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CEPS

Mapping the use of artificial intelligence in priority sectors and the competitiveness of Ukraine

UNIDO REPORT. AUGUST 2024

ACKNOWLEDGEMENT

This mapping has been undertaken by the Centre for European Policy Studies (CEPS) under the overall guidance of **Mr Tomoyoshi Koume**, Industrial Development Officer, and **Mr Nikolaus Martys,** Project Administrator, within the Division of Digital Transformation and AI Strategies, United Nations Industrial Development Organization (UNIDO) for the project Industrial capacity-building, policy advice and diagnostics for the green recovery of Ukraine.

The publication represents a collaborative effort, made possible by various inputs from CEPS colleagues. In particular, we would like to thank **Mr Andrea Renda, Mr Pierre-Alexandre Balland, Mr Robert Praas,** and **Ms Olesya Grabova** for their substantive inputs and rounds of technical reviews to refine and finalise the content of the publication.

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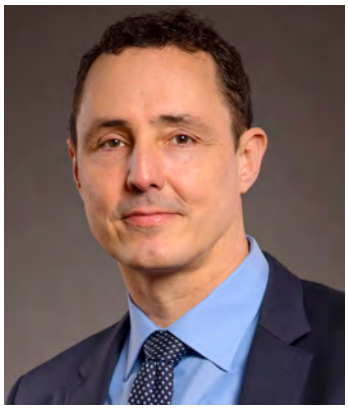
FOREWORD - UNIDO



As technological advancements continue to shape our world, integrating Artificial Intelligence (AI) into various sectors is crucial for sustainable development and economic growth. Ukraine is at a pivotal moment, ready to leverage AI to meet immediate reconstruction needs and integrate it into a long-term innovation strategy aligned with broader EU priorities.

The United Nations Industrial Development Organization (UNIDO) has long been committed to fostering inclusive and sustainable industrial development worldwide. With its expertise in emerging technologies, including AI, UNIDO has played a key role in assisting nations like Ukraine in navigating industrial transformation.

This report is an important step in realizing the potential of AI in Ukraine's key sectors. It offers comprehensive insights into the current landscape of AI adoption and identifies opportunities for strategic interventions. From manufacturing and agriculture to healthcare and education, AI has the potential to revolutionize processes, enhance productivity, and foster innovation across various industries. With this report, policymakers, industry leaders, and investors are enabled to pursue targeted AI-driven initiatives that enhance Ukraine's competitiveness, foster sustainable development, and strengthen economic resilience.

The regulatory environment in Ukraine is undergoing dramatic change related to the desired alignment to the EU Acquis. Against this backdrop, the report provides the basis for support of industrial digital development from policy to firm level; guidance on AI and related digital policies and applications in industry, digital competencies skills development and the for integration of digital technologies in industry. UNIDO is ready to support Ukraine on its related path forward.

I commend all those involved in preparing this report and thank the Government of Ukraine for their dedication to embracing AI as a driver of industrial growth and sustainable development. UNIDO remains a key partner for Ukraine, supporting both immediate reconstruction needs and the transition to an AI-led economy.

Sincerely,

Mr. Stephan Sicars

Senior Coordinator for Ukraine, UNIDO

FOREWORD - CEPS

It was an honor and a pleasure for us at CEPS to work with UNIDO on this report. It was also a learning experience, with elements of surprise, serendipity, and intellectual satisfaction.

When we started working on this report, we knew that Ukraine was a trailblazer in digital government solutions. The tragedy experienced by the country after Russia's brutal invasion in 2022 gradually unveiled the extraordinary resilience and preparedness of Ukraine's highly digitised society. Dozens of services were moved entirely online, as some Ukrainians fled the country, some were displaced, others went to the front lines. Life moved on, thanks to a well-shaped, diffuse and user-friendly digital public infrastructure that many countries around the world are now trying to emulate.

What we did not expect was to look at the data and find that Ukraine's Artificial Intelligence (AI) ecosystem, based on data on scientific publications, patents and venture capital investment in startups, ranks quite high in the region, punching well above its weight. And that Kyiv is a major AI hub in Europe, comparable and even outperforming vibrant cities such as Manchester and Brussels. We also found more encouraging evidence, that AI is and will be increasingly permeating many of the sectors that the Ukrainian government has selected as being priorities for its future economic development.

What these results suggest is that Ukraine can have a bright economic and industrial future. And that the European Union should see its future accession to the EU as a significant opportunity, not only from the geo-strategic and security angle, but also from an economic and technological sovereignty one. Cleverly integrating Ukraine's specialization in the European economic area would be an essential step towards reviving European competitiveness, creating prosperity in Ukraine and in the EU at once.

We hope that our findings will spur fresh thinking among policymakers and relevant stakeholders. And that this type of data-driven research can inspire policies and actions that look at Ukraine's long-term prosperity, beyond short term security stances.

Sincerely,

Mr. Andrea Renda

Director of Research, CEPS

FOREWORD - UKRAINE

On behalf of the Ministry for Strategic Industries of Ukraine (MSPU), we would like to sincerely thank UNIDO for the outstanding support provided to Ukraine. The Ministry for Strategic Industries of Ukraine are pleased to learn about the upcoming publication of the report "Mapping the use of AI in priority sectors & the competitiveness of Ukraine" in collaboration with the Center for European Policy Studies (CEPS). This initiative is of immense importance, especially in light of UNIDO's ongoing efforts to promote digital transformation and the adoption of artificial intelligence and robotics as part of Ukraine's industrial capacity building, policy advice, and diagnostics for the green recovery project.

AI is a key driver of transformation, disruption, and competitive advantage in today's rapidly changing economy and society. Globally, countries are increasingly integrating AI into various sectors to gain a competitive edge. Industries such as machine construction, healthcare, and agriculture are witnessing a surge in AI applications aimed at improving efficiency, reducing costs, and fostering innovation. These trends highlight the potential for technology-driven growth in economies like Ukraine's.

Ukraine is among the world's leading AI innovators. With over 200 tech companies active in the field of AI, the country's vibrant tech sector is rapidly developing AI products and applications. Ukraine is a leader in Eastern Europe in implementing AI in the corporate sector, with significant investment growth over the past decade continuing despite ongoing challenges.

Mapping the use of AI in Ukraine's priority economic sectors is crucial for leveraging new opportunities for economic prosperity, societal benefit, and sustainable development. Understanding where and how AI technologies are applied helps identify key investment areas, market gaps, and fosters targeted development efforts. This strategic approach is essential for propelling priority sectors forward and enhancing overall competitiveness and technological sovereignty on the global stage.

On behalf of the Ministry for Strategy Industries of Ukraine, I express our sincere thanks to the UNIDO and CEPS team for their outstanding research. We look forward to the next steps that will help Ukraine become more AI-competitive and economically resilient.

Yours Sincerely,

Dmytro Hryshchak

Deputy Minister for Digital Development, Digital Transformations and Digitalization

Ministry For Strategic Industries Of Ukraine

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Introduction

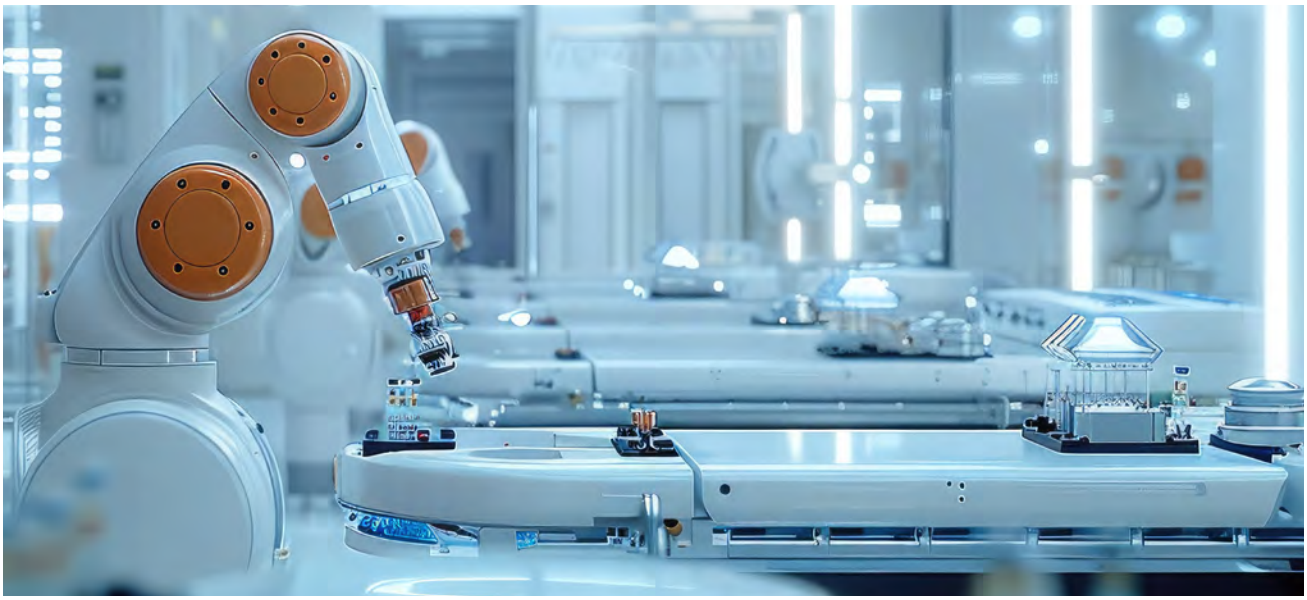
In March 2024, UNIDO launched the green industrial recovery programme for Ukraine 2024-2028 to support the response of the Government of Ukraine to the socioeconomic impact of the war in Ukraine, which started on 24 February 2022.

In March 2024, UNIDO launched the green industrial recovery programme for Ukraine 2024-2028 to support the response of the Government of Ukraine to the socioeconomic impact of the war in Ukraine, which started on 24 February 2022. As part of the preparatory phase undertaken in 2023-2024, and supported by the German Federal Ministry for Economic Cooperation and Development, UNIDO undertook a joint study with the Centre for European Policy Studies (CEPS) on the mapping of the use of artificial intelligence for priority sectors and competitiveness of Ukraine to support the implementation of the State Program for the use of artificial intelligence technologies in priority sectors of the economy for the period until 2026 by the Ministry of Strategic Industries of Ukraine.

This report contains a data-driven mapping of Ukraine's specialisation in artificial intelligence (hereinafter, AI), with a specific focus on the priority sectors chosen by the Ukrainian government in view of the reconstruction. The report uses existing data on patents, venture capital investment for start-up funding and scientific publications to build a new, granular picture of global trends in AI, as well as Ukraine's competitiveness and specialisation relative to other European countries. The results, as will be discussed at the end of the report, show that Ukraine possesses a remarkable potential to contribute to Europe's competitiveness, and should invest in framework conditions to facilitate the full emergence of its AI ecosystem.

More specifically, mapping the use of AI in Ukraine's priority sectors is crucial to leverage new opportunities for economic prosperity, societal benefit, and sustainable development. Understanding where and how AI technologies are being applied helps in the identification of key areas for investment, in spotting gaps in the market or research, and to foster targeted development efforts. This strategic approach is not only crucial to propel priority sectors forward but also for the overall competitiveness and technological sovereignty of Ukraine and Europe on the global stage. Moreover, it can also inform the earmarking of funds for the reconstruction of the country, leading to a more targeted and coordinated approach to future industrial development, and thus boosting Ukraine's competitiveness and its full and swift integration with the European economy.

That said, mapping the use of AI in priority sectors and the competitiveness of Ukraine in a systematic way is far from being an easy task. Domain expert knowledge is, by definition, narrow, and spread across sectors and geographies. In addition, the rapid pace of advancement in AI makes it hard to maintain a current and thorough understanding of the latest developments. In this report, we adopt a data science approach to leverage patent documents (OECD RegPat database), scientific publications (OpenAlex), and venture capital funding rounds in startups (Crunchbase). The core of our approach is the use of machine learning tools to flag innovative approaches that connect AI technologies to a



specific priority sector (for instance, education) through a specific use case (for instance, personalised learning). The report highlights four main findings.

First, it clearly emerges from the data that AI is revolutionising at the global level the sectors that Ukraine has identified as a priority. The report finds different AI penetration rates and identifies key use cases, enablers and blockers for each priority sector. The main takeaway is that AI will create a new geography of winners and losers in those sectors, and to stay relevant countries and companies will have to significantly enable AI's uptake.

The second finding is that Ukraine has strong capabilities in AI and punches well above its weight. This justifies further national investments to nurture AI progress but it also means that Europe can strengthen its competitiveness in AI by supporting a Ukrainian AI hub and better integrating it into a pan-European innovation system.

Third, the report finds that there are major differences between priority sectors in terms of AI Ukraine's level of competitiveness. That means that from a pure long-run economic and social perspective Ukraine needs to prioritise its investment efforts into some of the priority sectors (or even others not analysed in this report) instead of spreading investment equally thin. This finding must of course also be considered in light of considerations other than pure economic competitiveness: for example, Ukraine may need to invest in specific sectors due to non-economic reasons, such as security, technological sovereignty or strategic autonomy, all aspects that can be particularly important for Ukraine, both as a stand-alone country and in view of its future accession to the European Union.

Fourth, recovery projects need to be part of a long-run innovation strategy. This is anything but easy, and this thinking should obviously not compromise a short-run necessity to rebuild the basic infrastructure of Ukraine. But these projects are also an opportunity not just to bounce back but also to bounce forward. Recovery projects that align pressing reconstruction needs, a clear industrial vision and EU priorities are an opportunity to propel Ukraine forward.

Below, we present and discuss in more detail the data backing these findings.

2

AI is revolutionising Ukraine's priority sectors

Ukraine has identified 16 priority sectors: aerospace, agricultural, automotive, aviation, chemical engineering, coal, defence, education, energy, medicine, metallurgy, mining, nuclear, railway, robotics, and shipbuilding.

Ukraine has identified 16 priority sectors: aerospace, agricultural, automotive, aviation, chemical engineering, coal, defence, education, energy, medicine, metallurgy, mining, nuclear, railway, robotics, and shipbuilding. To analyse the use of AI in these priority sectors, we combine three main data sources: patent documents (OECD RegPat), start-up funding (Crunchbase), and scientific publications (OpenAlex). Innovation performance in general and AI use are difficult to perfectly measure but combining these three datasets provides a state-of-the-art estimation.

The data analysis clearly shows that all of Ukraine's priority sectors have the potential to be transformed by AI. This means that in the coming years, significant AI investments are needed to maintain (or gain) a competitive advantage in these sectors. However, the use of AI varies greatly across priority sectors. Robotics, defence, education, aerospace and aviation seem to be the sectors with the most AI activity, while coal, nuclear, mining, metallurgy, and chemical engineering are the ones with the lowest penetration rates.

2.1 PATENT DOCUMENTS SHOW THAT MOST PRIORITY SECTORS NOW LEVERAGE AI TECHNOLOGIES

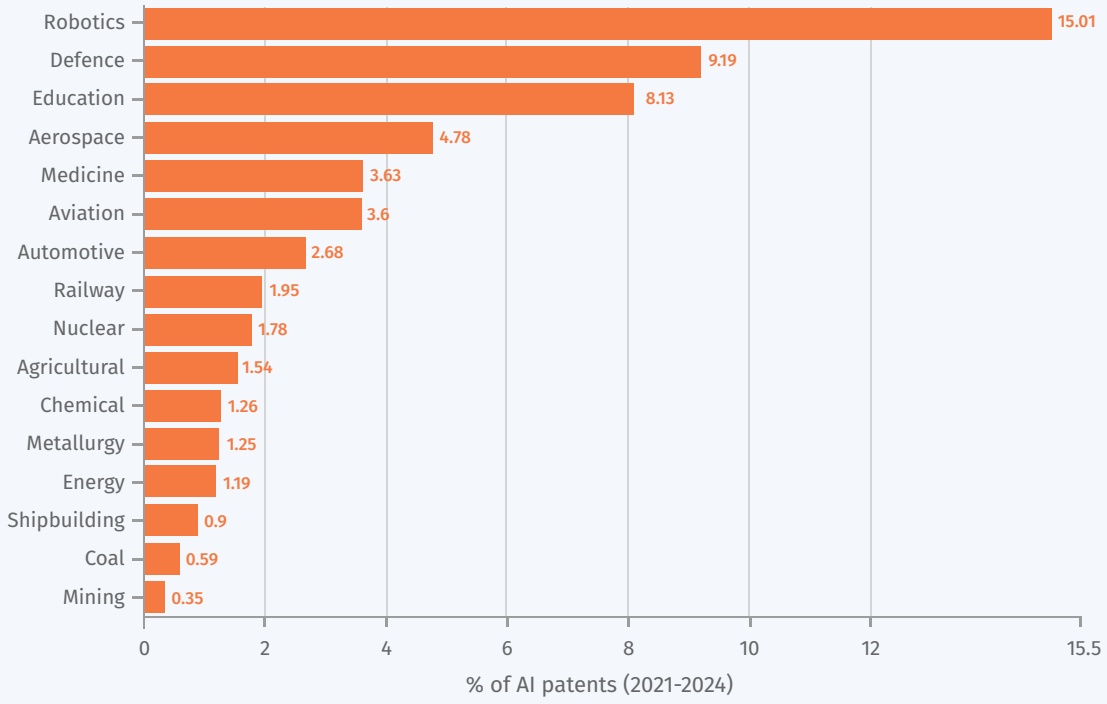
Patent documents offer a systematic and unique wealth of information by describing new inventions in detail. A patent gives the right to exclude others from the commercial exploitation of a specific invention. In exchange, the patent document must disclose and describe the invention so it allows further inventions to build upon a large codified knowledge stack. Most technological breakthroughs can be identified in patent documents and international treaties ensure standard quality of data and comparison. In this report, analyses are based on the OECD RegPat database (applications to the European Patent Office).

We classify all patent applications to the EPO from 2001 to 2024 into each of the 16 priority sectors, plus AI (so 17 categories in total). By nature, a patent can belong to one (or more) priority sectors and AI. This is precisely the information that will be used to assess the penetration rate of AI into priority sectors. A new invention can simultaneously belong to a given priority sector (education technology) and AI. More specifically, we assign the 16 sectors + AI into one or more of the 250 000+ sub-classes of the Cooperative Patent Classification (CPC) system based on an automated keyword search of the patent texts and CPC classification, graph-based machine learning, and human annotation. The crosswalk is then used to classify individual patents into priority sectors and AI.

Figure 1 shows the use of AI in the 16 priority sectors for any patent documents that have been published by the EPO since 2021 (included). We chose this timeframe because there is a right truncation in the data (because of a lag in the patent reviewing process) and the number of observations drops after 2021. Focusing on the most recent year might increase the level of accuracy – in particular for small priority sectors (or the ones with low AI rates). Switching timeframes, however, leads to qualitatively similar results (as shown in section 2).

Our results indicate that most priority sectors now leverage AI technologies. We observe that 15.01 % of the patents in robotics also belong to an AI category. Defence and education also show a very strong AI rate with respectively 9.19 % and 8.13 %. They are followed by aerospace (4.78 %), then medicine (3.63 %), and aviation (3.6 %). At the bottom of the ranking we find mining (0.35 %), coal (0.59 %), shipbuilding (0.9 %), energy (1.19 %), metallurgy (1.25 %) and chemical (1.26 %).

FIGURE 1: AI penetration measured from patents



2.2 SCIENTIFIC PUBLICATIONS SHOW THAT AI IS THE KNOWLEDGE FRONTIER OF MOST PRIORITY SECTORS

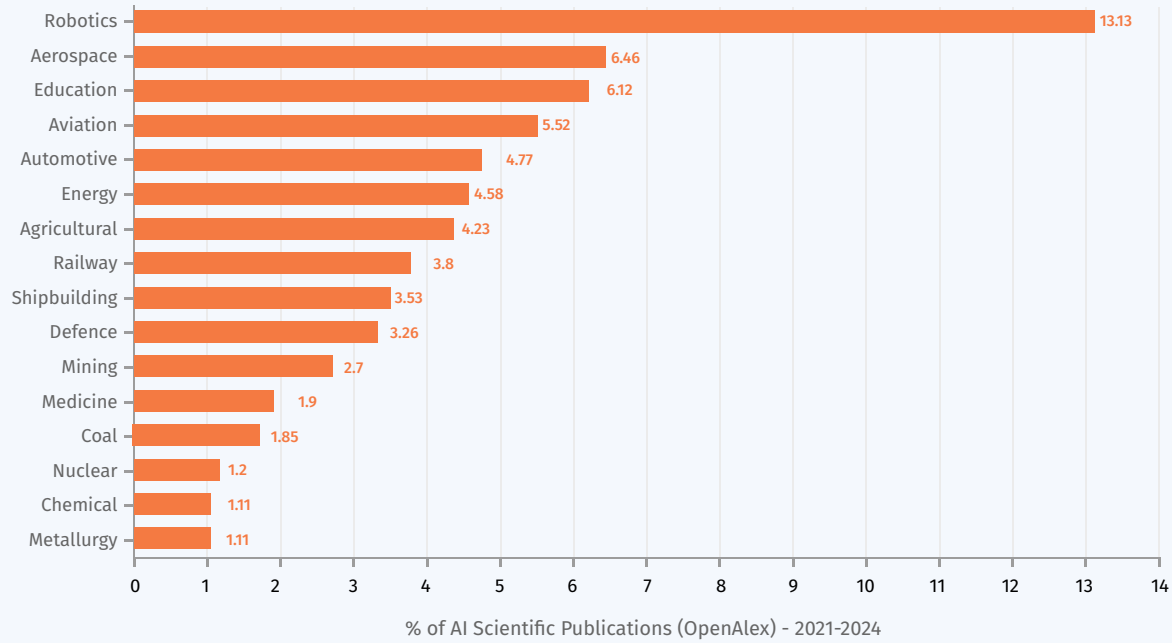
Having analysed patent documents in the previous sub-section, we now turn to the analysis of scientific publications. Combining information on patent documents with scientific publications provides additional insights as it combines information on the near commercial applications of AI and more foundational research developments. This can reveal additional insights on technological advancements and trends, but also more long-run AI uses and applications. In this report, analyses are based on the OpenAlex database (www.openalex.org). OpenAlex is a successor to the Microsoft Academic Graph (MAG), which was a large, structured dataset of scholarly works, citations, and other academic data that was discontinued in 2021. OpenAlex uses a similar model and builds upon MAG to aggregate and make accessible data on academic publications, authors, and institutions. It is open-access and now the most comprehensive dataset on academic publications, with data on about 250 million scientific publications.

We classify all scientific publications in OpenAlex from 2001 to 2024 into each of the 16 priority sectors, plus AI (so 17 categories in total). As with patents, a scientific publication can belong to one (or more) priority sectors and AI. More specifically we assign the 16 sectors + AI into one or more of the 65 000+ OpenAlex concepts based on an automated keyword search of concept hierarchical systems, graph-based machine learning, and human annotation. The crosswalk is then used to classify individual scientific publications into priority sectors and AI.

Figure 2 shows the use of AI in the 16 priority sectors for any scientific publication that has been published since 2021 (included). We chose this timeframe because there is also a right truncation in the data (not as strong as with patents) and to be consistent with the patent analysis. Switching timeframes, however, leads to qualitatively similar results (as shown in section 2).

Our results show that AI is often used in scientific publications of priority sectors and are broadly consistent with the patent analysis. We observe that 13.13 % of the scientific publications in robotics also belong to an AI category. Aerospace and education also show a very strong AI rate of 6.46 % and 6.12 % respectively. They are followed by aviation (5.52 %), then automotive (4.77 %), energy (4.58 %) and agricultural (4.23 %). At the bottom of the ranking, we find metallurgy (1.11 %), chemical (1.11 %), nuclear (1.2 %), and coal (1.85 %).

FIGURE 2: AI penetration rate measured from scientific publications



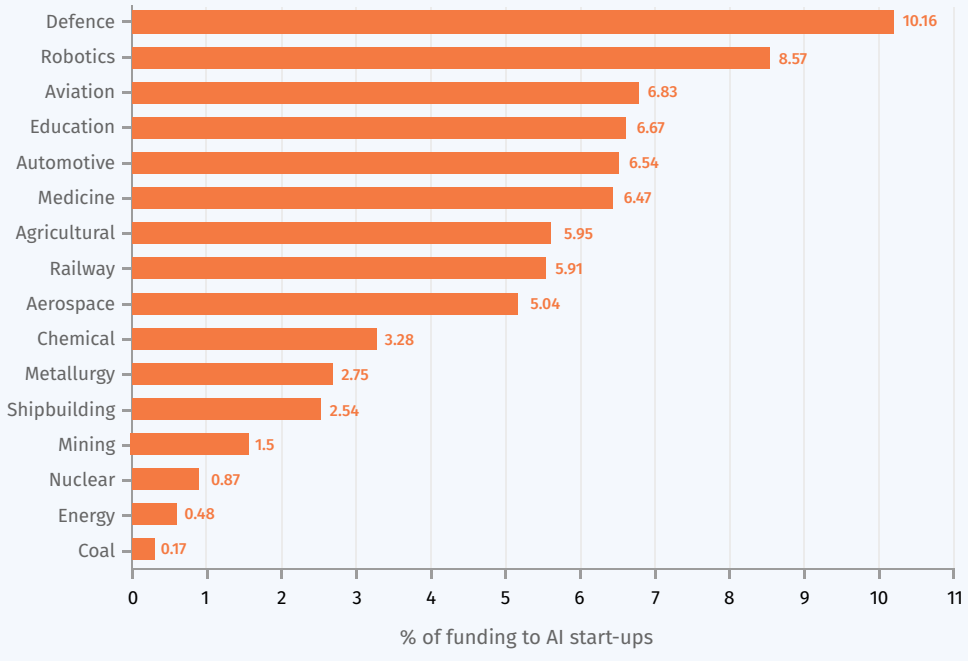
2.3 VENTURE CAPITAL FUNDING ROUNDS SHOW MASSIVE INVESTMENT IN AI WITHIN PRIORITY SECTORS

After having analysed patent documents and scientific publications in the previous sub-sections, we now turn to the analysis of Venture Capital (VC) funding rounds. VC investments are particularly useful because start-up activity can indicate product impact (that might have few or no patents or related scientific publications), newest and sharpest technological trends, emerging sectors, and the overall microstructure of the innovation ecosystem (while patents and publications might reveal activity from larger players and incumbents). In this report, we use Crunchbase Pro, which provides detailed information on start-up descriptions and activity, funding rounds, and investors.

Here we only focus on start-ups that have not yet exited. Tesla, for instance, was founded in 2003 and received hundreds of millions in funding until its initial public offering (IPO) in 2010. We exclude all companies that have exited to focus on emerging start-ups and avoid a crowding-out effect. We classify companies listed in Crunchbase into each of the 16 priority sectors, plus AI (so 17 categories in total). As with patents, and scientific publications, a company can belong to one (or more) priority sectors and AI. More specifically we assign the 16 sectors + AI into one or more of the Crunchbase industry tags and company description texts based on an automated keyword search of tags' hierarchical systems, graph-based machine learning, and human annotation. The crosswalk is then used to classify each company into priority sectors and AI. We only focus on the top 1000 companies in each sector (based on the cumulative amount of funding) to restrict the analysis to the most promising ones.

Figure 3 shows cumulative investments until March 2024 into start-ups that have not yet exited. Results indicate massive investments in AI across most priority sectors and the findings are consistent with the patent and scientific publication analysis. We observe that 10.16 % of the dollars invested in defence also belong to an AI company. Robotics also shows a very strong AI rate of 8.57 %. Defence and robotics are followed by aviation (6.83 %), education (6.67 %), automotive (6.54 %), and medicine (6.47 %). At the bottom of the ranking we find coal (0.17 %), energy (0.48 %), nuclear (0.87 %) and mining (1.5 %).

FIGURE 3: AI penetration rate measured from VC funding rounds

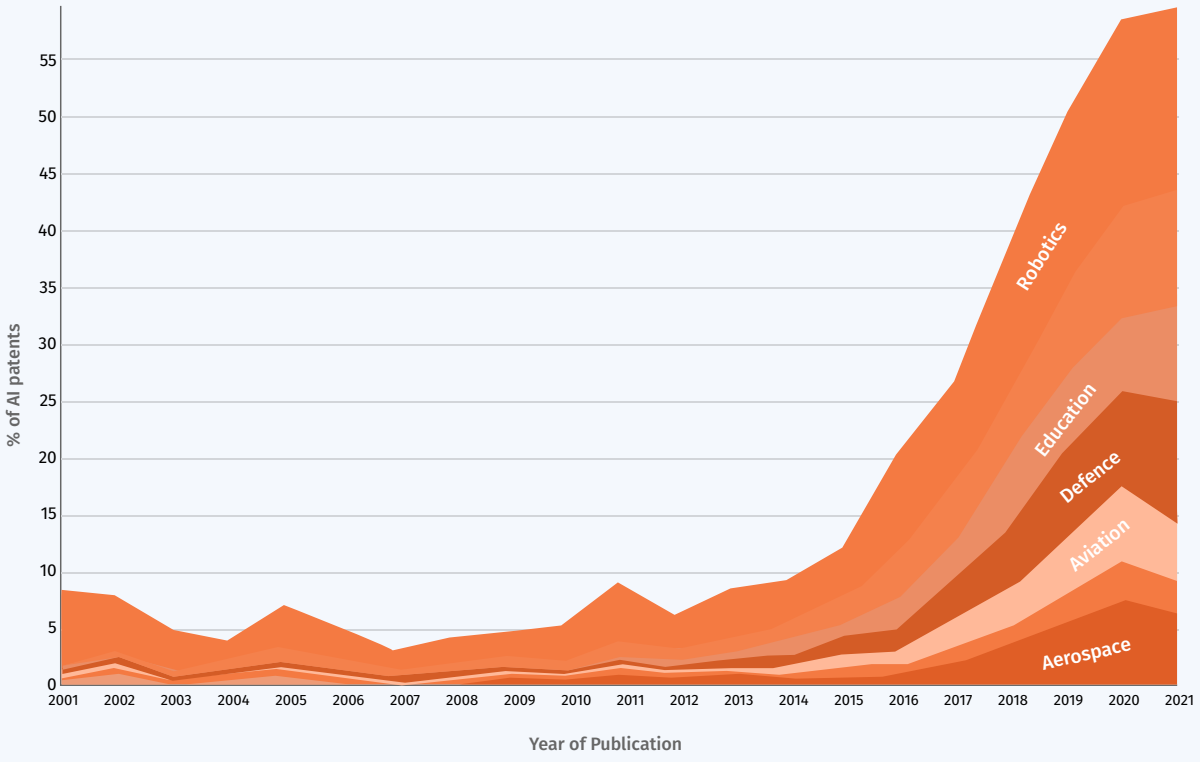


2.4 AI APPLICATIONS ARE ACCELERATING ACROSS PRIORITY SECTORS

Taking a dynamic perspective, it is clear that AI use in priority sectors is increasing at a very fast pace. Based on patent documents, Figure 4 shows a relatively stable penetration rate from 2001 to 2013, and then a very sharp acceleration from 2013 until now. On average across priority sectors, the use of AI in patented technologies has been multiplied by more than five.

For instance, in the defence industry between 2013 and 2021, the penetration rate of AI in patents grew from around 1 % to over 9 %, in education from less than 1 % to more than 8 %, and in robotics from 4 % to over 15 %. Other industries with fast-growing AI penetration rates are aerospace and aviation.

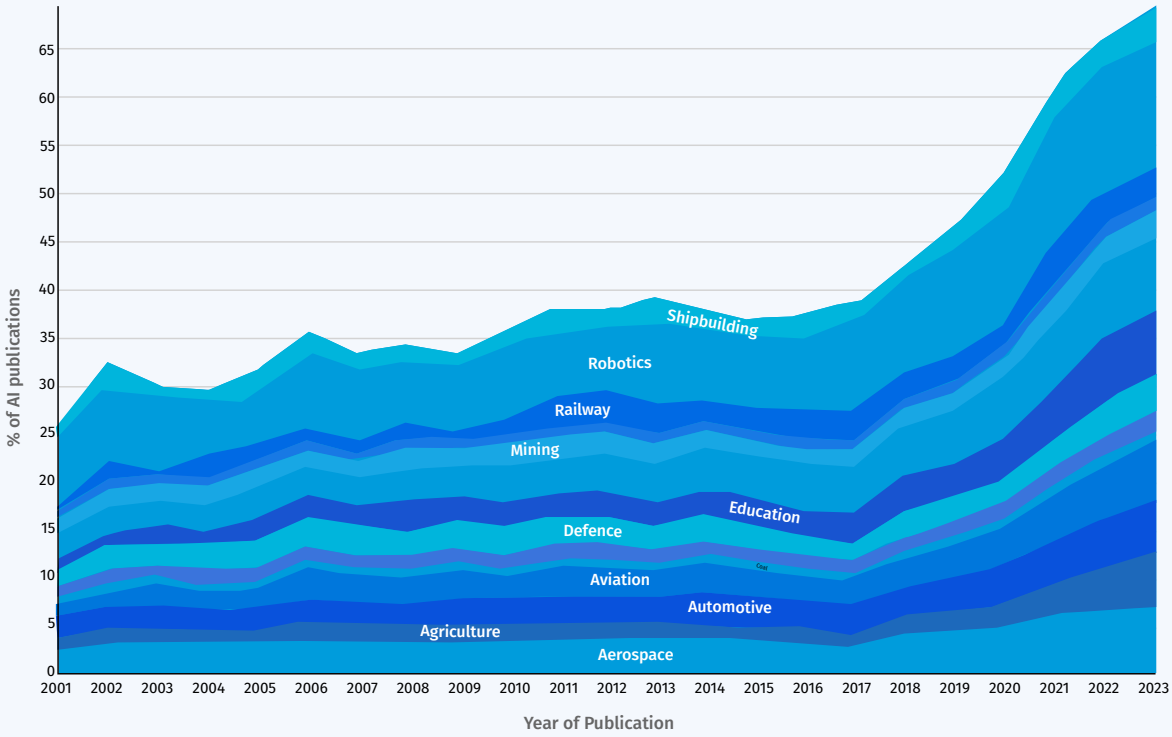
FIGURE 4: AI penetration rates in patents: 2001-2021



Turning to Figure 5, the analysis of scientific publications shows a higher penetration rate early on, but with a steady growth until 2018 and then a multiplication of the AI penetration rate by two.

Since 2018, the AI penetration rate in publications about education has nearly doubled to over 6 %. AI's share in robotics publications rose during the same timeframe from 9 % to 13 %. The rate of AI in agricultural publications only started increasing after 2018, however, when it almost quadrupled from about 1 % to 4 %. Similar to the findings for patents, aerospace and aviation complement the top five growing industries.

FIGURE 5: AI penetration rates in scientific publications: 2001-2023



2.5 THE USE OF AI RATE ACROSS PRIORITY SECTORS

As discussed in the three sub-sections above, there is strong heterogeneity in the AI penetration rate across priority sectors. This heterogeneity reflects the varying degrees of AI integration across sectors and is influenced by data standardisation, technological progress, investments, regulatory environments, and digital literacy among sectors. The main trends we see are listed below.

- **Robots are proving to be tremendously useful across a wide variety of sectors and tasks**

  They assemble automobiles, ships and planes. They eliminate weeds in agriculture, are deployed in mines, at all terrains of defence (air, land, water) and are used for caregiving in healthcare. Generative AI is expected to increase their performance even more.

- **AI is widely used for advanced analytics**

  Different data sources can be combined to optimise capacity planning in railways, match demand and supply in agriculture, operate infrastructure in defence and track learning objectives in education. Moreover, AI helps to control coal mines, nuclear power plants and energy grids.

- **AI is widely used to enhance safety**

  It is used in predictive maintenance, risk classification, autonomous driving, safer rail crossings and cancer detection.

- **AI is playing a role in the twin green and digital transition**

  Energy is an overarching priority sector and the most apparent AI use cases are connected to renewable energy sources: balancing the grid, analysing and optimising battery health, as well as applications in hydrogen and carbon capture.

- **The hype is mostly about generative AI**

  But priority sectors still rely heavily on more traditional expert systems or more simple machine learning tools. This holds for robotics and analytics, amongst other things.

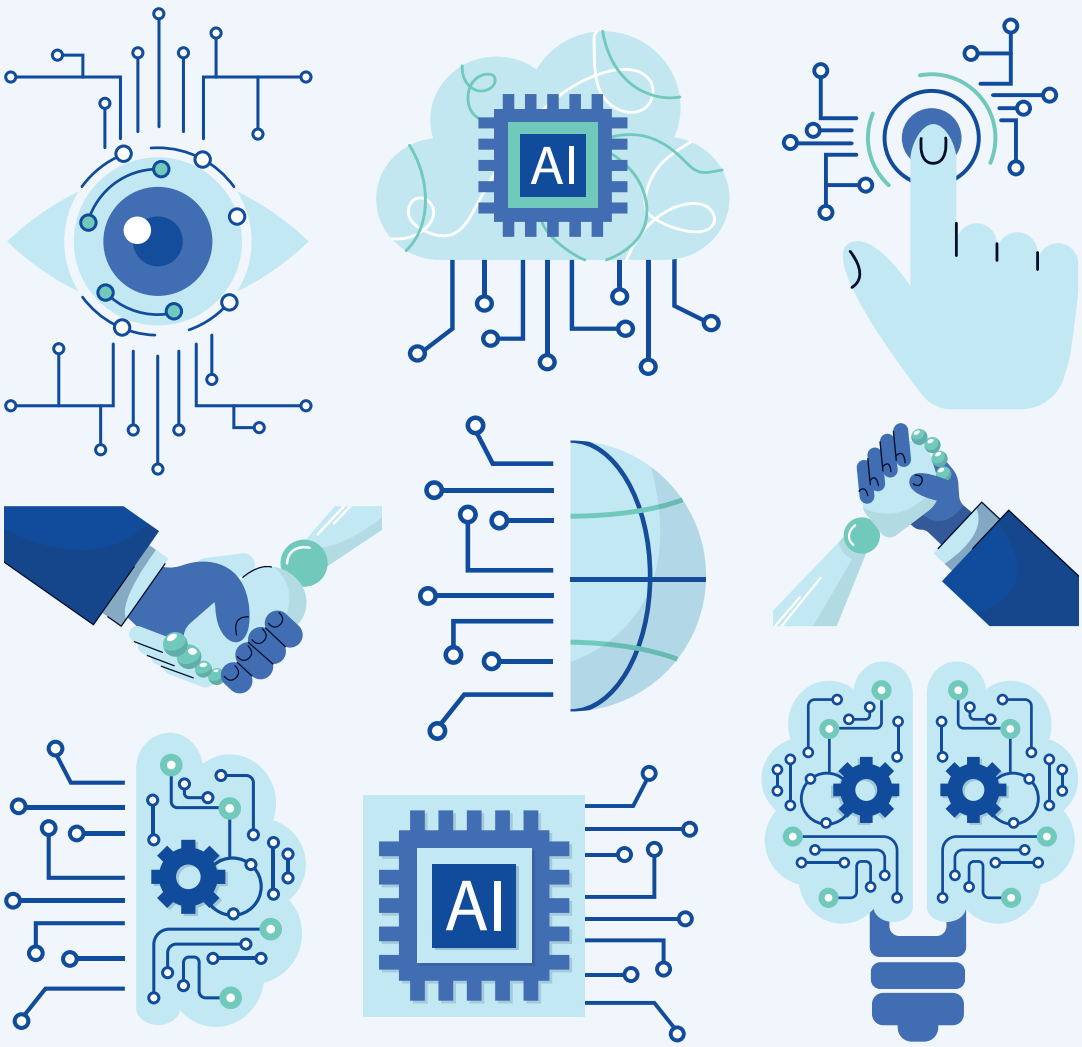
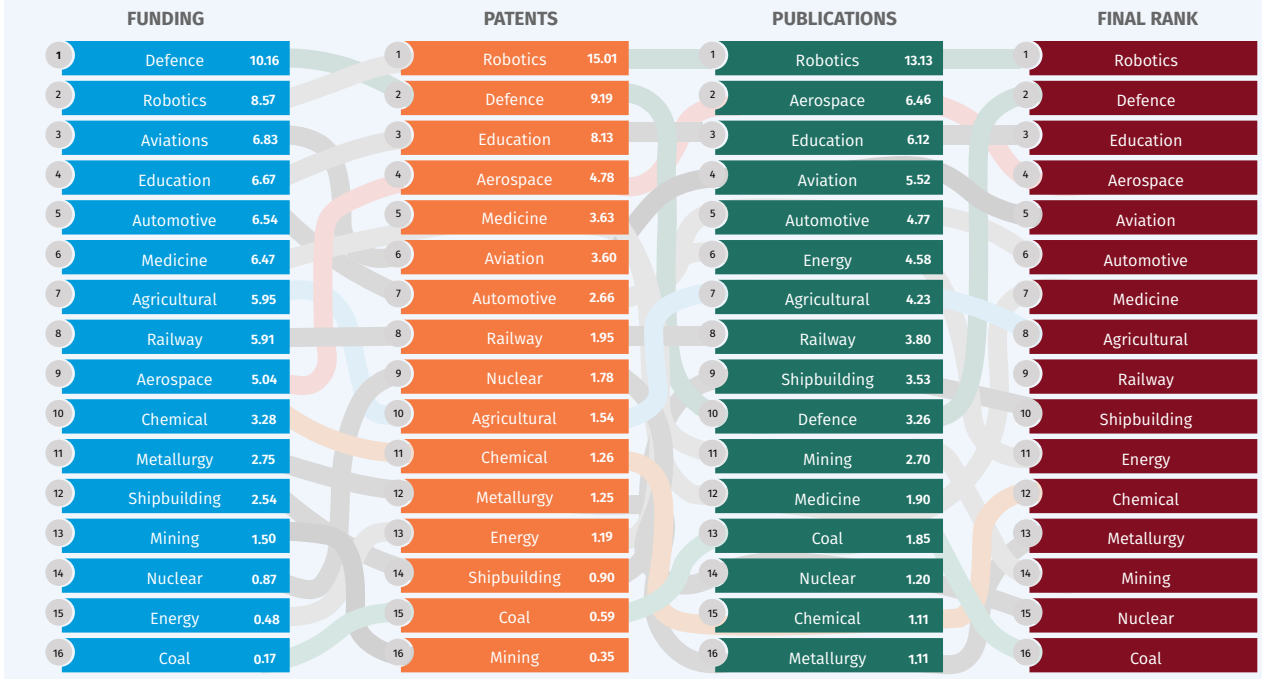


Figure 6 brings together the AI rate rankings of the different priority sectors for patents, publications and VC funding. Column 4 shows the average ranking. So, across the three dimensions, the top half AI penetration rate includes robotics, defence, education, aerospace, aviation, automotive, medicine, and agriculture. In the bottom half we find railway, shipbuilding, energy, chemical, metallurgy, mining, nuclear, and coal.

FIGURE 6: AI penetration rates in VC, patents, and publications



2.5.1 Sectors with the highest penetration

ROBOTICS

Robotics (#1) shows the highest AI penetration due to the intrinsic connection between cognitive and physical AI. The integration of sensors, machine learning, and real-time decision-making is key for designing and operating robots. They are further enabled by 3D vision, the integration of text processing (through large language models) and edge AI. Robots are used across sectors, with tasks such as performing inspections in mining and repairments in industrial settings. To reach their full potential, robots must be made to behave more like humans and to better communicate with them.

DEFENCE

The extensive use of AI in defence (#2) is explained mostly by surveillance activities, combat simulations, drone operations, and cybersecurity measures. It is enabled by a high standard of data collection and continuous tests in real-life settings. However, the operational environment is ever-changing and there is pushback on using AI on the battlefield. The war in Ukraine has accelerated the focus on the use of AI, exemplified by the company Palantir, which operates critical infrastructure and protects civilians.

EDUCATION

It is also clear that there is a significant transformation happening in education (#3). There is AI-driven personalised learning, automation of administrative tasks, and the development of virtual learning environments. Education is made more accessible through digitalisation, and AI can help teachers with tutoring, creating assignments and automated grading. The take-off of generative AI accelerates this and intensifies the task of plagiarism detection. However, the burden of integration is mostly on the teachers in class.

AEROSPACE

AI is crucial for aerospace (#4), which in our definition focuses on science and technology common to aircraft and space technology but with a focus on space technology. AI is key for robotic operations, satellite management, and optimising flight operations. Increasing machine learning capabilities of robotics, such as hive learning of robot swarms and increasing connectivity, enables further AI adoption in aerospace. A great example is the collision avoidance system developed by Iris Automation.

2.5.2 Sectors with high penetration

AVIATION

AI is increasingly used in aviation (#5) for navigation and autonomous flying, as well as flow management at air traffic control. For instance, Airbus developed the four-seat driverless urban air taxi. The challenges for adoption consist of regulatory requirements and a limited transition to the cloud, whereas certification and investments in data infrastructures enable the use of AI.

AUTOMOTIVE

One of AI's holy grails is found in the automotive sector (#6), with a focus on autonomous vehicles. Despite pessimism about the performance of autonomous vehicles, there is huge market demand. It is important to note that the vehicles are constrained by the complex environment they operate in. The high standard of safety leads to regulatory barriers and slow adoption. However, with the rapid electrification of cars, there is potential to harmonise the technology behind autonomous driving, which could drive further growth.

MEDICINE

If there is one field where successful AI adoption is longed for, then that is in medicine (#7). AI speeds up drug development by analysing genomic and clinical data and matching patients to trials. It helps oncologists classify CT scans and facilitates precision medicine. AI can also assist in screening demographics on a larger scale, as shown by the HIV case findings in Ukraine. However, medicine is a field with high stakes: legal uncertainty and biased training data have sometimes led to poor acceptability by professionals.

AGRICULTURE

AI in the agricultural sector (#8) ranges from intelligent crop planning to early pest warning and autonomous weed elimination. Advancements like these facilitate precision agriculture. For instance, Bowery Farms hosts a network of smart indoor farms to grow crops. In agriculture, governments and large companies hold power over regulations and key datasets, whereas 80 % of the farms are small. However, larger farmers usually find better uses for AI, and the take-off of the drone industry further enables AI adoption in agriculture.

2.5.3 Sectors with moderate penetration

RAILWAY NDUSTRY

The railway industry (#9) has a moderate interest in AI, where it can power driverless trains, planning and predictive maintenance. The sector is traditionally highly risk-averse, featuring slow progress in digitalisation, possibly also due to market concentration and high fixed costs, which make it very expensive to engage in systemic transformation. However, the growing availability of historical and real-time data, as well as good integrations of 'human-in-the-loop', enable further adoption. For example, the Dutch National Railway Company works with AI researchers to plan maintenance schedules and predict disruptions.

SHIPBUILDING

AI is more relevant for shipbuilding (#10) than one would expect. For instance, robotics is useful in development and maintenance. In one case, the RobotPlusPlus aerial robotic specialist climbs walls of ships, cargo holds and storage tanks to inspect, de-rust and clean. Shipbuilding further benefits from digital twins, decision-making support and remote control, despite the complexity of the supply chain

ENERGY

The energy sector (#11) has a surprisingly low penetration rate of AI, which works especially well when paired with renewable energy sources. The energy sector still relies on fossil fuels and is subject to external perturbations. However, the use of AI in hydrogen, batteries and grid control shows that AI has a role to play. Enhanced interoperability of energy systems, investments in the grid and the emergence of smaller grids require the deployment of AI. The AI-enabled energy demand forecasting application of the company ABB is a great example that can lead to load shifting and peak shaving for grid stability.

CHEMICAL ENGINEERING

Chemical engineering (#12) is a complex process where AI does not seamlessly fit in. There is a need for data on specific failure cases and machines frequently lack the compatibility to use AI. However, this could change with the help of embedded AI systems. Chemical engineering involves AI innovations in hydrogen solutions and lithium batteries. For example, West Virginia University pioneers a combination of quantum speed and the intelligent discovery of AI to find sustainable chemical designs.

2.5.4 Sectors with low penetration

METALLURGY

Metallurgy (#13) requires specific software and composition-structure-property data. There is a lack of existing automation. Without change, working manually still pays off. In metallurgy, AI is used to predict cooling needs, discover new material properties and automate diagnostics. For instance, Tata Steel's prediction systems for heating and cooling came to fruition when on-site staff was adequately trained in using them.

MINING

AI has low penetration in mining (#14). Mining is operated in a fixed setting, albeit one that depends on economic cycles, political interests and willingness to change. With long-term investment, AI could be surprisingly helpful in the field. In mining, AI predicts and controls blasts. It also drives inspection robots, autonomous haulage and intelligent drilling. As such, KoBold Metals is a mining unicorn that identifies rare metal deposits.

NUCLEAR SECTOR

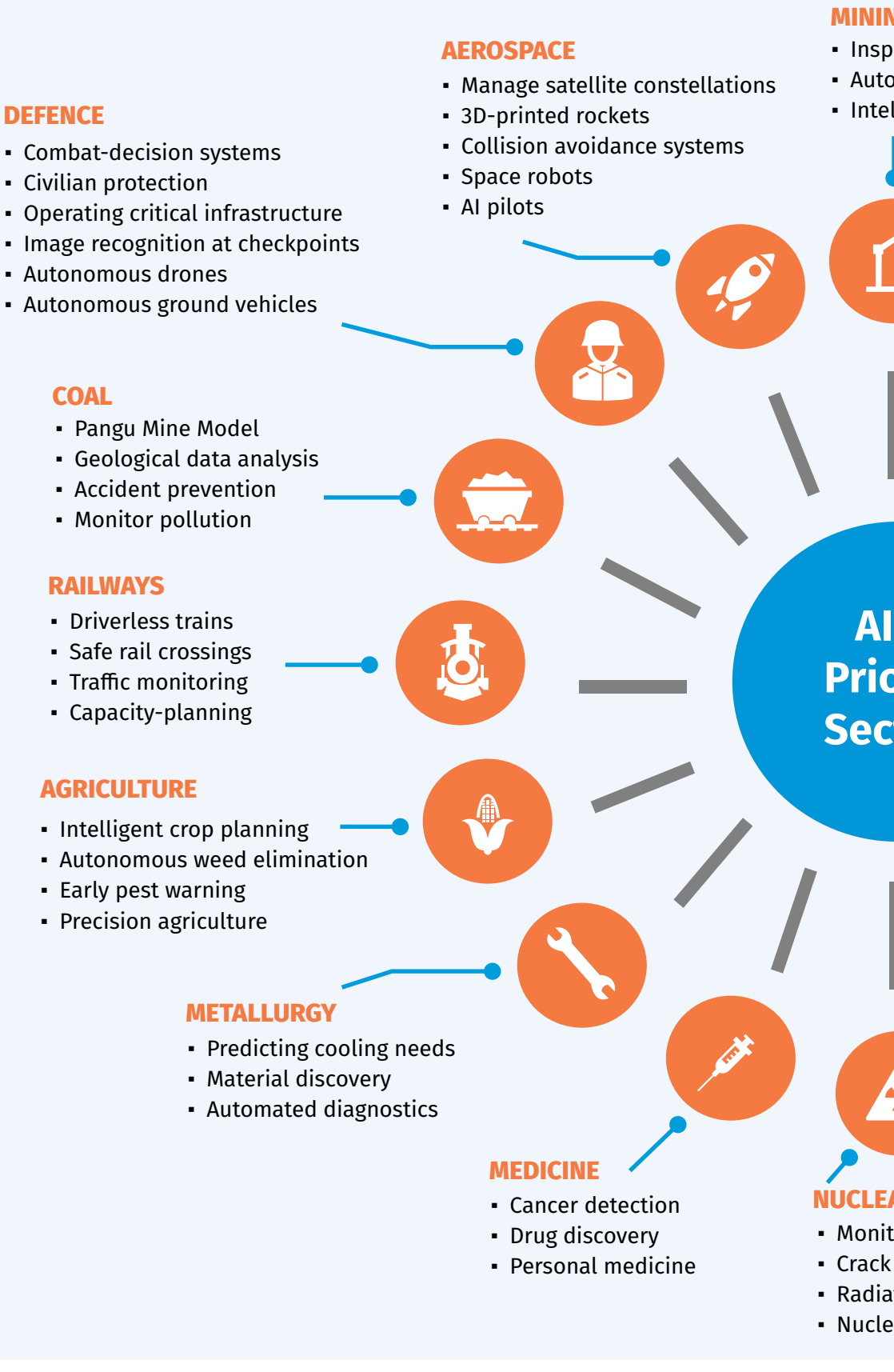
The nuclear sector (#15) requires extremely careful operations. Power plants need to be monitored extensively, without mistake. AI can screen tanks and pipes for cracks and automate nuclear fuel management. As an example, the firm Metroscope uses digital twins to identify faults early on. Yet the implementation of AI comes with model uncertainties and regulatory compliance, which are currently only partly solved by more explainability of the algorithms and collaboration between scientists and regulators.

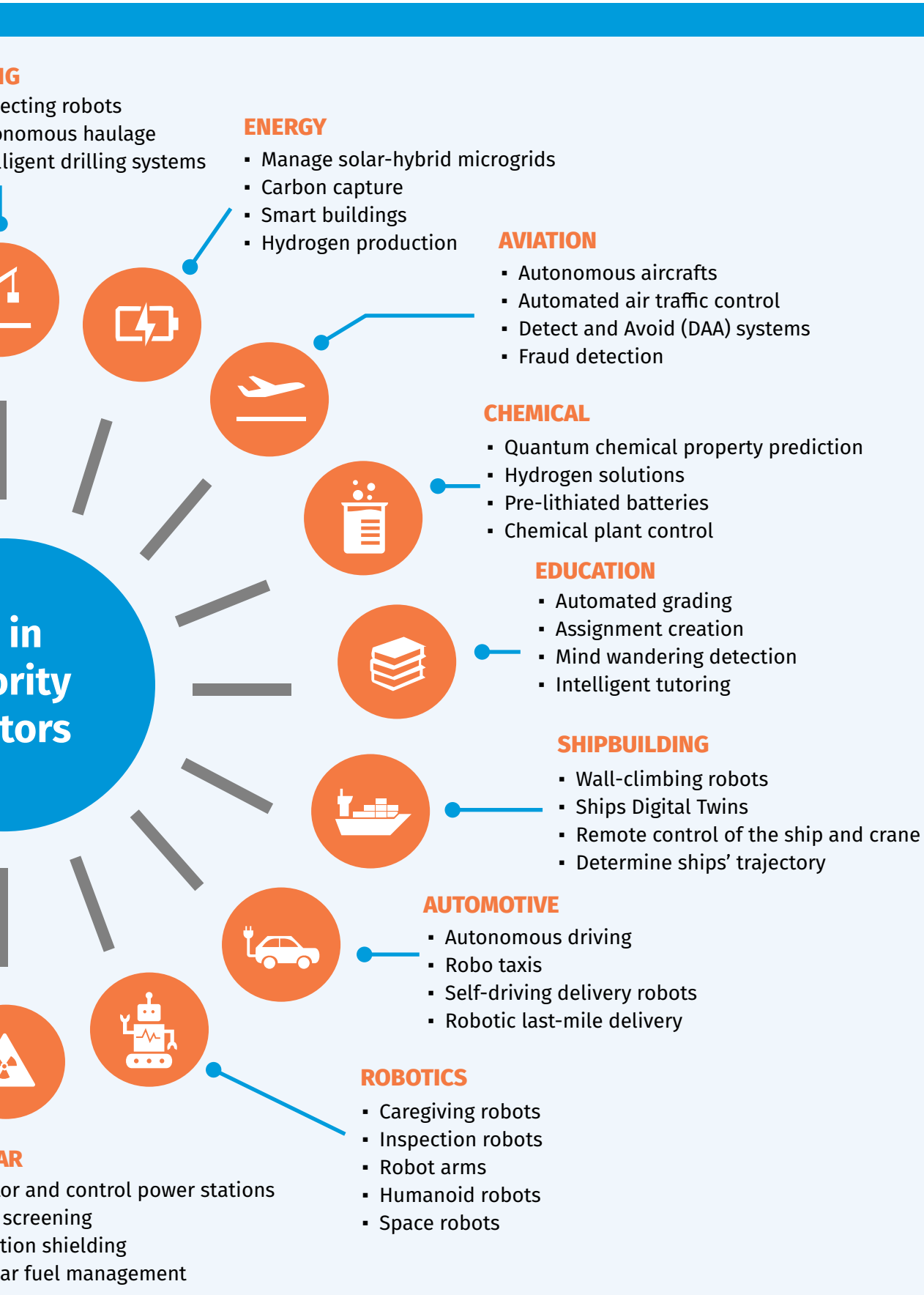
COAL

The lowest penetration rate of AI was found in the coal industry (#16). Although AI helps to analyse geological data, monitor pollution and prevent accidents, the data is often confidential and there is a lack of technical data expertise. Nevertheless, one successful project is the Pangu Mine Model of Huawei and the Shandong Energy Group, which has applications in tunnelling, transportation and rock burst prevention.

Figure 7 summarises the discussion on the use of AI in priority sectors.

FIGURE 7: The use of AI in priority sectors

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ENERGY
▪ Manage solar-hybrid microgrids
▪ Carbon capture
▪ Smart buildings
▪ Hydrogen production
AVIATION
▪ Autonomous aircrafts
▪ Automated air traffic control
▪ Detect and Avoid (DAA) systems
▪ Fraud detection
CHEMICAL
▪ Quantum chemical property prediction
▪ Hydrogen solutions
▪ Pre-lithiated batteries
▪ Chemical plant control
in
ority
tors
EDUCATION
▪ Automated grading
▪ Assignment creation
▪ Mind wandering detection
▪ Intelligent tutoring
SHIPBUILDING
▪ Wall-climbing robots
▪ Ships Digital Twins
▪ Remote control of the ship and crane
▪ Determine ships' trajectory
AUTOMOTIVE
▪ Autonomous driving
▪ Robo taxis
▪ Self-driving delivery robots
▪ Robotic last-mile delivery
ROBOTICS
▪ Caregiving robots
▪ Inspection robots
▪ Robot arms
▪ Humanoid robots
▪ Space robots
AR
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2.6 MANY BLOCKERS AND ENABLERS ARE SECTOR-SPECIFIC

Common enablers and blockers of AI deployment and uptake centre on data, infrastructure and security. Yet many are sector-specific, whether it is the human aspect in medicine and education, the complex structure of nuclear power plants and the energy grid, or the high-stakes situations in aerospace and defence. A few observations are put forward below.

First, ***the availability of high-quality data is a prerequisite for AI use across priority sectors***. There is a need for data sharing and smaller players need help with retrieving data from different sources. Data collection is naturally embedded in some (aerospace, chemical engineering, energy) and relatively less so in others (agriculture, shipbuilding). With access to the relevant data, AI saves costs across sectors with predictive maintenance, smarter scheduling and minimising waste.

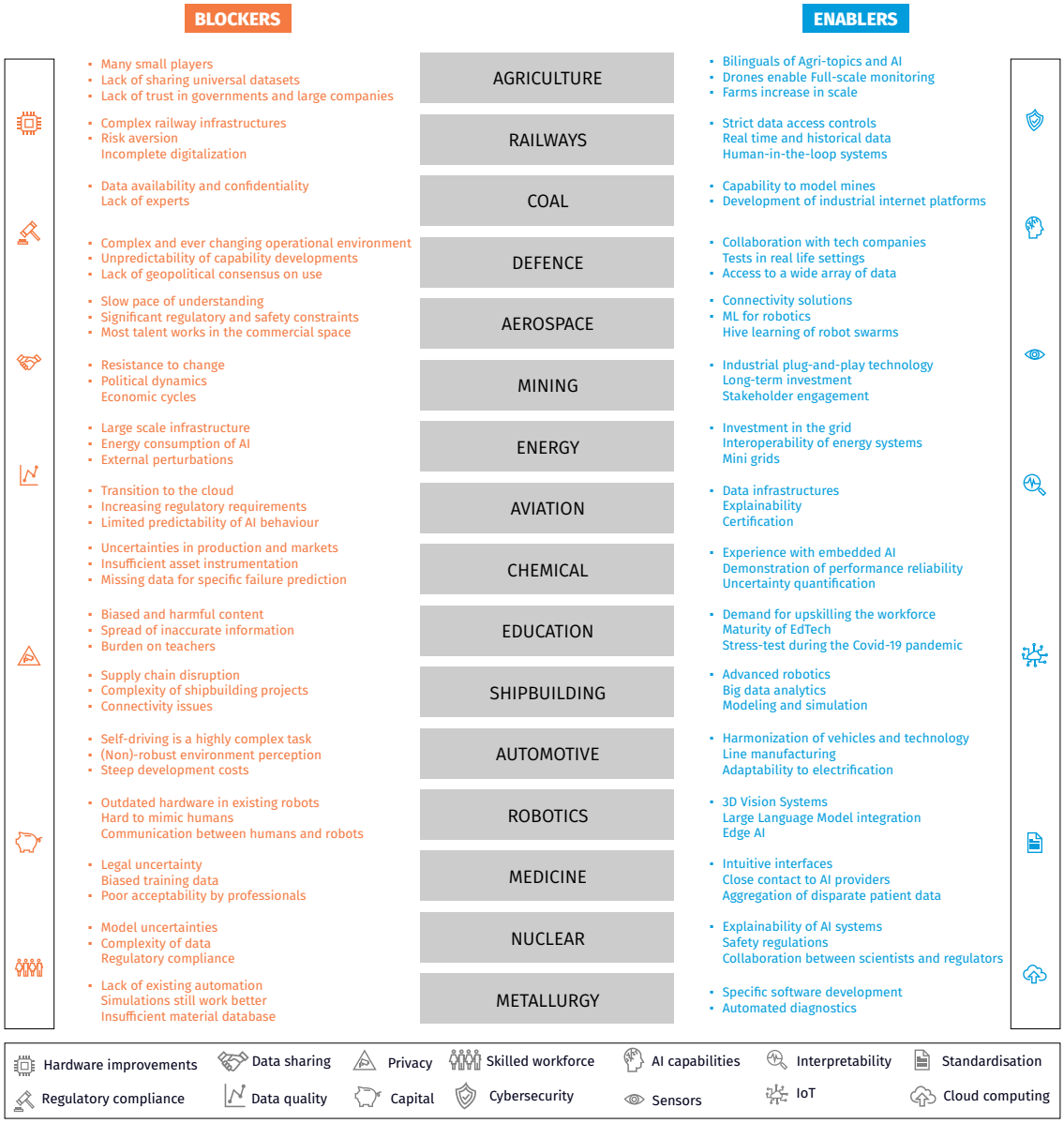
Second, ***cybersecurity is critical for all priority sectors*** but lacks concrete support strategies. Better data protection, the adoption of state-of-the-art techniques such as red-teaming and the reliance on a skilled workforce are all essential to guarantee a sufficient level of security.

Third, and more broadly, ***AI adoption is slowed down by a persistent lack of skilled workers***, more than by a lack of technology development or absorption. In many countries, the shortage of IT workers in general represents an important obstacle to innovative business practices and industrial transformation, as evoked also by many business leaders and associations.

Fourth, ***regulatory barriers are a more significant blocker for industries*** where there is direct contact with humans (medicine) or where multiple actors interact (automotive, aviation) than for industries operating in more defined and closed areas (mining, agriculture).

Finally, ***autonomous vehicles will further disrupt many sectors*** but need tailored adoption. The complexity of creating autonomous vehicles, for instance, turned out to be larger than for aviation.

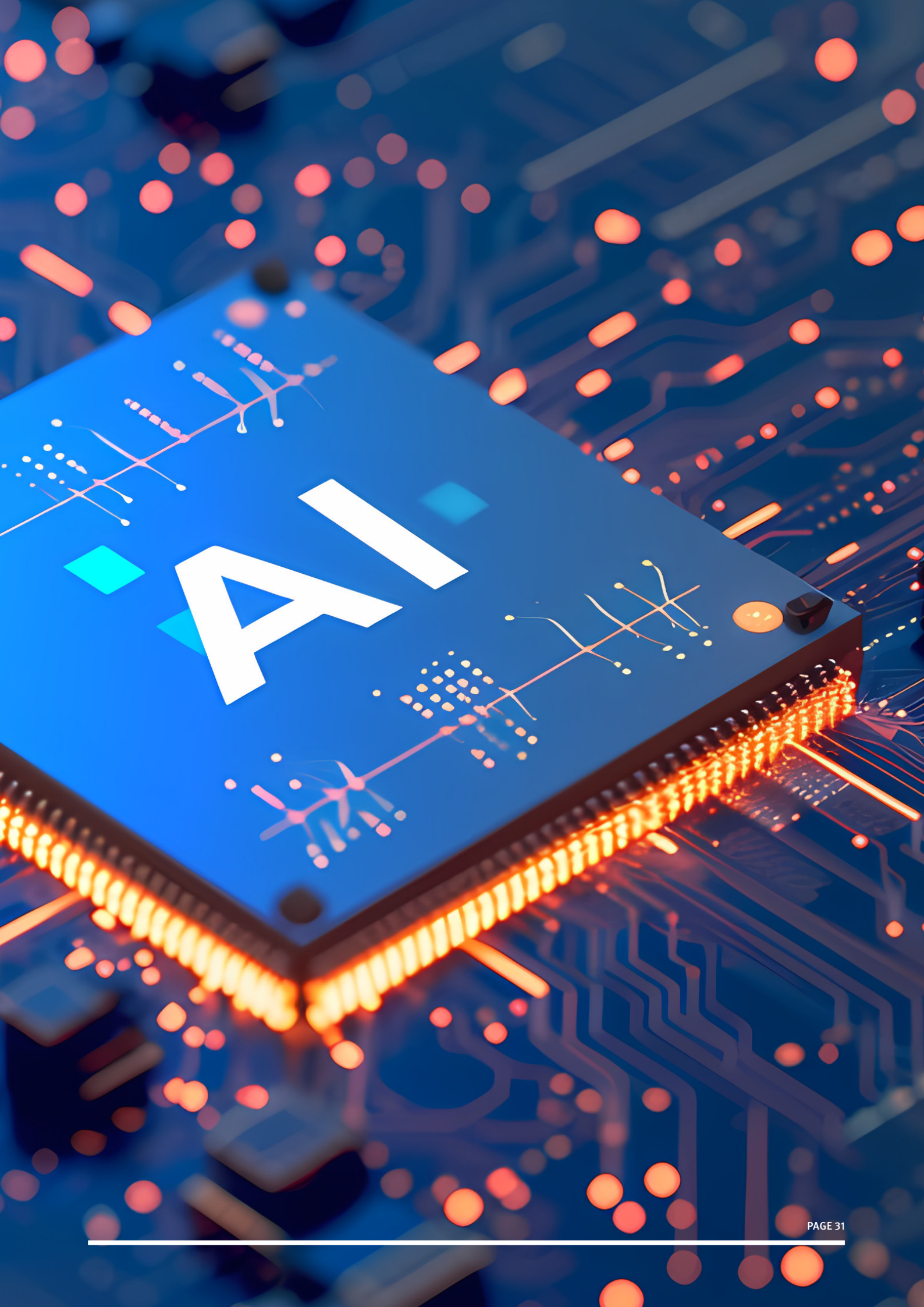
FIGURE 8: Enablers and blockers of AI use in priority sectors



3

Ukraine's strong AI capabilities

Our analysis shows that Ukraine has serious scientific, entrepreneurial, and technological capabilities in AI, punching well above its weight. This indicates that Ukraine – and Kyiv in particular – has a strong potential to become a European leader across several applications of AI.


AI

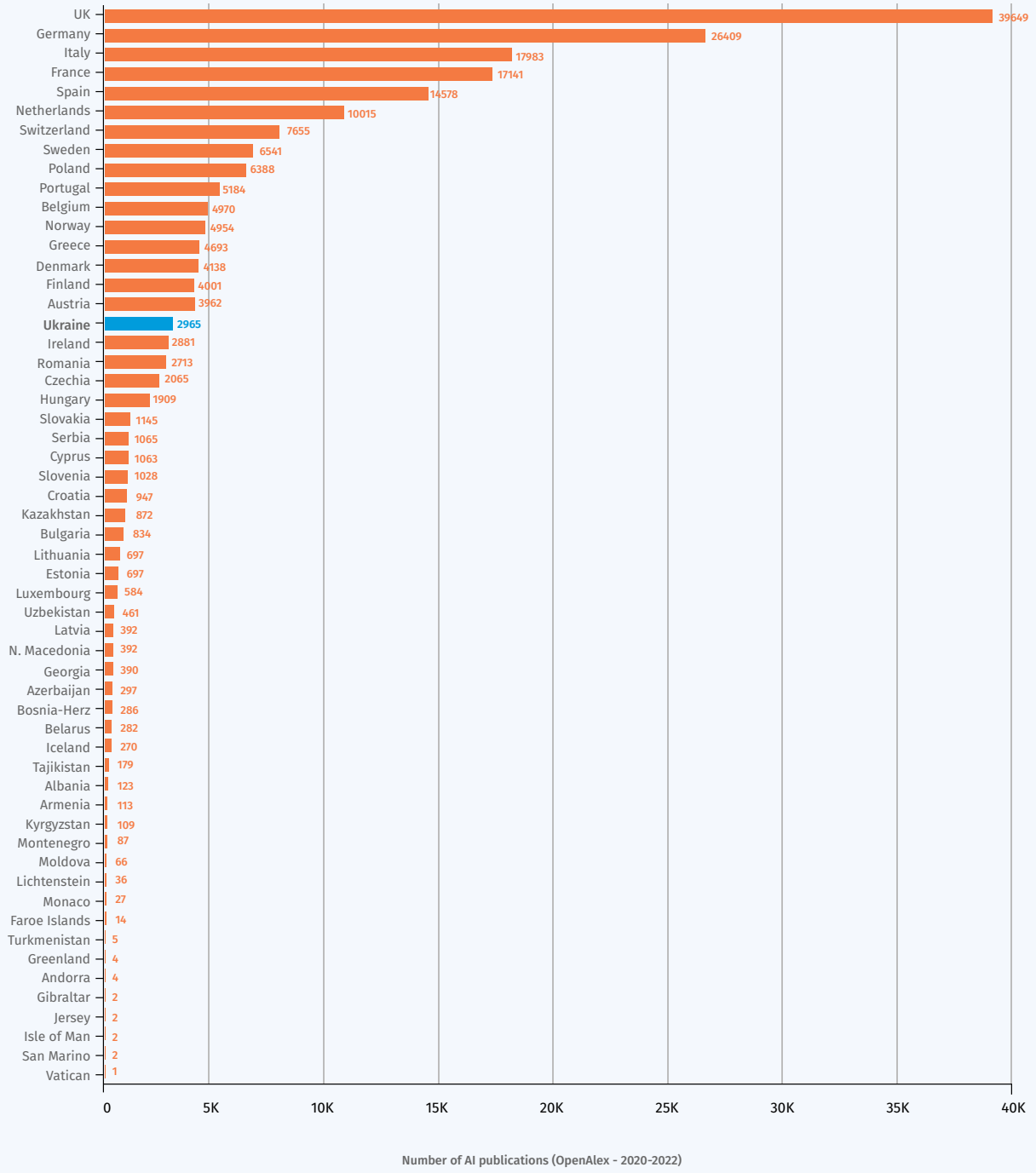
In the previous section, we used patent documents, start-up funding data, and scientific publications to evaluate the use of AI across various priority sectors. Building on this, we now incorporate geo-localised versions of these three data sources to specifically assess Ukraine's competitiveness in AI. Our analysis shows that Ukraine has serious scientific, entrepreneurial, and technological capabilities in AI, punching well above its weight. This indicates that Ukraine – and Kyiv in particular – has a strong potential to become a European leader across several applications of AI.

3.1 UKRAINE PUBLISHED A SIGNIFICANT AMOUNT OF AI SCIENTIFIC PAPERS

First, we assess Ukraine's research output competitiveness by allocating scientific publications from the OpenAlex database to various countries, based on the street addresses of the authors' affiliated institutions. Figure 9 illustrates the volume of AI scientific publications across European and Central Asian countries from 2020 to 2022. As expected, leading Western European nations such as the UK, Germany, Italy, France, Spain, the Netherlands, and Sweden dominate the ranking. This is due to a large extent to their established research infrastructures and investment programmes.

Ukrainian institutions have during this period published nearly 3000 AI papers, positioning Ukraine as the 17th most prolific contributor to AI research in Europe and Central Asia. Ukraine ranks as the second most productive country in Central and Eastern Europe in the AI domain, behind Poland but above EU27 countries such as Romania and Hungary. This highlights Ukraine's capability in the AI research landscape, digital literacy and its potential to play a major role in the coming years.

FIGURE 9: Number of AI papers in Europe and Central Asian countries



3.2 KYIV IS AN AI START-UP HUB IN EUROPE

To geo-localise start-up funding data, we use the locations of the headquarters of start-ups that have received funding. Figure 10 highlights this distribution across the 27 largest European cities and shows the concentration of AI start-ups in prominent Western European cities such as London, Paris, Berlin, Amsterdam, Munich, Barcelona, and Stockholm. These cities are recognised as significant AI hubs due in particular to their advanced technological ecosystems and supportive start-up infrastructure.

The analysis shows a quite remarkable performance for Kyiv, which, with 60 AI start-ups listed on Crunchbase, ranks relatively high – even surpassing traditional industrial centres like Frankfurt and Manchester. This underscores Kyiv's entrepreneurial capabilities and also mirrors its position in scientific outputs, as previously discussed. Kyiv's prominence is particularly notable within the context of Central and Eastern Europe, where it ranks second, just below Warsaw but ahead of other major AI hubs such as Bucharest and Budapest.

FIGURE 10: Number of AI start-ups in the 27 largest European cities

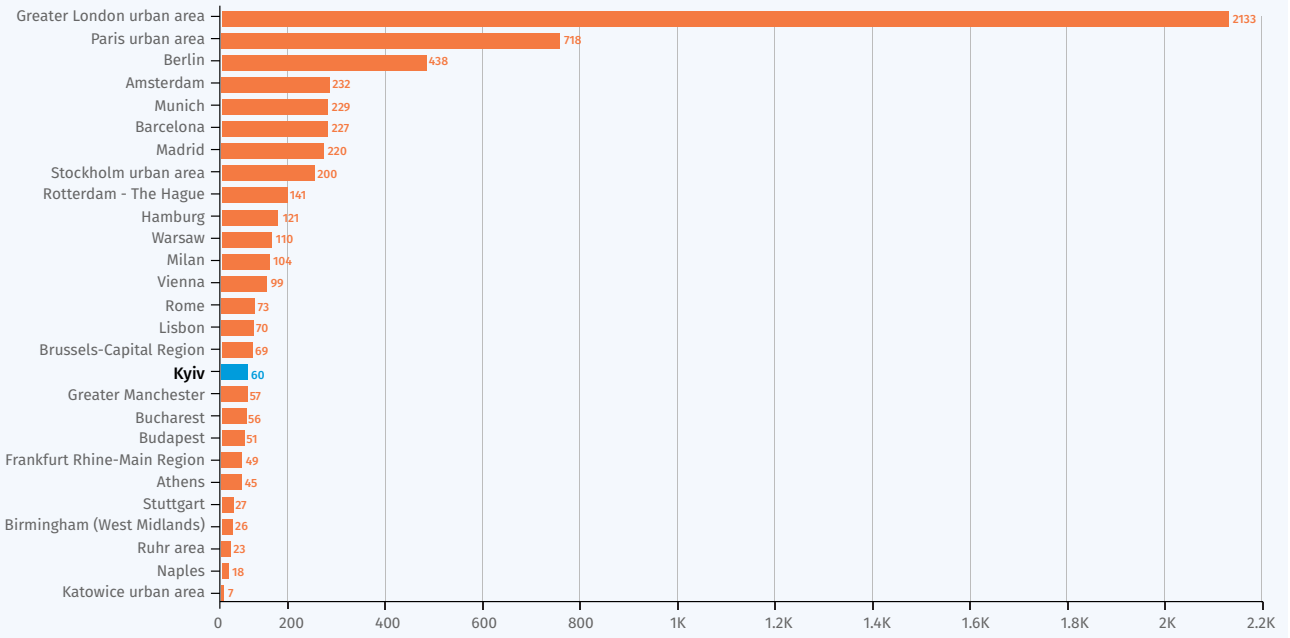
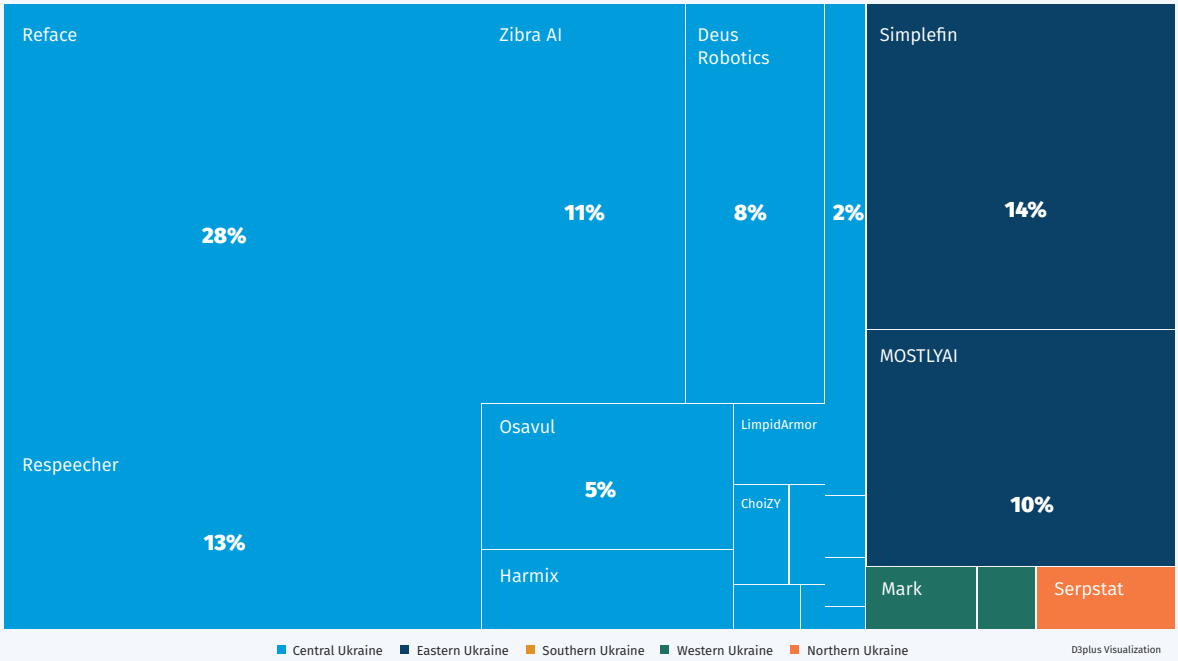


Figure 11 shows the composition of the AI start-up ecosystem in Ukraine for which specific funding is publicly available. Tiles are proportional to cumulative funding received until March 2024. The treemap shows that Kyiv and other Ukrainian regions have birthed several top AI companies such as Reface, Respeecher, and Harmix. Other internationally recognised companies, such as the billion-dollar company Grammarly, also have strong Ukrainian roots. Grammarly was founded by Alex Shevchenko, Max Lytvyn and Dmytro Lider, who were all educated in Ukraine, and the company still has R&D facilities in Ukraine.

FIGURE 11: The Ukrainian AI start-up ecosystem



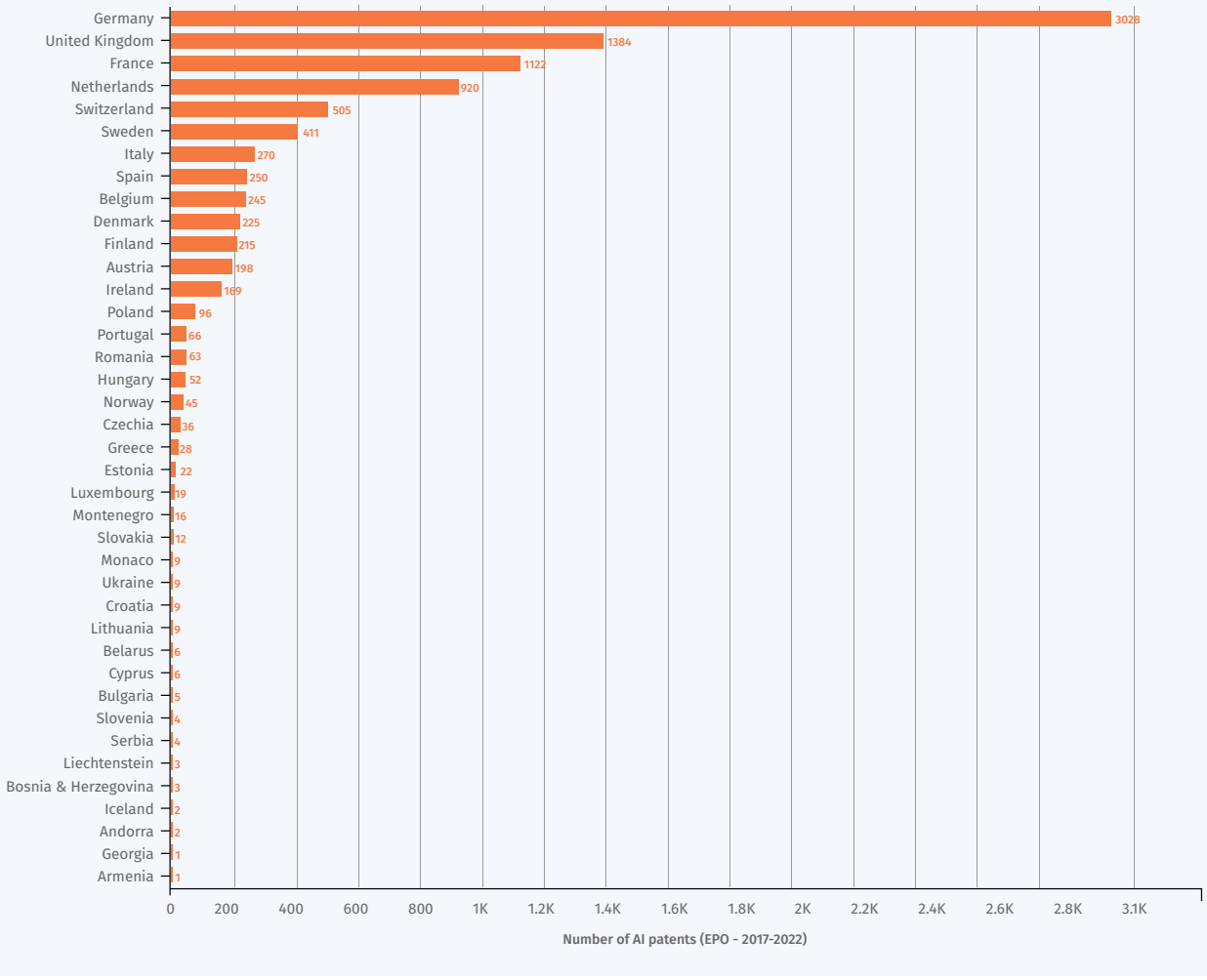
3.3 UKRAINE HAS PATENTED KEY AI TECHNOLOGIES

We geo-localised patent documents using the OECD RegPat database, specifically focusing on the home addresses of inventors as indicated during the patent filing process. Here we focus again on EPO patents, which represent a significant quality as they are patents that are particularly difficult and costly to obtain. The data, as visualised in Figure 12, shows that the most prolific countries in AI patenting activity are again Western countries, with Germany, the UK, France, the Netherlands, Switzerland and Sweden topping the list. By this metric, Northern European countries tend to perform particularly well.

Unlike its robust outputs in scientific publications and start-up activities, Ukraine's presence in the patent landscape is not as pronounced. This disparity in

performance can be attributed to several factors. The process of obtaining patents involves substantial financial costs and complex administrative procedures and we often see large and well-established companies topping the patent rankings. Consequently, Ukraine's relatively lower performance in this area could be linked to less foreign direct investment (FDI) and limited integration with the European Union's market, which is crucial for supporting the protection of new technologies. Compared to its Central and Eastern European neighbours such as Poland, Romania, and Hungary, Ukraine lags behind in the number of AI patents filed.

FIGURE 12: Number of AI patents in Europe and Central Asian Countries

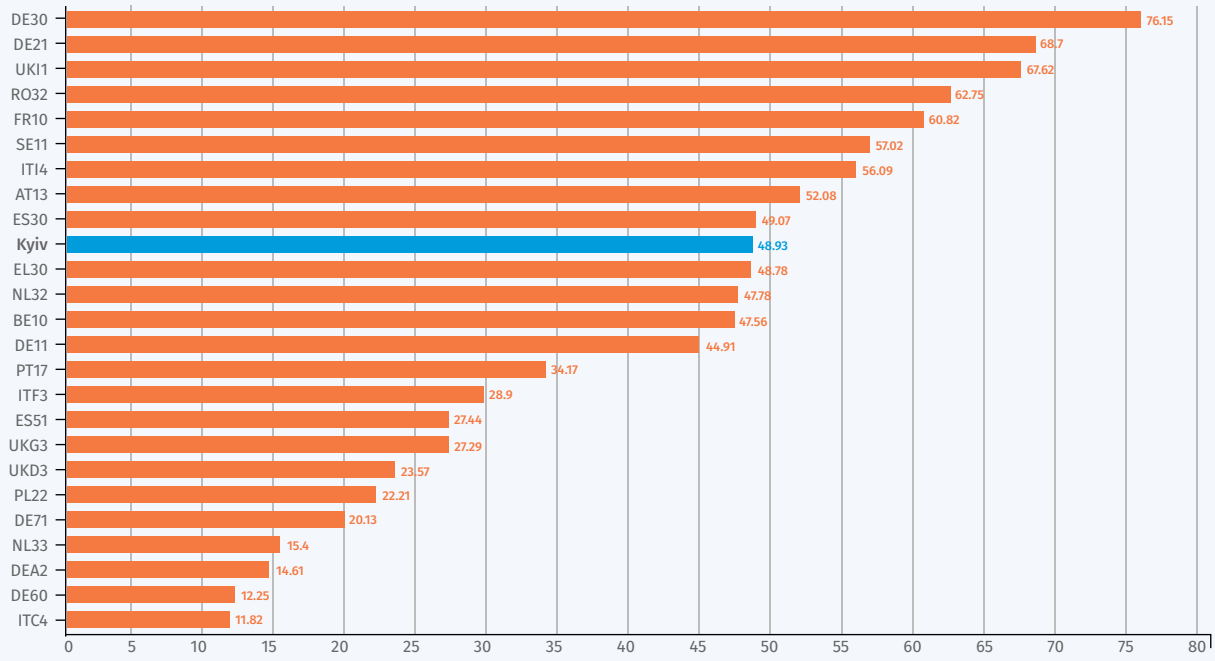


Although Ukraine only has a few AI patents, economic complexity analysis of Kyiv's technological ecosystem as evidenced by patent activity shows that it is particularly fit for AI. The literature on economic complexity applies network science, big data, and machine learning to understand economic development. One of the key findings of this literature is that regional diversification happens through the principle of relatedness (Hidalgo et al., 2020; Balland et al., 2022). The key idea is that inventors, companies, countries and regions develop new products and technologies by recombining pre-existing available capabilities. Mapping existing capabilities

allows us to estimate the distance with any new domain, measured by the concept of relatedness (see Figure 13). The higher the degree of relatedness between a country and AI, the higher the probability of diversification and future leadership. In simple terms, the principle of relatedness is similar to AI recommender systems. It is very powerful since we don't need to see much present activity in AI to predict future activity in AI.

Figure 13 shows that Kyiv has a relatedness density of 48.93 %. It means that Kyiv has a revealed comparative advantage in almost 50 % of the technologies that are related to AI, making it one of the fittest AI tech ecosystems in Europe.

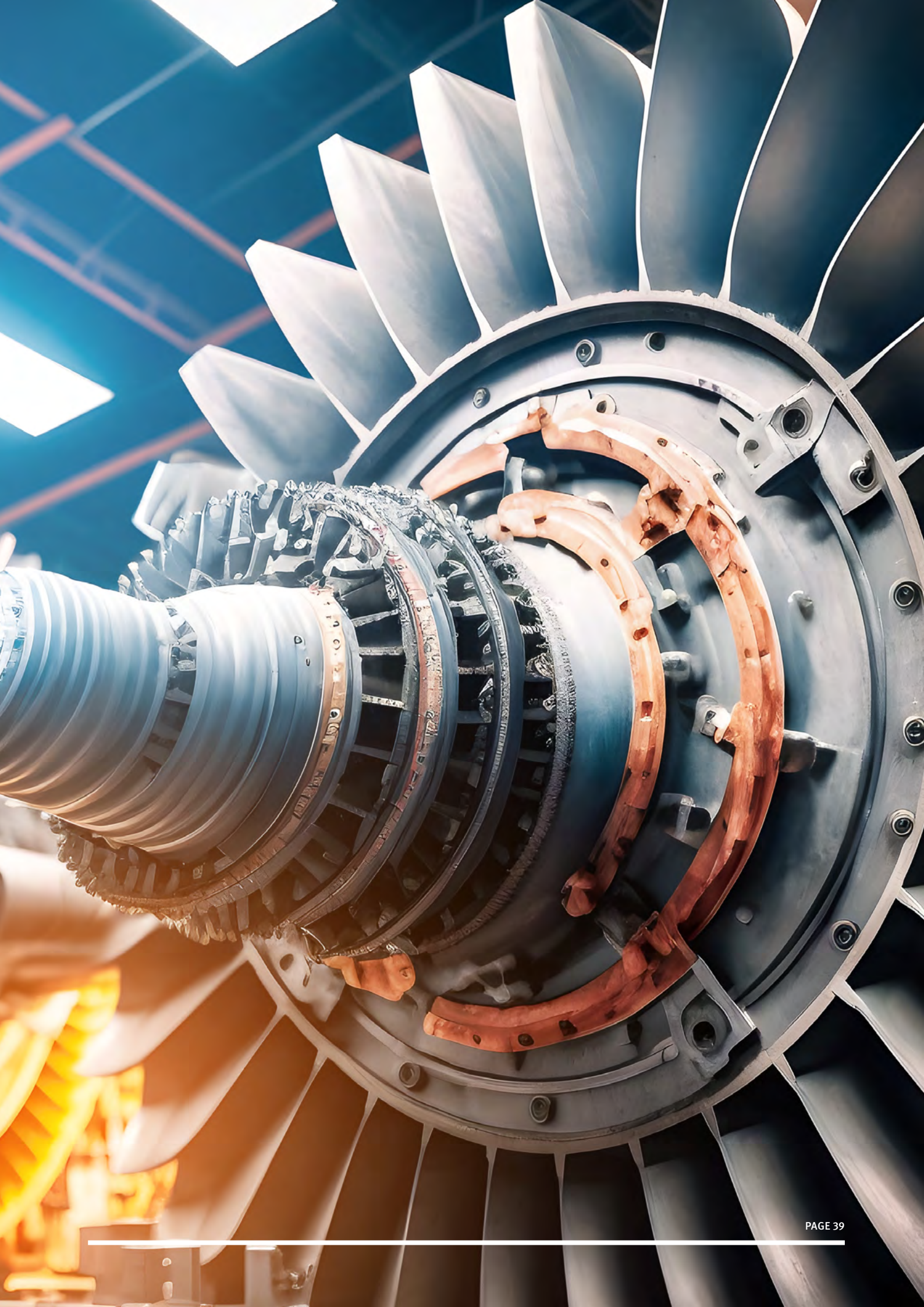
FIGURE 13: Relatedness density around AI in EU regions



4

Ukraine's competitiveness varies across priority sectors

Ukraine has a particularly strong comparative advantage in coal, defence, nuclear, metallurgy and aviation. But medicine, robotics, chemical, aerospace, shipbuilding and chemical rank at the bottom.



Using the approach as above for AI, we now analyse the competitiveness of Ukraine in all 16 priority sectors. In some fields, Ukraine is an EU and global leader – for instance, in the field of aviation it ranks #3 for scientific publications in EU and Central Asia for the period 2020-2022. But in other fields, it lags behind, for example in robotics where no EPO patenting activity at all has been recorded. There is therefore strong heterogeneity in the competitiveness of Ukraine across priority sectors. Figure 14 shows that Ukraine has a particularly strong comparative advantage in coal, defence, nuclear, metallurgy and aviation. But medicine, robotics, chemical, aerospace, shipbuilding and chemical rank at the bottom. This is important information when it comes to prioritising efforts in priority sectors.

FIGURE 14: Rank of Ukraine in different priority sectors

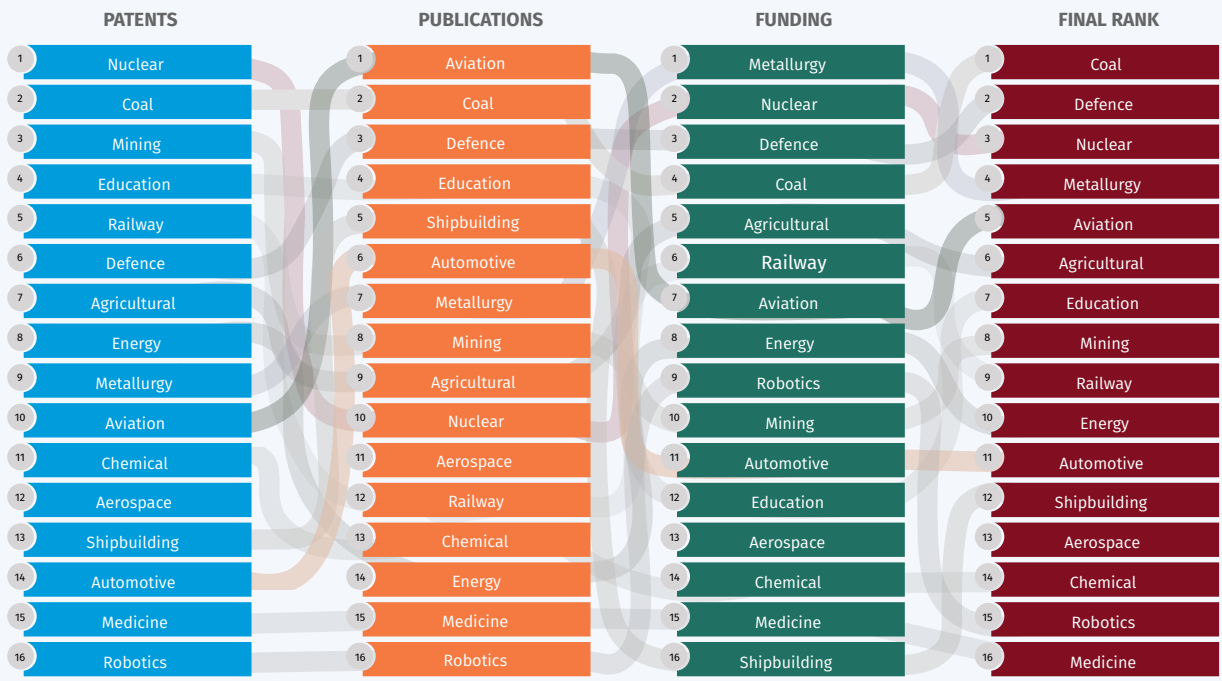


Figure 15 graphs the penetration rate of AI in all 16 different priority sectors (discussed in section 2) and the relative competitiveness in Ukraine. In the top right quadrant, we find the sectors that combine the strong competitiveness of Ukraine and a strong AI penetration rate: defence, education, aviation, and agricultural. These are the sectors in which Ukraine has the strongest chance to lead and at the same time the sectors that will bring massive economic opportunities. This is the high-reward low-risk zone (blue colour). These are usually the sectors that deserve special attention when it comes to prioritisation.

In the top left quadrant, we find the sectors that have a strong AI penetration rate but also show low competitiveness of Ukraine. This quadrant includes robotics, aerospace, automotive and medicine. This is the high-reward but high-risk zone (orange colour). These are the sectors that will bring massive economic opportunities but in which Ukraine needs capability building and specifically dedicated investments.

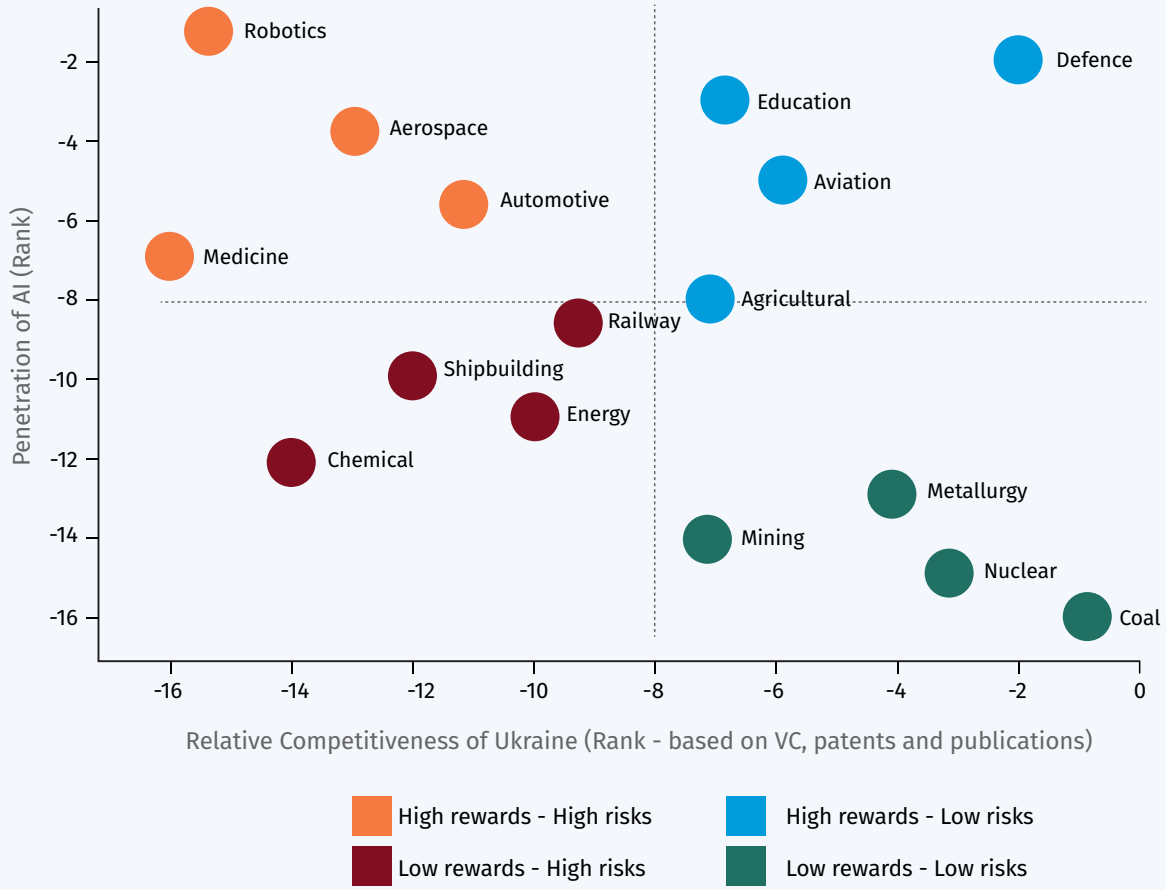
In the bottom right quadrant, we find the sectors that have a low AI penetration rate but also show a high competitiveness of Ukraine. This quadrant includes

metallurgy, mining, nuclear and coal. These are the sectors that might bring less economic upside and transformative potential but in which Ukraine has strong capabilities in relative terms. This is the low-reward but low-risk zone (green colour). These are sectors that usually should not be prioritised because a push is not necessary (capabilities are already there) and unless they bring additional benefits in terms of green transition or tech sovereignty, for instance.

In the bottom left quadrant, we find those sectors that have simultaneously a low AI penetration rate but also show a low competitiveness of Ukraine. This quadrant includes railway, shipbuilding, energy and chemical. These are the sectors that might bring less economic upside and transformative potential and in which Ukraine does not have strong capabilities in relative terms. This is the low-reward but high-risk zone (brown colour). These are sectors that usually should not be prioritised because a strong push would be necessary (capabilities are not there in relative terms) and unless they bring additional benefits in terms of green transition or tech sovereignty, for instance.

Again, this is important to note because there might be other very good reasons to prioritise sectors with low AI/ competitiveness. This could be for military reasons, to accelerate the green transition, or to avoid technological or critical resource dependency. These reasons are not in the scope of this analysis.

FIGURE 15: Prioritisation graphs for Ukraine



5

Recovery projects are an opportunity to leapfrog into an AI-powered economy

The Ukraine Recovery Plan is a vital blueprint for post-war reconstruction, aiming to rebuild critical infrastructure, including homes, schools, hospitals, roads, and utilities but also to stimulate economic growth across various sectors.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The Ukraine Recovery Plan is a vital blueprint for post-war reconstruction, aiming to rebuild critical infrastructure, including homes, schools, hospitals, roads, and utilities but also to stimulate economic growth across various sectors. It provides a strategic roadmap for revitalising key industries and adopting innovative technologies to ensure sustainable development.

Over 900 projects comprise Ukraine's Recovery Plan, with approximately one-third aligning with the 16 defined priority sectors. These projects could aim to not only restore what was lost but also to advance the nation's development significantly. As such they are a foundation for implementing AI to transform and accelerate Ukraine's recovery by integrating advanced technologies.

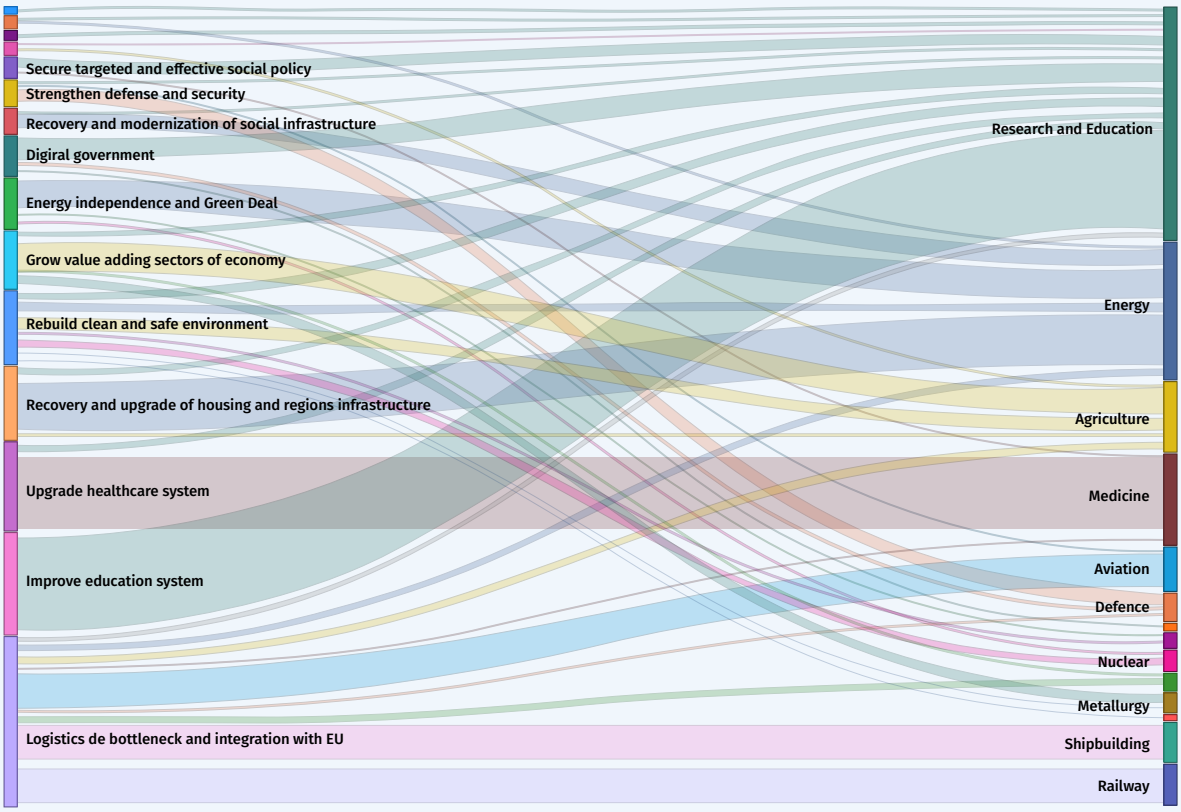
5.1 THE CLASSIFICATION OF THE PROJECTS

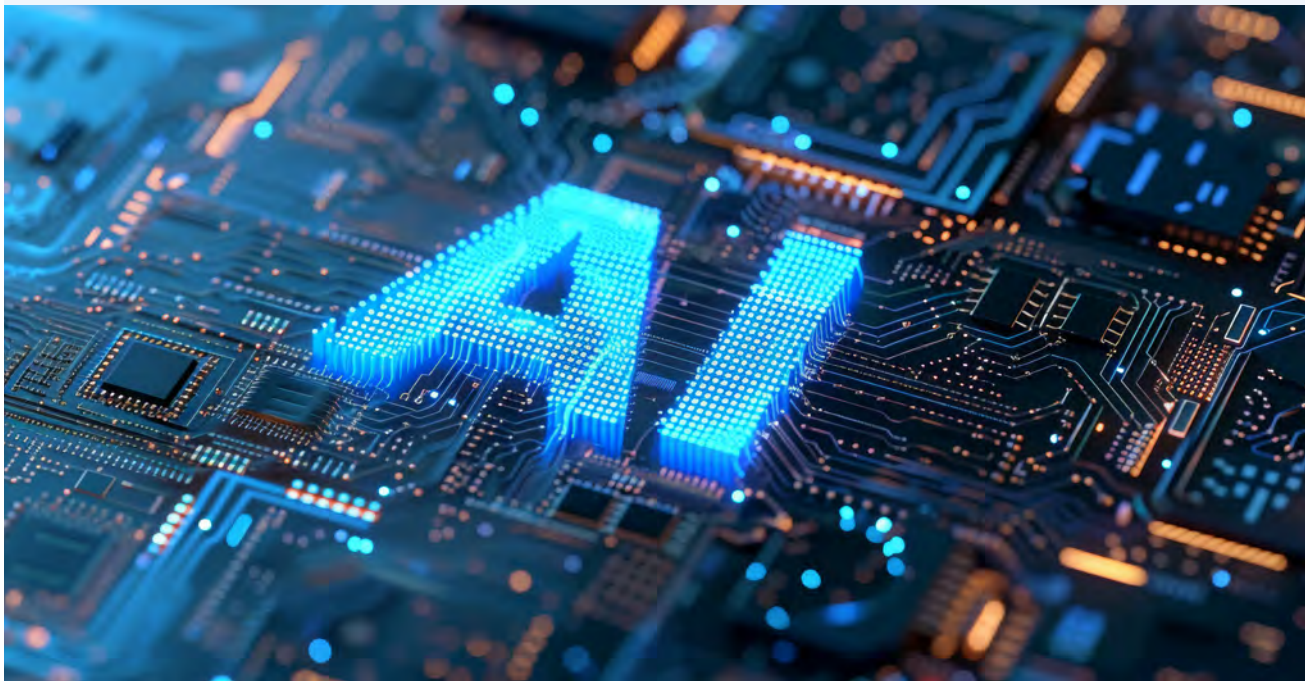
We sourced a total of 920 unique projects from the Ukraine Recovery Plan website through automated web-scraping techniques. We then classified these projects into the designated priority sectors using state-of-the-art Large Language Model techniques. Using OpenAI's GPT-4 API, we analysed the project titles and assigned each to the relevant sectors. This process successfully categorised 336 projects into priority sectors. With GPT-4, we then evaluated the potential benefits of incorporating AI into their implementation, drawing on historical data. Following this automated process, we manually verified each classification for accuracy and relevance. The largest proportions of these projects are distributed among priority sectors such as research and education (112 projects), energy (63), medicine (44), and agriculture (27). The smallest amount of projects belong to the sectors of robotics (1) and chemical engineering (1). The overview of the classification is presented in Figure 16 below.

By concentrating efforts on these strategic areas, Ukraine is positioned to bolster its capabilities in emerging fields such as EdTech, MedTech, and AgriTech. These initiatives are part of a broader vision, as outlined in the Ukrainian Global Innovation Vision 2030, which aims to propel the country towards significant technological and innovative growth.

As the Ministry of Economy, in collaboration with the Kyiv School of Economics, continues to gather and update the investment projects for presentation at the upcoming Ukraine Recovery Conference 2024 in Berlin, there remains a valuable window of opportunity. This time can be strategically used to enhance the recovery plan, particularly through the thoughtful integration of AI into planning.

FIGURE 16: Distribution of the Recovery Plan's national programme projects into priority sectors





5.2 PROMISING AI APPLICATIONS IN RECOVERY PROJECTS

AI implementation has shown promising results in various global projects, which could serve as valuable models for enhancing Ukraine's recovery efforts. By examining three selected priority sectors, we can understand how these advancements might be applied effectively.

5.2.1 Research and education

As part of the national programme *Improve Education System, AI-powered platforms could significantly enhance the Early childhood education at home-based centres project*. It could provide personalised learning experiences tailored to the developmental needs of each child. These platforms can use data analytics to recommend educational activities that are not only age-appropriate but also aligned with individual learning paces and preferences. By analysing children's interactions and progress, AI can identify patterns and learning styles, enabling educators and parents to offer more tailored support. This could include interactive games that adapt to skill levels or virtual story-telling sessions that focus on language acquisition. Moreover, continuous monitoring through AI can help in tracking developmental milestones, alerting caregivers to any areas where a child might need additional focus or intervention, thus supporting a more targeted educational approach. This tracking and possible singling out of learning patterns in the early years of education should occur, if anything, in a non-discriminatory and humancentric way, meaning for the benefit of the student only.

AI can also be used in the digital educational passport project, which is also part of the national programme *Improve Education System*. This project aims to create a digital educational ecosystem for the collection, processing and transmission of information regarding the individual educational trajectory of an education seeker. AI can significantly enhance a digital educational passport project by automating data integration and management from various educational sources. By automating the collection and integration of educational data from diverse sources like schools, online platforms, and extracurricular activities, AI ensures comprehensive and accurate data aggregation. Machine learning algorithms excel in cleaning, categorising, and storing data, which minimises errors and ensures uniformity across the digital ecosystem. Following the recent law on the introduction of individual educational trajectories by Ukraine's parliament, which allows students to customise their learning paths and pace, the potential for AI in education becomes particularly significant. This law's focus on personalised learning pathways underscores the importance of fully leveraging AI to optimise educational outcomes and enhance student experiences.

5.2.2 Energy sector

AI can contribute to the Build 30+ GW RES for H2 production project, which is part of the national programme *Energy Independence and Green Deal*. AI can enhance the project for hydrogen production by optimising site selection, forecasting resources, designing infrastructure, managing energy, predicting maintenance, integrating with grids, analysing markets, assessing environmental impact, optimising supply chains, and providing decision support.

In the same national programme, AI can also be useful to the *Build smart grids project*. Smart grids, powered by AI, can enhance grid stability, optimise energy flows, and facilitate the efficient distribution of electricity generated from renewable sources. AI can predict energy demand, detect and respond to grid disturbances, and enable dynamic pricing and load balancing.

5.2.3 Agriculture sector

As we saw, AI is also particularly powerful for agricultural applications. As part of the national programme *Grow value-adding sectors of economy* it could be used for the *Comprehensive planning of spatial development and land use in the communities project*. AI technologies enable precise data analysis and pattern recognition, which can inform decisions regarding crop rotation, irrigation scheduling, and pest management. By integrating AI with geographic information systems (GIS), planners can create detailed and dynamic models of land use that adapt to changing environmental conditions and market demands. Additionally, AI-driven predictive analytics can forecast weather patterns and environmental impacts, allowing for proactive planning and risk mitigation, ultimately leading to more resilient agricultural practices and community infrastructure.

In the same programme, AI could also add value to the *Mapping Ukraine and implementation of the National Geospatial Data Infrastructure project*. AI, particularly deep learning models, can process and analyse satellite imagery to classify different types of land uses, such as distinguishing agricultural fields, forests, water bodies, and urban areas. This helps in creating detailed land use maps which are essential for planning and development purposes. AI can also enhance GIS applications by automating the extraction of geographical features from large datasets, updating GIS databases in real time, and facilitating advanced spatial analysis.

In conclusion, the Ukraine Recovery Plan not only addresses immediate reconstruction needs but also sets the stage for a transformative leap into an AI-led economy. By focusing on AI integration within priority sectors, Ukraine can enhance its global competitiveness, foster sustainable development, and improve the quality of life for its citizens. The upcoming Ukraine Recovery Conference 2024 in Berlin presents a timely platform to attract investment and partnerships that will be essential in realising these goals. As AI continues to drive global innovation, Ukraine's focus on these technologies positions it well not only to recover but also to thrive in the post-war era.

Conclusion

The report highlights four key findings on the impact of artificial intelligence (AI) in Ukraine's priority sectors. First, AI is revolutionising these sectors globally, creating a new dynamic of winners and losers, meaning that countries and companies will need to adopt AI significantly to remain competitive. Second, Ukraine displays robust AI capabilities, suggesting that further national investment and European support for a Ukrainian AI hub could enhance Europe's overall competitiveness in AI. Third, there is a notable variance in AI competitiveness across Ukraine's priority sectors, indicating a need for targeted investment in specific sectors rather than thin and equal distribution across all. We find in particular defence, education, aviation, and agriculture to be the priority sectors that combine the best AI transformative potential and Ukraine's competitiveness. This strategic focus should consider not only the economic and technological factors presented in this report but also non-economic ones such as security and technological sovereignty. Lastly, the report advocates for recovery projects and immediate reconstruction to be integrated into a long-term innovation strategy (in particular around AI) that not only rebuilds Ukraine's infrastructure but also positions it for future advancements, aligning with immediate reconstruction needs and broader EU priorities.

For these results to be further validated and trigger more granular, actional policy recommendations, we recommend the following additional research perspective. First, the findings on the uses, enablers, and blockers of AI in the several priority sectors are mainly retrieved from desk research, providing a macro overview; they could be extended and validated by engaging with the relevant stakeholders. Second, a deep dive into the details of the current and future recovery projects could help to map the most promising uses of AI. Third, a separate exercise could map potential collaborations with other (neighbouring) countries, with a special focus on the European Union given the suggested soon-to-come accession. Fourth, a more detailed understanding of the possible specialisation of Ukrainian universities, and the skills they can produce in the future, would enable a better understanding of, at once, current potential and future reforms.

Finally, we recommend examining potential future reforms and investments to enhance Ukraine's framework conditions for a flourishing AI ecosystem. Key measures include strengthening digital connectivity and integrating Ukraine into the semiconductor supply chain. Furthermore, ensuring the availability of robust cloud infrastructure and facilitating Ukraine's early participation in European data spaces and projects such as the federated cloud infrastructure GAIA-X is crucial. Additionally, it is important to map the complementarity of skills and capabilities available in Ukraine and neighbouring countries and regions but also to guarantee adequate demand and uptake for AI solutions within the country through demand-side innovation policies, among other strategies.

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[4] Ukrainian Global Innovation Vision: https://winwin.gov.ua/en

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