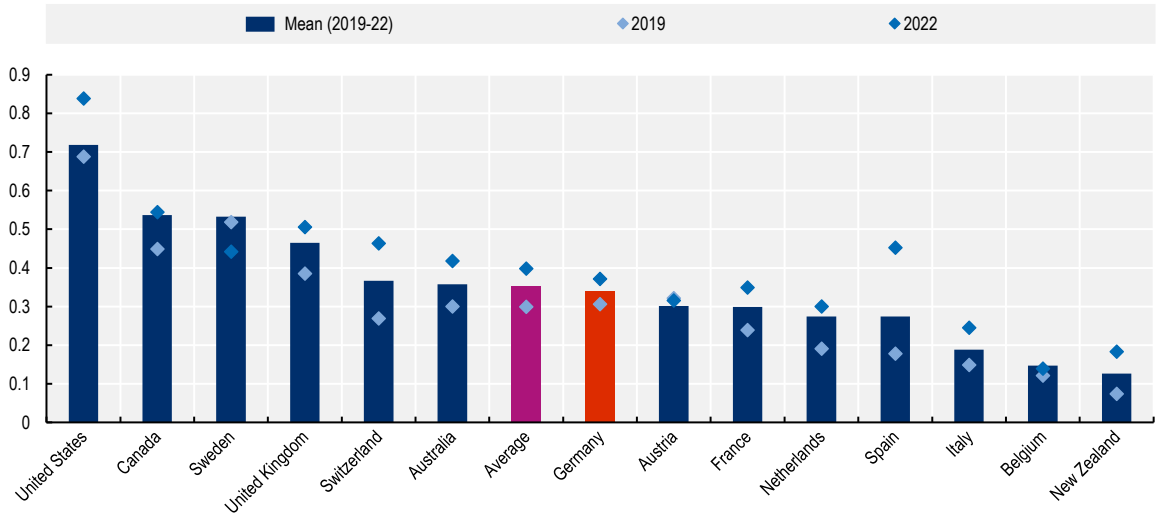
International evidence suggests that demand for AI skills is low but growing

International evidence from a new OECD study confirms this view, showing that specialised AI-related vacancies still account for only a small proportion of all job vacancies advertised online (Figure 5.2). In Germany, less than 0.4% of advertised vacancies explicitly required AI skills in 2022. This is slightly below the average of countries for which data are available and half that of the US, where 0.8% of advertised vacancies required such skills. However, demand for AI skills in Germany is growing rapidly and has increased more than 20% between 2019 and 2020 (Borgonovi et al., 2023[13]; Green and Lamby, 2023[1]).

The analysis also shows that the demand for AI-related jobs is highly concentrated in specific industries and occupations. Interestingly, Germany has the highest share of vacancies requiring AI skills that are in the manufacturing sector of the countries analysed (Borgonovi et al., 2023[13]).

Figure 5.2. Jobs requiring AI skills account for a small proportion of all advertised jobs

Percentage of online vacancies advertising positions requiring AI skills, by country



Notes: The figure shows the percentage of online vacancies advertising positions requiring AI skills by country. This corresponds to the total number of online vacancies requiring AI skills relative to all vacancies advertised in a country. Vacancies requiring AI skills are vacancies in which at least two generic AI skills or at least one AI-specific skill were required (see Borgonovi et al. (2023[13]) on generic and specific skills). Countries are sorted in descending order by the highest average share across 2019 to 2022 of vacancies requiring AI skills. Average refers to the average across countries with available data.
Source: Borgonovi, F. et al. (2023[13]), "Emerging trends in AI skill demand across 14 OECD countries", https://doi.org/10.1787/7c691b9a-en.

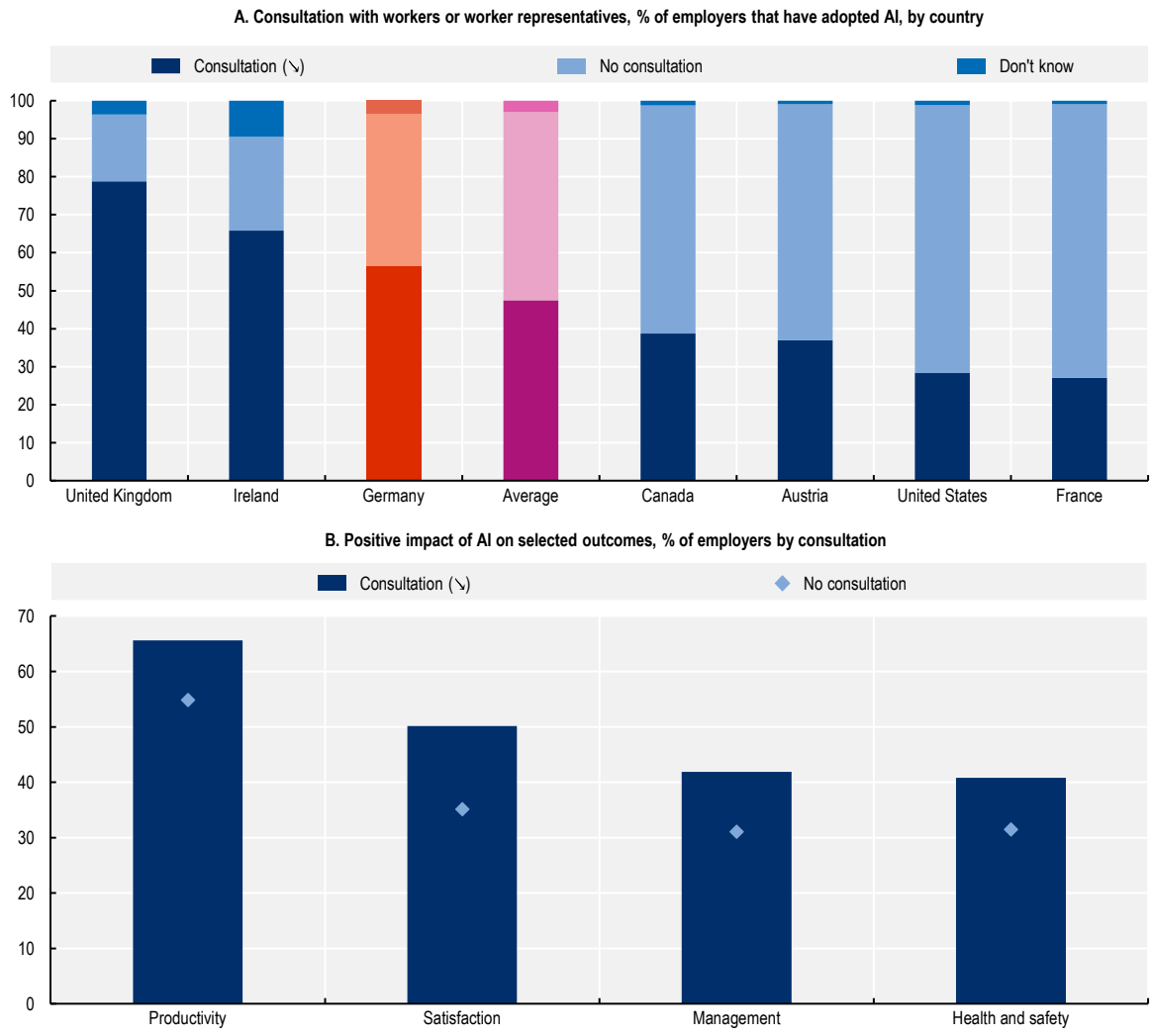
Social dialogue

Social dialogue is vital in navigating AI transitions. In the workplace, recent evidence points for example to the beneficial role of workers consultation for working conditions and performance. Yet, social partners face expertise and resource limitation. As seen in Germany's Works Council Modernization Act, training and expert consulting are instrumental for informed decision making on AI in workplaces.

Collective bargaining and social dialogue have an important role to play in supporting workers and businesses in the AI transition. Recent OECD work points notably to the beneficial role of workers' voice for working conditions and performance (Figure 5.3). Across OECD countries, both unions and employers' organisations have launched national and international initiatives. Social partners engage in outreach and awareness campaigns highlighting the need for new competencies and training requirements, as well as areas of concern such as the trustworthy use of AI (OECD, 2023[14]). Yet, social partners' activities are often limited by their lack of AI-related expertise and capacities and resources to attain it. In that context, it is crucial to offer them training opportunities or provide expertise on AI at the workplace or firm level.

One way to secure such expertise beyond the training of social partners themselves is the recruitment or consultation of technical experts. This could not only ensure better technical understanding within unions and employers' organisations, but also ensure the recognition of workers' interests in the workplaces where technology is developed. In turn, this could contribute to more trustworthy technology. One example in this respect is the German Works Council Modernization Act passed in 2021, which facilitates exercising the right to consult an external expert in cases where the Work Council has to assess the introduction or use of AI.[1]

Figure 5.3. Employers who consult workers or workers representatives are more likely to report positive impacts of AI on worker productivity and working conditions, 2022



Notes: In Panel A, employers were asked: "Does your company consult workers or worker representatives regarding the use of new technologies in the workplace?". In Panel B, employers that have adopted AI were "Has artificial intelligence had a positive effect, negative effect or had no effect on worker productivity/worker satisfaction/managers' ability to measure worker performance/health and safety in your company?". Figures in Panel B show the proportions of employers that reported a positive effect. Average is the unweighted average of countries shown in Panel A.
Source: Lane, M., M. Williams and S. Broecke (2023[2]), "The impact of AI on the workplace: Main findings from the OECD AI surveys of employers and workers", https://doi.org/10.1787/ea0a0fe1-en.

Interviews conducted with trade unions and employer representatives[2] confirm that limitations due to insufficient AI-related knowledge and resource constraints are among the main challenges they face regarding AI adoption in the workplace. They refer to AI as a "black box" and point to the diverse and complex range of AI topics that require technical expertise to understand AI potential. Time and resource constraints are also reported as a concrete challenge, especially for small and medium-sized enterprises (SMEs). Other important challenges outlined by the unions include the lack of a common definition (hence understanding) for AI between employers and employee representatives and of transparency from employers and AI providers regarding the use and goals of AI in the company. Finally, they also highlight insufficient experience and routines to cover AI in co-determination.[3]

Despite these challenges, several initiatives and projects have been launched by social partners to offer consulting or training services (websites, guides, trade unions' educational institutions, etc.), and by the government, such as the future centres and regional competences centres set up by the BMAS and the Ministry of Education and Research (*Bundesministerium für Bildung und Forschung*, BMBF). However, social partners point to the lack of co-ordination between the various initiatives. This multiplicity of training programmes may be confusing, notably for employer representatives trying to provide the best match for companies while monitoring effectiveness.

Finally, views about the introduction of the German Work Council Modernization Act are mixed even if generally seen as positive. Workers' representatives (unions) consider it as insufficient because it only applies to firms with a work council in place[4] and falls short of what is needed in terms of co-determination when it comes to AI and algorithmic systems. Trade unions consider that there needs to be enforceable co-determination for framework process agreements that cover all process stages of the operational use of AI and algorithmic systems (before introduction through to evaluation).[5] In addition, they hint to the potential source of conflict it may create when implementing the Act since employer and work councils first need to agree whether AI is really at stake and whether the involvement of an external expert is required, as employers support as much as possible the use of in-house expertise because it is less costly and less time consuming.[6]

Recommendations

Strengthen information collection on the supply and demand of AI skills

While the well-established narrative of a significant AI skills shortage in Germany might be true, there is no robust and granular national evidence on the supply and demand of AI skills in the labour market. To design employment policies that facilitate the successful and responsible adoption of AI, skills assessment and anticipation exercises urgently need improvement. Given the relatively small size of the labour market for specialised AI skills, this should be done as an ad hoc study. For example, the Skilled Labour Monitor could include this analysis as a focus in one of its editions.

Alternatively, the BMAS could commission a separate study as a research report. Any national analysis of supply and demand regarding AI skills should draw on international examples to define AI skills and assess demand, including from the OECD (Borgonovi et al., 2023[13]; Green and Lamby, 2023[1]). However, such an assessment and anticipation exercise should focus on the national context and occupations rather than skills in labour market. Given the dynamic nature of the AI skills market, any exercise should be repeated after a maximum of years, ideally. In all cases, strengthening skills assessment and anticipations will require close collaboration with industry stakeholders to identify emerging trends and gaps.

Promote education and training opportunities through PES and career guidance

The PES' role in guiding career choices and providing information on job prospects is crucial. Indeed, the German PES have recently extended their offer of career guidance to working people through the Lifelong Vocational Guidance programme (Bundesagentur für Arbeit, 2023[15]). Despite the mandate for neutral guidance, there's an opportunity to highlight the emerging opportunities within AI-related occupations strategically. By disseminating information on AI career prospects and offering clear pathways for skills development and career progression, PES can actively contribute to steering individuals towards AI-related opportunities. The recent move to provide PES guidance counsellors with teaching and learning materials on future digital skills, AI and cybersecurity is a positive development in this regard. Working closely with industry stakeholders and drawing on a strong evidence base of skills demand is critical to ensuring that guidance aligns with current and anticipated AI labour market needs. Good practices in steering training

choices through guidance and financial incentives can be found in Australia and Estonia, and elsewhere (OECD, 2017[9]).

However, data from the German Adult Education Survey show that the PES accounts for only around a third of all career guidance for adults in Germany (BMBF, 2019[16]), with 26% of individuals receiving guidance from educational institutions, 21% from further education providers, 18% from employers and employer organisations, and 16% from specialised guidance providers. Given the decentralised nature of career guidance provision in Germany, information on opportunities in AI-related occupations must be centralised for public use. This could happen on the newly developed national online portal for continuing education and training (My NOW, *mein NOW*). Denmark's *UddannelsenGuiden* (www.ug.dk) and New Zealand's *Occupation Outlook* app are among the many good examples of high-quality online portals for education and training opportunities (OECD, 2021[17]).

Increase flexibility and modularity in adult learning, especially in VET

AI technologies require a paradigm shift in adult education, particularly VET, which too often expect adults to take long courses leading to full qualifications, rather than participating in shorter, more targeted, and modular learning opportunities that are more reactive to technological developments (OECD, 2021[3]). VET courses must become diverse and modular to ensure accessibility and reflect the dynamic nature of AI-related skills. However, German education and training stakeholders often perceive modularity with scepticism (OECD, 2021[3]). To address this, Germany should make greater use of elective qualifications (*Wahlqualifikationen*), which are shorter, modular elements of full vocational qualifications. Introducing AI content into VET qualifications through these instruments allows them to adapt more frequently to new requirements and opens the door for individuals to take up this modular offer as part of their upskilling or reskilling pathway.

Incentivise employers to provide AI-related training

Most adult learning takes place in the workplace. However, German employers provide limited training in AI compared to other countries (Lane, Williams and Broecke, 2023[2]). Recognising the central role of employers in shaping a skilled AI workforce, policies to incentivise and support AI-related training initiatives should be strengthened. Looking at good practices, Estonia has extensive experience in supporting enterprises with digital skill development (OECD, 2021[18]).

This would primarily address obstacles to training faced by SMEs. Promising initiatives that develop employers' capacity to provide training to adapt to technological opportunities include Hubs for Tomorrow (*Zukunftszentren*) and Continuing Education and Training Associations (*Weiterbildungsverbünde*). These should be evaluated and strengthened as needed. Germany also supports in-company training through the Qualification Opportunities Act (*Qualifizierungschancengesetz*) and the Work of Tomorrow Act (*Arbeit-von-Morgen-Gesetz*). The BMAS could explore whether specific incentives for training in introducing AI could be provided through this instrument or if a specific financial incentive programme for AI would be more effective.

Encourage consultations and co-operation with social partners on AI introduction

Considering the positive role of social dialogue in the workplace, the government should encourage consultations and discussions on AI introduction with social partners, work council members, and employees. Policy makers should also support mutual understanding and shared diagnosis of challenges and use knowledge platforms and co-operation to share practices on new initiatives and technological innovation among actors. Getting involved early and regularly in AI-related issues brought up by employee and co-determination bodies could enhance trust and acceptance for introducing AI into the workplace.

Foster AI-related knowledge in the workplace and facilitate access to expertise

The government should add financial incentives for building AI competences – notably reaching out to SMEs – and join forces with social partners to promote AI-related expertise to management, work council members, and supervisory board members. Considering the variety of existing AI-related training initiatives, the government should encourage more transparent and systematic networking between actors and programmes. Finally, the government could facilitate access to external expertise by simplifying the implementation process.

References

BIBB (2020), *Fachinformatiker/Fachinformatikerin - Fachrichtung Daten- und Prozessanalyse (Ausbildung)*, Bundesinstitut für Berufsbildung, https://www.bibb.de/dienst/berufesuche/de/index_berufesuche.php/profile/apprenticeship/ujhz677 (accessed on 11 December 2023). [5]

BMAS (2023), *Das Bundesprogramm"Aufbau von Weiterbildungsverbünden"*, Bundesministerium für Arbeit und Soziales, https://www.bmas.de/DE/Arbeit/Aus-und-Weiterbildung/Berufliche-Weiterbildung/Weiterbildungsverbuende/weiterbildungsverbuende.html (accessed on 11 December 2023). [8]

BMAS (2022), *ESF Plus-Programm "Zukunftszentren"*, Bundesministerium für Arbeit und Soziales, https://www.bmas.de/DE/Arbeit/Digitalisierung-der-Arbeitswelt/Austausch-mit-der-betrieblichen-Praxis/Zukunftszentren/zukunftszentren.html (accessed on 11 December 2023). [7]

BMAS et al. (2019), *Nationale Weiterbildungsstrategie*, https://www.bmas.de/SharedDocs/Downloads/DE/Aus-Weiterbildung/strategiepapier-nationale-weiterbildungsstrategie.pdf?__blob=publicationFile&v=3 (accessed on 30 July 2020). [4]

BMBF (2019), *Weiterbildungsverhalten in Deutschland 2018. Ergebnisse des Adult Education Survey-AES-Trendbericht*, Bundesministerium für Bildung und Forschung, https://www.bmbf.de/SharedDocs/Publikationen/de/bmbf/1/31516_AES-Trendbericht_2018.html (accessed on 11 December 2023). [16]

Borgonovi, F. et al. (2023), "Emerging trends in AI skill demand across 14 OECD countries", *OECD Artificial Intelligence Papers*, No. 2, OECD Publishing, Paris, https://doi.org/10.1787/7c691b9a-en. [13]

Bundesagentur für Arbeit (2023), *Die Lebensbegleitende Berufsberatung der BA*, Bundesagentur für Arbeit, https://www.arbeitsagentur.de/datei/die-lebensbegleitende-berufsberatung-der-ba_ba035445.pdf. [15]

Bundesagentur für Arbeit (2023), *Engpassanalyse*, Bundesagentur für Arbeit, Nürnberg, https://statistik.arbeitsagentur.de/DE/Navigation/Statistiken/Interaktive-Statistiken/Fachkraeftebedarf/Engpassanalyse-Nav.html (accessed on 20 November 2023). [11]

Green, A. and L. Lamby (2023), "The supply, demand and characteristics of the AI workforce across OECD countries", *OECD Social, Employment and Migration Working Papers*, No. 287, OECD Publishing, Paris, https://doi.org/10.1787/bb17314a-en. [1]

IAB/BIBB/GWS (2023), *Fachkräftemonitoring fuer das BMAS. Mittelfristprognose bis 2027*, Institut für Arbeitsmarkt- und Berufsforschung, Bundesinstitut für Berufsbildung and Gesellschaft für Wirtschaftliche Strukturforschung mbH, https://www.bmas.de/SharedDocs/Downloads/DE/Publikationen/Forschungsberichte/fb-625-fachkraeftemonitoring-bmas-mittelfristprognose-2027.pdf?__blob=publicationFile&v=3. [10]

Lane, M., M. Williams and S. Broecke (2023), "The impact of AI on the workplace: Main findings from the OECD AI surveys of employers and workers", *OECD Social, Employment and Migration Working Papers*, No. 288, OECD Publishing, Paris, https://doi.org/10.1787/ea0a0fe1-en. [2]

OECD (2023), *OECD Economic Outlook, Volume 2023 Issue 2*, OECD Publishing, Paris, https://doi.org/10.1787/7a5f73ce-en. [14]

OECD (2021), *Career Guidance for Adults in a Changing World of Work*, Getting Skills Right, OECD Publishing, Paris, https://doi.org/10.1787/9a94bfad-en. [17]

OECD (2021), *Continuing Education and Training in Germany*, Getting Skills Right, OECD Publishing, Paris, https://doi.org/10.1787/1f552468-en. [3]

OECD (2021), *Training in Enterprises: New Evidence from 100 Case Studies*, Getting Skills Right, OECD Publishing, Paris, https://doi.org/10.1787/7d63d210-en. [18]

OECD (2017), *Financial Incentives for Steering Education and Training*, Getting Skills Right, OECD Publishing, Paris, https://doi.org/10.1787/9789264272415-en. [9]

OECD (2016), *Getting Skills Right: Assessing and Anticipating Changing Skill Needs*, Getting Skills Right, OECD Publishing, Paris, https://doi.org/10.1787/9789264252073-en. [12]

Vössing, M. (2023), "So kommt Künstliche Intelligenz in die berufliche Bildung", https://www.ihk.de/ulm/online-magazin/im-fokus/fachartikel-ki-berufliche-bildung-5692358 (accessed on 11 December 2023). [6]

Notes

[1] Similarly, the agreement between the General Staff council of the city of Stuttgart and the city as a public employer stipulates that the staff council may use external consulting services at the city's expense.

[2] Both trade unions and employers' representatives who were interviewed highlighted the critical role of work councils and co-determination actors in that area. Unfortunately, we could not manage to reach out work councils directly.

[3] A potential additional obstacle may arise when the main project managers for AI implementation are abroad (e.g. in the US) and lack complete knowledge about German codetermination functioning and needs.

[4] The workforce in companies with five or more employees can elect a works council on a voluntary basis. Works councils can only be established by an election of the workforce, so companies can operate without

a works council until the workforce elected one. Consequently, the number of companies that have a works council is limited.

[5] This point was emphasised by the *Deutscher Gewerkschaftsbund* (*DGB*) (German Trade Union Confederation) during the interview conducted for this study.

[6] Therefore, the importance of having a common definition of AI mentioned before. This problem led to the DGB's demand that the work council alone decide on the involvement of external expertise, regardless of the topic, i.e. even if is not about AI.

6 Policy and regulatory frameworks

This chapter examines Germany' policy and regulatory frameworks for the responsible development and deployment of artificial intelligence (AI) technologies. Several initiatives, such as sustainability and environmental programmes, transparent AI use in the workplace and regulatory frameworks addressing security matters show the country's commitment to responsible and human-centred AI. Germany also has a solid legal foundation for regulatory experimentation and a proactive stance on standardisation for trustworthy AI, both domestically and internationally. Recommendations emphasise the need for a clear and integrated vision at the highest political level, increased funding for AI ambitions, and the establishment of a central team to support regulatory experimentation at the regional level.

As an OECD member, Germany adheres to the OECD AI Principles included in the OECD Recommendation on AI [OECD/LEGAL/0449]. Its national AI strategy and policies demonstrate a commitment to the responsible and human-centric development and deployment of AI technologies. The country emphasises promoting inclusive growth, transparency, and accountability in AI systems. Its AI strategy supports democratic principles and trustworthy AI in the public sector, acknowledging the importance of high standards regarding non-discrimination, transparency, traceability, verifiability, fairness, participation, and data protection to uphold the public's trust in public-sector AI use. Furthermore, the Federal Government recognises that it needs a policy and regulatory framework for the responsible and public-good-oriented development and use of AI to address risks.

Box 6.1. Policy and regulatory framework: Findings and recommendations

Findings

- Germany was among the first countries to issue a national AI strategy, signalling an early commitment to human-centred AI.
- Germany is implementing the OECD AI Principles.
- Besides the 2018 national AI strategy and its 2020 update, Germany developed policies and initiatives in across fields of work.
- Germany's budget allocated to the national AI strategy is low compared to peer countries.
- Germany has clear plans and legal provisions for regulatory sandboxes. However, limited expertise at the *Länder* level often hinders their application.
- Germany can transfer its reputation for high-quality industrial products to trustworthy AI products and services.

Recommendations

- Develop a clear, agile, long-term, integrated vision of how Germany wants AI to serve societal progress and well-being, and detailed roadmaps for implementation.
- Create an oversight and co-ordination body for the national AI strategy at the top political level (i.e. the Federal Chancellery) to secure coherent implementation.
- Increase funding for national AI ambitions.
- Establish a central team/hub to help authorities implement regulatory experimentation.
- Better leverage influence on European Union (EU) regulation and standards development.
- Implement specific policies to promote the trustworthy use of AI in the workplace.

The German National AI Strategy

Germany's AI strategy, launched in 2018 and backed by a EUR 3 billion budget for implementation by 2025, aims for growth and trustworthy AI development, focusing on human-centred applications supported by the Federal Ministries of Labour and Social Affairs (*Bundesministerium für Arbeit und Soziales*, BMAS), of Education and Research (*Bundesministerium für Bildung und Forschung*, BMBF) and of Economic Affairs and Climate Action (*Bundesministerium für Wirtschaft und Klimaschutz*, BMWK). It targets competitiveness and integrating AI into society through societal dialogue and political action.

In 2018, Germany was among the first countries to issue a national AI strategy. The AI strategy's overall objective is to foster growth and competitiveness, and to ensure AI's responsible and trustworthy development. A key characteristic of the strategy is its emphasis on human-centred AI and understanding and shaping it to benefit workers and society. Given this focus, the BMAS is one of the three leading Ministries of the national AI strategy, alongside the BMBF and the BMWK.

The three main goals of the AI strategy are to: i) secure Germany's future competitiveness while making Germany and Europe leading locations for the development and application of AI technologies; ii) ensure that AI use and development are responsible and focused on the common good; and iii) embed AI in society ethically, legally, culturally, and institutionally through broad societal dialogue and active political efforts.

One year after the strategy's launch in November 2019, the German Federal Government published an interim report (BMBF, 2019[1]), presenting the main measures implemented and perspectives for the following years. In December 2020, Germany updated the national AI strategy in response to recent developments (German Federal Government, 2020[2]). In particular, the COVID-19 pandemic and questions of environmental sustainability and climate protection were brought to the fore, alongside the importance of European and international collaboration.

The national AI strategy positions the German Federal Government's intervention around five key areas: i) minds; ii) research; iii) transfer and applications; iv) regulatory framework; and v) society. The strategy also outlines new initiatives focusing on sustainability, environment/climate protection, health and pandemic control, and international/European co-operation.

The national AI strategy had an initial EUR 3 billion allocated budget until 2025, a funding commitment increased in June 2020 by an additional EUR 2 billion through the Economic stimulus and future package (German Federal Government, 2020[3]). However, it is not clear whether the overall commitment will be enacted. Up to today, EUR 3.5 billion have been distributed among the federal ministries. The strategy does not provide a breakdown of allocated funds to each of the areas nor a repartition of funds to federal ministries. In October 2023, a total of EUR 2.8 billion had been allocated to concrete projects to support implementation.

Considering the allocated budget of EUR 3.5 billion, Germany's funding for its AI ambitions appears to be lower than other European countries and the United States (US). On a per capita basis, German public investment in AI per year stands at EUR 6. In comparison to other European countries, Germany lags behind, as seen in France's commitment of EUR 6.6 per capita annually for its national AI strategy (Ministère de l'Économie, des Finances et de la Souveraineté industrielle et numérique, 2023[4]), and the United Kingdom (UK)'s allocation of EUR 6.5 per capita (HM Government, 2021[5]). Moreover, the US outpaces these figures, dedicating as much as EUR 7.5 per capita annually exclusively for AI research and development (Executive Office of the President, 2022[6]).

The strategy lists several measures and initiatives under each pillar but lacks an implementation roadmap detailing concrete steps, a timeframe and with limited exceptions, targets and indicators to measure progress. However, the 2018 National Strategy clarifies that ministries are responsible for monitoring progress of actions under their purview.

Along with the 2018 strategy and its 2020 update, Germany has developed policies and initiatives in adjacent fields. These include the National Digitalisation Strategy 2025 (BMWi, 2016[7]), the Data Strategy of the German Federal Government, updated in 2023 (*Datenstrategie der Bundesregierung*) (German Federal Government, 2023[8]), as well as sector legislation, such as the Mobility Data Act (*Mobilitätsdatengesetz*) (BMDV, 2023[9]), and legislation related to AI in the health sector (see Chapter 10). However, formal mechanisms for co-ordination are not in place for these initiatives which are all managed by different ministries.

German Länder *and municipal AI strategies*

Accompanying the 2018 national AI strategy and its 2020 update, Germany's federal states (*Länder*) have developed measures and strategic goals in the field of AI. Five out of the 16 *Länder* published AI strategies, whereas the remaining 11 have defined goals and measures regarding AI within their innovation or digital strategies. Looking at specific areas of focus, 15 out of 16 *Länder* prioritise the topic of "transfer and applications", displaying a significant overlap with the federal government's ambitions. The other fields with the most overlaps are health (13/16), research (12/16) and infrastructure (10/16).

Despite these overlaps, the co-operation and co-ordination between the federal government and the *Länder* remains limited. Several federal states have initiated dedicated state-level AI agencies or platforms, such as the Bavarian AI Agency and network, the Hessian Centre for Artificial Intelligence (hessian.AI), or the KI.NRW platform in North Rhine-Westphalia. Co-operation between these state institutions and federal ministries should be promoted and encouraged, for instance, through the recently established permanent conference of digital ministers, announced in November 2023 that could be expanded to include relevant AI stakeholders from the federal level.

AI is influencing municipalities and changing the working environment of local authorities. Germany's ten most populated cities (Berlin, Hamburg, Munich, Cologne, Frankfurt am Main, Stuttgart, Düsseldorf, Leipzig, Dortmund, Essen) have a digital strategy, and those of cities like Berlin, Cologne and Hamburg refer to the relevance of AI. None of these ten cities has developed an AI strategy, a finding that is not uncommon with other European municipalities. For example, only 5 of the 26 European capitals – Amsterdam (Netherlands), Brussels (Belgium), Luxembourg (Luxembourg), Madrid (Spain), and Vienna (Austria) – have an AI strategy. Given the critical role of municipalities in citizens' daily lives, it will be crucial for municipal authorities to be aware of potential challenges and opportunities presented by AI, and how they might respond. Co-ordination with state and federal authorities and responsible AI strategies can also help to ensure a cohesive national response across all levels of government.

Developing a responsible, trustworthy, and human-centric approach to AI

Germany aligns with OECD AI Principles, emphasising human-centred AI and societal dialogue in its national strategy, with initiatives for AI's social good, environmental and climate protection and assurance that public sector systems are responsibly developed with laws that foster workplace AI transparency. EU legislation such as the General Data Protection Regulation (GDPR) and the European Union Regulation on Artificial Intelligence (the "EU AI Act") (EU, 2024[10]) also guide its approach.

Germany solidified commitment to and implementation of principles for trustworthy AI

The OECD AI Principles include five values-based principles for the responsible stewardship of trustworthy AI. Consistently with the EU approach of excellence and trust in AI (EC, 2024[11]), Germany has been active in shaping the EU AI Act, the world's first comprehensive AI law. The EU AI Act aims to safeguard users' safety and fundamental rights and to boost the AI market by raising consumer trust in AI applications. The EU AI Act establishes obligations - including on transparency, human oversight, accountability and liability - for operators[1] of AI systems depending on the level of risk associated with their use. Risks are classified as unacceptable (prohibited), high (subject to conformity assessment procedures before placing an AI system on the market, as well as to post-market monitoring); limited (subject to transparency obligations), and minimal or no risk (not covered by the Regulation). The EU AI Act also introduces a tiered approach for providers of General-Purpose AI (GPAI) models, defined as AI models that can perform a wide range of distinct tasks and can be integrated into a variety of downstream systems or applications. The EU AI Act differentiates between those with potential systemic risks for society and others GPAI models. German officials say that they will issue guidance shortly after enactment to adapt and

contextualise implementation in Germany. Similarly, German officials interviewed cited the EU's proposed "AI liability directive" (European Parliament, 2023[12]) as being relevant to Germany's future approaches to accountability.

Germany adheres to the GDPR like all EU members, which includes regulations regarding the transparent and fair processing of personal data. This regulation impacts AI systems that involve the processing of personal data, ensuring that individuals are informed about how their data are being used.

Several initiatives at national level also illustrate Germany's alignment to the OECD AI Principles. Consistent with the OECD values-based principle on People and Planet, Germany's AI strategy states that AI applications must augment and support human performance. It also includes an explicit commitment to a responsible development and use of AI that serves the good of society and to a broad societal dialogue on its use. To this end, several federal initiatives promote the use of AI for social good (see Chapter 7).

Germany plans to leverage the power of AI systems and environment-related data to conduct impact assessments, ecosystem analyses or investigations of energy consumption behaviour. Charged with the task of bringing together the federal government and the *Länder* on these topics and developing applications in the relevant domains will be the newly founded Application Lab for AI Big Data. For the application development, the AI-Lab places particular emphasis on the responsible handling of data and a resource-saving use of AI and Big Data. The federal government also initiated the AI Lighthouse programme, a funding initiative that promotes AI development for environmental, climate, nature and resource protection. Additionally, the national AI strategy details plans about launching a brand called Sustainable AI, which is meant to assess and rate the consumption of resources of different AI systems.

Germany's Federal Government affirms its commitment to the "human-centric design" of AI systems inside and outside of the public sector, mentioning this principle in various sections of its 2018 and 2020 Strategy. Human-centric design is also a principle of the AI Observatory led by BMAS (BMAS and DenkFabrik, 2023[13]), which has an overarching focus on how AI may contribute to societal and workforce trends. One additional dimension of human-centred AI is user-orientation, which is a core part of the German Federal Government's strategy to improve public service efficiency and make them faster and more accessible to citizens. Finally, according to German officials, Germany's Legal Framework for the Public Sector supports human-centred AI by requiring that only humans make the final decision for anything of meaningful impact.

For public entities tasked with security, an Algorithm Assessment Centre for Authorities and Organizations with Security Tasks (*Algorithmenbewertungsstelle für Behörden und Organisationen mit Sicherheitsaufgaben*, ABOS) – a central body that certifies and assesses the conformity of AI systems – was called for in the national AI strategy but has not yet been formally launched (Merkur, 2023[14]).

Germany promotes the transparent use of AI in the workplace through the 2021 Works Council Modernisation Act (*Betriebsrätemodernisierungsgesetz*), which updated the German Works Constitution Act (*Betriebsverfassungsgesetz*, BetrVG). Even before the amendment, the works council had to be involved when implementing AI-assisted information technology tools. What is new since 2021, however, is that it is easier for the works council to call in external expertise in case a company wants to use AI internally. Involving the works councils at an early stage aims to foster trust in AI technology and gain acceptance within the workforce.

In 2017, Germany established an Ethics Commission on Automated and Connected Driving at sectoral level, which provides recommendations on the ethical aspects of autonomous driving (BMDV, 2017[15]). While it specifically addresses the automotive sector, it sets a precedent for considering ethical implications in using AI technologies. In 2021, Germany passed the first comprehensive national law on autonomous driving. Germany's Automated Vehicles Bill in the Road Traffic Act and its Act Amending the Road Traffic Act and the Compulsory Insurance Act (Autonomous Driving Act) aim to ensure the robust, secure and safe use of AI. These Acts legalise automated vehicles by modifying the Road Traffic Act and define the requirements for automated vehicles in public roads.

Regulatory experimentation in AI

Germany has various initiatives aimed at increasing agility in AI governance and is developing a comprehensive legal framework for regulatory sandboxes, with the federal regulatory sandbox law expected to be effective by 2025.

Germany has clear plans and legal provisions for regulatory experimentation

Since 2017, the BMAS has supported the launch of "company level spaces for learning and experimentation" (*Lern-und Experimentierräume*), which was expanded in 2019 to include a specific component focused on AI. The predominant focus of this initiative is to equip small and medium-sized enterprises (SMEs) with access to innovative technologies, but the programme is also open to agencies and entities in public administration. The 2020 update explicitly refers to this model and its use for both companies and the public service to develop innovative technical solutions.

In addition, the national AI strategy called for providing regulatory sandboxes (*Reallabore*) for new projects and AI systems. Regulatory experimentation in AI, especially through sandboxes, can contribute to increasing agility in AI governance. For example, AI innovators and regulators are able to test new products safely. The EU AI Act also proposes to use regulatory sandboxes to test and validate AI systems before they go onto the market. Germany already has several initiatives regarding regulatory sandboxes. These include:

- a handbook, i.e. a manual for the design, implementation, and evaluation of regulatory sandboxes (BMWK, 2019[16])
- a guide for formulating experimentation clauses for law makers (BMWi, 2020[17])
- a practical guide to data protection for regulatory sandboxes (BMWi, 2021[18])
- an inter-ministerial working group on regulatory sandboxes
- a federal-*Länder* working group on regulatory sandboxes
- a cross-cutting regulatory sandboxes network with more about 1 000 members
- workshops, provision of information, establishment of contact persons
- regulatory sandbox competitions ("innovation prize").

There are also several legal provisions for national regulatory experimentation (e.g. for autonomous driving, digital identities, or drone traffic management). Germany is currently in the process of developing a comprehensive legal framework for regulatory sandboxes. Set as a goal in the 2021 Coalition Treaty (German Federal Government, 2021[19]), the federal regulatory sandbox law is expected to be effective by 2025.

A green book launched on 10 July 2023 is part of this initiative. It includes a set of proposals and questions that pertain to four essential elements (BMWK, 2023[20]). These actions plan to i) introduce new legal possibilities and experimentation clauses designed for regulatory sandboxes in key innovation areas; ii) establish overarching standards to govern regulatory sandboxes; iii) implement an "experimentation clause check" within legislative frameworks; and iv) create a one-stop shop to streamline the regulatory sandbox process. Furthermore, a public consultation period ran from 10 July to 29 September 2023, to give an opportunity for engagement and feedback on these proposals.

Germany plays an important role in developing the legal basis for regulatory experimentation on the European level. In Europe, the Council Conclusions on Regulatory Sandboxes and Experimentation Clauses were adopted in November 2020 under the German Council Presidency (EU, 2020[21]).

As this diversity of efforts demonstrates, Germany has clear plans and legal provisions for regulatory sandboxes. The country has set up-to-date regulatory sandboxes in the field of automated driving. Furthermore, a regulatory sandbox operating in Hamburg lasted seven months and offered a testbed for an autonomous delivery robot. Other countries have set up AI sandboxes for several applications. For instance, Spain created an AI regulatory sandbox in 2022 as the first pilot programme to test the EU AI Act. The UK launched two regulatory sandboxes through the Financial Conduct Authority (FCA) and the Information Commissioner's Office (ICO). The FCA Sandbox (2016) focuses on financial technology while also admitting AI-related solutions applied in the financial sector. Inspired by the ICO regulatory sandbox, the Norwegian Data Protection Authority (*Datatilsynet*) Regulatory Sandbox (2020) aims to promote ethical, privacy-friendly, and responsible innovation within AI (OECD, 2023[22]).

The German federal structure determines when some areas including implementation of federal legislation are the purview of the *Länder* (Box 6.2), rather than the federal government. Legal competencies to implement sandboxes lie with the *Länder*, i.e. a competent authority at the *Länder* level needs to give a derogation to applicants. However, limited expertise at the *Länder* level oftentimes hinders provisions' applicability. To address this issue, Germany could finance a central team/hub that provides support to the competent authorities. Another option would be to centralise the competencies for regulatory experimentation at the federal level.

Box 6.2. *Länder* in the German federal system

According to Article 20 of German Basic Law, Germany is a federal system. Every state (*Land*) shares responsibilities with the federal government and the municipalities:

- The exercise of state powers and the discharge of state functions (especially administrative tasks) is a matter for the *Länder*; they are thus responsible for implementing federal legislation.
- Federal and regional powers can overlap in areas such as justice, social welfare, civil, criminal, labour, or economic law. If in conflict, federal law takes precedence.

Länder have exclusive legislative powers regarding culture, education, universities, local authority matters, and the police.

Standardisation activities in AI

Germany is creating standards for trustworthy AI, leveraging its quality reputation towards AI products and services and aiming to shape EU standardisation. The AI trust label and the CERTAIN programme for trusted AI techniques also contribute to shaping "*trustworthy* AI Made in Germany".

Germany can carry over its industry's reputation for high-quality goods to AI products and services

Germany is working on standardisation for trustworthy AI. The German Standardisation Roadmap for Artificial Intelligence is a unique multistakeholder endeavour and an excellent step to guide domestic efforts and position Germany in the international standards ecosystem. However, the Roadmap seems to lack clear and actionable objectives and commitment from engaged parties (DIN, 2023[23]).

Germany is also engaged in international AI governance and standardisation bodies. A German AI expert from the Association for Electrical, Electronic & Information Technologies (*Verband der Elektrotechnik Elektronik Informationstechnik*, VDE) chairs the European Committee for Standardization (CEN) and

European Committee for Electrotechnical Standardization (CENELEC) Joint Technical Committee 21 (JTC21) on Artificial Intelligence, that was mandated (together with European standardisation organisation ETSI) to develop harmonised European standards to implement the EU AI Act.

Germany has an opportunity to carry over its industry's reputation for high-quality goods to AI products and services and spearhead AI standard setting within the European Union. Germany could show compliance with the EU AI Act and make trustworthy AI a crucial factor for competitiveness. In this regard, German companies have already set up an AI trust label in co-operation with VDE and major French companies (VDE, 2022[24]). The objective is to promote trustworthy AI that can provide the German industry with a competitive advantage while, at the same time, helping to promote AI uptake among firms.

In September 2023, another initiative contributing to this approach introducing a national implementation programme called Trusted AI was launched by the consortium Centre for European Research in Trusted AI (CERTAIN), legally part of DFKI (DFKI, 2023[25]). CERTAIN focuses on researching, developing, deploying, standardising, and promoting Trusted AI techniques, with the aim of providing guarantees for and certification of AI systems.

Recommendations

Articulate a strategic vision for AI to address Germany's most pressing challenges

AI policy action requires political commitment, a clear vision, and effective co-operation and collaboration mechanisms. Interview participants voiced concern that, despite actions undertaken since 2018 to foster AI development in the country, Germany seems to have no strategic vision or leadership for the direction the country should take regarding AI. To address this, Germany should establish an agile, long-term, and integrated vision of how the German society wants AI to serve progress and well-being, and detailed roadmaps for implementation. An international example is the National Strategy for AI in Health and Social Care, currently being developed by the National Health Service (NHS) AI Lab in the UK within the context of the National AI Strategy, which will set the direction for AI in health and social care up to 2030 (NHS, 2023[26]).

Lead and co-ordinate AI policy design and implementation at the highest political level, and directly link Germany's AI, data, and digitalisation policies

Oversight, co-ordination, and adequate resources at the top political level (i.e. the Federal Chancellery) are required to implement the national AI strategy and generate synergies with Germany's digitalisation and data strategies. Promising practices elsewhere include the United Kingdom Government Office for AI – a unit of the Department for Science, Innovation and Technology responsible for overseeing the implementation of the National AI Strategy – and the US National Artificial Intelligence Initiative Office (NAIIO), located in the White House Office of Science and Technology Policy and mandated to co-ordinate and support the National AI Initiative Act. Further examples include the Secretary of State for Digitalisation and AI in Spain (depending on the newly created Spanish Ministry for the Digital Transformation and the Civil Service, which has broad competencies related to telecommunications, information society, digital transformation, and the development and promotion of AI), and the Ministry of AI in the United Arab Emirates.

Increase funding for AI ambitions

To safeguard technological independence in AI, vital for the German economy and society, interviewed experts concurred that substantial investments are imperative at both the national and EU levels.

Stakeholders have advocated for these investments to be on par with those made in the People's Republic of China and the US (Humboldt Foundation, 2023[27]).

Establish a central team/hub to help authorities foster expertise in regulatory experimentation at the Länder *level*

Germany set up a comprehensive and solid national legislative framework for regulatory experimentation. However, the implementation of sandboxes lies with authorities at the regional level. While some *Länder* have the competence to set up, oversee, and evaluate sandboxes, most lack such expertise. To address this, Germany could finance a central team to provide support to the competent *Länder* authorities. Another option would be to centralise the competencies for regulatory experimentation at the federal level.

Better leverage influence on EU regulation and standards development

There is an opportunity for Germany to carry over its industry's reputation for high-quality goods to AI products and services to spearhead AI standard-setting within the European Union. Germany should ensure that it continues to be well represented in European and global AI standardisation activities, leveraging existing key positions such as the current chairmanship on CEN-CENELEC by a German from VDE.

Implement specific policies to promote the trustworthy use of AI in the workplace

Beyond actions to invest in training and social dialogue, Germany will need to address the risks that AI used in the workplace can pose to the rights and safety of workers.

Existing anti-discrimination legislation and regulation on occupational safety and health, data protection, transparency, and freedom of association – while not specific to AI – provide a framework to address related risks. Monitoring the relevant case law will allow Germany to determine whether this regulation needs to be adapted in light of the use of AI.

The EU AI Act, the Product Liability Directive and the AI Liability Directive will include provisions to ensure accountability, but Germany will need to implement measures specific to workplace uses.

References

BMAS and DenkFabrik (2023), *Observatorium Künstliche Intelligenz in Arbeit und Gesellschaft*, https://www.ki-observatorium.de/en. [13]

BMBF (2019), *Interim Report: One Year of AI Strategy*, Bundesministerium für Bildung und Forschung, https://www.bmbf.de/bmbf/shareddocs/downloads/files/zwischenbericht-ki-strategie_final.pdf (accessed on 11 December 2023). [1]

BMDV (2023), "Veröffentlichung Eckpunkte Mobilitätsdatengesetz", Bundesministerium für Digitales und Verkehr, https://bmdv.bund.de/DE/Themen/Digitales/Digitale-Gesellschaft/Eckpunkte-Mobilitaetsdatengesetz/eckpunkte-mobilitaetsdatengesetz_node.html (accessed on 18 October 2023). [9]

BMDV (2017), *Automated and Connected Driving*, Federal Ministry of Transport and Digital Infrastructure, https://bmdv.bund.de/SharedDocs/EN/publications/report-ethics-commission-automated-and-connected-driving.pdf?__blob=publicationFile (accessed on 11 December 2023). [15]

BMWi (2021), *Praxishilfe zum Datenschutz in Reallaboren*, Bundesministerium für Wirtschaft und Energie, https://www.bmwk.de/Redaktion/DE/Publikationen/Digitale-Welt/praxishilfe-zum-datenschutz-in-reallaboren.pdf?__blob=publicationFile&v=1 (accessed on 18 October 2023). [18]

BMWi (2020), *Recht flexibel*, Bundesministerium für Wirtschaft und Energie, https://www.bmwk.de/Redaktion/DE/Publikationen/Digitale-Welt/recht-flexibel-arbeitshilfe-experimentierklauseln.pdf?__blob=publicationFile&v=1 (accessed on 2023 October 2023). [17]

BMWi (2016), *Digitale Strategie 2025*, Bundesministerium für Wirtschaft und Energie, https://www.bmwk.de/Redaktion/DE/Publikationen/Digitale-Welt/digitale-strategie-2025.pdf?__blob=publicationFile&v=1 (accessed on 24 October 2023). [7]

BMWK (2023), *Grünbuch Reallabore*, Bundesministerium für Wirtschaft und Klimaschutz, https://www.bmwk.de/Redaktion/DE/Downloads/G/gruenbuch-reallabore.pdf?__blob=publicationFile&v=10 (accessed on 18 October 2023). [20]

BMWK (2019), *Making Space for Innovation - The Handbook for Regulatory Sandboxes*, Federal Ministry for Economic Affairs and Energy, https://www.bmwk.de/Redaktion/EN/Publikationen/Digitale-Welt/handbook-regulatory-sandboxes.pdf%3F__blob%3DpublicationFile%26v%3D2 (accessed on 18 October 2023). [16]

DFKI (2023), *CERTAIN: The European Centre for Trusted AI starts with a kick-off celebration on September 19, 2023*, https://www.dfki.de/en/web/news/certain-european-centre-for-trusted-ai-starts-with-kick-off-celebration-on-september-19-2023 (accessed on 11 December 2023). [25]

DIN (2023), *Second Edition of the German Standardization Roadmap AI*, Deutsches Institut für Normung e.V., https://www.din.de/en/innovation-and-research/artificial-intelligence/ai-roadmap (accessed on 18 October 2023). [23]

EC (2024), *European Approach to Artificial Intelligence*, European Commission, https://digital-strategy.ec.europa.eu/en/policies/european-approach-artificial-intelligence (accessed on 11 December 2023). [11]

EC (2021), *Proposal for a Regulation of the European Parliament and of the Council laying down Harmonised Rules on Artificial Intelligence and amending certain Union Legislative Acts (Artificial Intelligence Act)*, European Commission, https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52021PC0206 (accessed on 28 March 2023). [28]

EU (2024), *Regulation (EU) 2024/ ..... of the European Parliament and of the Council laying down harmonised rules on artificial intelligence (Artificial Intelligence Act)*, https://data.consilium.europa.eu/doc/document/PE-24-2024-INIT/en/pdf. [10]

EU (2020), *Council Conclusions on Regulatory Sandboxes and Experimentation Clauses as Tools for an Innovation-friendly, Future-proof and Resilient Regulatory Framework that Masters Disruptive Challenges in the Digital Age*, Council of the European Union, https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52020XG1223(01) (accessed on 18 October 2023). [21]

European Parliament (2023), *Briefing - EU Legislation in Progress: Artificial Intelligence Liability Directive*, https://www.europarl.europa.eu/RegData/etudes/BRIE/2023/739342/EPRS_BRI(2023)739342_EN.pdf. [12]

Executive Office of the President (2022), *Supplement to the President's FY 2023 Budget*, National Science and Technology Council, https://www.nitrd.gov/pubs/FY2023-NITRD-NAIIO-Supplement.pdf. [6]

German Federal Government (2023), *Weiterentwicklung der Datenstrategie - Fortschritt dank besserer Daten*, https://www.bundesregierung.de/breg-de/themen/digitaler-aufbruch/datenstrategie-2023-2216620 (accessed on 18 October 2023). [8]

German Federal Government (2021), *Mehr Fortschritt wagen - Bündnis für Freiheit, Gerechtigkeit und Nachhaltigkeit*, https://www.bundesregierung.de/resource/blob/974430/1990812/1f422c60505b6a88f8f3b3b5b8720bd4/2021-12-10-koav2021-data.pdf?download=1 (accessed on 18 October 2023). [19]

German Federal Government (2020), "Economic stimulus package: An ambitious programme", https://www.bundesregierung.de/breg-en/news/konjunkturpaket-1757640 (accessed on 11 December 2023). [3]

German Federal Government (2020), *Strategie Künstliche Intelligenz der Bundesregierung - Fortschreibung 2020*, https://www.ki-strategie-deutschland.de/files/downloads/201201_Fortschreibung_KI-Strategie.pdf (accessed on 11 October 2023). [2]

HM Government (2021), *National AI Strategy*, https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1020402/National_AI_Strategy_-_PDF_version.pdf. [5]

Humboldt Foundation (2023), *Sieben Empfehlungen zur Künstlichen Intelligenz (KI) an die Deutsche Bundesregierung*, https://www.humboldt-foundation.de/fileadmin/Bewerben/Programme/Alexander-von-Humboldt-Professur/Positionspapier_zur_Kuenstlichen_Intelligenz_Recommendations_on_AI.pdf (accessed on 2023 October 2023). [27]

Merkur (2023), "Coalition wants to make AI applications in administration possible", https://www.merkur.de/politik/koalition-will-ki-anwendungen-in-verwaltung-moeglich-machen-zr-92489210.html (accessed on 11 December 2023). [14]

Ministère de l'Économie, des Finances et de la Souveraineté industrielle et numérique (2023), *La Stratégie Nationale pour l'Intelligence Artificielle*, https://www.entreprises.gouv.fr/fr/numerique/enjeux/la-strategie-nationale-pour-l-ia. [4]

NHS (2023), *The National Strategy for AI in Health and Social Care*, NHS England, https://transform.england.nhs.uk/ai-lab/ai-lab-programmes/. [26]

OECD (2023), "Regulatory sandboxes in artificial intelligence", *OECD Digital Economy Papers*, No. 356, OECD Publishing, Paris, https://doi.org/10.1787/8f80a0e6-en. [22]

UK Government (2021), *National AI Strategy*, https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1020402/National_AI_Strategy_-_PDF_version.pdf (accessed on 11 December 2023). [29]

VDE (2022), "Kann Künstliche Intelligenz wertekonform sein? VDE SPEC als Grundlage künftiger Entwicklungen", Verband der Elektrotechnik Elektronik Informationstechnik e.V., https://www.vde.com/de/presse/pressemitteilungen/ai-trust-label (accessed on 18 October 2023). [24]

Note

[1] “Operator” means the provider, the product manufacturer, the deployer, the authorised representative, the importer or the distributor.

7 Society

This chapter discusses initiatives to promote the use of artificial intelligence (AI) for social good, as well as public perceptions of AI in Germany. Germany has a strong commitment to fostering an AI ecosystem dedicated to societal well-being. The Civic Coding - Innovation Network AI for the Common Good serves as a central hub for promoting AI projects for the common good. Public perceptions of AI in Germany are generally positive but differ by age group and application sector. Trust in AI applications within healthcare is notably high, and concerns over data privacy and disinformation are very diffused. Recommendations include broadening stakeholder engagement in AI policy design and regularly monitoring public perceptions of AI.

The use of AI should be guided by economic interests and oriented towards the common good of German society. Both the 2018 national AI strategy and its 2020 update set out these goals. More specifically, the 2020 strategy aimed to establish an ecosystem for AI dedicated to the common good, promote AI applications supporting everyday consumer life (referred to as consumer-enabling technologies), and support AI projects for the preservation, exploration, accessibility, networking, and dissemination of cultural offerings. Furthermore, it outlined plans for building AI competence in exploring and verifying media content to safeguard the diversity of opinions.

Box 7.1. Society: Findings and recommendations

Findings

- The Federal Government launched several initiatives to promote the use of AI for social good.
- Overall public perception of AI in Germany is positive. Trust in AI applications is highest in healthcare and lowest in human resources.
- Potential threats to the positive public perception of AI come from mis- and disinformation. The federal government initiated various activities to address this.
- While social partners are involved in AI policy design, stakeholder participation could be broadened.
- Citizens are consulted on AI debate, but their involvement in AI policy design could be deepened.

Recommendations

- Involve a broader range of stakeholders in AI policy design.
- Launch an AI citizens' assembly.
- Regularly monitor public perceptions on AI.

Programmes supporting AI for the common good

Germany's Civic Coding Initiative fosters AI for the common good by bundling initiatives and projects across ministries. Through platforms and spaces for encounters such as the Civic Innovation Platform and the AI Ideas Workshop for Environmental Protection, the federal government supports the networking of civil society actors and enables the testing of digital technologies. Together with civil society organisations, it is committed to creating data spaces for the common good as part of the Civic Data Lab.

The federal government supports initiatives to promote the use of AI for social good

The Civic Coding – Innovation Network AI for the Common Good, founded by three ministries, stands out as the central hub for promoting AI projects for the common good (Box 7.2). The independent think tank iRights.Lab established the Centre for Trustworthy Artificial Intelligence (*Zentrum für vertrauenswürdige Künstliche Intelligenz*, ZVKI) with the support of the Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection (*Bundesministerium für Umwelt, Naturschutz, nukleare Sicherheit und Verbraucherschutz*, BMUV), in co-operation with the Fraunhofer Institute for Applied and Integrated Security (*Fraunhofer-Institut für Angewandte und Integrierte Sicherheit*, AISEC), the Fraunhofer Institute for Intelligent Analysis and Information Systems (*Fraunhofer-Institut für Intelligente Analyse- und Informationssysteme*, IAIS) and the Freie Universität Berlin. As a national and neutral

interface between science, business, and civil engagement, it provides information on many aspects relevant to consumers, facilitates public discussions and develops tools for the evaluation and certification of trustworthy AI (ZVKI, 2023[1]).

Box 7.2. *Civic Coding* - Innovation Network AI for the Common Good

Civic Coding - Innovation Network AI for the Common Good is an interdepartmental initiative of the Federal Ministry of Labour and Social Affairs (*Bundesministerium für Arbeit und Soziales*, BMAS), the BMUV and the Federal Ministry for Family Affairs, Senior Citizens, Women and Youth (*Bundesministerium für Familie, Senioren, Frauen und Jugend,* BMFSFJ). The initiative aims to create and leverage synergies by bundling and networking AI-related projects, programmes, structures, and communities of the three participating ministries. The goal is to develop a visible and effective innovation network that supports and secures the long-term use of AI that works for the public good and sustainable development (Civic Coding, 2023[2]). The following projects are part of the innovation network.

Civic Innovation Platform

The Civic Innovation Platform (CIP) is supported by the BMAS. The core of the project – a multifunctional internet platform for connecting cross-sectoral and/or interdisciplinary project teams – was integrated in the Civic Coding Initiative in 2023. Support for the human-centred development and use of AI applications for the common good and society benefits from two funding stages. First, financially and ideally through a prize of up to EUR 20 000 and in-kind support like consulting and workshop offerings. This is part of the idea contest “AI is what we make it!”, in which project teams submit their ideas for AI applications that benefit the common good. Second, a long-term project funding started in 2023 (Civic Innovation Platform, 2023[3]).

AI Ideas Workshop for Environmental Protection

The AI Ideas Workshop for Environmental Protection is supported by the BMUV. It serves as both a physical and virtual hub for civil society actors to support them in developing data-driven and AI-based solutions to address environmental challenges. An AI Ideation Workshop offers educational formats to impart skills in handling environmental data and, by using best practices, demonstrates how AI is already contributing to environmental protection today (KI-Ideenwerkstatt, 2023[4]).

Civic Data Lab

The Civic Data Lab is funded by the BMFSFJ. It helps organised and non-organised civil society actors to better achieve common good goals through with data by collecting, organising and structuring their data, evaluating it, linking it, reusing it for their target groups, making it available to others, and supplementing it with available data (Caritas digital, 2023[5]).

Source: Civic Coding (2023[2]), *Die Initiative*, https://www.civic-coding.de/ueber-civic-coding/die-initiative (accessed on 2 November 2023); Civic Innovation Platform (2023[3]), *Projekt und Leitbild*, https://www.civic-innovation.de/ueber-uns/projekt-und-leitbild (accessed on 2 November 2023); KI-Ideenwerkstatt (2023[4]), *Über uns*, https://www.ki-ideenwerkstatt.de/ (accessed on 2 November 2023); Caritas digital (2023[5]), *Projekt Civic Data Lab*, https://www.caritas-digital.de/projekte/civic-data/ (accessed on 2 November 2023).

Public perception of AI in Germany

German citizens generally perceive AI positively, with high awareness and trust levels. However, concerns about data privacy and disinformation exist. Germany could monitor regularly public perceptions on AI and step-up citizen and diverse civil society participation in policy making to reflect civil values in AI policies.

People in Germany have a positive perception of AI

When promoting a common good-oriented use of AI in the German society, it is also important to be familiar with the attitudes that people hold regarding AI. In general, people in Germany had a comparatively positive perception of AI in 2021, one of the highest in a sample of comparable countries (Lloyd's Register Foundation, 2021[6]). They also show a comparatively high willingness to trust and accept AI systems, ranking seventh in front of people in countries such as Australia, Canada, Estonia, Finland, France, Israel and the United Kingdom (UK). However, people in Germany are significantly less willing to trust and accept AI systems than those living in countries such as Brazil, the People's Republic of China, India or South Africa (KPMG, 2023[7]).

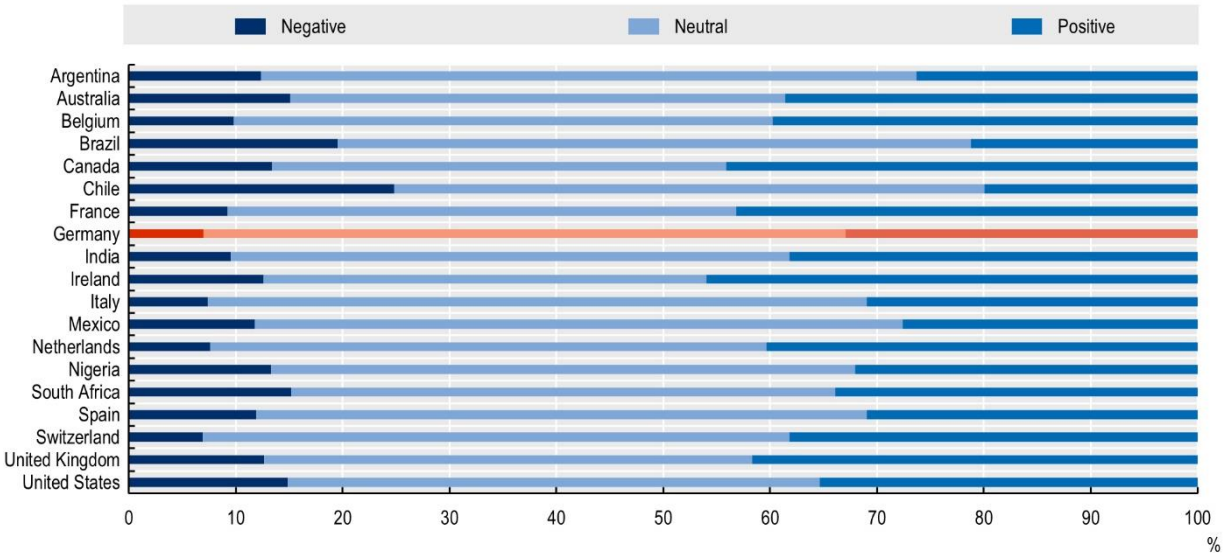
In a recent survey gauging the perspectives of Europeans on the impact of AI, Germany has an advantage over other countries in that more than 80% of respondents indicated that they knew a little or a lot about AI – the highest among countries involved in the survey. Regarding the overall applications of AI, opinions are divided, with roughly equal proportions believing AI to be either beneficial or harmful (21% and 22% respectively). More than half of respondents expressed neutrality or indicated that they did not have enough information; however, there was a significant difference between younger populations (19-25) where 36% of respondents believed AI would be beneficial, while only 13% of older respondents (65+) shared this view (bidt, 2023[8]).

Regarding the sector of AI applications, people living in Germany placed the highest level of trust in AI applications within the healthcare sector in 2023 (see Chapter 10). Conversely, AI applications in the human resources sector receive the least amount of trust. However, this difference is not specific to Germany but is also evident in other countries. It is likely a result of the significant and immediate benefits that improved precision in medical diagnoses and treatments provides to individuals, coupled with the generally high levels of trust in healthcare professionals in most countries (KPMG, 2023[7]).

In addition, most German X users also seem to have a rather neutral or positive sentiment regarding AI, displaying a lower baseline negative sentiment than in similar countries (Figure 7.1). However, it is essential to note that the data presented here extend only until 2022. Given that ChatGPT-3 was launched in November of that year, it is plausible that sentiments may have evolved since then. Taking into consideration the rapid development of AI technologies, it would be crucial for countries to stay aware of their citizens' public perceptions of AI. This is particularly relevant for Germany, given that its AI strategy explicitly emphasises a human-centred approach.

However, this positive attitude might be jeopardised if new AI applications do not reflect German values and are not trustworthy. Concerns over data privacy, social scoring, and disinformation are already prevalent among X users in Germany. The targeted use of AI applications to disseminate mis- and disinformation, for instance, could deepen these concerns, but also have negative consequences for German democracy as a whole. It is therefore imperative for the federal government to continue and expand its efforts to combat AI-generated mis and disinformation. Two promising examples of the many projects targeted at addressing these issues are DeFaktS and noFake (BMBF, 2022[9]).

Figure 7.1. Most German X users display a neutral or positive sentiment towards AI



Source: Analysis based on data from X, formerly Twitter.

The DeFaktS project, funded by the Federal Ministry of Education and Research (*Bundesministerium für Bildung und Forschung*, BMBF) takes a comprehensive approach to researching and combating disinformation. To achieve this goal, an AI model is trained using extracted data from suspicious social media and messenger groups, enabling it to recognise factors and stylistic elements characteristic of disinformation. Subsequently, this trained AI becomes a component for eXplainable Artificial Intelligence (XAI), which is used to develop an app that aims to transparently inform and warn users of online offerings about the possible occurrence of disinformation (BMBF, 2023[10]).

Funded with EUR 1.33 million by the BMBF, the goal of the AI-supported Assistance System for Crowdsourced Detection of Disinformation on Digital Platforms (noFake) project is to develop an assistance system that aids crowd workers in quickly identifying disinformation. This system automates the analysis of large datasets by pre-sorting suspicious text and image materials, associating them with similar content, and revealing the dissemination channels of the examined materials. The research finding will be combined with journalistic expertise for the development of the assistance system. Recognising that the success of the system depends not only on its functionality but also on how crowd workers use it, training materials and learning curricula are being developed to empower crowd workers to make informed assessments of information materials (BMBF, 2023[11]).

Simply measuring the attitudes of the German population, though, is not enough. In order to fully take their concerns into account when formulating AI policies, the involvement of civil society organisations and citizens in these processes should be encouraged. In this regard, the federal government does engage with stakeholders in the design of AI policies, for instance through an online consultation during the formulation of the 2018 national AI strategy. However, the organisations most strongly and frequently involved are primarily social partners (*Sozialpartner:innen*). In contrast, minority or environmental protection civil society organisations are relatively rarely invited to the table. For German AI policies to better reflect the diverse interests of its civil society, a more balanced participation of organisations would hence be required.

There is equally as much untapped potential with regards to engaging citizens in AI policy design. In Germany, this has so far been limited to consultations which take place very rarely. Countries such as

Canada, Norway and the UK could serve as a role model here, where AI policy design is much more strongly informed by citizens through public deliberations or co-construction workshops.

Recommendations

Involve a broader range of stakeholders in AI policy design

Social partners have been involved in the AI policy development process, primarily representing the interests of employees and employers. However, given AI's implications for various areas of society, focusing on only the economy is not enough. It is essential to strengthen the involvement of organisations from more areas affected by AI, including, environmental or minority rights organisations, among others.

Launch an AI citizens' assembly

In 2022, the project Citizens' Assembly (*Bürgerrat*), led by the organisation More Democracy (*Mehr Demokratie*), conducted a citizens' assembly to address AI in Germany (Bürgerrat, 2022[12]). However, to ensure that the topics and recommendations discussed in such assemblies reach policy makers, a federal ministry such as the BMAS could organise a citizen assembly on AI.

While randomly selected citizens' assemblies are currently employed as ad-hoc and irregular democratic instruments, they possess the potential to serve as a permanent tool supporting political decision making. Establishing ongoing citizens' assemblies bolsters public trust in political decision makers and fosters continuous dialogue. As elucidated by (OECD, 2021[13]), regularly practicing deliberative democracy allows people and decision makers to build mutual trust.

In this context, Germany could consider creating a permanent citizens' assembly dedicated to emerging technologies, specifically focusing on AI. Such an approach would contribute to sustained public engagement and enhance trust in the decision-making process. Furthermore, it would allow the federal government to expand its "common-good approach" from the development of applied AI projects to the formulation of AI policies.

Monitor public perceptions on AI regularly

It is crucial to be aware of the public's perceptions of AI and its implementation in various societal domains to be able to take them into account when developing AI policies. Notably, the AI Observatory (*KI Observatorium)* of the BMAS is already making efforts in this regard, publicly sharing the results of a monitoring initiative from 2021 on its website (KI Observatorium, 2021[14]). However, given AI's rapid advancements in recent years, it is imperative to conduct monitoring regularly, possibly with the AI Observatory's leadership.

References

bidt (2023), *Autorinnen und Autoren: Das bidt-Digitalbarometer. international*, Bayerisches Forschungsinstitut für Digitale Transformation, https://doi.org/10.35067/xypq-kn68. [8]

BMBF (2023), *DeFaktS*, Bundesministerium für Bildung und Forschung, https://www.forschung-it-sicherheit-kommunikationssysteme.de/projekte/defakts (accessed on 3 November 2023). [10]

BMBF (2023), *noFake*, Bundesministerium für Bildung und Forschung, https://www.forschung-it-sicherheit-kommunikationssysteme.de/projekte/nofake (accessed on 3 November 2023). [11]

BMBF (2022), “Fake News erkennen, verstehen, bekämpfen [Recognising, understanding and combating fake news]”, Bundesministerium für Bildung und Forschung, https://www.bmbf.de/bmbf/shareddocs/kurzmeldungen/de/2022/02/fake-news-bekaempfen.html (accessed on 11 December 2023). [9]

Bürgerrat (2022), “Citizens’ assembly discussed artificial intelligence”, https://www.buergerrat.de/en/news/citizens-assembly-discussed-artificial-intelligence/ (accessed on 25 January 2024). [12]

Caritas digital (2023), *Projekt Civic Data Lab*, https://www.caritas-digital.de/projekte/civic-data/ (accessed on 2 November 2023). [5]

Civic Coding (2023), *Die Initiative*, https://www.civic-coding.de/ueber-civic-coding/die-initiative (accessed on 2 November 2023). [2]

Civic Innovation Platform (2023), *Projekt und Leitbild*, https://www.civic-innovation.de/ueber-uns/projekt-und-leitbild (accessed on 2 November 2023). [3]

KI Observatorium (2021), *KI Indikatoren - KI in Arbeit und Gesellschaft*, Bundesministerium für Arbeit und Soziales, https://www.ki-observatorium.de/ki-indikatoren (accessed on 24 January 2024). [14]

KI-Ideenwerkstatt (2023), *Über uns*, KI-Ideenwerkstatt für Umweltschutz des Bundesministeriums für Umwelt, Naturschutz, nukleare Sicherheit und Verbraucherschutz, https://www.ki-ideenwerkstatt.de/ (accessed on 2 November 2023). [4]

KPMG (2023), *Trust in Artificial Intelligence: A Global Study*, https://assets.kpmg.com/content/dam/kpmg/au/pdf/2023/trust-in-ai-global-insights-2023.pdf (accessed on 31 October 2023). [7]

Lloyd’s Register Foundation (2021), *World Risk Poll 2021: A Digital World*, https://wrp.lrfoundation.org.uk/LRF_2021_report_a-digtial-world-ai-and-personal-data_online_version.pdf (accessed on 31 October 2023). [6]

OECD (2021), “Eight ways to institutionalise deliberative democracy”, *OECD Public Governance Policy Papers*, No. 12, OECD Publishing, Paris, https://doi.org/10.1787/4fcf1da5-en. [13]

ZVKI (2023), *Über uns*, Zentrum für vertrauenswürdige Künstliche Intelligenz, https://www.zvki.de/ueber-uns (accessed on 2 November 2023). [1]

8 Spotlight: AI in the public sector

This chapter discusses the strategic and trustworthy use of artificial intelligence (AI) in the public sector, such as for back-office functions of public-facing digital services. It examines existing strategy efforts in the public sector, how they align to broader European Union (EU) efforts, and potential levers for implementation. It covers real-world use cases, spotlighting large language models and emerging best practices. The chapter looks at the key governance capacities Germany has put in place (e.g. leadership, policy-making authority and co-ordination) and its enablers (e.g. data, funding, procurement mechanisms and skills). A focus on transparency notes actions taken and opportunities for further advancements. Finally, it identifies promising international practices that may provide Germany with lessons and makes seven recommendations for action.

The use of trustworthy AI in the public sector can significantly impact public policies and services. It can free up a significant amount of public servants' time, allowing them to shift from mundane tasks to high-value work, increasing public-sector efficiency and effectiveness. Governments can also use AI to design better policies and make better, more targeted decisions, enhance communication and engagement with citizens and residents, and improve the speed and quality of public services. While doing so, they need to ensure that the use of AI systems in the public sector is transparently communicated to citizens, and that the AI systems do not lead to discriminatory outcomes. Germany has embedded AI in the public sector as a strong component of its national AI strategy.

Box 8.1. AI in the public sector: Findings and recommendations

Findings

- Germany has solid strategies for public sector AI, though stronger enablers for implementation and co-ordination could drive progress. The 2023 Data Strategy begins to strengthen these.
- The establishment of expert-staffed data labs and the 2023 Data Strategy commitment to launch them in every ministry are excellent steps towards adoption of AI in the public sector, horizontal governance and co-ordination.
- Despite delays in establishing the Centre for Artificial Intelligence in Public Administration (*Beratungszentrum für Künstliche Intelligenz in der Öffentlichen Verwaltung,* BeKI) under the Federal Ministry of the Interior and for Community (*Bundesministerium für des Innern und für Heimat*, BMI), the effort is now underway. The Centre has initiated several projects and is positioned to be a source of guidance on AI use in the public sector. Public-sector organisations could benefit from additional clarification about roles and responsibilities in AI governance between BMI and ministries.
- The Federal Government demonstrated its ability to be meticulous and transparent in ad hoc reporting on the use of AI in the public sector. However, the public sector currently lacks systematic monitoring and transparency of AI use.

Recommendations

- Strengthen the focus on strategy implementation by publishing a periodically updated roadmap with specific commitments and actions for each goal, laying out responsible entities, allocated budget and milestones, and monitoring mechanisms.
- Strengthen co-ordination and collaboration among federal entities, and with *Länder* and cities, both formally (e.g. councils) and informally (e.g. networks and communities of practices).
- Through BMI and its BeKI, ensure the timely issuance of planned guidance on the use of AI in the public sector, which should also clarify the entity's roles and responsibilities with regards to horizontal policy making for public sector AI efforts.
- Encourage ministries to develop guidelines on adopting AI in the public sector in their own contexts, and work with them to ensure these guidelines are consistent with national strategies and governing rules and norms.
- Explore the development of front-end (e.g. algorithmic impact assessment) and back-end (e.g. algorithmic auditing) processes and guidelines.

- Consider developing a central, public, searchable registry of AI systems in use in the public sector. Depending on if and how the previous recommendation is implemented, this could be done automatically.
- Consider baseline training for all civil servants whose roles directly or indirectly involve using or being impacted by AI.

Strategic approach to AI in the public sector

Germany's AI strategy incorporates AI into public sector efficiency, open government data (OGD), and security. Its concrete actions and clear objectives include improving service delivery and emergency response capabilities. It complements national and EU strategies, emphasising human-centred AI and public-private partnerships to enhance public services and security.

Germany put in place solid strategies for AI in the public sector

Like most countries that have developed a national AI strategy, Germany embedded AI in the public sector as a strong component of its 2018 national strategy. While several parts have indirect implications for AI use in the public sector, two sections can be seen as particularly relevant: “Using AI for tasks reserved for the state and administrative tasks” and “Making data available and facilitating its use”. Across these, three main topics emerge:

- **Public sector efficiency and effectiveness**. The potential to utilise AI to improve services delivered by the public sector with regards to their efficiency, quality, and security. This could make administrative processes easier to understand and reduce processing times for citizens.[1]
- **Open Government Data**. One key priority for the Federal Government is the expansion of open access to government data, which was further strengthened in the 2021 Open Data Strategy.
- **Internal and external security**. The Federal Government affirms its interest in using AI for emergency response and the maintenance of internal and external security. One important component of this is information technology (IT) security, an area in which the Federal Government commits to promoting public-sector research and to ensure the development of adequate expertise for the relevant authorities.

The 2020 strategy update can be characterised as a move towards general capacity-building in the public sector. It also strongly reinforced the security elements of the original strategy, discussing the potential of AI for defending against cyber-attacks, emergency and disaster control, and earth observation.

The new 2023 Data Strategy serves to reinforce these focus areas by highlighting the potential for large language models (LLMs) for both back-end and public-facing activities, as well as highlighting the importance of data as an input to AI systems and proposing the introduction of chief data officers and open data co-ordinators in each federal ministry. It is also committed to identifying and preventing discrimination at the data level.

In some areas the path to implementation is less obvious

Roadmaps and enablers, i.e. clear objectives, specific actions, timeframes, funding, and monitoring mechanisms are essential for driving progress in implementing AI strategies in the public sector (Berryhill et al., 2019[1]).

With regards to public sector efficiency and effectiveness, the national AI strategy sets clear objectives for AI in the public sector: to provide citizens and residents with information and services in a more targeted, accessible, and tailored fashion. However, it generally does not contain granular, specific actions for meeting these objectives.

OGD's objective is also clear: to make data "open by default". Compared to public sector efficiency and effectiveness, specific actions regarding OGD are clearer through the combination of the AI strategy, the 2021 Open Data Strategy and the 2023 Data Strategy. For instance, the 2018 strategy called for amending the E-Government Act, establishing a new open data portal, and putting in place specific precautions to protect citizen privacy (e.g. pseudonymisation/anonymisation of data, differential privacy processes). Aside from publishing more data, it discusses actions to facilitate increased access and use.

With regard to internal and external security, the 2018 strategy included some fairly concrete actions, such as social media forensics and steps to protect children against sexualised violence on the internet. The 2020 update introduced more specific actions, including expanding AI-related capabilities of the Central Office for Information Technology in the Security Sector (*Zentrale Stelle für Informationstechnik im Sicherheitsbereich*, ZITiS), a service provider for all federal security authorities; using AI to monitor climate change and other systemic issues, and more related to law enforcement end defence. In addition, the 2023 Data Strategy introduced specific actions related to using LLMs for a variety of public sector use cases, potentially contributing to all three of the primary focus areas.

Germany has made significant progress on many of its goals outlined in its national AI strategy related to AI in the public sector, particularly in the domains of network- and capacity building and enhanced emergency response. In other domains, such as data, security, and regulation, it appears that many of the goals have not yet been met, though several elements appear to be gaining momentum.

The AI strategy's public-sector components align with complementary national strategies and the EU Co-ordinated Plan on AI

Overall, the public sector-relevant components of Germany's AI strategy were explicitly designed to be cohesive with other national strategies issued by the Federal Government, and they do indeed appear well-aligned. Other strategies include the Digital Strategy, Data Strategy, Open Data Strategy, the High-Tech Strategy 2025, the Government Digitalisation Strategy, and the Startup Strategy (BMWK, 2022[2]). Relevant strategies published by individual ministries, such as the Federal Ministry of Education and Research (*Bundesministerium für Bildung und Forschung*, BMBF) Digital Strategy are also consistent with the broader federal strategies.

Vertically, the national AI strategy is well aligned with the EU Co-ordinated Action Plan on AI. Alignment with strategies and guidelines from the EU appear particularly important for AI in the public sector. For instance, the European Union Regulation on Artificial Intelligence (the "EU AI Act") (EU, 2024[3]) takes a risk-based approach to AI use cases. Many AI systems used by the public sector may fall under heightened risk designations due to their connections with critical infrastructure and citizen services and benefits.

Components of Germany's national strategies relevant to AI in the public sector are also generally aligned with the EU co-ordinated plan (EC, 2018[4]). For instance, they address human-centred AI, although they do not include specific implementation actions. Human-centred AI has also been reinforced in the guidelines of a number of individual ministries (BMAS, 2023[5]).

The EU co-ordinated plan also encourages the use of AI across domains, from fighting climate change to enhancing security and curing diseases. As discussed in other parts of this section, these goals are also a high priority for the envisioned use cases for using AI in German public services. The EU co-ordinated plan mentions the trade-offs between using AI for security while still maintaining other standards and values, a tension that is also brought up in the German AI strategy.

The EU co-ordinated plan calls for more public-private partnerships, especially with start-ups and innovators. The 2018 strategy also calls for this, with the 2020 update calling for targeted public procurement processes and GovTech approaches to strengthen economic development among businesses that can, in turn, generate AI solutions for public sector use.

AI use cases in the German government

AI is increasingly used at national, state, and local levels across Germany

Germany tends to have lower public sector digital maturity and digitalisation of public services compared other OECD and peer countries (OECD, 2020[6]; bidt, 2023[7]; EC, 2022[8]). This includes a lack of networking between government databases, in part due to Germany's federal structure, which limits the ability to leverage public sector data as fuel for AI.[2]

Despite this context, there is already a wide variety of public sector AI initiatives at both national and subnational levels of government (Evers-Wölk, Kluge and Steiger, 2022[9]; Engelmann and Puntschuh, 2020[10]). The 2023 Government AI Readiness Index by consulting firm Oxford Insights (2023[11]) ranks Germany eighth out of 193 countries in terms of its government's capacity to integrate AI into the public administration for the public good.[3] Current use cases span the spectrum from front-office, public facing applications to back-office systems that help civil servants engage in the business of government (Table 8.1).

Table 8.1. Best practice examples of AI in the German public sector

Example	Key characteristics
Natural Language Processing (NLP) is used to **answer citizen's questions about the Covid-19 pandemic and current restrictions**, making them less dependent on opening times and response times of relevant authorities.	• Different ministries co-operated in the development of this service. • It was developed in only 40 days. • It can be used as a blueprint for chatbots in other domains.
A system that **classifies and extracts information from documents** (specifically Immatriculation Certificates) parents need to submit to be eligible to receive child assistance. The system checks submitted documents for a) whether it is a valid certificate (and with what probability it is), b) whether it is for the right child, c) whether it is for the right semester and d) whether it comes from a recognised German university. The system **suggests a decision** that is then approved by a human.	• Continuous learning: incoming data are anonymised and used as additional learning data. • Successfully and efficiently reduces the workload of administrative staff spent on a mundane task. • Waiting times are reduced for users. • There is potential transferability to other administrative domains where submitted documents need to be evaluated.
Indoor robots **measure buildings with laser scanners and cameras**. From the data it obtains, it **builds a 3-D model** that can be used on mobile devices. This enables blind and disabled people to autonomously navigate office buildings of administrative entities.	• The system was developed in close co-operation with involved stakeholders, e.g. wheelmap.com. • Training is provided to interested facility operators to aid quick proliferation of the system.
Light sensors **track the traffic situation** at a given intersection. The extracted data are used to **control traffic lights** at various intersections. Claimed results include reduced transit times (by 25%), reduced environmental pollution and reduced noise levels.	• The system produces and shares open data. • The system can be adjusted to different goals: Reducing stop-and-go, transit times, average speed or noise/pollution. • Transparency: A simulation was created to explain the process to interested citizens.
Automated image recognition is used to **differentiate between child pornography and similar but legal images** (e.g. from family holidays). Selected images flagged as abuse/pornography are **forwarded to staff**.	• Human judgement is not replaced by machines, but the effort for law enforcement is significantly reduced. • The deployment procedure involved iterative testing, including a comparison against human-generated results. • The programme has high IT and data security standards.

Example	Key characteristics
Evidence (publicly accessible data like news reports, NGO reports, socio-economic indicators and climate data) is gathered and a **multifactorial analysis is conducted to assess the likelihood of emerging political crises** (called PREVIEW: Prediction Visualisation and Early Warning). The risk of conflict and expected fatalities can be predicted. **Results are escalated to human staff** that conduct qualitative assessments.	• Models are constantly updated with new training data. • There is a huge degree of (internal) transparency around the codes and the models that are used to compute the predictions that are produced. • Workshops and a manual are available for agencies that are interested in using this system.
A **LLM assists public servants** by summarising texts for them, streamlining the work on cabinet bills by improving interoperability, assists in background research and generates text from human input (see Box 8.2 for additional details).	• Clearly defined scope: Staff aren't allowed to use LLMs for just any task, only a clearly pre-defined subset of tasks. • Lengthy administrative processes can be streamlined, freeing up administrators for personal interactions, e.g. with citizens or political decision makers.

Note: The source material did not always provide the exact name of the use case.
Source: Analysis of Engelmann, J. and M. Puntschuh (2020[10]), *AI in Authorities' Use: Experiences and Recommendations*, https://www.oeffentliche-it.de/documents/10181/14412/KI+im+Beh%C3%B6rdeneinsatz+-+Erfahrungen+und+Empfehlungen.

Dozens of initiatives are directly related to AI in the federal public administration, with an allocated budget of EUR 193 million (Bundestag, 2023[12]). The majority of these initiatives focus on back-office tasks, with the largest proportion of current uses involving improving government efficiency (e.g. motor vehicle administration), though some also touch on public sector integrity (e.g. monitoring financial requirements, payment tracking, and fraud prevention), scientific research (e.g. plant and weather research), public health (e.g. disease anomaly tracking), and civil security (e.g. early crisis detection, investigating deepfake detection, cyber threat defences). Some current efforts involve public-facing services, such as chatbots to answer questions related to motor vehicle taxes and customs laws, with more planned for the future, including voice assistants.

AI is also increasingly used at sub-national levels in states and cities, with a larger proportion focused on public-facing services. This is to be expected, as sub-national governments, especially cities, tend to have the closest contacts with the public. Besides the use of language models (LMs), discussed below, AI can be seen in service robots and automated services, such as:

- The city of Ludwigsburg uses the ServiceRobot L2B2 to greet people in the entrance area of the local city office and to provide information about responsibilities across offices.
- The city of Karlsruhe has established a "completely digital local city office" in which citizens can handle their concerns independently in an entirely digital process.
- With the help of the so-called Speed Capture Station, citizens of the city of Aschaffenburg can capture biometric photos, fingerprints, and signatures themselves on site in the citizen service office before they apply for an ID card or passport. This eliminates the time-consuming process of capturing the various biometric data at service counters and the need to bring passport photos with them.

Spotlight on language models

At the sub-national level, a number of cities are using LM-based tools to facilitate public services. The cities of Heidenheim and Heidelberg both use chatbots to help citizens and residents find information in a conversational manner. The state of Baden-Württemberg also has chatbots for citizen tax inquiries, and as a back-office took for public servants (Box 8.2). The state of Bavaria, too, uses a chatbot to help provide citizens with information on 2 800 different services (Initiative D21, 2023[13]).

Box 8.2. F13 in Baden-Württemberg

Introduced by the innovation laboratory Baden-Württemberg, F13 is a LM developed to assist public servants with their daily tasks, freeing them up and increasing their capacity to work on important projects by streamlining their work processes.

F13 was designed to:

- Summarise long texts. Administrators can choose different levels of compression, although a final review by a human is recommended.
- Streamline the work on cabinet submissions and bills. Comments from documents are automatically uploaded and shared with collaborators, and updates as well as status reports can be downloaded by staff members.
- Assist in research. Public servants can ask questions about documents they upload or questions relating to a database of legislative and official documents (including protocols from plenary meetings, etc.). Example: "What measures are currently being considered for encouraging commuting to work by bicycle?".
- Generate text from human input. Users can upload documents (including notes, studies, etc.) which are then synthesised into a coherent text. Adjustable parameters include the length and the thematic focus of the text. Example: "Summarise the current state of the discourse around the move to regenerative energies".

Source: Staatsministerium Baden-Württemberg (2023[14]), "Künstliche Intelligenz in der Verwaltung", https://stm.baden-wuerttemberg.de/de/service/presse/meldung/pid/kuenstliche-intelligenz-in-der-verwaltung.

AI-based voice assistants are also increasingly used in Germany. Since March 2019, Fraunhofer Institute for Open Communication Systems (*Fraunhofer-Institut für Offene Kommunikationssysteme,* FOKUS) and Fraunhofer Institute for Digital Media Technology (*Fraunhofer-Institut für Digitale Medientechnologie*, IDMT) have been working together on the project Speech Assistance for Citizen Services (S4CS). The goal is to develop an AI demonstrator that supports citizens in applying for administrative services through simple and intelligent communication in natural language. An example is applying for parental allowances, which has been tested in the city of Hamburg.

While LMs feature heavily in some of the use cases, LLMs and their use in the public sector have only recently started to be mentioned in the 2023 Data Strategy, according to which a simplification of unstructured data use for LLMs is planned. An examination of possible use cases is also foreseen, with a special focus on respecting data security, data protection and digital sovereignty. This process will be accompanied by BeKI, the Algorithm Assessment Centre for Authorities and Organizations with Security Tasks (*Algorithmenbewertungsstelle für Behörden und Organisationen mit Sicherheitsaufgaben*, ABOS), the Federal Commissioner for Data Protection and Freedom of Information (*Bundesbeauftragter für den Datenschutz und die Informationsfreiheit*, BfDI) and the data laboratories. The BMI also plans to develop overarching guidance on the use of LLMs in 2024 through BeKI. Switzerland recently issued guidance on the use of generative AI tools in the public sector (CNAI, 2023[15]), promoting responsible experimentation and specifying precisely what types of uses are allowed and prohibited, which may be a useful reference as Germany continues to explore this space.

Transparency on public-sector use of AI could be enhanced

The German Federal Government has demonstrated its ability to identify all AI initiatives and uses underway in the public sector and to report on them in a public and transparent manner. However, the strongest instance of this has occurred in response to a parliamentary inquiry from the political opposition (Drucksache, 2022[16]). As a result, Germany published details on federal ministries and subordinate ministries current and planned uses of AI, representing over 35 entities and nearly 80 use cases.

Such tracking and transparency can help inform citizens and build trust in how the public sector uses AI. While German citizens are open minded regarding the use of AI in the public sector, they often do not understand its potential benefits nor understand where and how AI and algorithmic systems are being used (Initiative D21, 2023[13]). Despite the huge potential to leverage this technology for public sector purposes, the 2023 Data Strategy lacks concrete plans for universal requirements and transparency standards for these systems that are, according to AlgorithmWatch (AlgorithmWatch, 2023[17]), already used in public administration. The Federal Government could take a more proactive stance in this regard by advocating and facilitating transparency measures, for example through the establishment of an open, searchable register of AI solutions used in the public sector. BMI officials reported that the development of such a register is underway as a project of BeKI, with a minimum viable product expected in the first half of 2024. In developing such a product, the AI registers of Helsinki (Finland) and Amsterdam (Netherlands) could be used as informative reference examples in that they track how algorithms are being used in municipalities (OECD.AI, 2023[18]). Furthermore, Germany could draw inspiration from the United Kingdom (UK)'s Algorithmic Transparency Recording Standard, which comprehensively organises how the public sector, including government, should disclose information when using algorithmic tools (OECD.AI, 2023[18]).

Building key governance capacities

High-level support

Success in public sector AI requires governments to set the right tone from the highest levels of government (Berryhill et al., 2019[1]). The inclusion of a solid public sector component in the national AI strategy is one part of this. In addition, OECD interview participants indicated that internal managerial recognition of the importance of AI in the public sector has been clear since the launch of AI system ChatGPT in November 2022, which has generally raised awareness on the technology.

However, another element is strong signalling and communication from national leaders regarding the importance and potential benefits of AI in the public sector. Enhanced visibility on this topic from national leaders could demonstrate that it is a priority and further provide support for public servants at all levels, enabling them to push for innovation and progress. The United States (US) Executive Orders on "Promoting the Use of Trustworthy Artificial Intelligence in the Federal Government" (The White House, 2020[19]), and "Safe, Secure, and Trustworthy Artificial Intelligence" (The White House, 2023[20]) are perhaps the most comprehensive recent examples, as they were issued by the President. The 2023 Executive Order has a strong overarching focus on AI in the public sector.

Policy making, co-ordination, and guidance

Overall, Germany appears to have a relatively low level of centralised policy making and co-ordination of public sector AI efforts in order to support the implementation of the AI and data strategies. However, this seems to be improving, and the Government recently stated that it is working on closer strategic alignment across government entities and on developing relevant procedures for AI (OECD, 2023[21]).

There appears to be a lack of clarity regarding responsibilities for issuing horizontal policies and guidance on AI in the public sector. The BMI is the appropriate entity for this role, with individual ministries responsible for implementation in alignment with their own mission and institutional context. BMI's guidance is to be provided through BeKI. Its establishment has been announced and is currently being built, although not at the necessary speed. BMI also plans to provide formal policies and guidance in 2024, as requested by several ministries.

Most of the work on AI in the public sector is handled by and within ministries, which can have different rules for if, when and how AI is used (Handelsblatt, 2023[22]). This may lead to inconsistency in approaches and the ability to learn lessons from experience, and to duplication of efforts in different ministries. Some ministries have put in place solid guidance on AI design and adoption that could serve as a model for others (BMAS, 2022[23]), while other ministries have not formalised an approach. For the implementation of AI efforts, ministries are often reliant on the co-operation of the *Länder*, which have recently been criticised for moving too slowly on incorporating AI into the public sector (Deutschlandfunk, 2023[24]).[4]

There are at present few mechanisms for horizontal co-ordination for public sector AI activities across the Federal Government. While semi-annual invitational events for ministries to discuss AI projects have been taking place in 2023, there is little evidence of more integrated co-ordination mechanisms at the national level. In other countries, such mechanisms take the shape of formal structures (e.g. inter-ministerial councils) and informal co-operation channels (e.g. networks and communities of practice). However, German official stated that they are taking steps to address this through BeKI, which will be responsible for cross-government co-ordination. Some pilot efforts are already underway, with several meetings and exchanges held on various topics (e.g. how to use LLMs in the public sector, what AI infrastructure is appropriate in the public), with members also able to connect organically and horizontally.

Transversal co-ordination with sub-national governments also appears limited, though the IT Planning Council (*IT-Planungsrat*) has been set up to co-ordinate the work of Germany's Federal and State Governments on matters relating to IT technology and has begun work to address AI co-ordination challenges. Its Federal IT Co-operation (*Föderale IT-Kooperation*, FITKO) has been created to co-ordinate and advance the digitisation of public administration (FITKO, 2023[25]). This is a common challenge in countries with a federal structure and remains perhaps one of the more difficult issues to address.

The 2023 Data Strategy includes plans to establish interconnected data laboratories with Chief Data Officers/Scientists and Open Data Co-ordinators within each federal ministry. These labs have already been launched in all ministries, receiving strong support and recognition as signs of success from interviewees. Similar actions have been taken by other countries, such as the US, with generally positive effects (Federal CDO Council, 2023[26]). Relatedly, a co-operation platform for data labs has been put in place called IMAG.

Such efforts are a step in the right direction and can help promote systems synergies and collective learning while avoiding duplication and overlap. Some existing promising practices with regards to forming cross-government networks or communities of practice could help inform or inspire German efforts, with some examples including Brazil's National Digital Government Network (Brazilian Government, 2023[27]), Chile's Network of Public Innovators, and the AI Community of Practice in the US (Centers of Excellence, 2023[28]).

While existing cross-cutting efforts are limited but growing, some success is apparent within individual ministries. In particular, the Federal Ministry of Labour and Social Affairs (*Bundesministerium für Arbeit und Soziales*, BMAS) has developed a collaborative network for interaction and exchange, the Network Artificial Intelligence in Employment and Social Protection Services, which began with a push by the ministry but is now growing organically to include more than 20 organisations. The network has been active in developing informal guidelines on how to implement AI in the public sector in a human-centred and trustworthy way, according to the BMAS officials interviewed. Such a model could be helpful in bridging siloes across ministries and could inform BMI efforts.

In terms of reaping the results and benefits of AI, the national AI strategy calls for "cross-project incentives for a sustainable utilisation of results, for instance by making algorithms available in open-source form, by disclosing the prepared project data, for instance as open AI training data, or by researchers liaising closely on best practices as well as on any setbacks and problems encountered". This approach is very promising, though the OECD could not find evidence of its implementation, and German officials interviewed were somewhat unsure to what extent any existing efforts would qualify under this, though they believed that Germany's new Data Strategy would help make data more transparent.

Promoting accountability

The Trusted AI initiative and the ABOS aims at facilitating accountability, such as through impact assessments, for entities with a high need for data protection and for those involved in security. However, such efforts are at an early stage.

For both security entities and beyond, Germany could look to best practices established by other countries with regards to front-end algorithmic impact assessment, which can help public officials take a risks-based approach to AI accountability before deployment, as well as back-end auditing processes to ensure AI systems are functioning in a trustworthy manner after deployment (OECD, 2023[29]; Ada/AI Now/OGP, 2021[30]). In terms of the front-end aspects, best practices can be provided by the Canada's Directive on Automated Decisions Making and associated Algorithmic Impact Assessment (Government of Canada, 2023[31]), Chile's General Instruction on Algorithmic Transparency (Consejo para la Transparencia, 2023[32]), and the US Government Accountability Office (GAO)'s AI Accountability Framework (US Government Accountability Office, 2023[33]). With regards to retrospective auditing, solid examples include the Netherlands Court of Auditors (NCA) algorithmic auditing framework. Germany's own Supreme Audit Institution also jointly developed an AI auditing white paper with Finland, the Netherlands, Norway, and the UK that can support efforts in this direction (auditing algorithms, 2023[34]).

Strategic foresight and anticipation

Overall, little work is done on anticipatory governance of public sector AI. One notable exception is the GIRAFFE project (Government Insight, Research, Analytic, Foresight, Function and Exploration) of the BMI which has as an explicit goal to aid the digital transformation of the administration. Some ministries like the BMBF outsource their foresight engagements to private actors, and the Federal Government commissions research by research institutes into strategic foresight. Additional efforts that are not AI-specific but relevant to the increasing use of AI in the public sector are the Competence Centre for Strategic Foresight (*Kompetenzzentrum Strategische Vorausschau*) which focuses on security policy and is housed under the Federal Academy for Security Policy (*Bundesakademie für Sicherheitspolitik*, BAKS), a roundtable for strategic foresight where all federal ministries are involved and a Future Council that briefs the chancellor (*Zukunftsrat des Bundeskanzlers*). Somewhat less directly the Competence Centre for Public IT (*Kompetenzzentrum Öffentliche IT*, ÖFIT), which is externally situated but funded by BMI, serves as a contact and think tank for the digitalisation of the public sector and seeks to take a systems approach considering emerging trends and new developments (BIH, 2023[35]).

Putting critical enablers in place

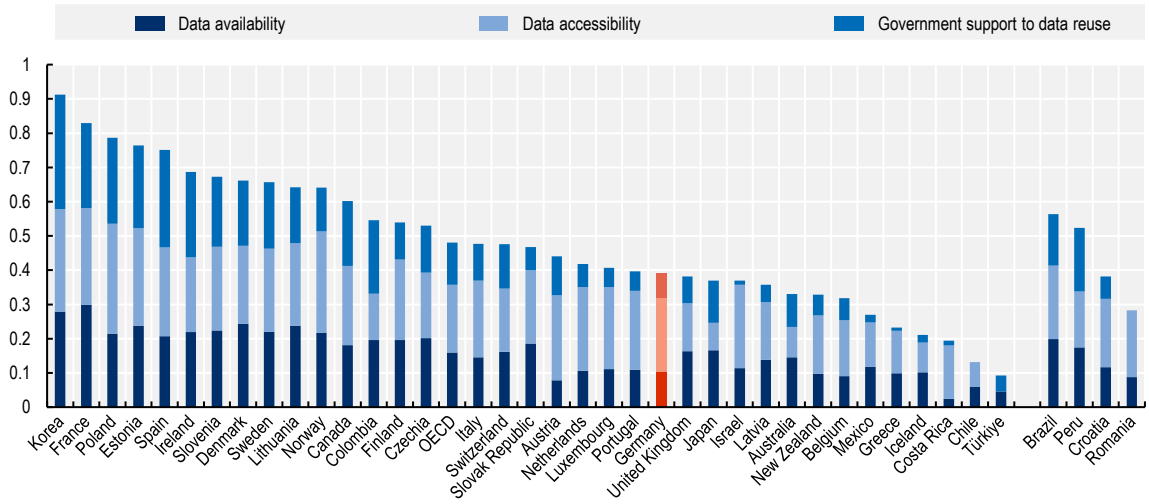
Open government data

Beyond its role to strengthen democracy and public governance, OGD remains important for fostering innovation, including the development of new public and private sector services and business models. Overall, OGD is a foundational element for advanced digital governments. By increasingly integrating with data-intensive systems like AI, OGD becomes a key input for data-driven decision making within and

outside the government, feeding into better policies and services. It also contributes to the trustworthiness of automated decisions by serving as a reliable and traceable data source.

According to the 2023 OECD Open, Useful, and Re-usable data (OURdata) Index, which benchmarks efforts made by governments to design and implement national OGD policies, Germany lags considerably in data availability and support to data re-use (Figure 8.1), even though data accessibility is relatively high.

Figure 8.1. Germany performs below the OECD average in data availability and re-use, above on data accessibility



Source: OECD (2023[36]), 2023 OECD Open, Useful and Re-usable data (OURdata) Index: Results and key findings, https://doi.org/10.1787/a37f51c3-en.

Enhancing internal expertise and resources

Talent development and expertise acquisition are of crucial importance to the Federal Government.[5] Although the need to develop AI expertise within the public sector is acknowledged in the national AI strategy, no implementation details or concrete plans are provided. A 2021 survey found that the number one issue in using AI in the public sector may be the lack of internal expertise (Figure 8.2; however, BMI officials suggest this may no longer be the case due to new upskilling efforts and the recruitment of experts, such as those staffed to the data labs.

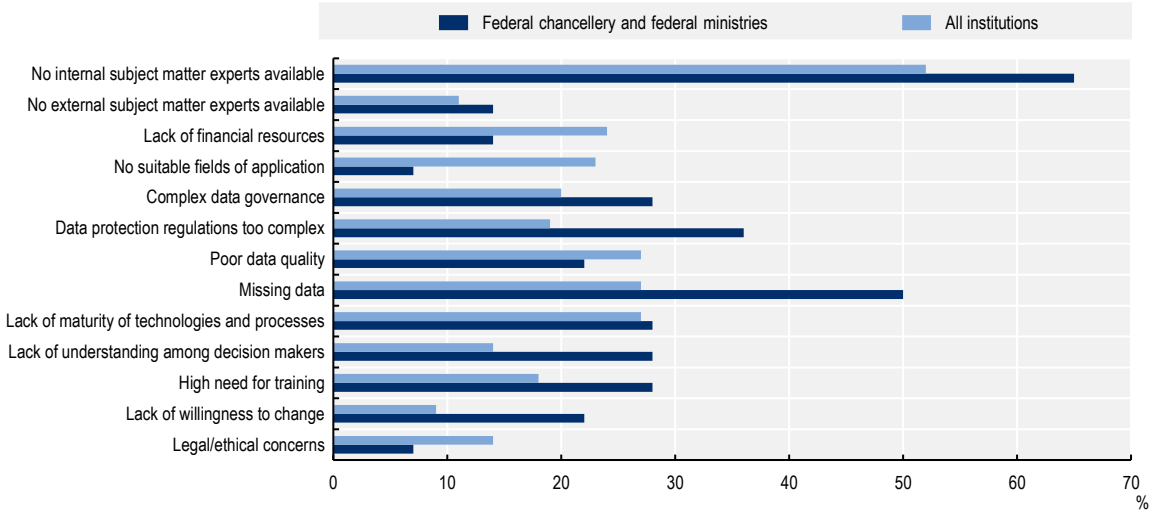
The recruitment of experts to work in the data labs was cited as a success by several interviewees, though, as common in other countries, the pay rate relative to the private sector was raised as a challenge. Interviewees also noted that literacy in data and AI of *existing* public servants was limited and that some baseline level of mandatory training could be helpful. Suggestions ranged from the reinforcement of courses already available (e.g. from the Digital Academy) to strengthening the role of the data labs in promoting AI literacy in their respective ministries.

Initiatives like Lower Saxony's Competence Centre for AI in Public Administration (*KI-Kompetenzzentrum für die niedersächsische Verwaltung*, KiKoN), with a goal to promote and accelerate the use of AI in public administration, exist only in individual states (Niedersachsen, 2023[37]); or with specific entity's or subject domains, as is the case of Competency Centre for AI in the Federal Office for Information Security (*Bundesamt für Sicherheit in der Informationstechnik*, BSI) (BSI, 2023[38]). Externally, the BMI funds the Competence Centre for Public IT (*Kompetenzzentrum Öffentliche IT*) which serves as a think tank and partner for matters of public IT, with a focus broader than just AI. Lastly, the private sector has filled some

gaps by providing courses and classes teaching public service employees about the basics of AI (bitkom, 2023[39]).

Figure 8.2. Lack of in-house expertise is a key challenge of AI use in the public sector

Challenges in using data analytics and artificial intelligence in the public sector in %, 2021



Source: Bundesrechnungshof (2023[40]), *Processes of Data Analysis and Artificial Intelligence in the Federal Administration*, https://www.bundesrechnungshof.de/SharedDocs/Downloads/DE/Berichte/2023/ki-da-volltext.pdf, based on German Federal Audit Office survey conducted in October 2021.OECD interviews found mixed views on internal skills and expertise.

Governments can obtain the necessary human capital internally through innovative approaches to training and recruiting in new talent. Germany has done an excellent job in doing this with regards to the recruitment of experts in the data labs that have been launched so far. External promising practices that could help inform or inspire approaches in Germany include an AI training curriculum in the US, which was required as part of the AI Training Act to train and upskill the federal workforce on AI (US Congress, 2022[41]).

Securing external expertise and resources

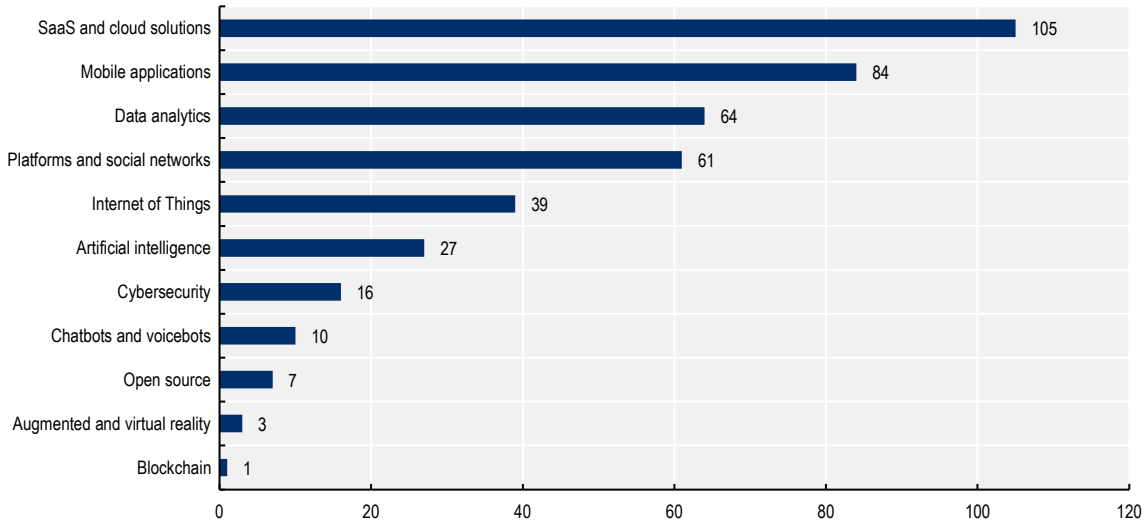
The national AI strategy includes plans to streamline and leverage public procurement processes to incentivise AI-based and open-source solutions provided by the private sector, especially by start-ups. In 2021, Germany had around 300 GovTech start-ups, with an annual growth rate in the three-digit range. Almost half of these are providing solutions for municipalities rather than for the federal government, mostly as cloud solutions and apps, with AI applications still being limited (Figure 8.3).

However, interviewees reported challenges in accessing public procurement opportunities for innovative solutions (see Chapter 4). The GovTech Campus Germany runs the Open Innovation Platform, where new ideas are being developed to make digital procurement solutions accessible to administrations at all levels of government. In its start-up strategy from 2022, the Federal Government commits to encourage and support public administrations in their co-operation with the tech scene to develop and test different use cases for AI systems, for instance through programmes like AI for Government, which provides infrastructure and compute capacity to businesses to promote AI solutions that can be incorporated by the public sector (BMWK, 2022[2]). The federal government also supports a programme called Procurement for Government. Finally, GovTech companies can also be supported by the Digital Hub Initiative, a project

co-ordinated and overseen by the Federal Ministry for Economic Affairs and Climate Action (*Bundesministerium für Wirtschaft und Klimaschutz*, BMWK).

Figure 8.3. Start-ups are providing technology solutions to the German government

Number of GovTech start-ups in Germany, 2021



Source: GovMind (2021[42]), *GovTech in Germany: A Systematic Market Review*, https://govmind.tech/wp-content/uploads/2021/06/20210607-GovMind-GovTech-in-Deutschland.pdf.

With regards to public procurement for AI, some potentially promising practices in other countries include the Government of Canada's AI Source List for the promotion of innovative procurement (Government of Canada, 2023[43]). AI Procurement in a Box from the OECD.AI Catalogue of Tools and Metrics may also be helpful (OECD.AI, 2023[44]).

Infrastructure

The national AI strategy outlines Germany's plan to establish a centralised and openly accessible national data infrastructure complete with a cloud platform and the necessary computing capacity. However, there is no evidence to demonstrate that a national data architecture has been developed.

Regarding interoperability, the 2023 Data Strategy affirms that guaranteeing the interoperability of systems will be crucial for ensuring competitiveness, although this is mostly focused on businesses rather than public administration. Support is also expressed for open specifications and the use of international norms and standards for technologies like AI and Distributed Ledger Technology (DLT). Concretely, the strategy references GAIA-X as an example of an open and decentralised European data infrastructure, making use of shared rules, open-source code and standards for interoperability.

Learning from others

This chapter has sought to introduce promising practices from other governments pursuing relevant efforts regarding AI in the public sector. While no comprehensive comparative assessments exist regarding AI in the public sector, some work has identified potential opportunity areas for other countries that may be worth considering for Germany.

Although much larger in size, the US is well placed to serve as a peer for comparison when it comes to AI in the public sector, as it has similarities to Germany in its federal structure and has also placed a strong emphasis on the topic, including through two aforementioned Executive Orders. A recent report from the US GAO (2023[45]) reviews important requirements in adopting AI in the public sector and assesses public sector organisations' action on achieving them. It takes into consideration over 1 200 current and planned public sector AI use cases. The report could provide useful lessons and help Germany avoid potential pitfalls. Key findings and recommendations touch on:

- the development of public roadmaps for implementing strategy and policy guidance
- the development and updating of public AI use case inventories
- the issuance of government-wide policies and guidance on AI in the public sector
- designating Responsible Artificial Intelligence Officers (RAIOs) – later renamed Chief Artificial Intelligence Officers (CAIOs) – in each top-level public sector department, charged with overseeing and co-ordinating AI plans and action and managing use case inventories
- establishing, and conducting needs assessments, for public servant occupations related to AI.

The OECD's comparative review of the use of AI in the public sector of Latin America and the Caribbean may also yield relevant approaches from the region (OECD/CAF, 2022[46]).

Recommendations

Strengthen the focus on strategy implementation

The existence of roadmaps and enablers is important for the implementation of AI strategies in the public sector. Germany's strategy includes solid high-level objectives but is light with regard to achieving them through granular, actionable and clear steps. Such a roadmap could leverage the growing momentum around AI in the public sector in Germany and direct it towards the goals and objectives of the strategy in a systemic way.

Strengthen co-ordination

As there are various levels of planning for and using AI across and within levels of government in Germany, stronger co-ordination can help Germany take a systems approach to achieve strategic goals while minimising duplication, overlap, and fragmentation of efforts. Formal mechanisms, like councils, can hold ministries and other public sector entities accountable for achieving national strategic goals. Informal mechanisms, such as networks, can build capacities and connections among public servants through sharing experiences and lessons, and navigating the hurdles of adopting new technologies and approaches. Like other countries with a federal structure, co-ordination between the federal and subnational governments is likely to be the most challenging aspect, necessitating additional and dedicated efforts to build such touchpoints, perhaps through the IT Planning Council (*IT-Planungsrat*).

Clarify roles and expand guidance for the implementation of AI in the public sector

A lack of clarity about responsibilities for issuing policies on the use of AI in the public sector might limit progress in AI exploration and adoption. Clarification of roles can help empower an entity to take ownership and action over designing and issuing guidance, and thus give other public sector organisations boundaries, scope of action, and paths for achieving national strategic objectives. This can ensure that entity-specific strategies and guidance align with horizontal, federal efforts and goals.

Explore the development of algorithmic impact assessment and auditing processes and guidelines

Germany is exploring how to put in place accountability mechanisms such as algorithmic assessments for public-sector entities dealing with sensitive data or security issues. However, such mechanisms can be useful in a broader range of AI cases. Some countries, like Canada, require impact assessments for all instances of automated decision making, with low-impact systems facing minimal risk-mitigation requirements and higher-impact systems having addition responsibilities to uphold. Likewise, audit frameworks can ensure that deployed AI systems remain trustworthy. Germany should consider whether such approaches would enhance accountability for public-sector use of AI in the country.

Increase the transparency of AI use in the public sector

Much reporting on public-sector AI use cases has been prompted by parliamentary inquiry. Proactively maintaining an updated registry of public-sector use cases could build accountability regarding AI in the public sector and trust among citizens and residents. Creation of such a system could be automated. For instance, if public-sector organisations were required (as in Canada) to publish impact assessments as open data, an automated system could harvest these files to populate a registry.

Strengthen AI-related skills in the public sector

The creation and staffing of expert-driven data and AI labs in the German public sector is considered a success and significant step. However, as AI becomes more ubiquitous and Germany increases the adoption of trustworthy AI in the public sector, it might need to focus on upskilling workers already in public service and new hires without AI expertise. This could involve training in AI basics for public servants who might use or encounter AI in performing their duties, and more in-depth technical training for some, creating a pathway besides external recruitment for cultivating AI expertise.

References

Ada/AI Now/OGP (2021), *Algorithmic Accountability for the Public Sector*, Ada Lovelace Institute, AI Now Institute and Open Government Partnership, http://www.opengovpartnership.org/documents/algorithmic-accountability-public-sector. [30]

AlgorithmWatch (2023), “Statement on the data strategy of the Federal Government”, https://algorithmwatch.org/de/wp-content/uploads/2023/09/Stellungnahme-Datenstrategie.pdf. [17]

auditing algorithms (2023), *Auditing machine learning algorithms - A white paper for public auditors*, https://www.auditingalgorithms.net./. [34]

Berryhill, J. et al. (2019), “Hello, World: Artificial intelligence and its use in the public sector”, *OECD Working Papers on Public Governance*, No. 36, OECD Publishing, Paris, https://doi.org/10.1787/726fd39d-en. [1]

bidt (2023), *Autorinnen und Autoren: Das bidt-Digitalbarometer. international*, Bayerisches Forschungsinstitut für Digitale Transformation, https://doi.org/10.35067/xypq-kn68. [7]

BIH (2023), *Kompetenzzentrum Oeffentliche IT*, https://www.oeffentliche-it.de/ (accessed on 11 December 2023). [35]

bitkom (2023), “eGovernment: AI basics for public sector employees”, https://bitkom-akademie.de/zertifikatslehrgang/egovernment-ki-grundlagen-oeffentlicher-dienst (accessed on 11 December 2023). [39]

BMAS (2023), *Selbstverpflichtende Leitlinien für den KI-Einsatz in der behördlichen Praxis der Arbeits- und Sozialverwaltung*, Bundesministerium für Arbeit und Soziales, https://www.bmas.de/SharedDocs/Downloads/DE/Publikationen/a862-01-leitlinien-ki-einsatz-behoerdliche-praxis-arbeits-sozialverwaltung.pdf (accessed on 11 December 2023). [5]

BMAS (2022), *Guidelines for the Use of AI in the Governmental Practice in Labour and Social Affairs*, Bundesministerium für Arbeit und Soziales, https://www.bmas.de/SharedDocs/Downloads/DE/Publikationen/a862-01-leitlinien-ki-einsatz-behoerdliche-praxis-arbeits-sozialverwaltung.pdf?__blob=publicationFile&v=2 (accessed on 11 December 2023). [23]

BMWK (2022), *Start-up Strategy*, Bundesministerium für Wirtschaft und Klimaschutz, https://www.bmwk.de/Redaktion/DE/Publikationen/Existenzgruendung/start-up-strategie-der-bundesregierung.html (accessed on 11 December 2023). [2]

Brazilian Government (2023), *Rede Nacional de Governo Digital*, https://www.gov.br/governodigital/pt-br/transformacao-digital/rede-nacional-de-governo-digital. [27]

BSI (2023), *Künstliche Intelligenz*, https://www.bsi.bund.de/DE/Themen/Unternehmen-und-Organisationen/Informationen-und-Empfehlungen/Kuenstliche-Intelligenz/kuenstliche-intelligenz_node.html#doc451100bodyText3. [38]

Bundesrechnungshof (2023), *Processes of Data Analysis and Artificial Intelligence in the Federal Administration*, https://www.bundesrechnungshof.de/SharedDocs/Downloads/DE/Berichte/2023/ki-da-volltext.pdf. [40]

Bundestag (2023), *Einsatz Künstlicher Intelligenz im Geschäftsbereich der Bundesregierung*, http://ttps://dip.bundestag.de/vorgang/einsatz-k%C3%BCnstlicher-intelligenz-im-gesch%C3%A4ftsbereich-der-bundesregierung/298588 (accessed on 11 December 2023). [12]

Centers of Excellence (2023), *Community of Practice: Artificial Intelligence*, https://coe.gsa.gov/communities/ai.html (accessed on 11 December 2023). [28]

CNAI (2023), *Instruction sheets for the use of AI within the federal administration*, https://cnai.swiss/en/products-other-services-instruction-sheets/ (accessed on 11 December 2023). [15]

Consejo para la Transparencia (2023), *Sector público chileno avanza en inédita normativa de transparencia algorítmica en América Latina*, https://www.consejotransparencia.cl/sector-publico-chileno-avanza-en-inedita-normativa-de-transparencia-algoritmica-en-america-latina/ (accessed on 11 December 2023). [32]

Deutschlandfunk (2023), “Scholz is urging federal states to respond to proposals to reduce bureaucracy”, https://www.deutschlandfunk.de/scholz-draengt-bundeslaender-zu-antworten-auf-vorschlaege-zu-buerokratieabbau-100.html (accessed on 11 December 2023). [24]

Drucksache (2022), "Antwort der Bundesregierung auf die Kleine Anfrage der Abgeordneten Anke Domscheit-Berg, Dr. Petra Sitte, Nicole Gohlke, weiterer Abgeordneter und der Fraktion Die Linke", https://dserver.bundestag.de/btd/20/004/2000430.pdf (accessed on 18 October 2023). [16]

EC (2022), *eGovernment Benchmark 2022*, European Commission, https://digital-strategy.ec.europa.eu/en/library/egovernment-benchmark-2022. [8]

EC (2018), *Coordinated Plan on Artificial Intelligence*, https://eur-lex.europa.eu/resource.html?uri=cellar:22ee84bb-fa04-11e8-a96d-01aa75ed71a1.0002.02/DOC_1&format=PDF. [4]

Engelmann, J. and M. Puntschuh (2020), *AI in Authorities' Use: Experiences and Recommendations*, https://www.oeffentliche-it.de/documents/10181/14412/KI+im+Beh%C3%B6rdeneinsatz+-+Erfahrungen+und+Empfehlungen. [10]

EU (2024), *Regulation (EU) 2024/ ..... of the European Parliament and of the Council laying down harmonised rules on artificial intelligence (Artificial Intelligence Act)*, https://data.consilium.europa.eu/doc/document/PE-24-2024-INIT/en/pdf. [3]

Evers-Wölk, M., J. Kluge and S. Steiger (2022), *Artificial Intelligence and Distributed Ledger Technology in Public Administration: An Overview of Opportunities and Risks including the Presentation of Internationally Relevant Practical Examples*, Institut für Technikfolgenabschätzung und Systemanalyse, https://publikationen.bibliothek.kit.edu/1000151158. [9]

Federal CDO Council (2023), *CDO*, https://www.cdo.gov/ (accessed on 11 December 2023). [26]

FITKO (2023), *Fitko*, https://www.fitko.de/ (accessed on 11 December 2023). [25]

GAO (2023), "Artificial intelligence: Agencies have begun implementation but need to complete key requirements", United States Government Accountability Office, https://www.gao.gov/products/gao-24-105980. [45]

Government of Canada (2023), *Algorithmic Impact Assessment tool*, https://www.canada.ca/en/government/system/digital-government/digital-government-innovations/responsible-use-ai/algorithmic-impact-assessment.html (accessed on 11 December 2023). [31]

Government of Canada (2023), *Artificial intelligence source list*, https://www.canada.ca/en/public-services-procurement/services/acquisitions/better-buying/simplifying-procurement-process/artificial-intelligence-source-list.html (accessed on 11 December 2023). [43]

GovMind (2021), *GovTech in Germany: A Systematic Market Review*, https://govmind.tech/wp-content/uploads/2021/06/20210607-GovMind-GovTech-in-Deutschland.pdf. [42]

Handelsblatt (2023), *Which ministries are already using AI – in surprisingly specific projects*, https://www.handelsblatt.com/politik/deutschland/kuenstliche-intelligenz-welche-ministerien-ki-bereits-einsetzen-in-erstaunlich-konkreten-projekten/29221386.html (accessed on 11 December 2023). [22]

Initiative D21 (2023), *eGovernment MONITOR 2023*, https://initiatived21.de/publikationen/egovernment-monitor. [13]

Niedersachsen (2023), "The state of Lower Saxony establishes a competence centre for artificial intelligence in administration", https://www.mi.niedersachsen.de/startseite/aktuelles/presseinformationen/land-niedersachsen-grundet-kompetenzzentrum-fur-kunstliche-intelligenz-in-der-verwaltung-219423.html (accessed on 11 December 2023). [37]

OECD (2023), "2023 OECD Open, Useful and Re-usable data (OURdata) Index: Results and key findings", *OECD Public Governance Policy Papers*, No. 43, OECD Publishing, Paris, https://doi.org/10.1787/a37f51c3-en. [36]

OECD (2023), *G7 Hiroshima Process on Generative Artificial Intelligence (AI): Towards a G7 Common Understanding on Generative AI*, OECD Publishing, Paris, https://doi.org/10.1787/bf3c0c60-en. [21]

OECD (2023), *Global Trends in Government Innovation 2023*, OECD Public Governance Reviews, OECD Publishing, Paris, https://doi.org/10.1787/0655b570-en. [29]

OECD (2020), "Digital Government Index: 2019 results", *OECD Public Governance Policy Papers*, No. 03, OECD Publishing, Paris, https://doi.org/10.1787/4de9f5bb-en. [6]

OECD.AI (2023), *AI Procurement in a Box*, https://oecd.ai/en/catalogue/tools/ai-procurement-in-a-box (accessed on 11 December 2023). [44]

OECD.AI (2023), *Database of National AI Policies and Strategies*, OECD, Paris, https://oecd.ai/en/dashboards/overview (accessed on 5 October 2023). [18]

OECD/CAF (2022), *The Strategic and Responsible Use of Artificial Intelligence in the Public Sector of Latin America and the Caribbean*, OECD Public Governance Reviews, OECD Publishing, Paris, https://doi.org/10.1787/1f334543-en. [46]

Oxford Insights (2023), *Government AI Readiness Index 2023*, https://oxfordinsights.com/wp-content/uploads/2023/12/2023-Government-AI-Readiness-Index-1.pdf. [11]

Staatsministerium Baden-Württemberg (2023), "Künstliche Intelligenz in der Verwaltung", https://stm.baden-wuerttemberg.de/de/service/presse/meldung/pid/kuenstliche-intelligenz-in-der-verwaltung (accessed on 11 December 2023). [14]

The White House (2023), *Executive Order on the Safe, Secure, and Trustworthy Development and Use of Artificial Intelligence*, https://www.whitehouse.gov/briefing-room/presidential-actions/2023/10/30/executive-order-on-the-safe-secure-and-trustworthy-development-and-use-of-artificial-intelligence. [20]

The White House (2020), *Executive Order on Promoting the Use of Trustworthy Artificial Intelligence in the Federal Government*, https://trumpwhitehouse.archives.gov/presidential-actions/executive-order-promoting-use-trustworthy-artificial-intelligence-federal-government. [19]

US Congress (2022), *S.2551 - AI Training Act*, https://www.congress.gov/bill/117th-congress/senate-bill/2551. [41]

US Government Accountability Office (2023), *Artificial Intelligence: An Accountability Framework for Federal Agencies and Other Entities*, https://www.gao.gov/products/gao-21-519sp. [33]

Notes

[1] Germans have for some time been optimistic about this: 68% responded in a survey that they expected AI to be able to speed up administrative processes and more recently, the proportion of people who primary see opportunities in using AI is higher in Germany than in other countries. Another recent survey found that a majority of citizens agree with the use of AI in the public sector so long as certain conditions are met (e.g. if fundamental decisions continue to be made by humans) (Initiative D21, 2023[13]).

[2] A full review of digitalisation of the public sector is beyond the scope of this study, but making progress in this area will be foundational in achieving the strategic and responsible use of AI in the public sector.

[3] The index considered 39 indicators across three pillars: i) government (including strategic vision, regulation, ethical considerations, capacities); ii) the technology sector (such as a mature ecosystem of innovative private-sector companies); and iii) data and infrastructure.

[4] There are varying levels of activity in the development and deployment of AI across *Länder*, as indicated by the map at https://www.plattform-lernende-systeme.de/ki-landkarte.html. However, this tool is not exclusive to public sector use cases.

[5] In a survey from 2021, more than half of all surveyed agencies reported a lack of internal experts.

9 Spotlight: AI and environmental sustainability

This chapter examines the intersection of artificial intelligence (AI) and environmental sustainability and outlines how the German AI ecosystem can strengthen its leading position to leverage AI for rapid decarbonisation and other sustainability goals. It offers an overview of initiatives across federal ministries, states, academia, industry, and civil society. It describes how AI can enable climate action and crucial uses cases in strategic sectors such as energy, transport, industry, and agriculture. The chapter looks at ways Germany can strengthen its AI-sustainability ecosystem through inter-ministerial and interdisciplinary co-operation, knowledge-sharing and AI education. Germany could apply a whole-of-government approach to AI and environmental sustainability. Finally, the chapter covers approaches to measuring and mitigating the environmental impacts of AI compute infrastructure, identifies critical gaps and makes four recommendations for future action.

The green and digital "twin transitions" promise to leverage digital technologies such as AI for a sustainable future. As a general-purpose technology, AI has the potential to decrease negative environmental impacts and lower emissions by accelerating progress in domains such as smart energy systems and interconnected transportation networks (OECD, 2022[1]). Germany is well-placed to build on its existing research base and initiatives across the AI ecosystem to become a global leader in AI for climate action and environmental sustainability.

Germany was among the first countries to recognise the potential of AI for environmental sustainability in its 2018 national AI strategy and in its 2020 strategy update, which put environmental and climate protection at the heart of new initiatives by "systematically identifying the potential harboured by AI [...] by funding and promoting AI-based instruments to solve specific challenges for sustainable development" (German Federal Government, 2020[2]). The 2020 update focuses on "making AI environmentally sound" by advancing green information and communication technology (ICT) methods and on "AI research to protect the environment and climate" with the stated goal of "funding and promoting AI-based instruments to solve specific challenges for sustainable development" (German Federal Government, 2020[2]). The strategy update also identified specific application areas such as "renewable energies and energy systems, energy efficiency, resource conservation and recycling, water protection and water management, emission control and health, nature conservation and mobility" (German Federal Government, 2020[2]).

Box 9.1. AI and environmental sustainability: Findings and recommendations

Findings

- Germany benefits from a range of AI and environmental sustainability initiatives across federal ministries, states, academia, industry, and civil society. However, initiatives are not typically interconnected, and long-term financing remains a challenge.
- AI has significant enabling potential for environmental sustainability and can be leveraged by the German government and industry for rapid decarbonisation across sectors.
- Home to leading researchers, practitioners, and pioneers in the field, Germany's AI and environmental sustainability ecosystem is ahead of most countries.
- As part of the larger digital compute infrastructure, AI has considerable environmental impacts, such as energy consumption and water use that are not yet systematically measured in Germany.

Recommendations

- Increase intergovernmental and interdisciplinary co-operation on AI and environmental sustainability to promote transfer and synergies between initiatives.
- Define strategic focus areas and break down silos in sectors such as energy, transport, industry, or agriculture to maximise AI's enabling effects for environmental sustainability and rapid decarbonisation.
- Extend Germany's leadership position in AI and environmental sustainability through knowledge-sharing and education programmes, the promotion of start-ups and small and medium-sized enterprises (SMEs) and the widening of the focus to include the circular economy, biodiversity and other planetary boundaries.
- Expand measurement efforts by the government and compute providers to assess and mitigate the energy, water and resource impacts of AI compute infrastructure.

The AI and environmental sustainability ecosystem

Germany is recognised for its significant AI and environmental sustainability initiatives, involving collaboration across federal ministries, states, academia, industry and civil society. These efforts are underpinned by substantial funding and focused on creating AI applications that support environmental and climate goals. Crucial work areas include leveraging AI for resource efficiency, promoting sustainable mobility, biodiversity preservation, and fostering sustainable agriculture. The country's approach also emphasises inter-ministerial co-operation and the active engagement of civil society to ensure that AI developments align with ecological and social sustainability principles.

Germany benefits from substantial, appropriately funded AI and sustainability initiatives across federal ministries, states, academia, industry, and civil society

Federal governments and ministries

Several federal ministries have ongoing activities and initiatives at the intersection of AI and environmental sustainability. Based on self-reported input from national governments, the OECD.AI Policy Observatory lists Germany amongst the top countries in the number of AI and environment initiatives, together with countries like Norway, Spain and the United Kingdom (UK) (OECD.AI, 2023[3]). The Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection (*Bundesministerium für Umwelt, Naturschutz, nukleare Sicherheit und Verbraucherschutz,* BMUV) has published a “five-point programme for AI in support of the environment and climate” with a planned investment of EUR 150 million over five years. This includes a funding initiative for several AI lighthouse projects for climate innovation and resource-efficient AI, a Green AI Hub for German SMEs, and the platform AI Idea Workshop for Environmental Protection that brings together non-governmental organisations, civil society, academia, and start-ups to develop pilot AI projects for a more sustainable society (BMUV, 2023[4]). The German Environmental Agency has recently opened a new Application Lab for AI and Big Data, financed until 2025 through the Federal Government’s economic stimulus and future technologies package. The lab will focus on leveraging AI and big data methods for environmental research and the sustainable use and operation of AI applications. The insights gained from data-based findings can serve as a basis for political decisions and promote a deeper understanding of complex environmental processes in the public (UBA, 2022[5]).

The BMUV pioneered inter-ministerial co-operation with the Federal Ministry of Labour and Social Affairs (*Bundesministerium für Arbeit und Soziales*, BMAS) and the Federal Ministry for Family Affairs, Senior Citizens, Women and Youth (*Bundesministerium für Familie, Senioren, Frauen und Jugend*, BMFSFJ) through its Civic Coding initiative. This innovation network aims to design AI applications that are social, sustainable and participative, such as the AI Idea Workshop for Environmental Protection, a Civic Data Lab for data collection based on the common good and the Civic Innovation Platform (Civic Coding, 2023[6]).

The Federal Ministry of Transport and Digital Infrastructure (*Bundesministerium für Digitales und Verkehr*, BMDV) promotes the use of AI for earth observation and funds model projects for sustainable mobility through its Artificial Intelligence and Mobility (AIAMO) project in partnership with local municipalities (BMDV, 2023[7]). The Federal Ministry of Education and Research (*Bundesministerium für Bildung und Forschung*, BMBF) has financed an application hub for a circular economy for plastic packaging through AI methods with EUR 30 million until 2025 (BMBF, 2021[8]) and has initiated a funding programme for research projects on AI as a tool for biodiversity preservation with a funding volume of up to EUR 20 million (BMBF, 2023[9]). The Federal Ministry for Economic Cooperation and Development (*Bundesministerium für wirtschaftliche Zusammenarbeit und Entwicklung*, BMZ) addresses environmental sustainability and AI through its FAIR Forward project for sustainable development, which provides partner countries in the Global South with access to “climate-smart” agricultural advice and has developed a practitioner’s guide to green data centres in co-operation with the World Bank, the International Telecommunication Union

(ITU), and the German Agency for International Cooperation (*Deutsche Gesellschaft für Internationale Zusammenarbeit*, GIZ) (ITU/World Bank, 2023[10]). The Federal Ministry of Economic Affairs and Climate Action (*Bundesministerium für Wirtschaft und Klimaschutz*, BMWK) funded projects like AI for advanced material science, predictive maintenance, and advanced groundwater analysis, while the Federal Ministry of Food and Agriculture (*Bundesministerium für Ernährung und Landwirtschaft*, BMEL) promotes the uptake of AI in smart and sustainable agriculture and rural areas with 36 co-operative projects with a budget allocation of EUR 44 million (BMEL, 2021[11]).

*Federal states (*Länder*)*

Various federal states (*Länder*) also run initiatives at the intersection of AI and environmental sustainability. For example, the Bavarian AI Agency co-ordinates projects on sustainable mobility and addresses environmental challenges through the Hub on Intelligent Robotics and the Hightech Agenda Bavaria (Baiosphere, 2023[12]). The Hessian Centre for AI is pursuing the build-up of sustainable AI compute infrastructure, hosting its supercomputer in the Green IT Cube of GSI *Helmholzzentrum*, one of Europe's most efficient and sustainable data centres (hessian.AI, 2023[13]). The competence platform KI.NRW in North Rhine-Westphalia supports lighthouse projects such as AI for flood protection and control, AI for combatting plastic litter in oceans and rivers, and AI for earth system data and environmental prediction (KI.NRW, 2023[14]). These examples showcase the substantial innovation ecosystems for environmentally beneficial AI systems and point to potential benefits and synergies from increased co-operation, both within federal states and between federal, state, and local authorities. The permanent conference of federal state digital ministers announced in November 2023 could serve as a potential forum for such co-operation efforts on AI and environmental sustainability (STMD, 2023[15]).

Academia and research institutes

Germany is home to some of the world's leading researchers and practitioners in the AI and environmental sustainability field. The Sustainable AI Lab at Bonn University aims to measure and assess the environmental impacts of AI, including in the context of the United Nations' Sustainable Development Goals (SDGs) (Sustainable AI Lab, 2023[16]). The German Research Centre for Artificial Intelligence (*Deutsches Forschungszentrum für Künstliche Intelligenz,* DFKI), one of the German Centres of Excellence for AI Research, bundles expert knowledge on the topic through its Competence Centre AI for Environment and Sustainability, DFKI4planet. The competence centre focuses on knowledge transfer and AI development for diverse environmental applications such as pollution detection, green mobility, circular economy, and resource conservation (DFKI, 2023[17]). At Technical University Munich and University of Applied Sciences of Munich, the sustAInability project educates interdisciplinary master students on social and environmental challenges at the intersection of AI and sustainability. Students also research and develop prototypes in various environmental application areas (sustAInability, 2023[18]). The BMUV's AI lighthouse initiative has also funded two projects on a green consumption assistant and circular textile intelligence at Technical University Berlin in co-operation with the Einstein Centre Digital Future (ECDF) (TU Berlin, 2020[19]). The University of Tübingen and the Hasso Plattner Institute (*Hasso-Plattner-Institut*, HPI) are part of ELIAS AI consortium, which aims to establish Europe as a leader in AI research for sustainable development (ELIAS, 2023[20]).

Civil Society

Another strength of the German AI and environmental sustainability ecosystem is the active involvement of civil society organisations that provide crucial perspectives on the ecological and social sustainability of AI systems. For example, AlgorithmWatch and the Institute for Ecological Economic Research (*Institut für ökologische Wirtschaftsforschung,* IÖW) created SustAIn, a sustainability index for AI systems funded by the BMUV. Based on the 17 SDGs, SustAIn developed a set of indicators and metrics for measuring the

sustainability of AI along its lifecycle (Rohde et al., 2021[21]). Other civil society organisations like the Green Web Foundation, Wikimedia Foundation, Germanwatch, and the Institute for Applied Ecology (*Öko-Institut*) have all called for a more sustainable approach to digitalisation and AI development (Bits & Bäume, 2021[22]).

Industry and start-ups

AI plays an important role for large German industrial companies and their environmental sustainability goals, both for improving energy efficiency and reducing a company's own environmental footprint and for providing innovative product and service solutions for customers. For example, the manufacturing company Siemens employs AI in a variety of industrial environmental sustainability solutions and regards the technology as a key enabler for environmentally sustainable infrastructure. Co-ordinated by a large core AI technology team and the Siemens AI Lab, it leverages AI for predictive maintenance, sustainable construction and building management, digital twins, and intelligent transport networks (Siemens, 2023[23]). The chemical company BASF uses AI for targeted prototyping and digital farming solutions, improving agricultural yields and developing new crops that are environmentally robust in the face of rapid climate change (BASF, 2023[24]). Automotive industry companies like Porsche, Audi, and Volkswagen use AI to identify environmental sustainability risks in their supply chain through a monitoring system that produces automatic warnings about environmental risks the entire procurement system and low-level supply chains (Porsche, 2021[25]).

Some of Germany's most valuable and innovative start-ups and scale-ups put AI and environmental sustainability at the core of their business models. For instance, Enpal provides solar energy solutions for customers and uses AI for installation services and home energy management (Enpal, 2023[26]). Software company TWAICE offers an AI-supported battery analytics platform to simulate battery behaviour and improve its lifetime while also building solutions for battery development, energy storage systems, and electric vehicle operations (TWAICE, 2023[27]). Celonis, a global pioneer in process mining, increasingly leverages process-specific machine learning models for environmental sustainability transformation solutions including emission reduction and order management (Celonis, 2023[28]). The Greentech Alliance brings together many of these start-ups to support them with venture capital (VC) and entrepreneurial advice (Greentech Alliance, 2023[29]), while the German AI Association has established a working group on climate and environmental sustainability to disseminate knowledge amongst its members (German AI Association, 2023[30]). Entrepreneurship innovation centres like the TUM Venture Lab have recognised the importance of environmental sustainability and have introduced dedicated labs that "boost the translation of deep tech into scalable, circular businesses" for "sustainable environmental impact" (UnternehmerTUM, 2023[31]). An example of a well-functioning start-up ecosystem is OroraTech, a provider of space-based and AI-driven thermal intelligence for wildfire prediction and mitigation that spun out of TUM and was supported by grants from the Bavarian and German government and a consortium of European VC investors (OroraTech, 2021[32]).

Use cases for environmental sustainability and rapid decarbonisation

Germany's AI strategy integrates environmental sustainability across multiple sectors. The BMUV's five-point programme commits EUR 150 million to AI for the environment, supporting initiatives like AI lighthouse projects and a Green AI Hub. The collaboration spans federal ministries, *Länder*, academia, civil society and industry, aiming to utilise AI for sustainable solutions in areas like climate innovation, healthcare, and agriculture. The strategy encourages cross-sectoral co-operation and public-private partnerships to advance environmentally sustainable AI applications.

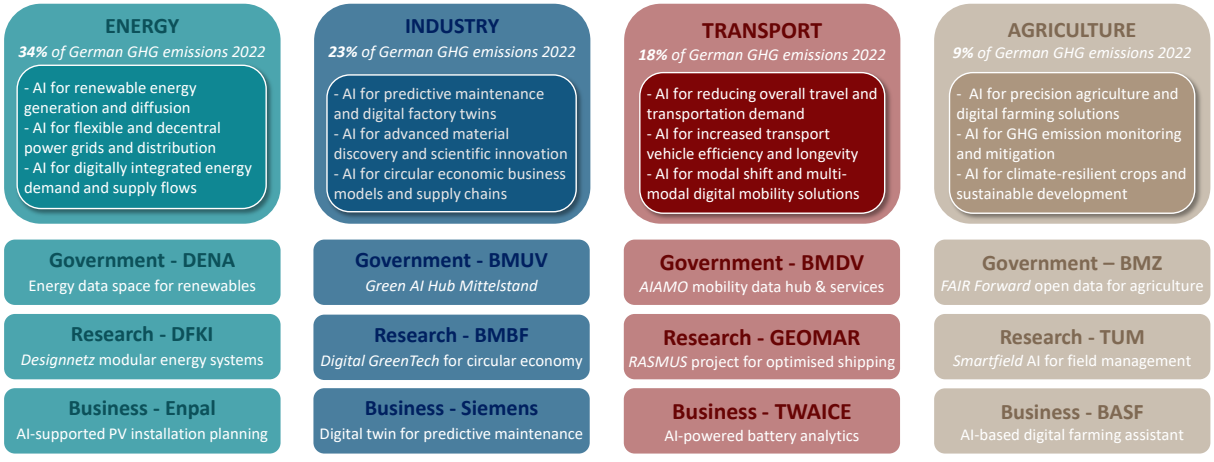
The German government and industry can leverage AI's huge enabling potential for environmental sustainability and rapid decarbonisation across sectors

Decarbonisation across sectors

AI can play a key role in achieving the German government's climate and environmental goals. AI can be leveraged for key transformational projects such as the clean energy transition, sustainable transport networks, or the rapid decarbonisation of Germany's industrial base. The German Advisory Council on Global Change (*Wissenschaftlicher Beirat der Bundesregierung Globale Umweltveränderungen*, WBGU), a scientific advisory body that advises the German government on the environmental sustainability transformation, states in a 2019 report that "digital technologies such as AI play a key role in enabling a global transformation of energy systems" (WBGU, 2019[33]). AI could help to reduce emissions in all six sectors of the German climate protection law: energy, transport, industry, buildings, agriculture, and waste (Rolnick et al., 2019[34]).

Many initiatives in the German AI and environmental sustainability ecosystem cover these critical sectors (Figure 9.1). According to several experts interviewed for this review, Germany could benefit from defining strategic focus areas and sectors and from bundling initiatives to create synergies, avoid the duplication of work, and share knowledge and best practices. While AI has various application areas in almost all sectors of the economy, four crucial sectors in Germany show particularly high potential: energy, transport, industry, and agriculture.

Figure 9.1. Several initiatives in the German AI ecosystem leverage AI for rapid decarbonisation across sectors



Smart energy systems and networks

According to the International Energy Agency, digital technologies like AI will play a fundamental role in enabling the transition to a resilient and clean energy grid by improving efficiency, reducing costs, and accelerating clean technologies and diffusion across supply chains (IEA, 2023[35]). Germany's energy sector was responsible for 34% of greenhouse gas (GHG) emissions in 2022 and has ambitious targets to increase the share of renewable sources to 80% of electricity consumption by 2030, with "energy savings and energy efficiency as top priorities" (OECD, 2023[36]). Initiatives for energy efficiency, smart energy solutions and renewable energy can be found across federal ministries, states, academia, and in industry and start-ups. This includes AI initiatives from the BMWK for the clean energy transformation or several lighthouse projects from the BMUV that address renewable power generation from wind and waterpower. Already in 2019, the German Energy Agency (*Deutsche Energie-Agentur*, DENA) recognised that

leveraging AI for the energy sector promises to accelerate Germany's *Energiewende* (energy transition) and the decarbonisation of the power grid, which enables the ecological transformation of other sectors such as transport and industry (dena, 2019[37]). While Germany's energy sector recently met its climate targets, "decoupled energy demand and carbon dioxide", and is "one of the G20 and EU27 countries with the highest levels of energy efficiency", challenges in the energy sector persist, especially in the wake of the global energy crisis (OECD, 2023[36]). Industry associations like the German Data Associations report on impaired competitiveness by Germany's high electricity costs and call for an acceleration of the availability of electricity from renewable energy (bitkom/eco/German Datacentre Association, 2022[38]). AI can be a key acceleration enabler, especially in energy bottlenecks like the digitalisation and expansion of electricity grids and energy infrastructure (OECD, 2023[36]).

Interconnected transport networks

One of the most promising application areas for AI is the transport sector. AI can help to reduce the overall demand for travel and transportation, for example through videoconferencing and teleworking. It can also increase fuel efficiency and infrastructure longevity through AI-enabled digital twins and reduce overall passenger transport activity through on-demand ride services or vehicle sharing (EEA, 2023[39]). Initiatives such as the BMDV's AIAMO project for sustainable mobility, start-ups such as TWAICE work on battery efficiency improvements, and academic excellence clusters focused on digital mobility, such as in Bavaria, are examples of German activities and expertise in this field. Another example is project RASMUS of German start-up north.io, which combines AI with oceanographic models to calculate shipping routes that leverage small dynamic ocean currents. The optimised routes could result in GHG emission savings of up to 10% for shipping operations (Christian-Albrechts-Universität zu Kiel, 2023[40]). Researchers have often observed that a narrow focus on increasing the efficiency of the transport sector might not be enough to meet the sector's climate goals, as an increase in overall transportation demand offset efficiency gains (Creutzig et al., 2015[41]). The International Transport Forum encourages policy makers to enable "modal shift" and demand management for urban environments and short-distance travel, nudging passengers towards low-carbon transport options, another significant application area for AI systems (ITF, 2023[42]). Harnessing these opportunities for decarbonisation could be especially relevant for Germany as the transport sector accounted for 18% of Germany's GHG emissions in 2022 and has been the slowest sector to cut emissions (OECD, 2023[36]).

Industry 4.0

AI can support the rapid decarbonisation of Germany's industrial sector, which accounted for 23% of Germany's total GHG emissions in 2022 (OECD, 2023[36]). This opportunity is reflected in several initiatives from federal ministries and the many applications and industrial solutions by some of Germany's largest companies. Companies like Siemens or Bosch deploy AI for predictive maintenance, digital twins, and the overall digital and ecological transformation of German industry – a cornerstone of the Industry 4.0 vision of interconnected machines and processes through digital technologies. AI can also be used for advanced material discovery and scientific innovation, which will be crucial for industrial companies to decarbonise their operations and reach environmental goals (IEA, 2023[35]). Platform Industry 4.0, a network platform for the digital transformation of the manufacturing sector led by the BMWK and BMBF, recognised environmental sustainability as a key aspect of the Industry 4.0 vision and introduced a task force on sustainability (BMWK, 2022[43]). The task force regards digital technologies such as AI as a key enabler of the sustainable transformation of German industry, which aligns with positions from industry associations such as Bitkom. Bitkom calculated that the GHG emission reduction potential of accelerated digitalisation for German industry could be up to 34% of the required emission cuts until 2030 (bitkom, 2023[44]). AI is also regarded as a key enabler for future circular economic business models of industry 4.0, characterised by the "connectivity and flow of information and data across value chains and processes" (One Planet Network, 2023[45]).

Smart agriculture

The *OECD-FAO Agricultural Outlook 2021-2030* highlights that the necessary improvements in productivity to feed the global population sustainably will not happen "without an important acceleration in digitalisation, technology, better data, and human capital" (OECD/FAO, 2021[46]). This presents an opportunity for Germany to leverage AI to improve agricultural yields and environmental sustainability in Germany's agricultural sector and to export AI-based technological solutions to support the sustainable development of farmers across the globe. As climate change accelerates rapidly, a strong increase in demand for advanced technology and climate-resilient crops is expected. Germany's agricultural sector could also benefit from more efficient and sustainable agricultural practices enabled by AI as the sector was responsible for around 9% of GHG emissions in 2022 and has not decreased significantly in the past decade (OECD, 2023[36]). Initiatives such as the promotion of AI for smart agriculture and rural areas by the BMBF or the FAIR Forward project from the BMZ that provides partner countries with access to climate-smart agricultural services could be cornerstones of an AI strategy for the agricultural sector. This builds on the BMEL programme on AI for sustainable agriculture (BMEL, 2021[11]). Industry partners like BASF that work on AI-based digital farming solutions and research institutes such as Fraunhofer and the DFKI could also co-operate with federal and state initiatives on the smart AI-enabled agriculture of the future.

Strengthening Germany's leadership role in AI and environmental sustainability

The German government actively endorses AI applications for the common good, illustrated by the Civic Coding Initiative, which fosters social, sustainable, and participative AI development. Key German initiatives include the Civic Innovation Platform, which supports human-centric AI ideas and projects; the AI Ideas Workshop for Environmental Protection, which fosters eco-friendly AI solutions; and the Civic Data Lab, which enhances data-driven efforts for social good. These programmes exemplify Germany's commitment to leveraging AI for societal and environmental advancement.

The German AI and environmental sustainability ecosystem is ahead of many countries, being home to leading researchers, practitioners, and pioneers in the field

The first important step in strengthening Germany's AI and environmental sustainability ecosystem is to significantly increase co-operation within the federal government, between federal and state governments, and on in knowledge sharing between government, universities, civil society, and industry. The intersection of two highly complex topics like AI and environmental sustainability requires interdisciplinary knowledge and skills that can be leveraged through widespread co-operation. The analysis of current initiatives in the ecosystem suggests that the ample opportunities in sectors such as energy, transport, and agriculture could be better explored by strategic clusters where specific domain knowledge is consistently shared. Examples of such co-operation are initiatives like the Community Sustainable Digitalisation of the BMUV that connects academia, start-ups, industry, municipalities, and the federal government (BMUV, 2023[47]). Germany could also mirror initiatives like the UK's Artificial Intelligence for Decarbonisation's Virtual Centre of Excellence (ADViCE) which serves as a central hub for AI and decarbonisation projects and aims to "foster cross-sector collaboration" and "disseminate information to relevant stakeholders" (Alan Turing Institute, 2023[48]). Another example is the whole-of-government initiative Clean Growth Hub in Canada, an inter-departmental "coordination centre for federal clean tech initiatives and a one-stop shop for information about funding and services" (Government of Canada, 2023[49]). Germany could replicate such an approach for its AI activities that target decarbonisation and other environmental sustainability initiatives.

A second crucial area is awareness of opportunities and challenges for AI and environmental sustainability. In the interviews conducted for the review, experts highlighted a lack of knowledge and cross-disciplinary environmental and technical knowledge in both the public and private sectors, which calls for implementing

AI literacy and upskilling programmes for German policy makers, higher education, research, and industry. Examples such as the sustAInability project at TUM Munich, which builds capacity amongst interdisciplinary students from both technical and non-technical backgrounds, could be expanded to more universities and research institutes and replicated in the context of government training programmes. Policy makers involved in climate-relevant legislation and AI policy should also be offered training programmes, as should leaders in civil society and high-emission sectors. Germany could follow examples such as the Stanford Institute for Human-Centred AI (HAI) Congressional Boot Camp on AI and introduce a similar programme dedicated to environmental sustainability (HAI, 2023[50]). Another important field of action is support for start-ups and German SMEs to leverage AI for environmental sustainability applications and business models. The BMUV's Green AI Hub Mittelstand shows that this is already on the federal government's agenda and could be further expanded to the start-up ecosystem nationwide.

The 2020 strategy update mentions diverse application areas for AI, such as "renewable energies and energy systems, energy efficiency, resource conservation and recycling, water protection and water management, emission control and health, nature conservation and mobility" (German Federal Government, 2020[2]). The expert interviews conducted for the review and the analysis of the ecosystem suggest that, in practice, many initiatives in Germany currently focus on energy and resource efficiency, which already bring significant energy and raw material savings in various sectors. However, researchers have consistently argued that a general focus on efficiency can result in rebound effects, and efficiency savings do not always translate into overall emission reductions (Creutzig et al., 2015[41]). The focus of the AI and environmental sustainability ecosystem could therefore be widened to include other environmental dimensions such as circular economic models, biodiversity preservation, or water consumption, which the 2020 strategy update already identified as key focus areas. Comparable initiatives exist in countries like France, where the National Agency for Research (*Agence nationale de la recherche*, ANR) has launched a research challenge to converge the French National Artificial Intelligence Research Strategy and the France's National Biodiversity Plan (ANR, 2021[51]). Such initiatives could further strengthen Germany's leadership in the area as they represent a more holistic view on the sustainable use of AI that could serve as a role-model for other countries.

Measuring and mitigating the environmental impacts of AI compute infrastructure

Germany is recognised for its significant AI and environmental sustainability initiatives, involving collaboration across federal ministries, states, academia, industry, and civil society. These efforts are underpinned by substantial funding and are focused on creating AI applications that support environmental and climate goals. Key work areas include leveraging AI for resource efficiency, promoting sustainable mobility, biodiversity preservation, and fostering sustainable agriculture. The country's approach also emphasises inter-ministerial co-operation and the active engagement of civil society to ensure that AI developments align with ecological and social sustainability principles.

The environmental impacts of AI's digital compute infrastructure such as energy consumption and water use are not systematically measured

As the computational needs for advanced AI systems grow, so are sustainability concerns regarding the environmental impacts of AI compute infrastructure (OECD, 2023[52]). Across its lifecycle, AI compute has direct impacts from production, transport, operations, and end-of life stages such as energy consumption, water use, and resource consumption. Digital technologies like AI also have further indirect impacts such as enabling effects (through applications in specific sectors) and systemic effects (by changing social or cultural behaviour). While AI only represents a fraction of overall impacts from digital technologies, the proliferation of AI applications and the exponential dynamic of AI compute requirements call for

implementing measurement standards and expanding data collection on the environmental impacts of AI compute infrastructure and applications (OECD, 2022[1]).

With the Energy Efficiency Act (*Energieeffizienzgesetz*, EnEfG), the German Federal Government has proposed one of the first laws of its kind regarding reporting requirements for data centre operators. It is the first European country to implement the European Union (EU) Energy Efficiency Directive. Operators will be obliged to report on various environmental indicators, procure renewable energy for their operations, meet energy efficiency targets, make economical use of cooling system power, and utilise waste heat (German Federal Government, 2020[2]). The utilisation of waste heat from data centres is regarded as an often-untapped opportunity by the International Energy Agency (IEA), which recommends governments and policy makers work together with operators and local communities to provide district heating and supply industrial heat users wherever possible (IEA, 2023[53]). Many German data centre operators already capture waste heat, although bureaucratic hurdles often limit the effective distribution.

The German government recognises the need for environmentally specific standards and measurements in its 2020 strategy update. It aims to make AI environmentally sound by "systematically expanding its funding and research linking digitalisation and ecological sustainability goals" and to "advance energy- and resource-saving information and communication technology (green ICT)" (German Federal Government, 2020[2]). It proposes to develop an advanced "concept for environmental impact assessment of AI and step up its funding for research on the environmental impacts of AI, in particular commissioning the collection of empirical data and a systematic analysis of the carbon dioxide (CO_2)-saving potential of AI, duly taking into account possible negative effects (such as rebound effects)" (German Federal Government, 2020[2]). Recognising the high complexity of such a concept, other countries have not implemented an environmental impact assessment of AI that includes rebound effects and would represent a trailblazing contribution to global efforts on measuring the environmental impact of AI.

Regarding best practices and knowledge dissemination, the strategic goal of advancing energy- and resource-saving ICT is already being implemented across ministries and the private sector. For instance, the BMBF and the Research Fab Microelectronics Germany (*Forschungsfabrik Mikroelektronik Deutschland*, FMD) sponsor the Green ICT initiative, a competence centre for sustainable information and communication technology. Green ICT provides resources and expertise to project partners from industry and science to develop sustainable microelectronics and energy-efficient technology infrastructure. It also provides educational offerings for students, industry specialists, start-ups and SMEs (Green ICT, 2023[54]).

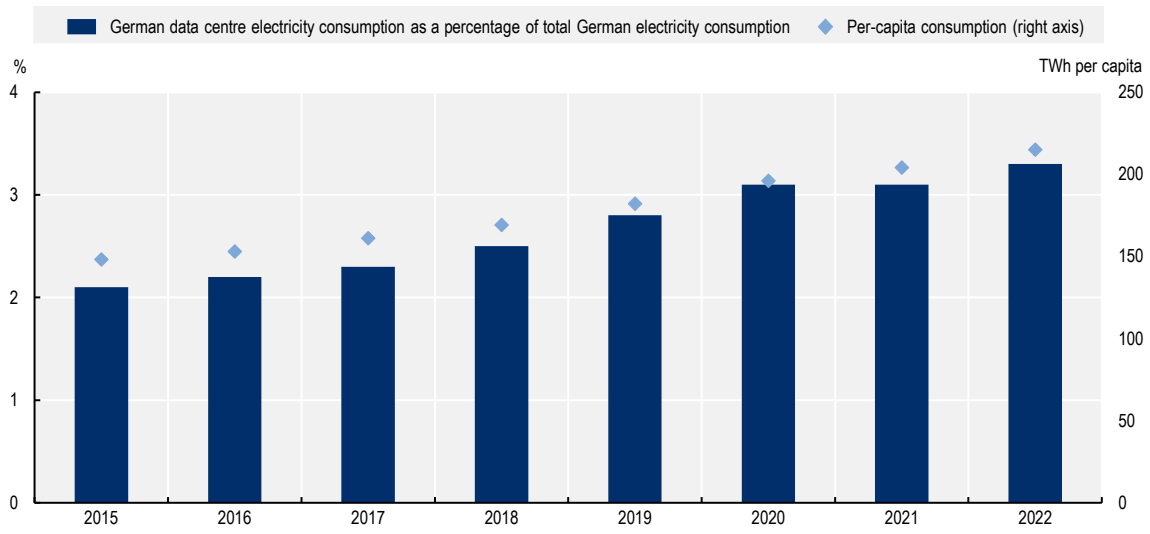
Public compute providers in Germany have pioneered green ICT methods. For example, the Leibniz Supercomputing Centre (LRZ) of the Bavarian Academy of Science and Humanities (*Bayerische Akademie der Wissenschaften*, BAdW) has worked on and implemented energy-efficient computing infrastructure for over a decade, for instance through implementing a warm water-cooling loop that results in significant energy savings. The LRZ researches green information technology (IT) methods under a methodology examining the environmental impacts of building infrastructure, hardware, management software, and sustainability applications (LRZ, 2023[55]). Amongst the world's 50 most energy-efficient supercomputers, Germany has 11 supercomputers and is second only to the United States (US) (14), ahead of France (6), Japan (5) and Australia (2) (TOP500, 2023[56]). The BMZ and the GIZ have developed a practitioners' guide to *Green Data Centers: Towards a Sustainable Digital Transformation* together with the ITU and the World Bank. The guide encourages public and private investment in green data centre infrastructure through public procurement strategies and wider policies and regulations (ITU/World Bank, 2023[10]).

The energy consumption of Germany's servers and data centres has increased since 2015 (Figure 9.2). Estimated at 17 billion kilowatt-hour (kWh) in 2021, data centres consumed 6.5% more energy than in 2020 and 14% more than in 2019 (14 billion kWh). This represented around 3.3% of the German national electricity supply in 2021, compared with 2.7% in the Netherlands and 2.5% in the UK (Statistics Netherland, 2021[57]); (nationalgridESO, 2022[58]). Extrapolating current trends forward could mean a consumption of around 28 billion kWh by 2030 (Borderstep Institute, 2022[59]). The Office for Technology

at the German Bundestag (*Büro für Technikfolgen-Abschätzung beim Deutschen Bundestag*, TAB) arrives at similar numbers, estimating German data centre energy consumption at 14.9 billion kWh in 2019 and at a projected 30.6 billion kWh by 2030 (including telecommunication networks) if current trends continue. However, the authors of the TAB note that "the state of knowledge on energy requirements of ICT infrastructure is incomplete and often contradictory", stating a "considerable need for more research" and for "regular data collection and reporting including real data from companies" (Grünwald and Caviezel, 2022[60]).

Figure 9.2. Data centres' share of total German electricity consumption has steadily increased in recent years

German data centre electricity consumption



Note: Estimating data centre electricity consumption dedicated to AI is technically and methodologically challenging.
Source: Borderstep Institute (2022[59]), "Cloud computing drives the growth of the data centre industry and its energy consumption", https://www.borderstep.de/wp-content/uploads/2022/08/Borderstep_Rechenzentren_2021_eng.pdf.

Recommendations

Increase inter-government and interdisciplinary co-operation on AI and environmental sustainability to promote transfer and synergies between initiatives

The German AI and environmental sustainability ecosystem benefits from a range of initiatives, funding, and strong public and private institutions that put AI and environmental sustainability on their agenda. At the same time, initiatives are often isolated and do not share knowledge and best practices or create synergies through co-operation. This is a critical issue because working at the intersection of AI and environmental sustainability requires technical and environmental expertise. Germany's 2020 AI strategy update aims to "bolster the links between SMEs, start-ups and public interest actors and research so as to promote the transfer and application of research findings across the breadth of the economy and society" (German Federal Government, 2020[2]). This goal should be expanded to create an authentic multistakeholder and multidisciplinary approach that benefits from the resources and knowledge of Germany's AI experts, environmental groups, and academic thought leaders.

Define strategic focus areas to maximise AI's enabling effects for environmental sustainability and rapid decarbonisation

Germany has strong potential to cluster AI and environmental sustainability initiatives and knowledge in strategic focus areas. While initiatives exist in sectors like energy, transport, industry, and agriculture, AI can be used in nearly every sector of the economy, such as buildings and cities, green financing, or green consumption. Germany could prioritise areas to align research efforts, streamline funding, and define objectives, for example, in inter-ministerial working groups or whole-of-government initiatives.

Extend the German leadership position in AI and environmental sustainability through knowledge-sharing, education programmes, promoting start-ups and SMEs; widen the focus to include the circular economy, biodiversity, and other planetary boundaries

Germany is positioned to become a leader in the field of AI and environmental sustainability based on its strong strategic and political mandate, diverse and appropriately funded initiatives, leading academics and researchers in the field, and innovative industrial companies and start-ups that export sustainable AI solutions. This could be strengthened by encouraging and promoting knowledge-sharing and transfer, educating policy makers and students, supporting German start-ups and SMEs, and widening the focus of what constitutes sustainability beyond energy and resource efficiency to include circular economic models, biodiversity preservation, land-system change, freshwater depletion, and other planetary boundaries, to make AI work for the good of the planet.

Expand measurement efforts to assess and mitigate the energy, water, and resource impacts of AI compute infrastructure

Germany recognises the need for systematic and standardised measurement of the environmental impacts of AI and ICT infrastructure, including direct impacts, such as energy and water consumption, and indirect enabling and systemic effects from application across sectors. Germany took important first steps in collecting data on environmental impacts, such as the reporting requirements for data centre operators in the upcoming EnEfG. Such efforts should be expanded, for instance, by implementing the environmental impact assessment of AI with the Federal Statistical Office and in partnership with research institutes that track indicators like data-centre energy consumption. The resulting indicators could be included in public databases such as the high-performance computing map of the Gauss Alliance to increase transparency (GCS, 2023[61]). Germany should widen the focus from operational energy consumption and GHG emissions to wider environmental impacts such as biodiversity degradation, the lifecycle impacts of producing compute equipment, impacts from water consumption and rare-earth mining (OECD, 2022[1]). An environmental impact assessment of AI as envisioned in the national AI strategy update would benefit from intra-ministerial co-operation. It would pioneer a comprehensive ecological review of national AI compute resources and could set international standards to shape the development of metrics such as those proposed in the European Union Regulation on Artificial Intelligence (the "EU AI Act") (European Union, 2024[62]).

References

Alan Turing Institute (2023), *ADViCE Introduction*, https://www.turing.ac.uk/research/research-projects/advice#:~:text=Artificial%20Intelligence%20for%20Decarbonisation%27s%20Virtual,the%20transition%20to%20Net%20Zero (accessed on 11 December 2023). [48]

ANR (2021), *Challenge IA-Biodiv: Research in Artificial Intelligence in the Field of Biodiversity*, Agence nationale de la recherche, https://anr.fr/en/call-for-proposals-details/call/challenge-ia-biodiv-research-in-artificial-intelligence-in-the-field-of-biodiversity/ (accessed on 11 December 2023). [51]

Baiosphere (2023), *Über die baiosphere*, https://baiosphere.org/baiosphere/ (accessed on 11 December 2023). [12]

BASF (2023), *Innovative and Disruptive Technologies for Sustainable Future Success*, https://www.basf.com/global/en/who-we-are/digitalization/artificial-intelligence.html (accessed on 11 December 2023). [24]

bitkom (2023), *Klimaeffekte der Digitalisierung*, https://www.bitkom.org/sites/main/files/2021-10/20211010_bitkom_studie_klimaeffekte_der_digitalisierung.pdf. [44]

bitkom/eco/German Datacentre Association (2022), *Perspectives for a Sustainable Data Centre Industry by 2030*, https://www.germandatacenters.com/fileadmin/documents/publications/Perspectives-for-a-sustainable-data-center-industry-by-2030.pdf. [38]

Bits & Bäume (2021), *Forderungen*, https://bits-und-baeume.org/konferenz-2022/forderungen/ (accessed on 11 December 2023). [22]

BMBF (2023), “Bekanntmachung Methoden der Künstlichen Intelligenz als Instrument der Biodiversitätsforschung”, Bundesministerium für Bildung und Forschung, https://www.bmbf.de/bmbf/shareddocs/bekanntmachungen/de/2023/01/2023-01-04-Bekanntmachung-Biodiversit%C3%A4tsforschung.html (accessed on 11 December 2023). [9]

BMBF (2021), “Bekanntmachung”, Bundesministerium für Bildung und Forschung, https://www.bmbf.de/bmbf/shareddocs/bekanntmachungen/de/2021/09/2021-09-17-Bekanntmachung-KI.html (accessed on 11 December 2023). [8]

BMDV (2023), “Artificial Intelligence and Mobility - AIAMO”, Bundesministerium für Digitales und Verkehr, https://bmdv.bund.de/SharedDocs/DE/Artikel/DG/KI-Projekte/aiamo.html (accessed on 11 December 2023). [7]

BMEL (2021), *Künstliche Intelligenz (KI) für eine nachhaltigere Landwirtschaft*, Bundesministerium für Ernährung und Landwirtschaft, https://www.bmel.de/SharedDocs/Downloads/DE/Broschueren/k-i-fuer-nachhaltige-landwirtschaft.pdf?__blob=publicationFile&v=7 (accessed on 11 December 2023). [11]

BMUV (2023), *Community “Nachhaltige Digitalisierung”*, Bundesministerium für Umwelt, Naturschutz, nukleare Sicherheit und Verbraucherschutz, https://www.bmuv.de/themen/digitalisierung/community-nachhaltige-digitalisierung (accessed on 11 December 2023). [47]

BMUV (2023), *Künstliche Intelligenz für Umwelt und Klima*, Bundesministerium für Umwelt, Naturschutz, nukleare Sicherheit und Verbraucherschutz, https://www.bmuv.de/themen/digitalisierung/kuenstliche-intelligenz-fuer-umwelt-und-klima (accessed on 11 December 2023). [4]

BMWK (2022), *Industrie 4.0 gestalten. Resilient, nachhaltig, wettbewerbsstark*, Bundesministerium für Wirtschaft und Klimaschutz, https://www.bmwk.de/Redaktion/DE/Publikationen/Industrie/industrie-40-gestalten-resilient-nachhaltig-wettbewerbsstark.pdf?__blob=publicationFile&v=1 (accessed on 11 December 2023). [43]

Borderstep Institute (2022), "Cloud computing drives the growth of the data center industry and its energy consumption", Borderstep Institute for Innovation and Sustainability, https://www.borderstep.de/wp-content/uploads/2022/08/Borderstep_Rechenzentren_2021_eng.pdf. [59]

Celonis (2023), *Sustainability Transformation*, https://www.celonis.com/solutions/sustainability-transformation/ (accessed on 11 December 2023). [28]

Christian-Albrechts-Universität zu Kiel (2023), *Rasmus: Cost-efficient Ship Routing Utilizing Ocean Currents*, https://www.ai.informatik.uni-kiel.de/de/projects/current-projects-2/copy_of_rasmus-ship-routing (accessed on 11 December 2023). [40]

Civic Coding (2023), *Die Initiative*, https://www.civic-coding.de/ueber-civic-coding/die-initiative (accessed on 2 November 2023). [6]

Creutzig, F. et al. (2015), "Transport: A roadblock to climate change mitigation?", *Science*, Vol. 350/6263, pp. 911-912, https://www.science.org/doi/10.1126/science.aac8033. [41]

dena (2019), *Künstliche Intelligenz für die integrierte Energiewende*, Deutsche Energie-Agentur GmbH, https://www.dena.de/fileadmin/dena/Publikationen/PDFs/2019/dena-ANALYSE_Kuenstliche_Intelligenz_fuer_die_integrierte_Energiewende.pdf. [37]

DFKI (2023), *Artificial Intelligence for Environment and Sustainability*, Deutsches Forschungszentrum für Künstliche Intelligenz GmbH, https://www.dfki.de/en/web/applications-industry/competence-centers/ai-for-environment-and-sustainability (accessed on 11 December 2023). [17]

EEA (2023), *Transport and Environment Report 2022*, European Environment Agency, https://www.eea.europa.eu/publications/transport-and-environment-report-2022/transport-and-environment-report/view. [39]

ELIAS (2023), *European Lighthouse of AI for Sustainability*, https://elias-ai.eu (accessed on 11 December 2023). [20]

Enpal (2023), *Über Enpal*, https://www.enpal.de/ueber-uns (accessed on 11 December 2023). [26]

European Union (2024), *Regulation (EU) 2024/ ..... of the European Parliament and of the Council laying down harmonised rules on artificial intelligence (Artificial Intelligence Act)*, https://data.consilium.europa.eu/doc/document/PE-24-2024-INIT/en/pdf. [62]

GCS (2023), *Our Centres*, Gauss Centre for Supercomputing, https://www.gauss-centre.eu/about-us/our-centres (accessed on 11 December 2023). [61]

German AI Association (2023), *Working Groups*, https://ki-verband.de/en/working-groups/ (accessed on 11 December 2023). [30]

German Federal Government (2020), *Artificial Intelligence Strategy of the German Federal Government: 2020 Update*, https://www.ki-strategie-deutschland.de/files/downloads/Fortschreibung_KI-Strategie_engl.pdf. [2]

Government of Canada (2023), *About the Clean Growth Hub*, https://ised-isde.canada.ca/site/clean-growth-hub/en/about-clean-growth-hub (accessed on 11 December 2023). [49]

Green ICT (2023), *About Green ICT*, https://greenict.de/en/ (accessed on 11 December 2023). [54]

Greentech Alliance (2023), *What We Do*, https://www.greentech.earth/what-we-do (accessed on 11 December 2023). [29]

Grünwald, R. and C. Caviezel (2022), "Energieverbrauch der IKT-Infrastruktur. TAB-Fokus", Institut für Technikfolgenabschätzung und Systemanalyse (ITAS), Karlsruher Institut für Technologie (KIT), https://publikationen.bibliothek.kit.edu/1000151166. [60]

HAI (2023), *Congressional Boot Camp on AI*, Stanford University, https://hai.stanford.edu/congressional-boot-camp-ai (accessed on 11 December 2023). [50]

hessian.AI (2023), "Supercomputer for cutting-edge AI research in Hesse", https://hessian.ai/supercomputer-for-cutting-edge-ai-research-in-hesse/ (accessed on 11 December 2023). [13]

IEA (2023), *Data Centres and Data Transmission Networks*, International Energy Agency, https://www.iea.org/energy-system/buildings/data-centres-and-data-transmission-networks (accessed on 11 December 2023). [53]

IEA (2023), *Energy Technology Perspectives 2023*, International Energy Agency, https://www.iea.org/reports/energy-technology-perspectives-2023. [35]

ITF (2023), *ITF Transport Outlook 2023*, OECD Publishing, Paris, https://doi.org/10.1787/b6cc9ad5-en. [42]

ITU/World Bank (2023), *Green Data Centers: Towards a Sustainable Digital Transformation - A Practioner's Guide*, International Telecommunication Union and the World Bank, https://www.bmz-digital.global/wp-content/uploads/2023/08/Guide-to-Green-Data-Centers-Final.pdf. [10]

KI.NRW (2023), *Selected Examples of the North Rhine-Westphalian AI ecosystem*, https://www.ki.nrw/en/ai-highlights/ (accessed on 11 December 2023). [14]

LRZ (2023), *Green IT at Leibniz Supercomputing Centre*, Leibniz-Rechenzentrum, https://www.lrz.de/wir/green-it_en/ (accessed on 11 December 2023). [55]

nationalgridESO (2022), "Data centres", https://www.nationalgrideso.com/document/246446/download (accessed on 11 December 2023). [58]

OECD (2023), "A blueprint for building national compute capacity for artificial intelligence", *OECD Digital Economy Papers*, No. 350, OECD Publishing, Paris, https://doi.org/10.1787/876367e3-en. [52]

OECD (2023), *OECD Environmental Performance Reviews: Germany 2023*, OECD Environmental Performance Reviews, OECD Publishing, Paris, https://doi.org/10.1787/f26da7da-en. [36]

OECD (2022), "Measuring the environmental impacts of artificial intelligence compute and applications: The AI footprint", *OECD Digital Economy Papers*, No. 341, OECD Publishing, Paris, https://doi.org/10.1787/7babf571-en. [1]

OECD.AI (2023), *AI and the Environment*, OECD, Paris, https://oecd.ai/en/dashboards/policy-areas/PA9. [3]

OECD/FAO (2021), *OECD-FAO Agricultural Outlook 2021-2030*, OECD Publishing, Paris, https://doi.org/10.1787/19428846-en. [46]

One Planet Network (2023), *Rethinking, Extending, Re-using. Harnessing Digital Technologies for the Circular Economy*, https://www.oneplanetnetwork.org/sites/default/files/2023-11/RETHINKING%2C%20EXTENDING%2C%20REUSING-%20HARNESSING%20DIGITAL%20TECHNOLOGIES%20FOR%20THE%20CIRCULAR%20ECONOMY%20-%205%20%281%29.pdf. [45]

OroraTech (2021), "Maintain control of wildfires: OroraTech launches global thermal intelligence services", https://ororatech.com/ororatech-launches-global-thermal-intelligence-service/ (accessed on 11 December 2023). [32]

Porsche (2021), "Porsche, Audi and Volkswagen use artificial intelligence to minimise sustainability risks", https://newsroom.porsche.com/en/2021/sustainability/porsche-audi-volkswagen-pilot-project-artificial-intelligence-minimisation-sustainability-risks-supply-chain-23801.html (accessed on 11 December 2023). [25]

Rohde, F. et al. (2021), *Nachhaltigkeitskriterien für künstliche Intelligenz*, https://www.ioew.de/fileadmin/user_upload/BILDER_und_Downloaddateien/Publikationen/2021/IOEW_SR_220_Nachhaltigkeitskriterien_fuer_Kuenstliche_Intelligenz.pdf. [21]

Rolnick, D. et al. (2019), "Tackling climate change with machine learning", https://arxiv.org/abs/1906.05433. [34]

Siemens (2023), *The Climate Crisis – Solutions in the Ecosystem*, https://www.siemens.com/global/en/company/stories/research-technologies/energytransition/sustainability-solutions-in-the-ecosystem.html (accessed on 11 December 2023). [23]

Statistics Netherland (2021), "Electricity supplied to data centres, 2017-2019", https://www.cbs.nl/en-gb/custom/2020/51/electricity-supplied-to-data-centres-2017-2019 (accessed on 11 December 2023). [57]

STMD (2023), "Bundesländer setzen ständige Digitalministerkonferenz ein / Digitalminister Mehring: „Meilenstein für die Digitalisierung in Deutschland!"", Bayerisches Staatsministerium für Digitales, https://www.stmd.bayern.de/bundeslaender-setzen-staendige-digitalministerkonferenz-ein-digitalminister-mehring-meilenstein-fuer-die-digitalisierung-in-deutschland/ (accessed on 11 December 2023). [15]

sustAInability (2023), *About sustAInability*, https://sustainability-ai.de (accessed on 11 December 2023). [18]

Sustainable AI Lab (2023), *About Us*, https://sustainable-ai.eu/about-us/ (accessed on 11 December 2023). [16]

TOP500 (2023), *Green500 - November 2023*, https://www.top500.org/lists/green500/2023/11/ (accessed on 11 December 2023). [56]

TU Berlin (2020), "KI-Leuchttürme für die Umwelt", https://www.tu.berlin/ueber-die-tu-berlin/profil/pressemitteilungen-nachrichten/ki-leuchttuerme-fuer-die-umwelt (accessed on 11 December 2023). [19]

TWAICE (2023), *TWAICE Battery Analytics Platform*, https://www.twaice.com/products/battery-analytics-platform (accessed on 11 December 2023). [27]

UBA (2022), *UBA Application Lab for AI and Big Data*, Umweltbundesamt, https://www.umweltbundesamt.de/en/topics/digitalisation/uba-application-lab-for-ai-big-data (accessed on 11 December 2023). [5]

UnternehmerTUM (2023), *TUM Venture Labs Sustainability and Circular Economy*, https://www.unternehmertum.de/en/about/tum-venture-labs (accessed on 11 December 2023). [31]

WBGU (2019), *Flagship Report - Towards Our Common Digital Future*, German Advisory Council on Global Change, https://www.wbgu.de/fileadmin/user_upload/wbgu/publikationen/hauptgutachten/hg2019/pdf/wbgu_hg2019_en.pdf. [33]

10 Spotlight: AI and healthcare

This chapter outlines key opportunities for Germany to advance artificial intelligence (AI) capabilities in health care. Germany has started meaningful action to advance AI in health, including legislative measures aimed at boosting the integration of digital health technologies and actively promoting AI applications in medicine. Despite public optimism about AI's potential to improve patient experiences and reduce the workload of health workforce, Germany faces challenges to enabling AI in health due to fragmented health data and impracticable data privacy and security measures. Germany has started its journey into AI in health and should continue work to establish a comprehensive health data governance and interoperability strategy with legislation that enables innovation while providing appropriate protections. This strategy will be vital for building a national health information framework that fosters timely access to quality data, enabled by collaboration among all key stakeholders to benefit Germany and everyone living in Germany.

AI has the potential to save lives, helping health professionals dedicate more time to care, and improving public health and safety (OECD, 2024[1]). However, these benefits are limited in reach due to a fragmented policy, data, and technology foundation. This is true in Germany and many other countries.

Germany's 2018 AI Strategy reflected the imperative for action on AI in health as it identified opportunities to improve health outcomes, support nursing, and drive innovation. This was re-articulated in the 2020 update to the AI Strategy.

Germany is taking action to build a stronger policy, data, and technical foundation for AI, reflective of the 2018/20 AI Strategy. Developing and training AI applications requires access (policy) to large, high-quality, and detailed datasets (data) while ensuring the security of these data (technology). The art of developing AI solutions requires effective stewardship of millions of personal health records that consolidate information across populations and organisations.

Box 10.1. AI and healthcare: Findings and recommendations

Findings

- Broad-based support for acts related to health data and digital tools (GDNG, Digi-G, upcoming act restructuring gematik) will strengthen foundations for AI in health in Germany.
- Cautious interpretation of data protection legislation is hampering the ability to innovate with AI.
- Poor interoperability is due to lack of accountability, trust, and incentives.
- The public and health providers believe AI will benefit health outcomes and systems, although there are differences by age.

Recommendations

- Continue with legislation and policy re-design.
- Develop guidance for secondary-use access to health data that supports development of AI and protects citizens and respects privacy rights.
- Establish a health-data governance and interoperability strategy and framework with accountability, a roadmap, measurements, financial levers and oversight.
- Involve the public and health providers in the development of AI solutions, design of controls and oversight mechanisms for trust.

Germany's journey to health in the digital age

Germany is advancing its digital health ecosystem, focusing on patient-centred care and leveraging AI for clinical, administrative, and research improvements. The Government's strategy includes substantial funding for diverse health-related AI projects and legislation to enhance data availability and use. These efforts aim to improve health outcomes, system efficiency, and innovation, aligning with the European Union (EU)'s health data space for better cross-border data collaboration.

Germany, an OECD country with higher-than-average health spending (OECD, 2022[2]), has made considerable strides in health digitalisation. Almost one-fourth (23%) of all residents used teleconsultation at the height of the COVID-19 pandemic, well below the average of 39% across the EU27 (OECD/EU, 2022[3]). Germany acknowledges that it lags in its digital transformation efforts. In the 2022 OECD report on the Recommendation on Health Data Governance, Germany ranked 18th among the 23 responding OECD countries for dataset governance and last (23rd) among those countries for data linking (OECD,

2016[4]). As reported at a conference in June 2023, Germany is the 18th country in Europe to adopt e-prescription services nationwide since the first of January 2024. Germany starts to prepare for the European Health Data Space to simplify cross-border data collaboration and improve portability of personal health records later than many European peers.

Germany has taken proactive measures to address these areas. Based on a broad stakeholder consultation process (more than 500 actors), the Federal Ministry of Health (*Bundesministerium für Gesundheit*, BMG) has developed a strategy for health digitalisation in 2023 (BMG, 2023[5]). The strategy aims to facilitate a people-centric and learning digital health ecosystem to ensure the well-being of patients (Gerlach et al., 2021[6]).

Germany is an international pioneer in the structured assessment and reimbursement of patient-centred digital health applications. The procedure for assessing eligibility for reimbursement is open to development, including for AI-based applications. To support research and innovation in this field, the Federal Ministry of Education and Research (*Bundesministerium für Bildung und Forschung*, BMBF) offers a range of funding schemes:

- Medical informatics initiative
- Digital Hubs: Advances in Research and Healthcare
- National Research Data Infrastructure
- Funding Line Computational Life Sciences
- Funding Line Modelling Network for Serious Infectious Diseases
- Funding Line Data Analysis and Data Sharing for Cancer Research.

In addition to enhancing digitalisation for improved information sharing and individual empowerment, the German government has a parallel objective to promote AI. To this end, the German Federal Government devised a strategy for AI usage in 2018 to "to safeguard Germany's outstanding position as a research centre, to build up the competitiveness of German industry, and to promote the many ways to use AI in all parts of society" (German Federal Government, 2018[7]).

AI in a digitalised health system – developed and adopted responsibly – provides the conditions for improved clinical care, healthcare system efficiency, protection from public health emergencies, medical research, and burgeoning innovation. AI in health can be applied to biomedicine (precision medicine, drug discovery, matching individuals to clinical trials, prediction, and prevention), administration (scheduling, billing, coding, managing workflow and payment), and clinical practice (clinical audits, diagnostic imaging interpretation for radiology, robot remote control surgery, develop personalised treatment plans) (Oliveira Hashiguchi, Slawomirski and Oderkirk, 2021[8]). Germany is actively pursuing several projects to increase AI use in medicine, including in radiology to decrease exposure to radiation (Nensa, Demircioglu and Rischpler, 2019[9]) as well as supporting the development and adoption of health applications (Lantzsch et al., 2022[10]). The BMG funded and is funding a total of 38 projects between 2020 and 2025. These projects underline the wide range of possible applications and uses of AI in healthcare and show how innovative technologies can be used to further develop research and patient care.

To help accelerate the better use of health data in Germany, including its role in AI applications, the German Federal Government has plans for legislative measures aimed at enhancing the health data ecosystem:

- The Act on Health Data Use (*Gesundheitsdatennutzungsgesetz*, GDNG) aims to promote the common use of health data by creating the basis for better availability of health data and paving the way for the European Health Data Space (EHDS).
- Another critical piece of legislation will be the Registry Act (*Registergesetz*), for which the first official draft is expected in the first half of 2024. It aims to strengthen and regulate medical registries as well as to enhance transparency through the establishment of a centre for medical

registries. The centre would keep a register directory, offering an overview of master and process data of these registries. The legislation seeks to promote treatment reviews, research, and care by improving data usability and accessibility for research and care and offering support for medical registries to develop quality and utility.

When implemented, these measures will collectively help improve the accessibility and linkability of data across Germany (and across Europe via the EHDS). This will be accomplished in part with the health data hub (*Forschungsdatenzentrum Gesundheit*). The better use of health data will help improve health outcomes for individuals, enable health system-level insights for population health and safety, support preparedness for public health emergencies, and drive research and innovation for long-term systemic improvements.

The overall goal is to provide patients with the highest quality of care, including new, innovative medical technology applications. Achieving this goal requires the best possible knowledge from medical research which, in modern medicine, involves the use of AI.

Public and healthcare provider perspectives

In Germany, attitudes are optimistic about AI's potential in healthcare, with many recognising its benefits in diagnosis and disease detection when accompanied by human oversight. Despite some fears, there's an emphasis on the need for inclusive digital literacy to prevent a divide. Healthcare workers view AI as an augmentation tool rather than a replacement, advocating for its application in administrative tasks to enhance efficiency and patient experiences. At the same time, they highlight a cautious approach to adoption out of trust and value concerns.

Several recent surveys have gauged the opinion of Europeans on AI, including of people living in Germany (see Chapter 6). In this context, there is more optimism among people living in Germany for the use of AI in health, compared to other AI applications, as 80% of respondents believe there are good or balanced opportunities for AI for disease detection (bidt, 2023[11]). 85% believe that AI would have benefits in diagnosis with a large majority preferring a human intermediary between the AI and the patient. These were perceived to be the highest beneficial opportunities of AI. The report (bidt, 2023[11]) provided a caution where: “In a country comparison, there is a relatively large digital divide among the population in Germany”. People with limited digital literacy, possess low digital skills and thus face the risk of being left behind. For Germany to be able to keep pace internationally with digitalisation and not to fall behind from an economic and social perspective, the backlogs in the identified problem areas must be made up as quickly as possible and existing differences in skills among the population must be mitigated.

A second survey demonstrated similar positive sentiment towards AI among the public with 81% perceiving AI as an opportunity, 70% believing that doctors should be supported by AI, and 87% acknowledging the need for regulation. It is also important to note that 23% express fear of AI, although the survey did not go into more detail (Wintergerst, 2023[12]).

On the broader topic of digitalisation, some groups may have overemphasised the demands for privacy and security among the public. In practice, patients have repeatedly shown positivity towards digital infrastructure (Schmitt, Haarmann and Shaikh, 2022[13]; Heidel and Hagist, 2020[14]). The same sentiment, of acceptance towards digitalisation, is echoed among service providers.

Discussions with health workers revealed their pragmatism that their jobs were unlikely to be replaced by advancements in AI. Nevertheless, there is a perception that there has been slow adoption of digital tools that are connected across a broader network of health organisations. Rationale for the slow adoption includes: i) a lack of trust due to early missteps in the implementation of digital tools; ii) concerns about a loss of autonomy in the role of health providers due to digital tools; and iii) physicians not seeing the value of investing their time to create better outcomes for providers and their patients.

To that end interviews noted that valuable areas for implementation of AI would include functions that reduce the workload for healthcare providers and improve the patient experience (e.g. appointment booking, clinical documentation, and invoicing) to improve adoption of AI in clinical settings. These would also have the advantage of being lower risk applications of AI as clinical outcomes are not directly impacted. This would require a shift of focus from senior decision makers, funders, and innovators whose apparent focus is on advanced clinical care including diagnostics, robotics, or genomics.

Barriers to adoption of AI for health in Germany

Germany's approach to integrating AI in healthcare faces challenges, including cautious interpretation of data protection laws and fragmented health data systems. While initiatives like the Act on Health Data Use aim to improve data availability, practical issues such as data silos and varying state laws complicate data sharing and AI development. To fully utilise AI, Germany must balance data protection with the need to use health data to improve care and enhance data interoperability and public trust in AI solutions.

As Germany embarks on its AI for health journey, it faces several barriers to harnessing the potential of health data and AI. While the legislation noted above (*Registergesetz*, GDNG) will help, additional efforts are needed to identify and resolve long-standing barriers that are preventing the development and use of AI for health. Specifically, the progress of AI for health is hindered by factors that challenge the ability to scale innovations across health care organisations. Scaling AI relies on: i) data access with protections; ii) data interoperability; iii) trust from impacted stakeholders – notably providers and the public; and iv) sufficient human and computing capacity to develop, deploy, operate, and sustain AI solutions.

Cautious interpretation of data protection legislation

Data privacy and security legislation is designed to protect patient information. This legislation is grounded in the EU regulations such as General Data Protection Regulation and the fundamental right to informational self-determination enshrined in the German constitution. Germany has developed and is in process of updating federal data protection laws. In addition, the *Länder* have developed state-specific laws regarding health data (Schmitt, 2023[15]). In general, these legislations set guidelines for health data access and use, including necessary controls and obligations on the part of data holders, intermediaries and users.

The current balance between enabling the positive goals of health data research and avoiding associated data protection risks is reportedly skewed towards risk avoidance. This makes reaching the goals of health data research and other secondary data uses extremely difficult. This is important because “it is widely recognised that there is an ethical imperative to use health data to improve care” (McLennan et al., 2022[16]). Current interpretations of data protection also create a problematic conflict with Germany’s ambitions to be a leader in AI (McLennan et al., 2022[16]).

The result is that health-related datasets in Germany often remain isolated in silos, making them unavailable for secondary use. Therefore, accessing comprehensive health data may be more challenging than in other countries. This challenge is related to cautious interpretations of data privacy and security regulation (anecdotally related to historic concerns over data mis-use causing harms), multiple regulations, and decision makers concerning privacy and access across German states, and a lack of coherent technical standards. While acts such as GDNG and Digi-G signal positive advancements – along with the activities to participate in the EHDS – it is important to engage with people so their actions will bring the intended outcomes of the acts and EHDS into being.

Regulations in health are particularly important because health care involves highly sensitive data that, if mismanaged, can have major negative consequences. For instance, privacy breaches resulting from data sharing can cause emotional harm and financial implications, among other challenges. Conversely,

non-data sharing may result in poor-quality care, duplicative health services, and systemic health inequities. Both perspectives should be considered when making decisions about data access and use to minimise harms and optimise health outcomes. This is especially important for AI, given that timely access to quality representative data is essential for its effectiveness (Box 10.2).

Box 10.2. AI diagnostics and the importance of training data

In the world of AI diagnostics, a common drawback is the inability to scale and inaccuracies across different populations due to a lack of access to comprehensive datasets. Furthermore, training AI applications requires extensive patient datasets, but the use of such data can inadvertently introduce biases, rendering the results less applicable to specific population sub-groups, thus prompting concerns about their appropriateness. For example: "Among women with breast cancer, Black women had a lower likelihood of being tested for high-risk germline mutations compared with white women, despite carrying a similar risk of such mutations. Thus, an AI algorithm that depends on genetic test results is more likely to mischaracterise the risk of breast cancer for black patients than white patients" (Parikh, Teeple and Navathe, 2019[17]).

Another popular example to highlight the issue is 'Watson for Oncology', which, due to a lack of training data, experienced a downturn in accuracy (O'Leary, 2022[18]).

An AI tool produced by Google DeepMind showed promising results in the early prediction of acute kidney injury. They trained the AI system on data containing 703 782 adult patients from the United States (US) Department of Veterans Affairs. However, the dataset contained majority male patients (94% male), making other researchers concerned about the representativeness and, thus, the generalisability and accuracy of predictions across other populations. Cao et al. (2022[19]) evaluated the model performance using the female veteran population and found that the model performed worse on females than males. These results make imperative the need of training the AI systems with quality, interoperable, and diverse data, to create accurate and sensitive models for applying them to population panels. This will accelerate a reliable risk stratification for people.

Timely access to quality data is the catalyst to develop and scale accurate AI systems and models. It is notable that the BMBF is funding interdisciplinary projects to develop new approaches for data analysis and data sharing for cancer research including the development of training data sets to be provided to the broader research community.

Source: Parikh, R., S. Teeple and A. Navathe (2019[17]) , "Addressing bias in artificial intelligence in health care", https://doi.org/10.1001/jama.2019.18058; O'Leary, L. (2022[18]), "How IBM's Watson went from the future of health care to sold off for parts", https://slate.com/technology/2022/01/ibm-watson-health-failure-artificial-intelligence.html (accessed on 7 November 2023); Cao, J. et al. (2022[19]), "Generalizability of an acute kidney injury prediction model across health systems", https://doi.org/10.1038/s42256-022-00563-8.

While there are clauses within legislations that allow for the accessibility of data in scenarios for the public good, the clarity around what constitutes uses in the public good is not defined, even as guidelines. The uncertainty around what constitutes the public good will often cause decisions that err on the side of caution. This results in either requests being denied, or requests being fulfilled with a high level of data aggregation that renders the data unusable for secondary use and AI applications.

Without addressing this barrier, it could be considered unethical to invest significant amounts of public funds into AI development while limiting data access through strict privacy measures, as this constitutes an inefficient use of public resources. The AI revolution in healthcare can only realise its full potential if a transparent process spells out the values underlying national data governance policies and their impact on AI development and priorities are set accordingly (Bak et al., 2022[20]).

Fragmented data interoperability without guardrails for progress

Disparities in data collection and data standards between stakeholders and across German states are making it difficult to develop AI solutions and integrate them into the German health system. From the researchers' perspective, fragmented decision structures lead to administrative burdens that decrease the effectiveness and productivity of resources with excess time spent on data acquisition, assessment of data quality, and data management to normalise the data for use in AI systems.

Without clear accountability and guardrails, individual health organisations (or states) develop their own standards to achieve their projects' delivery, without consideration for the contribution of the project to the broader health ecosystem. This lack of interoperability may cause inefficiencies and harms in several ways. Patients and their providers may struggle to gain the information they need to provide quality care for people who receive care from multiple health facilities. This leads to over-testing, patients falling between the cracks with missed diagnoses, or harmful results when potential drug interactions are missed. Researchers and innovators need to invest time acquiring data and cleansing the data to be useful for their purposes. Public health professionals are not able to respond quickly and with precision to public health emergencies. Health ministries across German states and at the federal level are challenged to generate timely evidence-based decisions and monitor health policy effectiveness.

Measuring the interoperability across organisations – from both the perspective of data exchange and the policy environment – can expose where end-to-end processes are taking too long or cost too much. Without a policy, data, and technical approach to interoperability, the process to access data can far exceed necessary timelines and appropriate costs. This lack of interoperability across policy and data hindered innovation, as others have also encountered similar challenges (Box 10.3).

Progress is being made in Germany. The BMBF is taking action by funding the Medical Informatics Initiative to improve interoperable data exchange for medical research. The intention is to establish a common data infrastructure across all university hospitals.

Box 10.3. Incremental policy and data development can lead to excess cost and time

Health innovation is an economic driver. Fragmented policies designed without consideration for the overall objectives of health systems can prevent or impair innovation.

In 2018 the province of Ontario in Canada found that innovation had stalled despite its world-leading reputation and rich health data assets. Innovators complained that they could not get access to patient health data despite receiving expressed consent from the patients who wanted to benefit from their innovation. A task force examined the problem and found that the end-to-end process to granting data access was complex, ineffective and inefficient to support innovation and better personal health outcomes.

Over the span of many years, organisational, personnel, and priority changes had created what was referred to as a 'Franken-process' for granting access to health data for innovation. A team mapped the process, including which procedures needed to be followed (e.g. privacy impact assessments and threat risk assessments), where hand-offs occurred between organisations, and the estimated duration of each step.

The analysis showed that the process had ballooned to involve ten different approvals across three different legal entities in more than fifty process steps. Overall, there were 40 different hand-offs across organisations for the end-to-end data access process to work. Looking at the average time for each step, it was determined that for an innovator to gain access to a data asset, it would take a minimum of 18 months and cost the innovator CAD 50 000.

The overall process had evolved in idiosyncratic pieces with each organisation ensuring that their local risks were appropriately and fully mitigated. While those organisations had the intention of mitigating potential harm from privacy and security, they resulted in actual harms where patients could not receive benefits of innovation due to a lack of coherence across the overall process. The overall process had evolved in a way that was reasonable for each individual organisation but failed to achieve collective objectives of improved health outcomes.

The team re-designed the process so that privacy and security risks would still be mitigated; however, they minimised the hand-offs across organisations and consciously leveraged collective strengths and controls. The re-vamped process took less than three months for access to be granted. The new process provided the same level of privacy and security control while driving innovation and benefit for patients.

Implementations of AI will be more complex and involve more organisations each of which will have their own approaches to access and privacy. When designing AI solutions that involve multiple organisations, it will be important to collaborate to keep focus on achieving collective objectives while mitigating local risks.

Lack of involvement of the public and providers in developing AI solutions

There is a growing perception that governments lack trustworthiness as responsible managers of data, which hinders the progress of AI projects for health. Rebuilding trust and working collaboratively towards the common goal of delivering high-quality care will necessitate transparency and engagement at every stage of AI solution design, development, implementation, and sustainability. This is also necessary to overcome the inherent fear that 23% of the population feels towards AI.

Without focusing on the trust of the public in the use of AI solutions, there is a risk that many in Germany will choose to opt out of the use of their data for legitimate public purposes, such as to improve patient safety, or to prepare for future public health emergencies. Without data that are representative of the population, AI solutions will be biased, possibly ineffective, and at an extreme, could cause harm.

In addition, failing to consider the perspective of health care providers can also lead to adverse outcomes. Providers are, for many, the "face" of the health care system and the person that patients trust to help them in their times of need. Providers may be resistant to the use of new tools due to a lack of involvement in their design, resulting in concern that the new tool will add administrative burden, will question their professional judgement, or cause them to lose their autonomy while still being accountable for delivery of high-quality care.

The European Union Regulation on Artificial Intelligence (the "EU AI Act") (EU, 2024[21]) sets common guardrails for designing, implementing, and maintaining AI solutions. The tenets of this act will be operationalised by the EU member states and contextualised for AI in health.

Box 10.4. AI helps to prevent patients falling between the cracks

In the healthcare sector, substantial volumes of data are generated daily and stored within local electronic medical record (EMR) systems. This vital information, essential for enhancing health outcomes, exists in diverse, non-uniform formats across EMR systems. Where patients experience care from a single institution, this has limited impact; however, when care spans practitioners and institutions, the impacts can be significant. The inefficiency of clinicians manually sifting through multiple EMRs, but the true harm lies in the potential lack of access to these data, posing a risk to patients' well-being. This challenge spans the entire healthcare spectrum, affecting individuals ranging from leading researchers and renowned physicians to global pharmaceutical companies. This challenge is addressed by the electronic patient record (*elektronische Patientenakte*, ePA) which will soon be automatically provided to every person insured in the German statutory health insurance unless they choose to opt out. Healthcare providers transfer data from their local medical record to the patient's ePA so that other practitioners and institutions can access them (again unless the patient chooses to opt out). In the ePA, data should be documented in a structured way in accordance with standardised specifications and be interoperable. If this is the case, possible future filtering and search functions can assist the physician in analysing the data. In addition, AI can also help the physician to check the abundance of data stored in the ePA from a medical point of view.

AI systems have the capability to unlock value automatically and seamlessly from millions of clinical data points embedded in complex textual documents. AI-powered tools ensure accessibility and the active utilisation of critical insights, preventing patients from slipping through the gaps in conventional data handling. For instance, tools have been employed to extract real-world patient-level data, exploring treatment patterns and outcomes for patients with advanced lung cancer and identifying patients that would benefit from adjustments to their treatment programme to align with clinical best practices.

In addition to improving health outcomes, AI tools can do the work of scanning data repositories in a fraction of the time that it would take humans to identify where relevant medical records exist to simplify the search for comprehensive health records. Estimates are that AI can scan health records for a health practice to identify patients that would benefit from changes in care in less than an hour, whereas a health providers would take more than 200 hours – an improvement in time and quality.

This application at scale demonstrates the evolution of treatment patterns and clinical covariates impacting real-world patient outcomes.

Source: Cheung, W. et al. (2021[22]), "82P Exploring treatment patterns and outcomes of patients with advanced lung cancer (aLC) using artificial intelligence (AI)-extracted data", https://doi.org/10.1016/j.annonc.2021.10.100.

Recommendations

Develop guidance for secondary-use access to health data that supports AI development, protects citizens, and respects privacy rights

It is necessary to update current data access and privacy practices to enable the networked (and exponential) value of data and the implementation of responsible AI to align with the EU Data Governance Act and EU AI Act. Legacy approaches to affirmative consent are effective in predictable, paper-based and linear processes. However, the potential AI uses of health data are broader and challenging to predict, requiring a modern approach to consent. Such an approach would clarify scenarios under which data may never be used, scenarios were affirmative consent is required, and scenarios where data must be shared

to protect communities and the public good, including controls and measures that protect individual privacy in that scenario. This would improve the use of health data created in the early transition to the digital age so that longitudinal records can be analysed for patterns that identify prevention, promotion, and treatment opportunities.

Establish a health-data governance and interoperability strategy and framework with accountability, a roadmap, measurements, financial levers, and oversight

As a part of the German strategy for health and care digitalisation (BMG, 2023[5]), Germany will clarify accountability for a digital health agency (required as part of the EHDS) to support the development and adoption of digital tools. Further, the strategy will clarify accountability for the digitalisation of processes and identification of interoperability standards. Germany could strengthen accountability by reorganising existing structures. Reforming the digital health space by simplifying and clarifying authority aims to contribute to a more transparent interpretation of regulations for the reuse of data.

The work of gematik and other stakeholders would benefit from developing and implementing a strategy that advances health data governance and interoperability, including guidance on data access that minimises harm and optimises outcomes. The strategy would establish a target for timely and high-quality collection of health data; the ability to access, link, and use health data across organisations; and governance that oversees progress towards achievement of the target. This strategy could be inspired by recent work from Canada on a Shared Pan-Canadian Interoperability Roadmap (Canada Health Infoway, 2023[23]), in particular, as Canada has a federal structure similar to Germany's. Efforts in interoperability in Germany should align with the EHDS and projects such as XpandH.

Health data are the catalyst for high-quality care and research, and work on interoperability is critical to Germany's aspirations for "one patient, one record" established through electronic patient records, which will soon be automatically provided to every person insured in the German statutory health insurance – unless they choose to opt-out. It is planned that, by 2025, 80% of persons insured in the German statutory health insurance shall have an electronic patient record (BMG, 2023[24]). This will reinforce record-keeping and enhance the use of e-prescription, telemedicine, and health applications. These valuable data assets will be available (with appropriate protections) to generate high quality insights through AI and other secondary uses. Financial incentives embedded in the strategy should encourage adoption by i) risk-sharing with early adopters; and ii) penalising late adopters when a lack of compliance causes demonstrable harm (poor outcomes, waste, etc.).

Liability around the use of AI in health will need to be determined. A standard practice has yet to be defined, but leading practice assigns liability to the health provider regardless of whether AI is used in the provision of care. An anticipated outcome, once AI systems have been determined to be trustworthy, would be requiring the use of AI in the medical standard for care, while treating physicians would have the final determination of diagnosis and treatment.

Involve the public and health providers in developing AI solutions, control design, and oversight mechanisms for trust

The public and health service providers must accept AI for the successful and sustainable transition to and deployment of the technology. To accomplish this, stakeholder groups – like patients or nurses – should be approached about specific problems and be provided relevant information.

The OECD Recommendation on Health Data Governance (OECD, 2016[4]) recommends engagement and participation, clear provision of information, and transparency in the governance of heath data. Furthermore, the OECD [OECD/LEGAL/0449]. and G20 highlight trust in their principles for AI (OECD.AI, 2019[25]).

Support (re-)education for health providers and technology professionals for AI development and operations

Building knowledge among the public and healthcare providers about the use of health data and the methodology of AI is an antidote to mistrust and negative backlash when implementing new technologies. Finland strategically increased knowledge about AI in the population. As a result, Finland aimed to benefit from AI being accepted by the public as a tool for the common good (University of Helsinki, 2023[26]). Other initiatives to increase public AI and digital knowledge include the Australian training module for electronic health records (Australian Digital Health Agency, 2023[27]) and the Norwegian AI course (Norwegian Cognitive Center, 2020[28]).

With that knowledge, stakeholder groups are more able to shape the success of AI in health. This ties to the human factor of acceptance, and thus trust, as the foundation for stakeholder support for the uptake of AI. Maassen et al. (2021[29]) surveyed practitioners and found the acceptance of AI to be associated with people's self-rated technical affinity. A reasonable conclusion is that fostering acceptance and trust requires a knowledge base among stakeholders, which translates into successful implementation as AI in health progresses.

For practitioners, AI literacy must go beyond acceptance. As AI integrates into health systems, practitioners need competency to assess an AI model's potential bias and suboptimal prediction. This can be difficult, as AI models often provide outputs without describing how it got them, also referred to as "black box" due to the lack of explainability. Clinical support AI systems in healthcare sometimes produce false positives and negatives, such as in predicting sepsis (Goodman, Rodman and Morgan, 2023[30]). Accordingly, engaging with providers to share and learn how to respond and evaluate AI systems is elemental for the success of AI. Consolidation and co-operation in the development and design of AI systems are important for user-friendliness and, ultimately, value of AI in health.

Other considerations

Other areas where investment in healthcare related to AI could contribute to improving overall adoption of AI in Germany are outlined below.

First, it is necessary to ensure sufficient computing power to develop, implement, and sustain the use of AI for health. While there are concerns about ensuring that AI systems have sufficient and appropriate data, once the data become available, the computing systems will also need to be ready.

Second, Germany should collaborate with peers to investigate the use of privacy-enhancing technologies (OECD, 2023[31]). These capabilities could reduce the risk of privacy breaches while optimising the use of data through AI. Given parallel work in many countries and across industries, there is value in engaging in this collaboratively.

Finally, Germany should continue to investigate the use of federated learning and technologies such as data mesh to support cross-regional data collaboration (Rieke et al., 2020[32]), which is already being funded through projects such as PrivateAIM (PrivateAIM, 2024[33]) and FAIrPaCT (UMG, 2024[34]). Federated learning reduces privacy risks by minimising data copies and optimising the use of data for analytics, such as in public health, health system oversight, and research. Prioritisation of federated learning models requires strong policy, data, and technical foundations. The advancement of those foundations can happen in parallel with, or be directed towards, the implementation of federated learning solutions.

References

Australian Digital Health Agency (2023), *Online Learning Portal*, https://training.digitalhealth.gov.au/ (accessed on 27 October 2023). [27]

Bak, M. et al. (2022), "You can't have AI both ways: Balancing health data privacy and access fairly", *Frontiers in Genetics*, Vol. 13, https://doi.org/10.3389/fgene.2022.929453. [20]

bidt (2023), *Autorinnen und Autoren: Das bidt-Digitalbarometer. international*, Bayerisches Forschungsinstitut für Digitale Transformation, https://doi.org/10.35067/xypq-kn68. [11]

BMG (2023), *Act to Accelerate the Digitalization of the Healthcare System (Digital Act – DigiG)*, Bundesministerium für Gesundheit, https://www.bundesgesundheitsministerium.de/ministerium/gesetze-und-verordnungen/guv-20-lp/digig.html (accessed on 7 November 2023). [24]

BMG (2023), *Digital Together - Germany's Digitalisation Strategy for Health and Care*, Bundesministerium für Gesundheit, https://www.bundesgesundheitsministerium.de/fileadmin/Dateien/3_Downloads/D/Digitalisierungsstrategie/Germany_s_Digitalisation_Strategy_for_Health_and_Care.pdf (accessed on 11 December 2023). [5]

Canada Health Infoway (2023), *Shared Pan-Canadian Interoperability Roadmap*, https://www.infoway-inforoute.ca/en/component/edocman/resources/interoperability/6444-connecting-you-to-modern-health-care-shared-pan-canadian-interoperability-roadmap (accessed on 11 December 2023). [23]

Cao, J. et al. (2022), "Generalizability of an acute kidney injury prediction model across health systems", *Nature Machine Intelligence*, Vol. 4/12, pp. 1121-1129, https://doi.org/10.1038/s42256-022-00563-8. [19]

Cheung, W. et al. (2021), "82P Exploring treatment patterns and outcomes of patients with advanced lung cancer (aLC) using artificial intelligence (AI)-extracted data", *Annals of Oncology*, Vol. 32, p. S1407, https://doi.org/10.1016/j.annonc.2021.10.100. [22]

EU (2024), *Regulation (EU) 2024/ ..... of the European Parliament and of the Council laying down harmonised rules on artificial intelligence (Artificial Intelligence Act)*, https://data.consilium.europa.eu/doc/document/PE-24-2024-INIT/en/pdf. [21]

Gerlach, F. et al. (2021), *Executive Summary of the Council Report 2021 "Digitalisation for Health-Aims and Framework Conditions for a dynamically learning Health System"*, https://www.svr-gesundheit.de/fileadmin/Gutachten/Gutachten_2021/Executive_Summary_Englisch.pdf. [6]

German Federal Government (2018), *Strategie Künstliche Intelligenz der Bundesregierung*, http://www.ki-strategie-deutschland.de (accessed on 11 December 2023). [7]

Goodman, K., A. Rodman and D. Morgan (2023), "Preparing physicians for the clinical algorithm era", *New England Journal of Medicine*, Vol. 389/6, pp. 483-487, https://doi.org/10.1056/nejmp2304839. [30]

Heidel, A. and C. Hagist (2020), "Potential benefits and risks resulting from the introduction of health apps and wearables into the German statutory health care system: Scoping review", *JMIR mHealth and uHealth*, Vol. 8/9, p. e16444, https://doi.org/10.2196/16444. [14]

Lantzsch, H. et al. (2022), "Digital health applications and the fast-track pathway to public health coverage in Germany: Challenges and opportunities based on first results", *BMC Health Services Research*, Vol. 22/1, https://doi.org/10.1186/s12913-022-08500-6. [10]

Maassen, O. et al. (2021), "Future medical artificial intelligence application requirements and expectations of physicians in German university hospitals: Web-based survey", *Journal of Medical Internet Research*, Vol. 23/3, p. e26646, https://doi.org/10.2196/26646. [29]

McLennan, S. et al. (2022), "Practices and attitudes of Bavarian stakeholders regarding the secondary use of health data for research purposes during the COVID-19 pandemic: Qualitative interview study", *Journal of Medical Internet Research*, Vol. 24/6, p. e38754, https://doi.org/10.2196/38754. [16]

Nensa, F., A. Demircioglu and C. Rischpler (2019), "Artificial intelligence in nuclear medicine", *Journal of Nuclear Medicine*, Vol. 60/2, pp. 29S-37S, https://doi.org/10.2967/jnumed.118.220590. [9]

Norwegian Cognitive Center (2020), "Free AI course for everyone", https://norwegiancognitivecenter.com/blog/free-ai-course-for-everyone (accessed on 7 November 2023). [28]

OECD (2024), *AI in Health: Huge Potential, Huge Risks*, OECD Publishing, https://www.oecd.org/health/AI-in-health-huge-potential-huge-risks.pdf. [1]

OECD (2023), "Emerging privacy-enhancing technologies: Current regulatory and policy approaches", *OECD Digital Economy Papers*, No. 351, OECD Publishing, Paris, https://doi.org/10.1787/bf121be4-en. [31]

OECD (2022), *Health Spending (data)*, OECD, Paris, https://data.oecd.org/healthres/health-spending.htm. [2]

OECD (2016), *Recommendation of the Council on Health Data Governance*, OECD, Paris, https://legalinstruments.oecd.org/en/instruments/OECD-LEGAL-0433. [4]

OECD.AI (2019), *G20 AI Principles*, OECD, Paris, https://oecd.ai/en/wonk/documents/g20-ai-principles. [25]

OECD/EU (2022), *Health at a Glance: Europe 2022: State of Health in the EU Cycle*, OECD Publishing, Paris, https://doi.org/10.1787/507433b0-en. [3]

O'Leary, L. (2022), "How IBM's Watson went from the future of health care to sold off for parts", Slate, https://slate.com/technology/2022/01/ibm-watson-health-failure-artificial-intelligence.html (accessed on 7 November 2023). [18]

Oliveira Hashiguchi, T., L. Slawomirski and J. Oderkirk (2021), "Laying the foundations for artificial intelligence in health", *OECD Health Working Papers*, No. 128, OECD Publishing, Paris, https://doi.org/10.1787/3f62817d-en. [8]

Parikh, R., S. Teeple and A. Navathe (2019), “Addressing bias in artificial intelligence in health care”, *Journal of the American Medical Association*, Vol. 322/24, p. 2377, https://doi.org/10.1001/jama.2019.18058. [17]

PrivateAIM (2024), *Privacy-Preserving Analytics in Medicine*, https://privateaim.de/eng/index.html (accessed on 11 December 2023). [33]

Rieke, N. et al. (2020), “The future of digital health with federated learning”, *npj Digital Medicine*, Vol. 3/1, https://doi.org/10.1038/s41746-020-00323-1. [32]

Schmitt, T. (2023), “Implementing eectronic health records in Germany: Lessons (yet to be) learned”, *International Journal of Integrated Care*, https://doi.org/10.5334/ijic.6578. [15]

Schmitt, T., A. Haarmann and M. Shaikh (2022), “Strengthening health system governance in Germany: looking back, planning ahead”, *Health Economics, Policy and Law*, Vol. 18/1, pp. 14-31, https://doi.org/10.1017/s1744133122000123. [13]

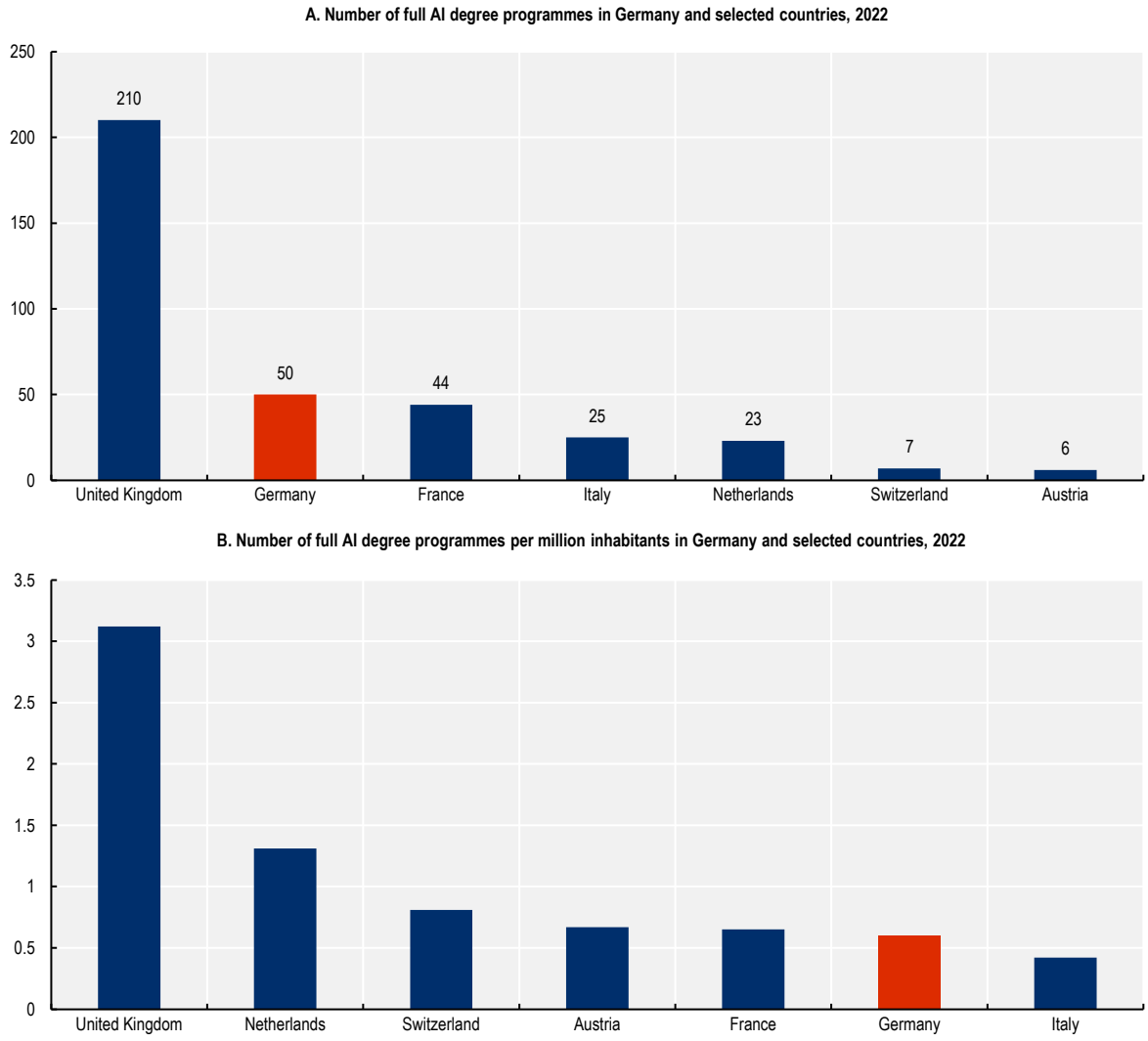
UMG (2024), *FAIrPaCT - Federated Artificial Intelligence Framework to Optimise the Treatment of Pancreatic Cancer*, University Medical Center Göttingen, https://bioinformatics.umg.eu/research/projects/fairpact/ (accessed on 11 December 2023). [34]

University of Helsinki (2023), *Elements of AI*, https://www.elementsofai.com/ (accessed on 31 October 2023). [26]

Wintergerst, R. (2023), *Digital Health*. [12]

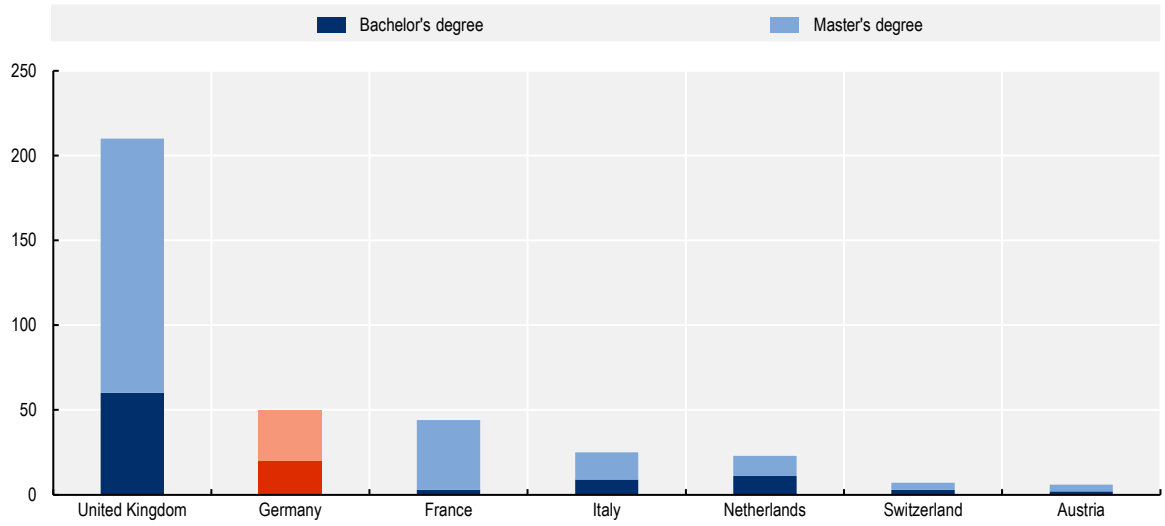
Annex A. Additional figures

Figure A A.1. AI degree programmes in Germany and selected countries



Notes: "Full AI degree programmes" are defined as degree programmes containing in their title "Artificial Intelligence", "AI", "Machine Learning", or "ML" in English or in their national language. The keywords were searched in the study programme databases of the respective countries (e.g. the *Hochschulkompass* database in Germany).
Source: Calculations based on HRK (2022[1]), *Hochschulkompass - Studium*, https://www.hochschulkompass.de/studium.html and national sources.

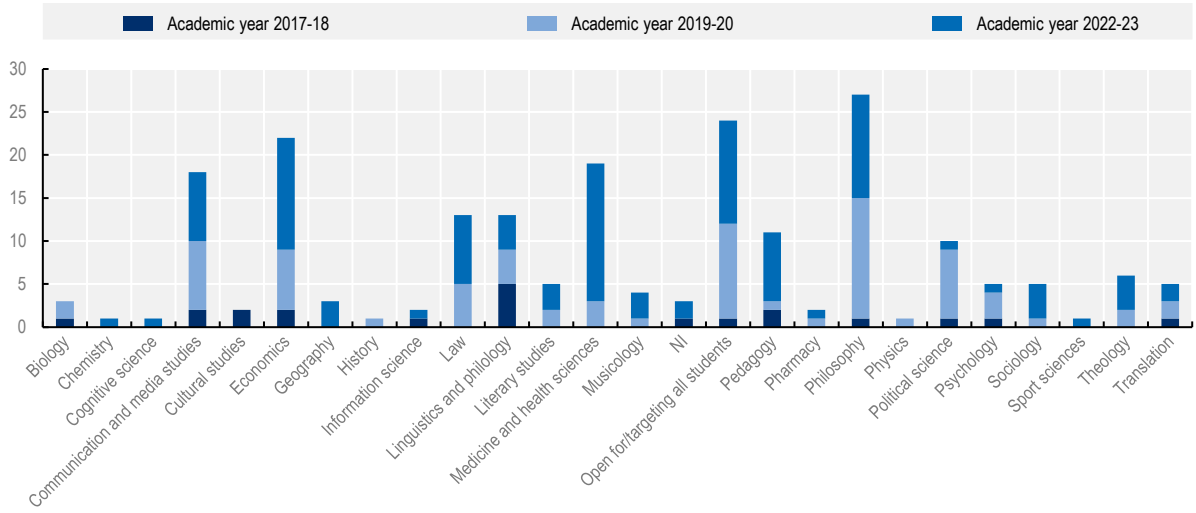
Figure A A.2. AI degree programmes in Germany and selected countries by educational level



Source: Calculations based on national sources.

Figure A A.3. AI courses are increasingly offered outside computer science departments at German universities

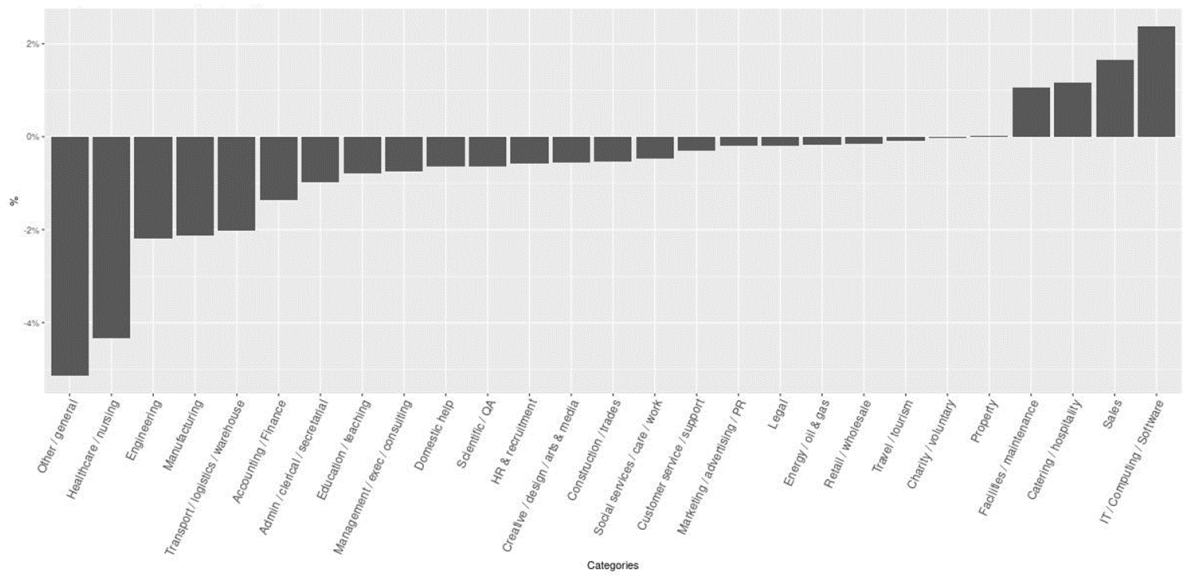
Number of AI courses, per department, 2017/18 to 2022/23 academic years



Notes: This graph shows the number of AI courses offered outside computer science departments at German universities for three different time periods. It includes data from the general course registries of the 50 largest German universities in terms of students registered on AI courses for 3 different time periods: academic years 2017/18, 2019/20, 2022/23. For academic years 2017/18 and 2019/20, no data were available for LMU München, Friedrich-Alexander Universität Erlangen-Nürnberg, Universität Leipzig, Justus-Liebig-Universität Gießen, Rheinland-Pfälzische Technische Universität Kaiserslautern-Landau, Universität Augsburg, Hochschule für angewandte Wissenschaften München, Technische Hochschule Mittelhessen – THM, and Hochschule Darmstadt. No data were available for academic year 2019/20 for Heinrich-Heine-Universität Düsseldorf. No data were available for winter term 2017/18 for Julius-Maximilians-Universität Würzburg, and Karlsruher Institut für Technologie. When combining the data for all 3 periods, the courses offered at these 13 universities were removed from each period.
Source: Analysis based on HRK (2023[2]), *Statistik - Hochschulen in Zahlen - 2022*, https://www.hrk.de/themen/hochschulsystem/statistik/.

Figure A A.4. Vacant online job postings in Germany, by occupation

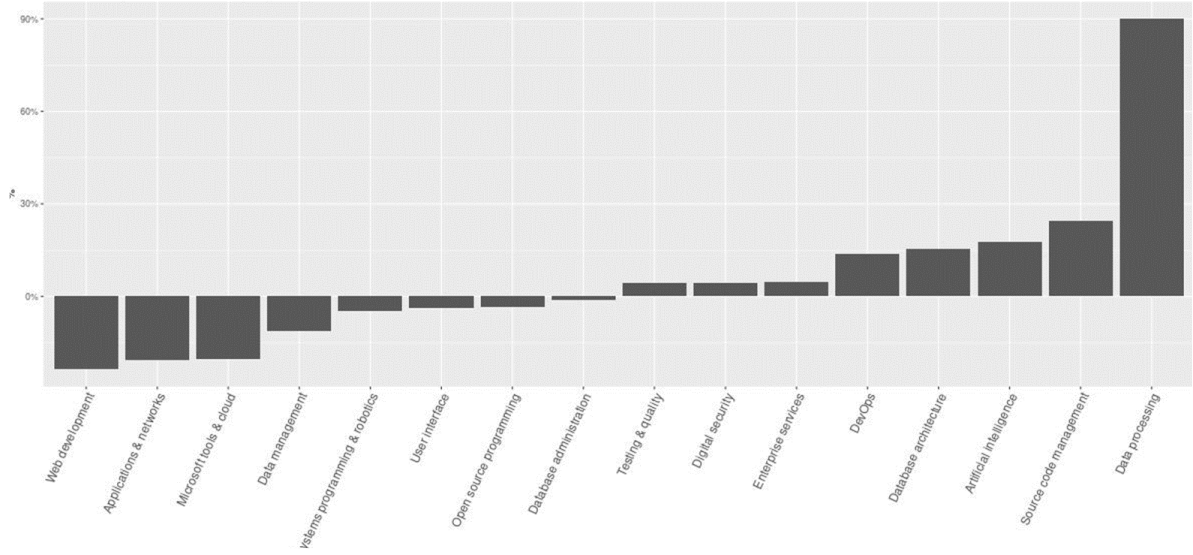
Percentage change in the distribution of online job postings in Germany after 3 months, by occupation



Source: Calculations using online job postings data from Adzuna.

Figure A A.5. Vacant online job postings in Germany, by type of AI skill

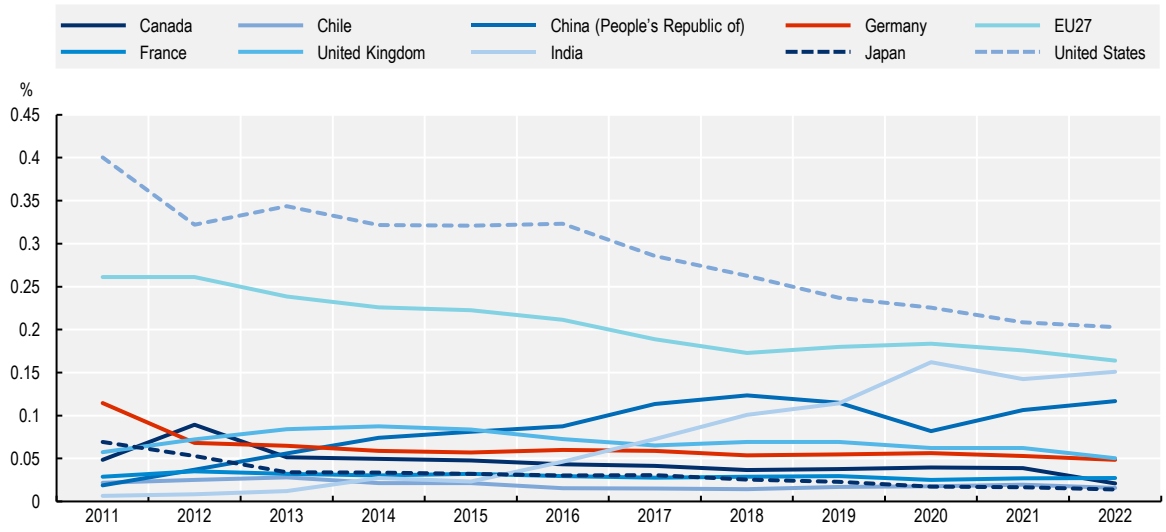
Relative percentage change in the distribution of online IT job postings in Germany after 3 months, by type of IT skill



Source: Calculations using online job postings data from Adzuna.

Figure A A.6. Contributions to high impact public AI projects by country

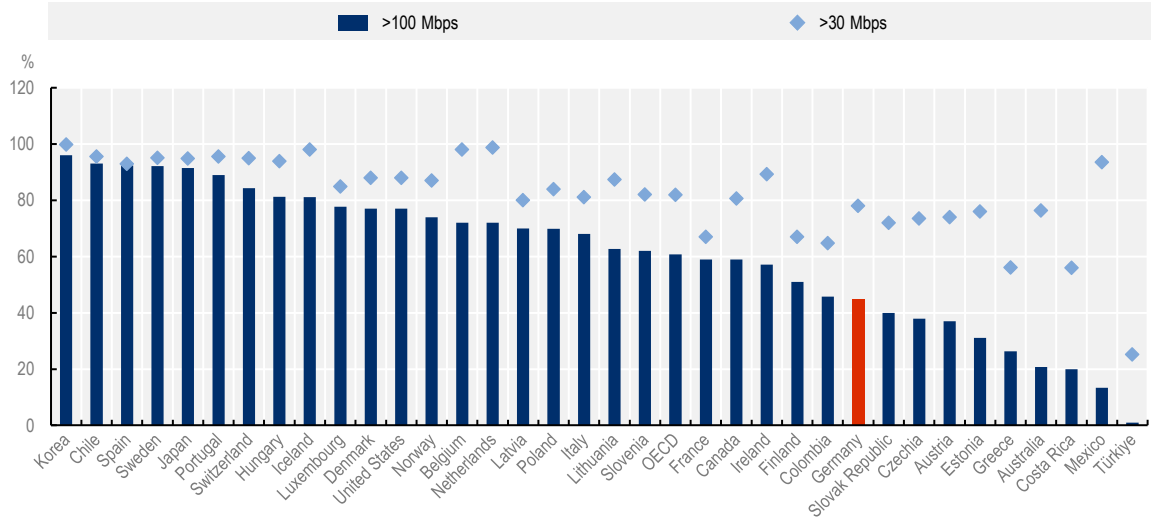
Contributions to high impact public AI projects by country



Notes: This chart shows the share of contributions (i.e. "commits") made to high-impact AI projects (i.e. AI-related GitHub "repositories") by country and over time. Project impact is determined by the number of managed copies (i.e. "forks") made of that project.
Source: OECD.AI (2023[3]), *Contributions to Public AI Projects by Country and Project Impact*, https://oecd.ai/en/data?selectedArea=ai-software-development&selectedVisualisation=contributions-to-ai-projects-by-country-and-project-impact (accessed on 3 October 2023).

Figure A A.7. Speed of fixed broadband subscriptions in OECD countries

Percentage of fixed broadband subscriptions with contracted speed faster than 30 Mbps and 100 Mbps, 2022



Source: OECD (2023[4]), *Broadband Portal*, https://www.oecd.org/digital/broadband/broadband-statistics/ (accessed on 3 October 2023).

Annex B. List of interviewees

Table A B.1. List of interviewees

Organisation	Interviewee(s)
Aachen University Centre for Artificial Intelligence (*Aachen Universität Center* für *Künstliche Intelligenz*, RWTH)	Prof. Dr Holger Hoos
Acatech German Academy of Science and Engineering *(Acatech Deutsche Akademie der Technikwissenschaften*)	Simon Boffen
Acatech German Academy of Science and Engineering (*Acatech Deutsche Akademie der Technikwissenschaften*)	Dr Crispin Niebel
ADA, General Counsel Medical Law	Dr Julian Braun
Aleph Alpha	Jonas Andrulis
AlgorithmWatch	Matthias Spielkamp, Anne Mollen
AppliedAI	Dr Till Klein, Dr Christian Burkhardt
Artificial Intelligence Entrepreneurship Centre (*Künstliche Intelligenz Entrepreneurship Zentrum*, K.I.E.Z.)	Dr Tina Klüwer
Association of Electrical Engineering and Information Technology (*Verband der Elektrotechnik Elektronik Informationstechnik e.V.*, VDE)	Dr Sebastian Hallensleben
Baiosphere Bavarian AI Agency (*Baiosphere Bayrische KI-Agentur*)	Tamara Tomasevic
Bavarian Digital Agency (*Byte Bayrische Agentur für Digitales*)	Dr Laura Crompton
Bonn University Sustainable AI Lab (*Universität Bonn Sustainable AI Lab*)	Prof. Dr Aimee van Wynsberghe
Borderstep Institut für Innovation und Nachhaltigkeit (Borderstep Institute for Innovation and Sustainability)	Simon Hinterholzer
Confederation of German Employers' Associations (*Bundesvereinigung der Deutschen Arbeitgeberverbände*, BDA)	Mareike Kuhl
Data 4 Life	Karina Oberheide
Data Saves Lives – Germany (*Data Saves Lives Deutschland*)	Birgit Bauer
Deloitte Germany	Olly Salzmann
Federal Commissioner for Data Protection and Freedom of Information (*Bundesbeauftragter für den Datenschutz und die Informationsfreiheit*, BfDI)	Rebecca Haehn, Andries Kueter, Christian Referat
Federal Institute for Vocational Education and Training (*Bundesinstitut für Berufsbildung*, BIBB)	Tobias Maier
Federal Ministry for Digital and Transport (*Bundesministerium für Digitales und Verkehr*, BMDV)	Theresa Kösters, Tim Rittmann
Federal Ministry for Economic Affairs and Climate Action (*Bundesministerium für Wirtschaft und Klimaschutz,* BMWK)	Manfred Meiss, Dr Konstantin Kolloge, Jens Brinckmann, Katrin Rosendahl
Federal Ministry for Family Affairs, Senior Citizens, Women and Youth (*Bundesministerium für Familie, Senioren, Frauen und Jugend,* BMFSFJ)	Friederike Schubart
Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection (*Bundesministerium für Umwelt, Naturschutz, nukleare Sicherheit und Verbraucherschutz,* BMUV)	Rafael Bendszus, Dr David van Treeck

Organisation	Interviewee(s)
Federal Ministry of Education and Research (*Bundesministerium für Bildung und Forschung,* BMBF)	Dr Christoph March, Dr Andrea Seifert
Federal Ministry of Economic Development and Cooperation (*Bundesministerium für wirtschaftliche Zusammenarbeit und Entwicklung,* BMZ)	Yilmaz Akkoyun
Federal Ministry of Food and Agriculture (*Bundesministerium für Ernährung und Landwirtschaft*, BMEL)	Dr Rainer Kaicher
Federal Ministry of Health (*Bundesministrium für Gesundheit*, BMG)	Thomas Mueller
Federal Ministry of Labour and Social Affairs (*Bundesministerium für Arbeit und Soziales*, BMAS)	Judith Peterka, Doreen Molnar, Helke Knütter, Linda Wichman
Federal Ministry of the Interior and Community (*Bundesministerium des Innern und für Heimat,* BMI)	Christian Erb, Dr Maximilan Wehage, John Weitzmann
Federal Public Employment Agency (*Arbeitsagentur*)	Benjamin Illik, Mark-Cliff Zofall, Monika Hackel
Fraunhofer Institute for Industrial Engineering (*Fraunhofer-Institut für Arbeitswirtschaft und Organisation*, IAO)	Dr Matthias Peissner
Fraunhofer Institute for Manufacturing Engineering and Automatisaion (*Fraunhofer-Institut für Produktionstechnik und Automatisierung*, IPA)	Prof. Dr Marco Huber
German Agency for International Cooperation (*Deutsche Gesellschaft für Internationale Zusammenarbeit*, GIZ)	Kathleen Ziemann
German AI Association (*Bundesverband Künstliche Intelligenz*)	Daniel Abbou
German Association of General Practitioners (*Hausärztinnen- und Hausärzteverband e. V*)	Dr Jana Husemann, Dr med. Kristina Spohrer
German Chamber of Commerce and Industry (*Deutsche Industrie- und Handelskammer*, DIHK)	Luise Ritter
German Commission for UNESCO (*Deutsche UNESCO-Kommission*)	Dr Maximilian Müngersdorff
German Datacentre Association (GDA)	Norbert Lemken
Germany Embassy to France (*Botschaft der Bundesrepublik Deutschland Paris*)	Julia Helen Jauer
German Environmental Agency (*Umweltbundesamt*)	Dr Robert Wagner
German Hospital Association (*Deutsche Krankenhausgesellschaft e.V*, DKG)	Henriette Neumeyer, Peter Geibel, Moritz Esdar
German Institute for Standardisation (*Deutsches Institut für Normung e.V.*, DIN)	Katharina Sehnert
German Research Centre for Artificial Intelligence (*Deutsches Forschungszentrum für Künstliche Intelligenz*, DFKI)	Prof. Dr Antonio Krüger, Helmut Ditzer
German National Agency for the Digitalization of the Healthcare System (*Gematik Gesellschaft für Telematikanwendungen der Gesundheitskarte*)	Dr med Markus Leyck Dieken, Samer Schaat, Beatrice Kluge, Lukas Wrosch
GND GEIGER | NITZ | DAUNDERER GMX / GND-LAW	Philipp Kircher
German Trade Union Confederation (*Deutscher Gewerkschaftsbund*, DGB)	Roman Kormann
German Start-up Association (*Bundesverband Deutsche Startups e.V.*)	Dr Alexander Hirschfeld
Harvard Business School	Ariel Dora Stern
Health Innovation Hub	Prof. Jörg Debatin,
Hertie School	Prof. Dr Joanna Bryson
Imperial College	Dr Axel Heitmueller
Kompass Frankfurt	Wolf Gunter Schlief
Leibniz-Centre for European Economic Research (*Leibniz-Zentrum für Europäische Wirtschaftsforschung*, ZEW)	Dr Christian Rammer

Organisation	Interviewee(s)
Leibniz Supercomputing Centre (*Leibniz Rechenzentrum*, LRZ)	Prof. Dr Dieter Kranzlmüller, Dr Nicolay Hammer
Max Planck Institute for Innovation and Competition (*Max-Planck-Institut für Innovation und Wettbewerb)*	Dietmar Harhoff
Microsoft Germany	Thomas Langkabel
Mittelstand Digital (SMEs Go Digital)	Christian Märkel
Munich School of Politics and Public Policy (*Hochschule für Politik München an der Technischen Universität München*)	Prof. Dr Stefan Wurster
NHR-Network National High Performance Computing (*NHR-Verbund Nationales Hochleistungsrechnen*)	Dr Barbara Diederich, Prof. Dr Christian Plessl, Prof. Dr Christof Schütte
North.io	Jann Wendt
Offensive for German SMEs (*Offensive Mittelstand*)	Bruno Schmalen
Office of the President of the Federal Republic of Germany (*Bundespräsidialamt*)	Christian Referat
Research Centre Jülich High Performance Computing (*Forschungszentrum Jülich Supercomputing Centre*, JSC)	Dr Stefan Kesselheim
Research Institute for Sustainability Helmholtz Centre Potsdam (*Forschungsinstitut für Nachhaltigkeit Helmholtz-Zentrum Potsdam*, RIFS)	Stefanie Kunkel
SAP	Dr Johannes Hoffart, Dr Sebastian Wieczorek
Siemens	Dr Michael May, Bernd Blumoser
Stuttgart University (*Universität Stuttgart*)	Prof. Dr Stefan Wagner
Technical University of Munich (*Technische Universität München*, TUM)	Prof Dr Alena Buyx
Tracebloc	Lukas Wuttke
Transatlantic AI eXchange	Thomas Neubert
Tübingen AI Centre	Matthias Bethge
TUM School of Computation, Information and Technology	Prof. Dr Alexander Pretschner
TUM School of Engineering and Design	Prof. Dr Marco Körne, Farzan Banihashemi
TUM School of Social Sciences and Technology	Prof. Dr Urs Gasser
TUM Think Tank	Dr Markus Siewert, Dr Philip Pfaller
TUM Venture Labs	Antoine Leboyer
UK Muenster (UKM Management Solutions GmbH)	Katja Kuemmel
University Erlangen-Nuremberg AI.FAU (*Universität Erlangen-Nürnberg KI.FAU)*	Bjoern Eskofier, Sven Laumer
University of Erlangen–Nuremberg (*Friedrich-Alexander-Universität*, FAU), Machine Learning and Data Analytics	Prof. Dr Björn Eskofier
Verd.i - trade union (*Vereinigte Dienstleistungsgewerkschaft*)	Nadine Mueller

References

HRK (2023), *Statistik - Hochschulen in Zahlen - 2022 [Statistics - Universities in Numbers - 2022]*, Hochschulrektorenkonferenz, https://www.hrk.de/themen/hochschulsystem/statistik/ (accessed on 11 October 2023). [2]

HRK (2022), *Hochschulkompass - Studium*, Hochschulrektorenkonferenz, https://www.hochschulkompass.de/studium.html (accessed on 11 December 2023). [1]

OECD (2023), *Broadband Portal*, OECD, Paris, https://www.oecd.org/digital/broadband/broadband-statistics/ (accessed on 3 October 2023). [4]

OECD.AI (2023), *Contributions to Public AI Projects by Country and Project Impact*, OECD, Paris, https://oecd.ai/en/data?selectedArea=ai-software-development&selectedVisualization=contributions-to-ai-projects-by-country-and-project-impact (accessed on 3 October 2023). [3]

OECD Artificial Intelligence Review of Germany

This report provides an international benchmarking of Germany's artificial intelligence (AI) ecosystem and discusses progress in implementing its national AI strategy. The report draws on quantitative and qualitative data and insights from the OECD.AI Policy Observatory and from the OECD Programme on AI in Work, Innovation, Productivity and Skills (AI-WIPS) – an OECD research programme financed by the German Federal Government – and results from a series of interviews with a wide range of stakeholders in Germany. The review discusses Germany's strengths, weaknesses, opportunities, and challenges in AI, and provides recommendations to steer AI policy in Germany in the coming years. The evidence is presented according to the core focus areas outlined in Germany's national AI strategy, which include: 1) minds; 2) research; 3) transfer and applications; 4) the world of work; 5) policy and regulatory frameworks; and 6) society. Furthermore, the report discusses AI infrastructure and it includes three sector spotlights on AI in the public sector, AI and environmental sustainability and AI and healthcare.

PAPERBACK ISBN 978-92-64-88673-5
PDF ISBN 978-92-64-62650-8

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