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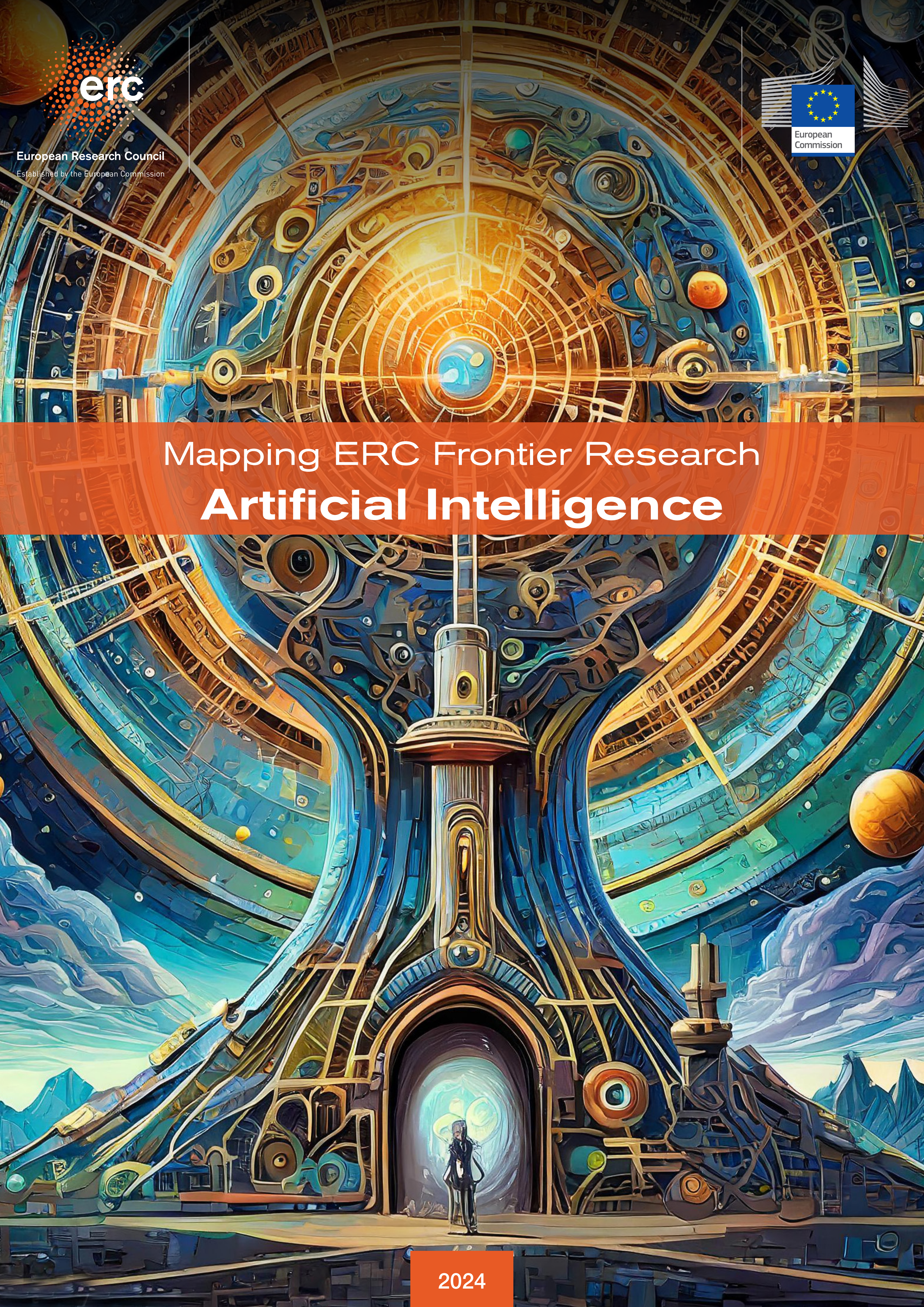


Mapping ERC Frontier Research
Artificial Intelligence

2024

Mapping ERC Frontier Research Artificial Intelligence

Under the Horizon Europe Framework Programme, the European Commission has delegated a new task to the ERC Executive Agency (ERCEA) to identify, analyse and communicate policy relevant research results to Commission services. The ERCEA has developed a Feedback to Policy (F2P) framework for ERCEA to guide these activities, adapted to the specificities of the ERC as a bottom-up funding programme.

This report is part of a series aiming to demonstrate the relevance of ERC-funded frontier science, for addressing societal, economic, and environmental challenges and thus its contributions towards key EU policy goals. This F2P series does not offer any policy recommendations.

More information: https://erc.europa.eu/projects-statistics/mapping-erc-frontier-research

Foreword

As digital technologies continue to reshape our world, understanding the nuances of Artificial Intelligence (AI) has never been more crucial. The European Research Council (ERC) has long championed curiosity-driven research, resulting in a diverse portfolio of over 1000 projects exploring AI across scientific disciplines. These projects, selected solely for their excellence, span the breadth from computer science to engineering, and from neuroscience to applications in healthcare and elsewhere. This analysis stems from the Mapping ERC Frontier Research, an initiative of the ERC Scientific Council with the aim of highlighting the frontier science pursued by ERC grantees.

Beyond mere enumeration, this report provides a comprehensive insight into the substantial contributions of ERC-funded AI projects to key EU policy domains, health, environmental sustainability and the green transition, democracy, justice, employment and education - as part of the ERC feedback to policy activities for the European Commission. The report underscores the indispensable role of ERC-funded frontier research in addressing societal, economic, and ethical challenges posed by AI.

Acknowledging the rapid pace of advancements in the field, particularly in generative AI, the ERC Scientific Council remains vigilant, stressing the importance of researcher accountability, as also emphasized in a recent ERC foresight report. We must ensure that we stay ‘smart in a smart world’, a concept that encompasses staying informed, adaptable, and responsible in our engagement with AI.

The ERC Scientific Council warmly welcomes this report and is pleased to see ERC-funded research at the forefront of generating a robust evidence basis for the ongoing policy reflections on this important topic. Ultimately, this endeavour is about being proactive in harnessing the benefits of technology while mitigating its risks and ensuring it serves the collective good.

Gerd Gigerenzer

Vice-President of the ERC Scientific Council

Introduction

The European Research Council (ERC) is the premier European funding organisation for excellent frontier research. Since its establishment in 2007, it has been a cornerstone of the EU's research and innovation funding programmes. The ERC gives its grantees the freedom to develop ambitious research projects that can lead to advances at the frontiers of knowledge and set a clear and inspirational target for frontier research across Europe.

The ERC funds a rich and diverse portfolio of projects in all fields of science and scholarship, without any predefined academic or policy priorities. These projects can have an impact well beyond science and provide frontier knowledge and innovation to help solve societal challenges and inform EU policy objectives.

This report aims to highlight how **ERC-funded curiosity-driven research projects are developing or using Artificial Intelligence in their scientific processes**, and how these projects and their outputs can help to both define and enable the implementation of policies related to AI and its cross-cutting applications.

This report represents the first comprehensive analysis of the ERC's AI portfolio and it is structured as follows:

1. **Chapter one** provides an overview of ERC-funded projects developing or using AI in science.
2. **Chapter two** focuses on their scientific landscape by offering a more detailed analysis of their evolution and distribution in ERC scientific domains, disciplines, and topics.
3. **Chapter three** gives an overview of their policy landscape, that is, by linking the projects to specific policy areas and providing examples that are relevant to the EU policies on AI.
4. **Chapter four** covers an analysis of a subset of ERC-funded AI projects that pose particularly pressing ethical, legal, and social questions surrounding the development or use of AI.

Policy context

Artificial Intelligence is defined here as *"machines or agents that are capable of observing their environment, learning, and based on the knowledge and experience gained, taking intelligent action or proposing decisions"* (Annoni et al. 2018, p.19). We selected this definition as it follows closely the logic behind the AI Act (see below), and it includes a variety of models and approaches:

- logic- and knowledge-based systems (e.g. inference and deductive engines, symbolic reasoning and expert systems;
- statistical approaches, Bayesian estimation, search and optimization methods;
- machine learning (e.g. supervised, unsupervised and reinforcement learning, deep learning.

The **field of AI and its applications across scientific domains** is experiencing rapid growth.

According to the Stanford University 2023 AI Index (Maslej et al., 2023), the total number of AI publications has more than doubled since 2010 (from 200,000 in 2010 to almost 500,000 in 2021). A bibliometric analysis revealed a consistent increase in the proportion of research papers mentioning AI or machine-learning terms across all fields over the past decade, reaching around 8% in total (Van Noorden and Perkel, 2023). Another bibliometric analysis found that global scientific activity grew by around 5% per year between 2004 and 2021, while during the same period, the annual growth rate of AI-related publications has consistently remained at or above 15%, except for the years between 2010 and 2012 (Arranz et al., 2023a).

AI is also on top of the EU policy agenda since the launch of the European AI Strategy in 2018. This strategy aims to establish the EU a premier hub for AI, emphasising a human-centric and trustworthy approach. The high-level expert group on AI (AI HLEG) laid the groundwork for the Commission's AI approach, producing key documents such as the Ethics Guidelines for Trustworthy AI in April 2019. These efforts culminated in the adoption of the Communication Building Trust in Human Centric AI in April 2019 and the White Paper On AI - A European approach to excellence and trust in February 2020.

A key milestone came in April 2021 when the European Commission presented its AI package, which included: the Communication Fostering a European approach to Artificial Intelligence, an updated Coordinated Plan on AI 2021 Review (with EU Member States), and a regulatory framework proposal, known as the AI Act. This act represents the first-ever legal framework on AI, positioning Europe as a global leader. It advocates for a risk-based approach, defining unacceptable risk/prohibitions and identifying high-risk applications that may impact individuals' fundamental rights and/or safety. In December 2023, a political agreement on the AI Act was reached between the European Parliament and the Council. To bridge the transitional period until the AI Act becomes applicable, the European Commission will launch an AI Pact, seeking voluntary commitments from the AI industry to adhere to key obligations ahead of the legal deadlines.

While science and the scientific community have played a key role in shaping the EU's approach to AI, it is important to acknowledge that the science too will increasingly rely on AI to progress, innovate, and deliver solutions to societal challenges. Therefore, in a recent policy brief "AI in science: Harnessing the power of AI to accelerate discovery and foster innovation", the European Commission outlines policy ideas to leverage the power of AI to enhance research, accelerate scientific breakthroughs, boost innovation, and stimulate economic growth. This policy development will be informed by the opinion of the Group of Chief Scientific Advisors (GCSA), mandated to provide the Commission with recommendations on how to accelerate a responsible uptake of AI in science. The transformative role of AI in science is illustrated by CORDIS Results Pack, showcasing a set of EU-funded projects (including 8 ERC projects) where AI was indispensable for their success.

Both the current report and a ERC foresight report on the use and impact of AI in the scientific process will bolster these policy initiatives within the framework of ERCEA F2P activities, as requested by the ERC Scientific Council. In December 2023, the ERC Scientific Council released its latest stance on AI, acknowledging researchers' use of AI technologies or human third parties, especially in proposal preparation. It delineates authorship responsibilities concerning acknowledgments, plagiarism, and adherence to good scientific and professional conduct.

At the international level, numerous organisations and governments are advancing the policy agenda. In May 2019 OECD countries adopted the OECD AI Principles, and the OECD AI Policy Observatory currently provides tools, metrics and other policy resources. In October 2023 G7, leaders agreed on both International Guiding Principles on AI and a voluntary Code of Conduct for AI developers under the Hiroshima AI process. Additionally, the US White House released an Executive Order in October 2023 aimed at establishing new standards for AI safety and security, while also addressing issues related to privacy, equity and civil rights, consumers and workers protection, innovation and competition. In November 2023, 28 countries convened by the UK and including the US, the EU and China, endorsed the Bletchley Declaration, which acknowledges the risks and opportunities of AI safety and research, and advocates for increased international collaboration, particularly through science.

1. ERC frontier research on Artificial Intelligence

This report focuses on 1,048 ERC-funded projects on AI, which are **developing AI technology or systems**, as well as **using AI in concrete applications**, and **studying its impact and effects**, or a combination of these elements.

Most of the analysed projects (59%) received funding under the Horizon 2020 framework programme (2014-2020). The study also covered the first two years of Horizon Europe (up to 2022), accounting for 28% of the projects, while the remaining projects (13%) received funding under the Seventh framework programme (2007-2013).

Regarding their distribution across scientific domains, the majority of projects were selected in the ERC evaluation panels in the Physical Sciences and Engineering (51,8%) domain, followed by Social Sciences and Humanities (27,7%), and Life Sciences (20,5%)

Figure 1: ERC AI portfolio in numbers

1,048
Projects

25
Countries

EUR 2.010 bn

137 projects
FP7 (2007-2013)

615 projects
H2020 (2014-2020)

296 projects
Horizon Europe (2021-2027)[1]

290 projects
Social Sciences and Humanities

215 projects
Life Sciences

543 projects
Physical Sciences and Engineering

More specifically regarding the scientific domains[2], in Physical Sciences and Engineering, the majority of projects fall within computer science and informatics (ERC panel PE6), systems and communication engineering (ERC panel PE7), and products and processes engineering (ERC panel PE8).

In Social Sciences and Humanities, projects primarily focus on human mind and its complexity (ERC panel SH4), while also addressing institutions, governance and legal systems (ERC panel SH2), and cultures and cultural production (until 2023 ERC panel SH5).

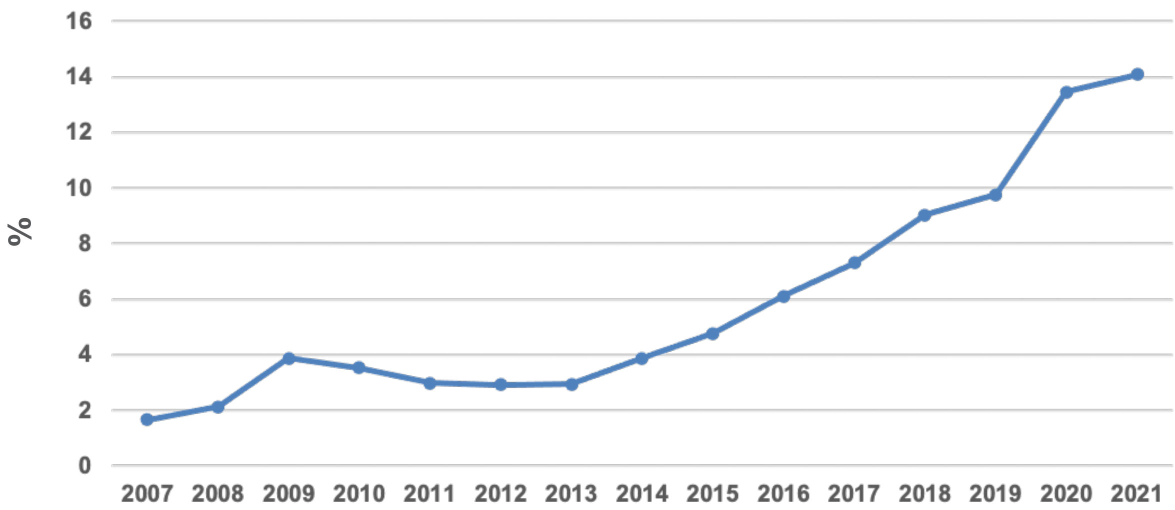
In Life Sciences, projects mainly concentrate on neuroscience and disorders of the nervous system (ERC panel LS5), and also prevention, diagnosis and treatment of human diseases (ERC panel LS7). Additionally, there are twenty-one larger projects, led by more than one researcher, funded by Synergy grants.

2. Scientific landscape

This section provides a description of key statistics on the ERC portfolio of projects developing, using or studying AI from 2007 up to 2022. It is important to note that the analysis captures only the first two years (2021 and 2022) of the Horizon Europe programme.

Overall, **ERC-funded AI projects represent around 7%** of all ERC-funded projects during the period under examination. Focusing on the **year-on-year evolution** (Fig.2), the incidence of ERC-funded AI projects, relative to the total number of ERC-funded projects in the same year, has continuously increased since 2007. While this proportion remained stable below 5% between 2007 and 2013, it then sharply rose and reached a peak of almost 15% in 2021[3].

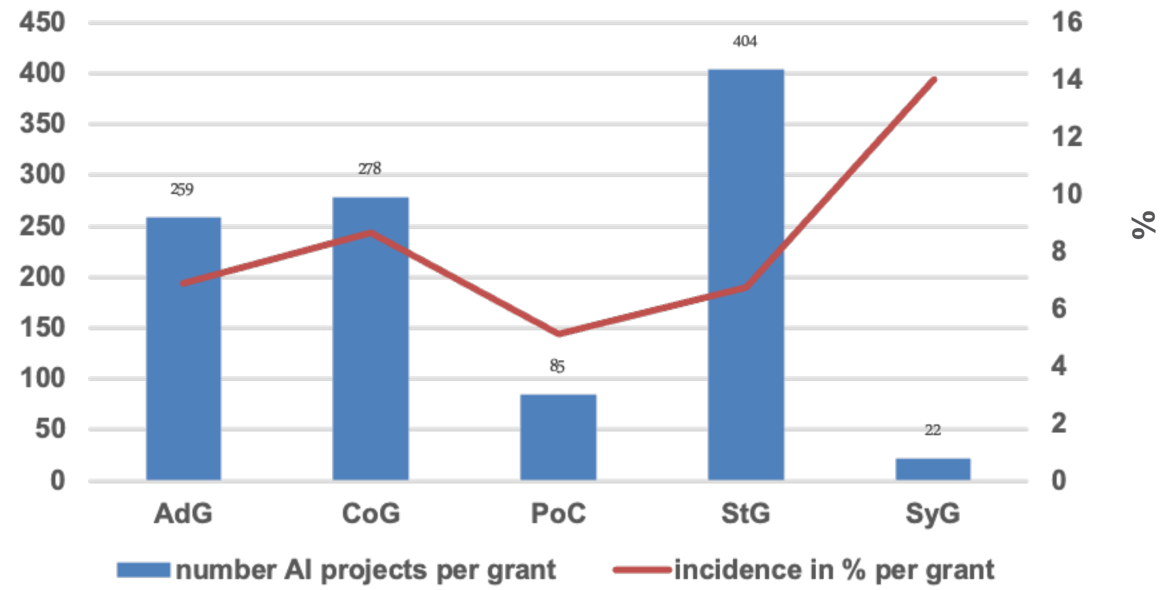
Figure 2: Incidence of ERC-funded AI projects per year



The **distribution of projects in absolute numbers per ERC grant type** (Fig.3) shows that the highest number of AI projects were funded through an ERC Starting Grants (404), followed by Consolidator Grants (278) and Advanced Grants (259). Proof of Concept (85) and Synergy Grants (22) funded the remaining projects.

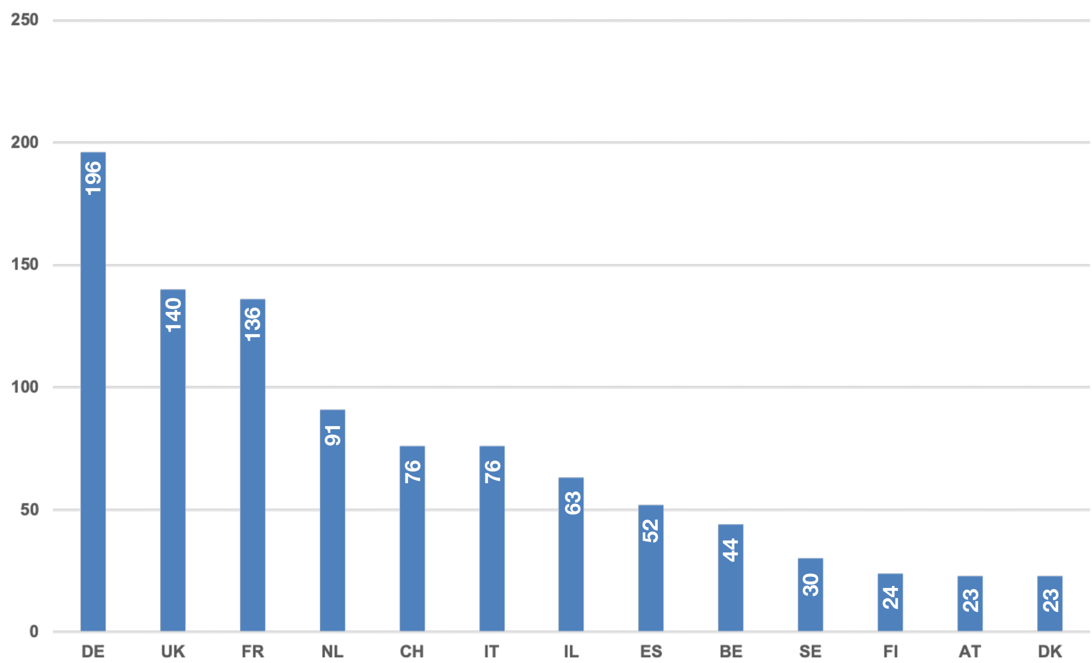
However, when considering the **incidence of AI projects per ERC grant type** relative to the total number of ERC projects (Fig.3), Synergy Grants exhibit the highest incidence at 14%, although this percentage is not representative due to the low number of projects from this call. Consolidator Grants follow closely with an incidence of 8,7%, while the difference between Advanced Grants (6,9%) and Starting Grants (6,8%) is minimal.

Figure 3: Number and incidence of ERC-funded AI projects per grant type



In terms of **geographic distribution** (Fig.4), the countries hosting the highest number of AI projects (in absolute numbers) are Germany, the United Kingdom, France, and the Netherlands, collectively representing almost 54% of the portfolio. Additionally, Switzerland, Italy, Israel, Spain, and Belgium contribute significantly, accounting for approximately 30% of the projects.

Figure 4: Number of ERC-funded AI projects per country (host institution)

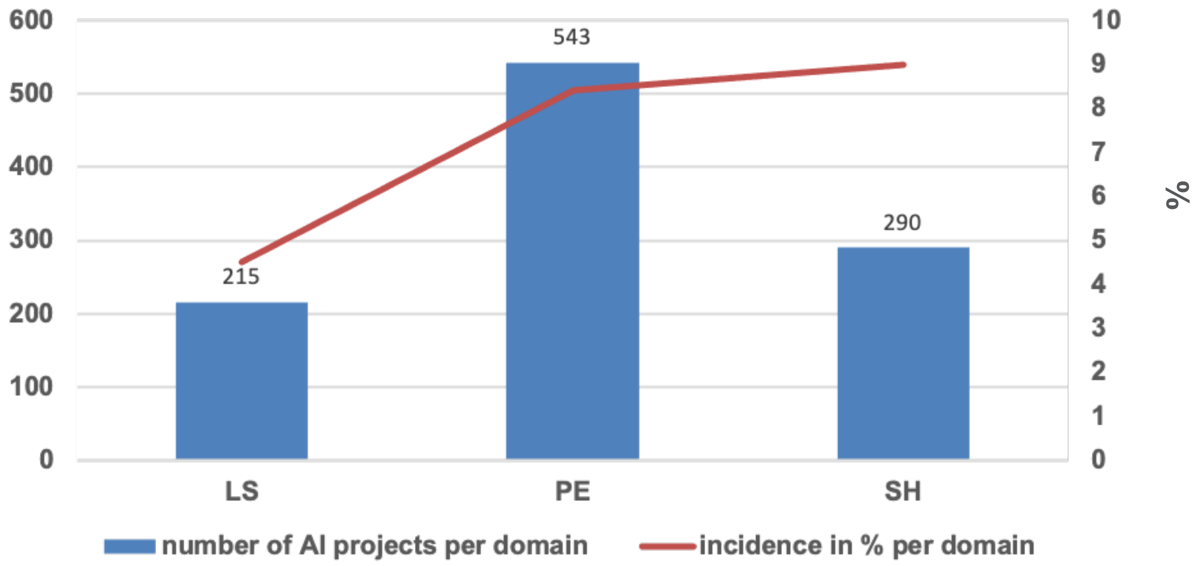


2.1 Domains, disciplines, and topics

Looking at the distribution of scientific domains in absolute numbers (Fig.5), most ERC-funded AI projects originate from the Physical Sciences and Engineering domain (543), followed by 290 projects from the Social Sciences and Humanities and 215 projects from the Life Sciences. However, when considering the **incidence of ERC-funded AI projects within each scientific domain** relative to the total number of ERC-funded projects in the same domain (Fig.5), the incidence of AI projects in SH (9.0%) and PE (8,4%) is nearly the same.

Figure 5: Number and Incidence of ERC-funded AI projects per domain

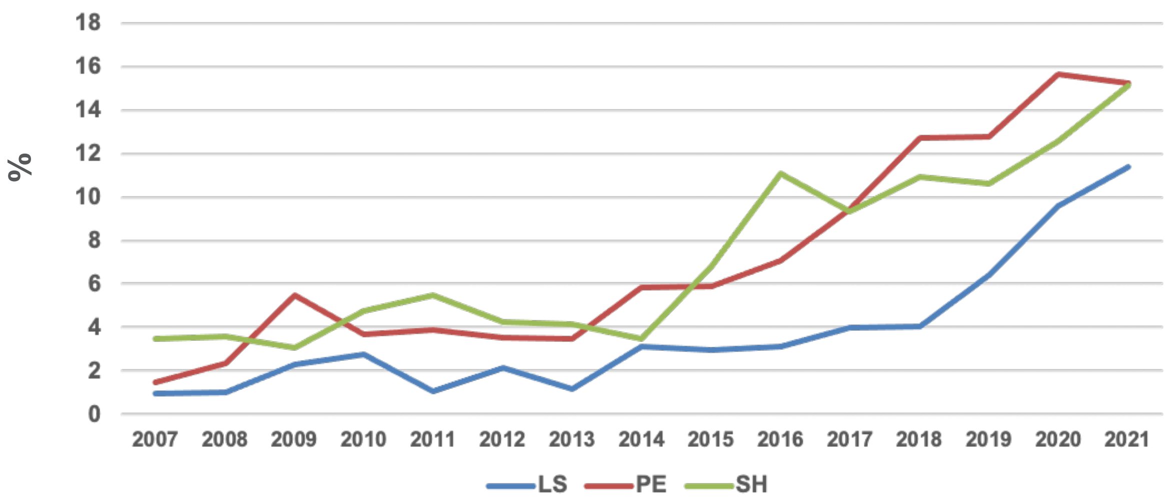
(PE: Physical Sciences and Engineering • SH: Social Sciences and Humanities • LS: Life Sciences)



When examining the **incidence of ERC-funded AI projects per domain per year** relative to the total number of ERC-funded projects per domain per year (Fig.6), it becomes evident that each domain experienced a steep increase after 2013. Growth was particularly pronounced in the domains of Physical Sciences and Engineering in 2013, and Social Sciences and Humanities in 2014. Both domains reached their peak seven years later. Physical Sciences and Engineering reached its peak share in 2020, with almost 16% of the projects using, developing or studying AI. The growth trajectory of AI projects in Life Sciences follows a somewhat different path, with steep growth starting only in 2018[4].

Figure 6: Incidence of ERC-funded AI projects per domain per year

(PE: Physical Sciences and Engineering • SH: Social Sciences and Humanities • LS: Life Sciences)



An overview of the ERC AI portfolio via the [ERC Mapping Frontier Research (MFR)](#), an internal ERCEA classification system, also provides further insights on the key scientific disciplines and topics[5].

In terms of common disciplines represented in the AI portfolio (Fig.7), artificial intelligence, applied computer science, web and information systems are prominent. Additionally, disciplines such as musicology, linguistics and communication, cognitive neuroscience, computational biology and personalised medicine, are also well represented.

Regarding topics (Fig.8), several core set of AI terms emerge, including deep learning, machine learning, natural language, computer vision, adaptive and autonomous systems, and robotics.

Figure 7: Word cloud of the main MFR disciplines of ERC-funded AI projects

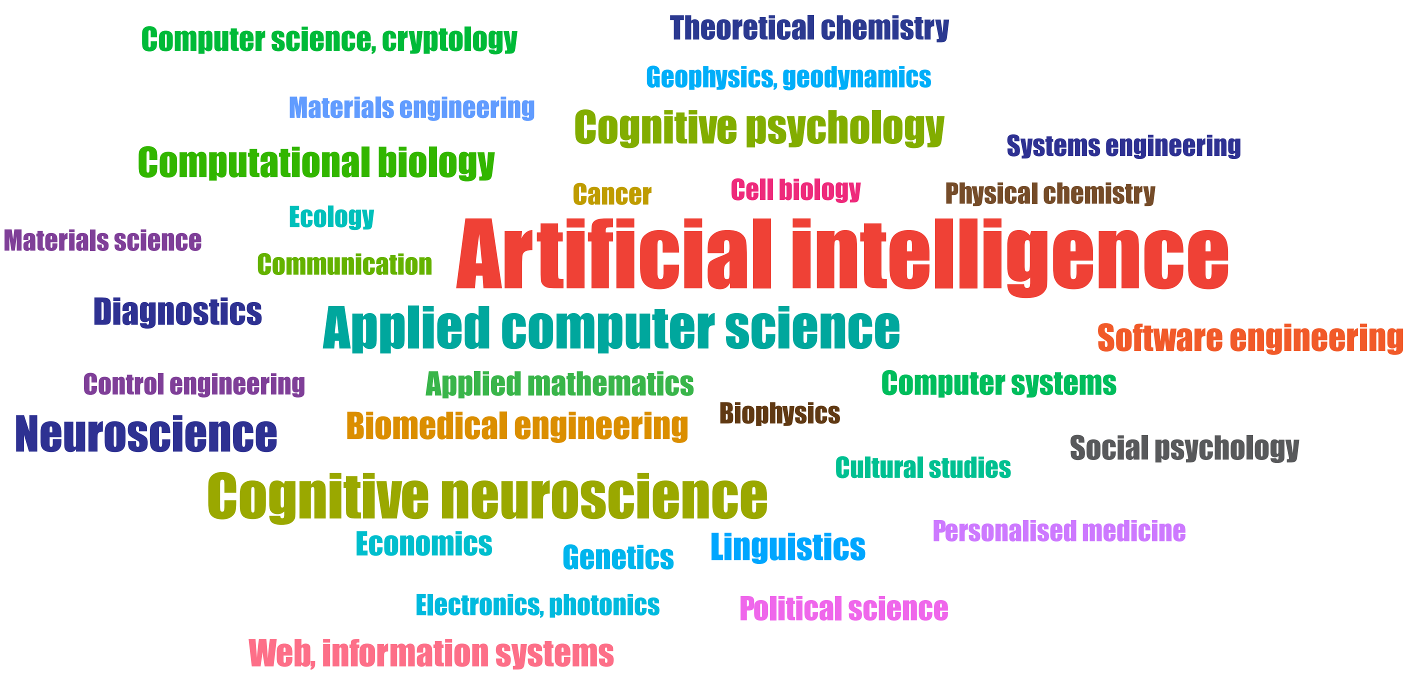
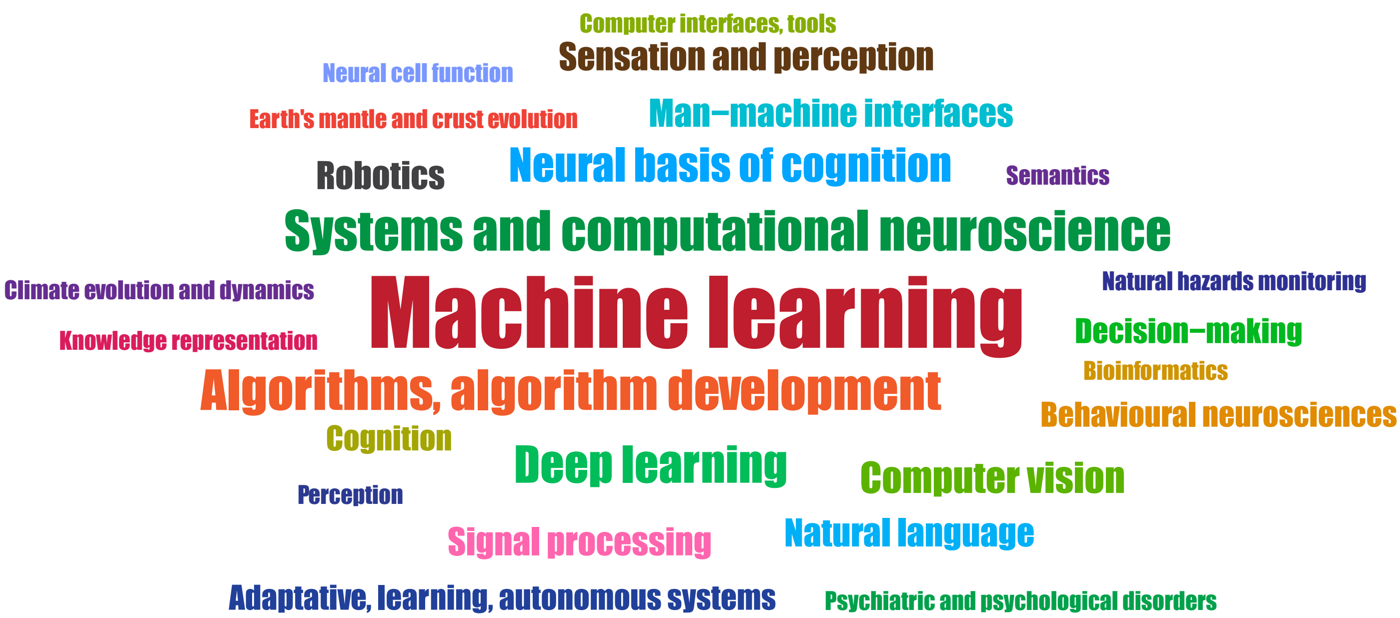


Figure 8: Word cloud of the main MFR topics of ERC-funded AI projects



2.2 Project examples

Physical Sciences and Engineering

- At the **intersection of computer vision and linguistics**, HELIOS led by Philip H.S. Torr at the University of Oxford from 2014 to 2018, focused on an algorithm capable of generating relevant sentences describing a scene based on one or more images. This work resulted in two spinout companies - Aistetic (specialising in remote avatar creation from body scans) and Oxsight (specialising in augmented-reality glasses for people with visual impairments). Additionally, Torr played a pivotal role in launching FiveAI, a platform dedicated to autonomous vehicle development and safety assurance, where he serves as Chief Scientific Advisor. His achievements include winning the Marr prize in 1998 and being elected as a Fellow of the Royal Academy of Engineering in 2019, and the Royal Society in 2021 in recognition of his significant contributions to computer vision. In 2021 he was honoured as a Turing AI World-Leading Researcher Fellow. Visit Torr's research group.

- Led by Ricardo Henriques at the Calouste Gulbenkian Foundation, SelfDriving4DSR aims to merge computational optical microscopy with machine learning to develop **self-driving microscopes.** These innovative systems will have the capacity to adapt in real-time to the biological phenomenon being observed. They will intelligently adjust parameters such as illumination, resolution, speed and others to optimise imaging conditions automatically. This novel approach will enable 4D live-cell nanoscopic imaging for the first time, allowing researchers to observe nanoscale previously unseen cellular events over extended periods, such as the progression of viral infection. The team has also developed the ZeroCostDL4Mic platform, a free toolbox providing deep learning networks, pre-trained models and datasets in microscopy for researchers. Read more.

- AI programming has the capability to generate text from data, a process known as **natural language generation (NLG)**, which transforms complex data into human-like language. Led by Ondřej Dušek at Charles University, NG-NLG explores neural approaches to NLG. Currently, neural NLG systems lack transparency and reliability, requiring extensive training data and processing power, and they exhibit poor generalisation, while primarily supporting English-only languages. To address these limitations, the project integrates neural approaches with explicit symbolic semantic representations. It is testing these approaches in various NLG tasks, including data-to-text generation (e.g., weather or sports reports), summarisation and dialogue response generation. Visit the project's website.

Social Sciences and Humanities

- Led by Christopher Stuart Henshilwood at the University of Bergen from 2010 to 2015, TRACSYMBOLS examined the **emergence of key cultural innovations among Homo sapiens and Homo neanderthalensis** in Africa and Europe between 160,000 and 25,000 years ago. Combining archaeological methods with palaeoclimatic indicators, the team used predictive computational tools to enhance their analysis. The project provided significant new evidence on the behavioural evolution of Homo sapiens in southern Africa. It led the team to conclude that symbols were already in use by Homo sapiens as far as 75,000 to 100,000 years ago. Read more and visit the project's website.

- Led by Louise Amoore at the University of Durham, ALGOSOC focuses on the **social and ethical-political implications of machine learning algorithms,** which increasingly influence decision-making in individual's lives. The project includes various case studies spanning areas such as behavioural biometrics and biomedical object recognition, consumer recommendation, criminal justice scoring, oncology treatments, security anomalies, rules and examples, generative adversarial networks, and transformer models. By examining these case studies, the project aims to address how machine learning algorithms learn to recognise, attribute, and infer characteristics of entities (people, objects, and scenes). Additionally, the project critically evaluates the impacts of generative AI, large language models, and new parallel infrastructures. Visit the project's website.

- The human face serves as a powerful tool for social interaction, capable of conveying a wide range of emotions. Through an interdisciplinary approach combining social/cultural psychology, 3D dynamic computer graphics, vision science psychophysical methods, and mathematical psychology, FACESYNTAX led by Rachael Jack at the University of Glasgow, aims to develop the first formal **generative model of human face signalling within and across cultures**. By using computer-generated faces and subjective human perceptual responses, the team has shown that facial expressions can convey complex combinations of emotions. These results have direct implications for the design of socially interactive AI, including social robots and digital avatars. Read more and visit the project's website.

Life Sciences

- NeuroSyntax led by Stanislas Dehaene at the French Alternative Energies and Atomic Energy Commission, investigated the **brain mechanisms responsible for humans' remarkable capacities** to grasp, memorize, and produce complex sequences and rules. The team conducted experiments using artificial "mini-languages" while simultaneously measuring human behaviour, and underlying brain activity through techniques such as functional MRI, magnetoencephalography (MEG), electro-cortigraphy (ECOG), and machine learning techniques. They compared these findings with neural networks associated with natural language and mathematics in adult humans, and conducted similar experiments in non-human primates. The project's findings demonstrated that only humans possess the cognitive capacity to flexibly combine mental symbols using "language of thought". The results have strong implications for understanding of the origins of human uniqueness and cognitive singularity.

- Advancements in sequencing technologies present an unprecedented opportunity to uncover the mechanisms driving the **evolution of microbes responsible for human infectious disease** and to understand the emergence of multi-drug resistant bacteria. Led by Jukka Corander at the University of Oslo from 2017 to 2022, SCARABEE aimed to harness scalable inference methods through a unique combination of machine learning algorithms and statistical models in evolutionary epidemiology driven by population genomics. The team developed scalable methods for analysing the population structure of bacteria and performing genome-wide association studies (GWAS). They established ELFI as an open-source software platform for interpretable simulator-based models. Read more.

- Building upon the achievements of the previous ERC Consolidator Grant cis-CONTROL, the EnhancerDesign Proof of Concept project, led by Stein Aerts at VIB VZW, integrated AI with techniques to study gene activity at the individual cell level. This innovative approach aims created a pipeline for the **design of new gene therapies**. By specifically targeting cell types implicated in various diseases, the project enhanced the specificity and safety of existing gene therapy applications, while also exploring new avenues for treatment. Notably, Aerts continues his pioneering work through an ERC Advanced Grant Genome2Cells that started in June 2023. This project aims to advance single-cell assays using massively parallel reporter assays, complemented by computational biology and AI techniques. Visit the researcher's lab.

3. Policy landscape of ERC-funded AI portfolio

The applications of AI span across various sectors, with profound implications for our economies, politics, and society at large. Consequently, the policy landscape surrounding AI is vast and complex.

At the core of EU policies on AI lies the AI Act, designed not only to establish a uniform legal framework for the development, market placement, and use of AI systems, but also to promote the uptake of **human centric and trustworthy AI** while ensuring a high level of protection of health, safety, fundamental rights, democracy and rule of law, and the environment.

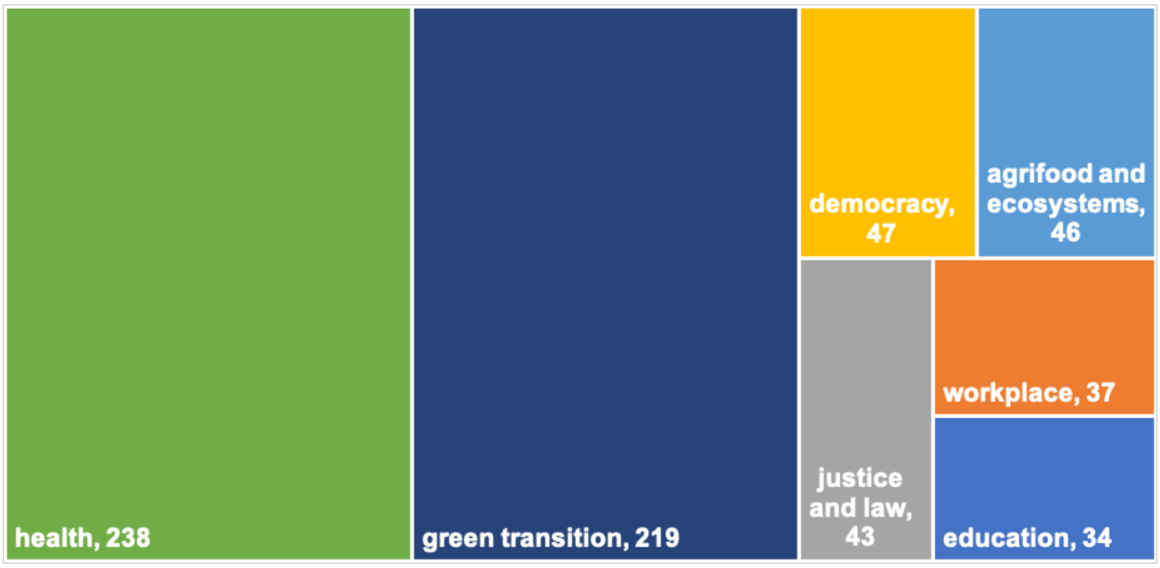
Building upon this broad framework, a selection of policy areas for this report was made primarily through an analysis of EU policy documents and current debates (see European Commission, European Parliament and OECD in the references section). It is important to note that this selection is not exhaustive and may not encompass all ERC-funded AI projects relevant to each policy area[6].

ERC projects are expected to advance the frontier of knowledge in AI, even if immediate applications are not always apparent. While some projects have direct relevance to specific policy areas, others may indirectly inform future applications or shape AI policies, both within the EU and globally.

This chapter highlights ERC-funded AI projects and their alignment with various policy areas. As depicted below (Fig.9), a substantial number of projects fall within the domains of health and green transition. To provide a comprehensive overview, these policy areas will be further subdivided into categories due to the wide range of topics covered.

Figure 9: Number of ERC-funded AI projects relevant to AI policy areas

A project may be relevant for more than one policy area.



3.1 Health

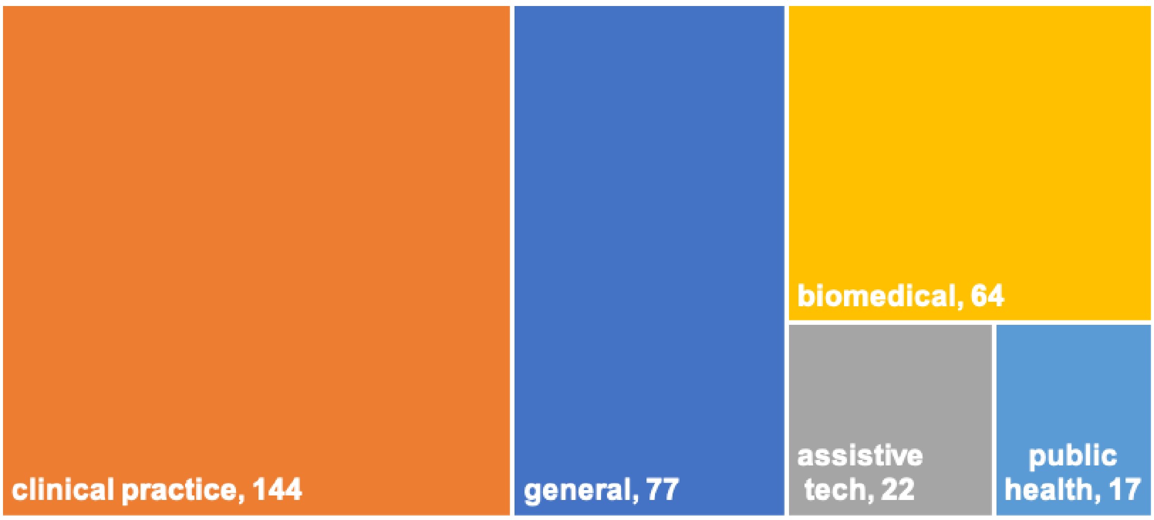
The application of AI in healthcare and clinical research is set to make substantial advancements in disease prevention, diagnostics, and treatment (EP/EPRS 2022b). AI technologies have the potential to enable early disease detection, tailor treatments to individual patients, and forecast risk factors and outcomes. They pave the way for precision or personalised medicine, that integrates multi-omics, phenotypic and health data. Moreover, AI plays a crucial role in supporting the entire lifecycle of medicines (EMA-HMA 2023), from drug discovery to clinical trials, as well as the monitoring of outbreaks and disease progression. Overall, recent years have seen a boom in AI-related biomedical science publications, exceeding 80,000 globally from 2017 to 2021. The US and China lead with over 18,000 publications each, followed by the EU with over 15,000 (Arranz et al., 2023a).

However, the broader implications of AI applications on individuals' physical and mental health, societal wellbeing, and environmental sustainability, including future generations, warrant further analysis (Gómez-González and Gómez 2023).

ERC-funded AI projects in this policy area (total of 238) mostly cover a wide range of themes (Fig.10) within **clinical practice**. These projects include automation of image analysis, diagnostic processes, risk prediction, and therapeutic support or decision making. Additionally, they address applications in surgery, mental health, and cancer research. A substantial number of projects is devoted to **biomedical research**, ranging from drug discovery, omics data processing, and personalised medicine. Some projects are classified as **general,** focusing on fundamental research. Finally, a subset of projects falls in the category of **assistive technology and robotics**, including healthcare monitoring and self-management, medical and surgery technologies, and **public health initiatives** such as digital epidemiological monitoring, disease prevalence assessment, and environmental and occupational health.

Figure 10: Number of ERC-funded AI projects contributing to health

A project may be relevant for more than one category.



Highlighted below are ERC-funded AI projects that illustrate the applications within this policy area and its respective categories.

- Depression affects around 40 million people in Europe, with many young people experiencing prolonged periods of depressive states. Led by Eiko Fried at Leiden University, WARN-D aims to develop a **personalised early warning system for depression** to identify young adults at risk and facilitate timely intervention. The project involves monitoring 2,000 students in the Netherlands over a two-years period, using smart-phone-based ecological momentary assessment (EMA) and smart-watch-based digital phenotype data to measure mood, anxiety, stress, impairment, sleep, and activity. The collected data will be used to build the prediction model WARN-D using state-of-the-art machine learning techniques. The project's outcomes may extend to personalised prediction for other conditions, such as post-traumatic stress disorder (PTSD) in military personnel, burnout in high-risk teachers, or manic episodes in bipolar disorders. Read more and visit the project's website.

- Disruptions, referred to as dysbiosis, in the **gut microbiome** can lead to conditions such as obesity, diabetes, inflammatory bowel disease, Crohn's disease, and cancer. Led by Eran Elinav at the Weizmann Institute of Science from 2014 to 2019, META-BIOME conducted ground-breaking research on molecular mechanisms driving such disruptions. The project's findings have paved the way for new microbiome-targeting treatments against chronic diseases. Elinav's significant contributions to microbiome research have been recognised through several prestigious awards, including the Rappaport prize (2015), the Levinson award (2016), Lindner award (2016), and the Landau prize (2018). In 2021, he was inducted into the American Academy of Microbiology. Additionally, in 2015, Elinav co-founded the startup/app DayTwo, which utilises a **machine learning algorithm to predict blood sugar response** based on each individual's microbiome analysis prior to eating. Read more here and here.

- Led by Valentina Cauda at the Polytechnic University of Turin, the AI CUrES Proof of Concept project focuses on the **early diagnosis of cancer metastases** though a real-time and predictive approach. The project aims to predict potential patient's outcomes and assist in the implementation of timely pre-emptive therapies. Nanosized agents will be employed to label extracellular vesicles (EVs) produced by tumours, and images of these EVs (collected via multi-modal bioimaging technology) will be analysed using AI algorithms. The objective is to predict the development of metastasis. The research builds upon previous research in nanomaterials for drug delivery, tumour cell targeting, and bioimaging, which were developed under the ERC Starting Grant Trojananohorse. Visit the project's website and the researcher's multidisciplinary lab.

- Automated decision-making has become instrumental in managing data and processing decisions. However, these automated decisions can involve biases or unfair. Led by Fosca Giannotti at the Scuola Normale Superiore, XAI seeks to address this challenge by developing methods for constructing **meaningful explanations of opaque AI/ML systems**. The primary goal of the project is to empower individuals to mitigate the undesired effects of automated decision-making by implementing the "right of explanation". This initiative aims to assist individuals in making informed decisions while preserving (and expanding) human autonomy. The project is conducting several case studies in explanation-by-design, mainly focused on **healthcare (AI-supported decision-making for clinicians)** and **fraud detection applications**. Read more and visit the project's website.

- Initiated in October 2022 and led by Johan Sundström at the Uppsala University, EmergAI is developing a **clinical decision support system for emergency medicine doctors**. The AI-driven algorithms will be trained on health data from up to six million patient visits to accident and emergency (A&E) departments. Data will include, for example, electrocardiograms (ECGs), reasons for visits, vital indicators, previous disease history and self-reported symptoms. The system will provide doctors with a probabilistic assessment of the most efficient diagnostic route based on standard triage practice. It will be validated in a randomised clinical trial in Hospital ER rooms in Sweden.

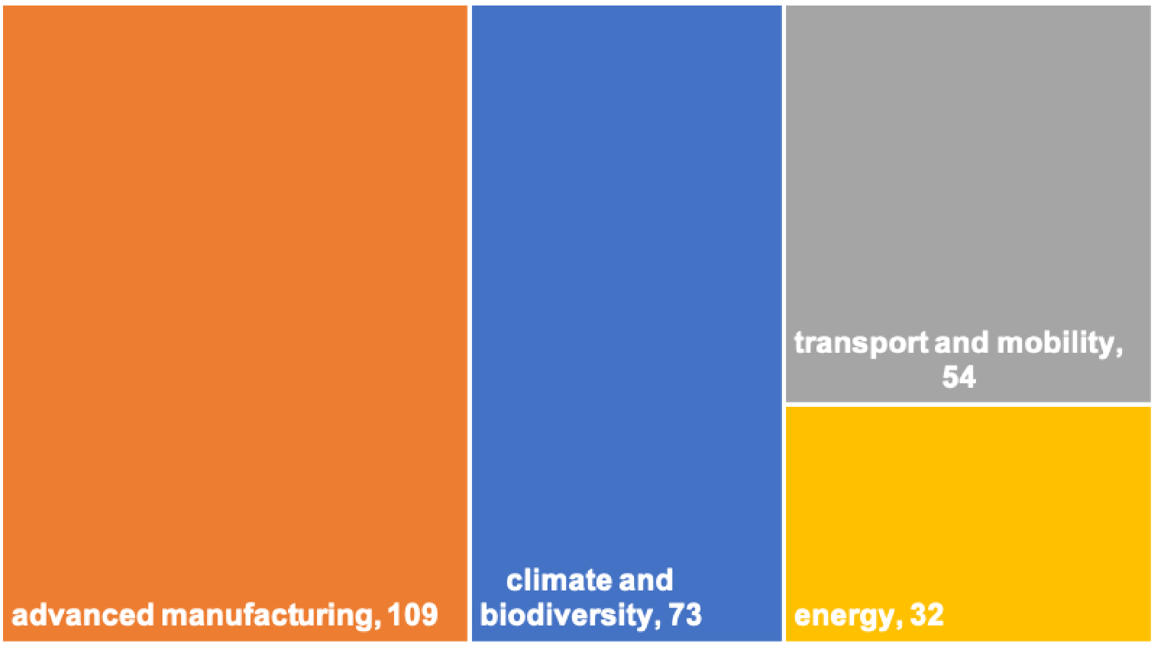
3.2 Green transition

AI is expected to play a crucial role in achieving carbon neutrality and facilitating the transition toward a fair and prosperous society, as outlined in the European Green Deal. Across various sectors (EP, 2021), AI is being widely applied for tasks such as monitoring and optimising energy consumption, controlling grid networks, and forecasting supply and demand. AI accelerates the design process for products, components, and materials with longer lifespans, while also enhancing our understanding of urban mobility patterns and improving traffic guidance systems. Furthermore, it contributes to environmental research by aiding in weather forecasting, climate modelling, and overall environmental management.

ERC-funded AI projects within this policy area (totalling 219) cover a diverse range of topics (Fig.11), with a significant focus on **advanced manufacturing, materials, and sensors.** These projects explore clean technology, resource-efficient solutions, smart manufacturing, and predictive maintenance. Many projects also focus on **climate action, environmental conservation, and biodiversity preservation**[7], conducting research on climate neutrality, emission reduction, pollution tracking, and ecosystem protection. Additionally, several projects in the **transport and mobility** sector dive into self-driving vehicles, sustainable transport, and smart mobility solutions. Finally, a few projects focus on **energy-related research**, including energy efficiency, security, performance, renewable energies, and energy market analysis.

Figure 11: Number of ERC-funded AI projects contributing to the green transition

A project may be relevant for more than one category.



Highlighted below are ERC-funded AI projects that serve as illustrative examples within this policy area and its respective categories.

- By combining neuroscience, mathematics, computer science, and engineering, the neuroP project led by Giacomo Indiveri at the University of Zurich from 2011 to 2017, designed new analog electronic circuits mimicking the functionality of real neurons and synapses. These circuits are used to build compact and **ultra-low power neuromorphic computing systems** tailored for autonomous sensory-motor agents. Indiveri's work led to the establishment of the startup aiCTX (SynSense since 2017), a leading commercial supplier of ultra-low-power brain-inspired AI processors and smart sensors. Applications include edge computing and Internet of Things devices, intelligent security, precision farming, autonomous driving, and drones. SynSense was listed in 2022 among the "50 Smart Companies" by MIT Technology Review, and in "Silicon 100" by EE TIMES, an annual list of electronics and semiconductor startups to watch.

- COeXISTENCE initiated in March 2023 and led by Rafal Kucharski at the Jagiellonian University, seeks to understand the **future of urban mobility.** The project will explore the implications of autonomous, intelligent robots into urban transport systems. By creating virtual environments, the project will simulate scenarios where human and deep learning agents compete for limited resources to reach destinations faster, more reliably, and at a lower cost. The project applies a multidisciplinary approach drawing from reinforcement learning, discrete choice theory, game theory, (social) equilibrium cooperative multi-agent systems, and urban mobility and traffic flow analysis. Visit the project's website.

- Led by Graeme Day at the University of Southampton, the ADAM project aims to change the way in which we discover new molecular materials for a wide range of fields, including healthcare, data storage, energy production and pollution control. The idea is to automate the **materials discovery process** as much as possible, freeing up researcher's time for exploring new ideas. The researchers are developing a computational brain that will control the **"robot chemists"** as well as provide the instructions to robots to test and find new properties. Visit the project's website.

- Led by Eleni Chatzi at ETH Zürich from 2018 to 2020, the WINDMIL RT-DT Proof-of-Concept project designed a real-time monitoring and diagnostics platform for the **operation and maintenance of wind turbines** (WT), both onshore and offshore. The autonomous RT-DT platform runs WT telemetry data through a machine learning based algorithm in real-time for detecting faults, errors, damage patterns, anomalies and abnormal operation. It developed from the ERC Starting Grant WINDMIL, which established a smart framework for the monitoring, inspection and life-cycle assessment of WTs, able to guide WT operators in the management of these assets from cradle-to-grave. Read more about the PoC project, and the previous project.

- Biodiversity is declining globally at an unprecedented rate. Representing around 30% of the biodiversity hotspots, islands are particularly vulnerable. To understand the **complexity of the ecological interactions on islands**, IslandLife, initiated in November 2022 and led by Anna Traveset at the Spanish National Research Council, focuses on five archipelagos, encompassing four oceans. For the first time, the team compares the food web structure of 'pristine' (little-disturbed) islands with areas of similar size in nearby disturbed (human-inhabited) islands. They are combining direct observations during fieldwork, automated-video monitoring and deep-learning, and cutting-edge molecular techniques to detect trophic interactions. Read more and watch the documentary film about the researcher's expeditions to islands around the world.

3.3 Agrifood and ecosystems

AI could enable automation and optimisation of processes for more sustainable agriculture and food systems[8] and use of key natural resources (soils, plants, but also forestry, fisheries and oceans). In close complementarity with the previous section, such systems are essential for the link between healthy people, healthy societies, and a healthy planet at the core of the European Green Deal. Intensive data collection via autonomous sensors and large-scale AI processing of diverse data can support the **management of complex land and water ecosystems**, for instance in relation environmental changes, resource availability, demography, and consumption patterns. Such tools can monitor the **quality and safety of agricultural products, plant health and animal health**, and help to move into precision agriculture in field crops, animal production or automated greenhouse production (EP/EPRS 2023a).

Within this policy area, the portfolio of ERC-funded AI projects (total of 46) contributes to a wide range of themes, for example via **models of land degradation and land use** by cross-linking AI-based geospatial data with population census data, or exploration of land-based adaptation practices designed to mitigate heat episodes. Several projects lie at the **intersection of evolution and ecology** by reconstructing species interactions in local habitats, current and past, while others are developing new models of distributed intelligent systems in new bio-machine environments. Other projects are looking into **personalised nutrition** by optimising health-promoting molecular profiles of foods, or by allowing for intelligent mobile logging of stress and eating behaviour.

Highlighted below are ERC-funded AI projects that serve as illustrative examples in this policy area:

- Most of our diets is based on fruits, vegetables, and animals that depend on **pollination**. Led by Mathieu Lihoreau at the French National Centre for Scientific Research (CNRS), BEE-MOVE monitors the **spatial movement patterns of bees** and experimentally study their consequences on plant reproduction. A new radar system records and analyses the individual movements of hundreds of bees foraging simultaneously. Radars and robotic plants will be used to study how bees search and exploit food resources. This information will be applied to computational agent-based models to investigate the influence of bee spatial strategies on pollination efficiency. The results will inform the design of practical interventions for conservation, sustainable agriculture, and green development to help stem pollinator decline. Read more and visit the project's webpage.

- Led by Rupert Seidl at the Technical University of Munich, FORWARD sheds light on the **causes and consequences of reorganisation in forest ecosystems** on three continents. It investigates why reorganisation takes place, when and where reorganisation is likely to happen, and what impacts reorganisation has on biodiversity and ecosystem services. A next-generation forest landscape model iLand 2.0 is used to investigate how climate change and alien species alter long-term forest dynamics. A map of global hotspots of forest reorganisation will be created using a machine learning synthesis of big data sets. In 2020, Seidl was among the 1% most cited scientists in the field and was listed in the top 100 of Reuters' list of the 1000 most influential climate scientists.

- The ocean's biological carbon pump plays a crucial role in storing atmospheric carbon dioxide in the deep ocean. Led by Griet Neukermans at the University of Ghent, CarbOcean intends to gain a better understanding of the workings of this pump by integrating new observations of carbon carried by microscopic particles in the ocean with biogeochemical modelling. The researchers will develop an **autonomous robotic ocean profiler** to simultaneously observe fluxes of particulate organic carbon (POC) and particulate inorganic carbon (PIC). The IP for the PIC autonomous sensor has been patented. The testing of this technology in a real-world environment will take place in a research vessel in May/June 2024 in Icelandic waters. Visit the project's webpage.

3.4 Democracy

AI holds the potential to enhance the democratic process in our societies, as shown in a recent ERC Mapping Frontier Research report[9]. For example, political recommender systems facilitate citizens' understanding of policy issues, while AI tools could provide concise summaries of complex topics. Additionally, AI could manage political forums in chat rooms or online events, categorise and process feedback, and generate personalised responses from politicians to citizens (EP/EPRS 2023b). Yet, AI technologies also pose heightened risks to democracies, for example by propelling **disinformation** and fake news, **hate speech**, **foreign information manipulation and interference**, or **synthetic content** on online platforms.

There is a growing focus on to the interaction of AI and democracy, as seen for example in the AI Act (and its reference to AI systems used to influence the outcome of elections and voter behaviour, or generated content such as deepfakes), or a recent Commission's public consultation on draft Digital Services Act (DSA) guidelines for election integrity, or other initiatives such as the Regulation on transparency of political advertising, the strengthened Code of Practice on Disinformation and the Commission's recommendation to promote free, fair and resilient elections.

ERC-funded AI projects in this policy area (total of 47) address these opportunities and challenges, with perspectives across scientific domains and varied themes. Some projects study AI within **general trends in democracy**, with particular focus on **social media platforms**, **search engines and ad platforms** for instance on content moderation, recommender systems and other targeted information. Projects also look in the **effects on public sphere and discourse** of automated or AI powered tools, including filter bubbles or echo chambers, coupled with propagation of disinformation and fake news. Other projects study more closely the influence of AI in **election campaigns and voting**, namely analysis of voting patterns, microtargeting, social or chatbots, or deepfakes (images, videos, etc.)

Highlighted below are ERC projects that serve as illustrative examples in this policy area:

- Through **online advertising platforms,** third parties can pay to show specific information to particular groups of people through targeted ads. Many fear the risks of such technologies to engineer polarisation or manipulate voters. Initiated in October 2022 and led by Oana Goga at the French National Centre for Scientific Research (CNRS), MOMENTOUS studies the risks of AI-driven information targeting by employing randomized controlled trials in social media. It is looking into its potential influence on an individual's beliefs. It will also study the capability of AI-driven algorithms to exploit users' vulnerabilities and the quality of the received information. The project will propose efficient protection methods and technologies for users, groups and platforms. In October 2023, Goga received the Lovelace-Babbage Award from the French Academy of Science and the French Computer Society. Visit her website.

- The expanded reach of the internet and media have made it necessary to quickly and easily verify facts online. However, automatic fact checking methods often use opaque deep neural network models, whose inner workings cannot easily be explained. ExplainYourself, initiated in September 2023 led by Isabelle Augenstein at Copenhagen University, studies **explainable automatic fact checking**, the task of automatically predicting the veracity of textual claims using machine learning methods, while also producing explanations about how the model arrived at the prediction. It is expected that the project's innovative work will apply to explanation generation for other knowledge-intensive natural language understanding (NLU tasks), such as question answering or entity linking. Visit the researcher's website.

- Led by Camille Roth at the French National Centre for Scientific Research (CNRS), SOCSEMICS studies so-called **"echo chambers" or "bubbles"** in the digital public space. In such communities, actors are more or less open to interaction and information coming from "outside". The project will develop a comprehensive theory of reinforcing and self-sustaining socio-semantic communities. It will focus on automated analysis of not only what is being talked about, but what is being actually said by whom in what context. Case studies were or will be conducted, for instance the European Elections in 2019 or debates around the sanitary crisis in 2020, in English-, French-, German- and Italian-speaking portions of Twitter. The project already led to the creation of the graphbrain subproject, a natural language processing (NLP) open-source platform. Visit the project's website.

3.5 Justice and law

AI is increasingly used by public administrations, governments and other bodies to provide their services or run internal processes, ranging from **justice and courts**, management of **public benefits**, up to **law enforcement and policing**. For instance, AI can speed up access and reuse of case law by organising files and summarising information or help to anonymise or pseudonymise judicial documents. It can also support the monitoring and identification of criminal activities across jurisdictions and platforms. However, the breadth and scope of such activities have raised some concerns, namely when applying predictive analytics for scoring and classifying human behaviours, ranging from recidivism risk estimation and predictive policing to credit scoring and profiling welfare recipients.

In this policy area ERC-funded AI projects (total of 43) cover a range of these topics while also looking in the potential effects on the principles of fairness, discrimination and the rule of law in general. Several projects study the sensitive implications of **automated rating systems** ranging from **credit assignment and scoring**, processing of legal and forensic evidence and **crime analytics**, up to **recidivism prediction** and **predictive justice**. Other projects are developing or studying AI technologies for biometric authentication, which can be potentially applied to monitor social media for malicious activities or threats, to police crowded places and border controls, or to support internet security and counter-terrorism activities.

Highlighted below are ERC-funded AI projects that serve as illustrative examples in this policy area:

- Recent advances in digital forecasting claim to provide a predictive score for individual persons or singular events. Led by Elena Esposito at Bielefeld University, PREDICT is developing a comprehensive approach to study the social, technical, and theoretical aspects of prediction in digital society. It focuses on three social areas – **personalised insurance, precision medicine and predictive policing**. In the field of insurance, it is looking into how individualised risk forecasting can affect the business model and the social role of insurance. In the medical field, the team is investigating how medical practice can manage the combination of statistical methods and algorithmic prediction. In the field of crime prevention, the analysis is focusing on how information about future crimes can affect preventive and repressive activity by the police. Visit the project's website.

- AI is applied increasingly in courts and informal arenas, replacing judges and mediators, as well as supporting and predicting judicial outcomes. Such developments are called **dispute resolution automation** (DRA). DRA led by Orna Rabinovich-Einy at the University of Haifa, aims to develop a new theory of access to justice (barriers), procedural justice (perceived fairness) and substantive justice (just outcomes) for DRA. The team will (1) develop a normative framework for just DRA, (2) conduct empirical study in France, the Netherlands, the U.S. and Israel, lab experiments, and interviews with designers and users of DRA; (3) generate a typology for the design of just automated processes and devise procedural rules for the adoption of DRA in courts, and (4) develop novel methods for its evaluation.

- Led by Mireille Hildebrandt at Vrije Universiteit Brussels (VUB), CoHuBiCoL investigates how counting and computation transforms many of the assumptions, operations and outcomes of the law. It targets two types of **computational law (and their hybrids)**: the use of natural language processing for legal search and quantified legal prediction (data-driven law), and the use of dedicated software to represent or enact legislation or regulation, to support and potentially automate legal decision making (code-driven law). The project is exploring novel relationships between law and computer science. It made available online a typology of 'legal tech', with various filters to obtain an overview of different types of technologies, including legal search engines, prediction of judgments, argumentation mining, rules as code technologies etc. Visit the project's website.

3.6 Workplace and employment

AI technologies may greatly affect the nature of work and employment, with potential significant implications for jobs, productivity, and worker well-being (OECD 2023b). As it diffuses across sectors, AI is furthering the automation of routine and non-routine tasks, from information retrieval used to power chatbots up to AI support to writing code. It is also increasingly used in labour market matching, including writing job descriptions, applicant sourcing, analysing CVs, shortlisting tools, or facial and voice analysis during interviews (OECD 2023a). On the one hand, opportunities are related to more efficiency, cost savings, or reduction of tedious tasks. But on the other hand, the use of AI in the workplace brings about concerns about more surveillance, dehumanising of work, and ethical issues such as privacy, fairness, and discrimination (OECD 2022b).

ERC-funded AI projects within this policy area (total of 37) cover a range of themes, from general trends in work, employment, and jobs, up to concrete uses of AI for **hiring and labour market matching**, for instance for recruitment or selection, screening, or filtering applications, or evaluating candidates. A few projects study the effects of **workers' management and monitoring**, for instance for task allocation, evaluation of performance, impacts on well-being, among others. A few other projects focus on the **platform and gig economy** and its recent impacts on labour and employment.

Highlighted below are ERC-funded AI projects that serve as illustrative examples in this policy area:

- AI depends on human labour to conduct tasks such as data cleaning, coding, and classifying content. This on-demand work is offered and performed online, paid by the task, on platforms like Amazon Mechanical Turk. This so-called 'ghost work' is rapidly growing but is largely unseen: workers are unable to speak with managers, do not get feedback, and lack labour protections. Led by Claartje ter Hoeven at Erasmus University Rotterdam, GHOSTWORK is conducting an in-depth study of **ghost workers' working conditions** and how these impact their overall well-being. The team is conducting in-depth interview-based fieldwork and qualitative diary studies of the short-term dynamics of ghost work. A 4-wave longitudinal panel study is also investigating the relationship between ghost work and well-being over time. Visit the project's website.

- **Algorithmic management** is on the rise, leading to increased reliance on monitoring technology and sophisticated algorithms to measure, control, and sanction workers. Led by Jeremias Adams-Prassl at the University of Oxford, iManage is developing the first systematic account of algorithmic management, examine its implications for legal regulation of labour markets, and developing concrete solutions. The team has devised a blueprint for regulation, including specific strategies to tackle regulatory gaps such as increased privacy harms and the demise of managerial agency. They have engaged with policy makers from the United States (EEOC) and Europe (incl. MEPs and representatives of the European Commission). Visit the project's website.

- Employment agencies and HR companies are increasingly using AI methods to ensure the best **match between jobs and employees**, provide workers with career prospects and job satisfaction, and maximize productivity. Building upon the results from the previous ERC Consolidator project FORSIED, the FEAST Proof of Concept led by Tijl De Bie at the University of Ghent, developed a platform utilising AI technology that gathers all relevant entities in the job market: jobs, job seekers, skills and competences, training courses, among others. This platform enables the development of specific services such as job matching, identifying skills gaps, giving curriculum advice, identifying new and emerging skills in the job market, and HR strategy and recruitment tools.

3.7 Education

In the area of education, AI is promising to bring about novel ways of resource management, teaching, learning and skills development for educators and students. Most of the recent focus is on AI systems becoming 'smart companions', 'learning partners' or 'cognitive tools' to support the development of capabilities for learning (Tuomi et. al. 2023). 'Intelligent', 'adaptive' and 'personalised' tutoring systems are increasingly being deployed in schools and universities around the world, creating a market expected to be worth US$6 billion in 2024 (UNESCO, 2021, p.5). However, challenges such as potentially widening of digital divide, profound changes in the development of human skills, and ethical responsibility and privacy concerns are also associated with AI in education.

Most of the ERC-funded AI projects with a focus on education (total of 34) are within **AI for learning and assessment**. These projects primarily focus on AI-enabled adaptive and personalised tools (such as 'intelligence tutoring systems'). They aim to adjust the content and pace of learning for individuals based their strengths and weaknesses, with varying degrees of automation and collaboration. Other ERC projects focus on exploring the opportunities and challenges presented by AI in education, particularly for the **development of skills (mathematical, music, and others), pedagogical innovation, or enhanced accessibility**. A few projects tackle the challenges of **empowering teachers and enhancing teaching** by helping to automate certain tasks such as selection of content, assessment, plagiarism detection, and feedback. Finally, only a few ERC projects focus on **education management and delivery**, where AI-based analytics can inform university admissions, the assignment of teachers to classrooms, or the design of school choice matching markets.

Highlighted below are ERC-funded AI projects that serve as illustrative examples in this policy area:

- Led by Inge Molenaar at Radboud University, HHAIR studies Hybrid Human-AI Regulation (HHAIR) to enhance learners' **Self-Regulated Learning (SRL) skills** while using Adaptive Learning Technologies (ALTs). It focuses on young learners (10-14 years), many of whom already use ALTs to learn mathematics and languages in school. ALTs adapt the materials based on the students' learning performance but cannot offer them the option to adjust the level of the teaching materials. The HHAIR system first provides students with insight into how AI is influencing their learning process and will gradually transfer the responsibility for the regulation of the learning process to the student. The project will develop the first hybrid systems to train human SRL skills with AI.

- Led by Bob Sturm at KTH Royal Institute of Technology, MUSAiC sits at the frontier of AI and music. It studies the impacts and ethical issues surrounding AI in three interrelated music practices: 1) listening, 2) composition and performance, and 3) analysis and criticism. The project is implementing the **first music pedagogy for AI**. It is testing novel AI systems that dynamically adapt to specific users as "digital apprentices", thus further developing human-AI music partnerships. The aim is not only to prepare music practitioners and audiences of the present (human and artificial) for new ways of listening and developing the art form, but also pave the way for analysing and broadening the AI transformation of the other arts. Visit the project's website.

- Computational thinking and problem-solving skills are seen as essential for both students to excel in STEM+Computing fields and for adults to thrive in the digital economy. Educators are putting increasing emphasis on pedagogical tasks in open-ended domains such as programming, conceptual puzzles, and virtual reality environments. Led by Adish Singla at Max Planck Society for the Advancement of Science, TOPS is developing next-generation technology for **machine-assisted teaching in open-ended domains**. The team is designing novel algorithms for assisting the learner by bridging reinforcement learning, imitation learning, cognitive science, and symbolic reasoning. Its computational framework will model the learner as a reinforcement learning agent who gains mastery with the assistance of an automated teacher.

4. Addressing the ethics of AI

Ethical values and principles underpin reflections on the responsible development and use of AI. They serve as the foundation for existing guidance instruments at both the European and international level, including the Ethics Guidelines for Trustworthy AI, UNESCO Recommendation on the Ethics of AI, industry codes of conduct, among others. These frameworks' aim is to realise the full potential of AI while mitigating the risk of harm and misuse.

At the level of EU-funded research, these reflections are translated into ethical guidelines focusing on the development, deployment and use of AI. These guidelines are outlined in specific sections of documents such as "How to complete your ethics self-assessment" or in the guidelines on "Ethics By Design and Ethics of Use Approaches for AI"[10]. As a general principle, these guidelines recommend incorporating ethical principles into the development process as early as possible and tailor them to the specific use case or nature of the AI application.

This section presents examples from ERC-funded projects that raise pressing **ethical, legal and social questions** regarding the development or use of AI (Fig.12), as outlined in Annex I - Methodology. The **ethical sensitivity** of research activities involving AI largely hinges on the risk of causing individual or collective harm. Such risks depend on factors such as:

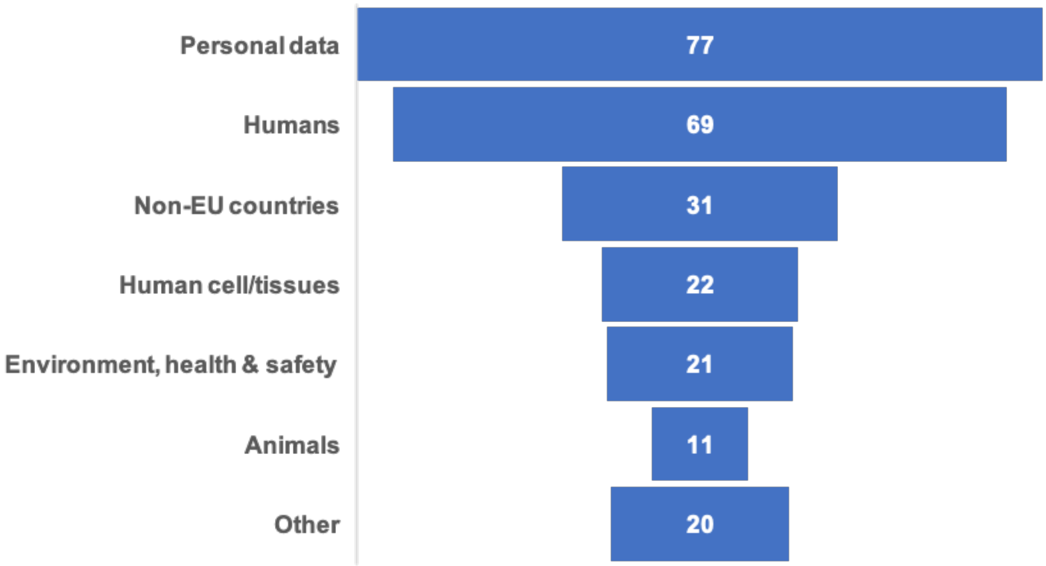
- the **domain of application**,
- the level of **technological readiness**,
- the level of **human agency and oversight**,
- the technical **robustness and safety** of the system,
- and the existence of adequate mechanisms to protect **privacy**, to ensure **transparency** and to establish clear **accountability**.

Some contextual factors can heighten the sensitivity of ethical considerations, such as the involvement of patients or other vulnerable groups (e.g., children), the use of sensitive data, or the application of AI technology in high-risk domains.

The **use of personal data** exemplifies the need to assess varying levels of sensitivity depending on the specific research context. Given that AI technologies rely on substantial data sets, concerns regarding privacy, confidentiality, and the protection of data subjects' rights were prevalent across many ERC projects using AI technologies (77 of the 92 sensitive use cases of AI).

The sensitivity of personal data collection and processing varied greatly, primarily contingent upon the intended purpose of AI practices and the potential risk of harm. Additionally, it was influenced by the type of personal data being processed, and the measures in place to safeguard the rights and freedoms of data subjects. These measures also included efforts to identify and mitigate biases in training data and results.

Figure 12: Overview of ethics issues in ERC-funded AI projects with higher sensitivity



In the portfolio of ERC projects under analysis, cases involving AI for data mining, computer-assisted analysis, statistical modelling or the development of new computational tools were associated with a low sensitivity and were excluded from further analysis. Conversely, other cases presented higher risks and raised serious ethical concerns, as illustrated by the examples described below:

- **Precision medicine**: uses large amounts of sensitive, health data to enable the personalisation of treatments or the early risk prediction of a disease through improved diagnostics. The collection and processing of **genetic** or **genomic data** may expose individuals (but also their biological relatives) to a high risk of re-identification. It can also entail the risk of incidental findings with life-changing consequences. Of particular concern are research activities coupling the processing of genetic or genomic data with interventions in or on the human body (implants, drugs, etc.), which may have long-term or irreversible physical or psychological effects.

- **Misrepresentation**: this issue was frequently identified in **surveillance tools,** such as smart policing systems. However, it was also present in medical studies. For instance, when training data are collected from a group of patients or healthy individuals, there is a risk of comparing results against a biased norm. This risk was also identified in studies where information about individuals was categorised based on **training data likely to entail bias**, for example in terms of gender, age, social or ethnical diversity.

- **Automated classification**: especially when its outcome could have a significant impact on individuals' fundamental rights and freedoms, such as the right to health, education, but also fundamental rights such as impartial judgment, equality, and fair treatment. For instance, research using automated classification systems (using sensitive personal data on health, ethnicity, political opinion or sexual orientation) may lead to long-lasting impacts on the life of concerned individuals, beyond the scope of the research activity and consent.

- **AI-powered surveillance tools**: includes examples such as **biometric technology** (e.g. facial recognition systems) and **smart policing systems**, but also **tracking tools** to collect sensitive data over long periods of time (e.g. collection of geolocation data, voice recordings, health or behavioural data via wearable devices or mobile apps). The granularity of information entails risks of violating the privacy of individuals (e.g. when scraping information from social media platforms without consent). Visual AI systems for autonomous vehicles or social robots could also enable the collection of information from individuals who are neither aware nor consenting to such activities.

- **Security implications**: examples include machine learning applications for debiasing statistical outputs or to find flaws in IT systems. While promising for the development of trustworthy AI, this strand of research is particularly sensitive for its potential to generate knowledge and technologies for criminal or terrorist activities. Certain safeguards may be considered, such as restricting the disclosure of findings (e.g. limitation of the level of detail, publishing only part of the research results, security clearance for those involved in the project, compulsory safety training for staff, etc.).

In a nutshell

This report presents an overview of ERC-funded AI projects, as well as how curiosity-driven research funded by the ERC contributes to policies aimed at making the EU a world-class reference for human-centric and trustworthy AI. The portfolio identifies 1,048 projects that are developing AI technologies, using or applying AI, or studying its impact and effects, or a combination. With a total budget of EUR 2.010 bn, the porfolio covers projects funded from 2007 up to 2022 from all ERC scientific domains as well as all ERC grant schemes (Starting, Consolidator, Advanced, Synergy, and Proof of Concept).

Overall, the **share of ERC-funded AI projects amounts to 7%**. However, when looking at its evolution per year, there was a strong increase after 2015. The share of ERC-funded AI projects exceeded 10% each year, with a peak of almost 15% in 2021.

The **scientific landscape** presented in this report shows that, while most of the projects are within Physical Sciences and Engineering (543, in absolute numbers), projects in the Social Sciences and Humanities are closely balanced (9% in terms of total share of projects per domain, compared with 8,4% from Physical Sciences and Engineering). Within the scientific domains (and corresponding to the ERC evaluation panels), most Physical Sciences and Engineering projects are in computer science and informatics. In Social Sciences and Humanities, most projects focus on the human mind, coming from cognitive science, psychology, and linguistics. Within Life Sciences, projects mainly focus on research areas such as neuroscience and disorders of the nervous system, as well as prevention, diagnosis, and treatment of human diseases.

The **policy landscape** showcases relevant ERC-funded AI projects to a selection of policy areas, ranging from concrete case studies and applications, up to potential future developments. A substantial number of projects were identified in the broad policy areas of **health** (238 projects) and **green transition** (219 projects). In health, projects are conducting fundamental and applied research within clinical practice. This includes automation of diagnostics, risk prediction, and other areas. Additionally, projects focus on biomedical research, such as drug discovery, processing of omics data, and personalised medicine. As for the green transition, there is a broad spectrum of projects within advanced manufacturing and materials, climate action, environment and biodiversity, transport and mobility, and energy. Other policy areas - **agrifood and ecosystems, education, workplace and employment, justice and law, and democracy –** are also well-represented in the portfolio of ERC-funded AI projects.

Finally, the report provides an analysis of **key ethics issues** raised by ERC-funded AI projects, as well as their varying levels of sensitivity depending on the specific research context.

Throughout both the scientific and policy landscapes, the report **highlights examples** of completed and ongoing ERC projects. These projects are either developing or using AI in their scientific processes. They also produce models, methods, tools and assessments available to researchers and policy makers. This report represents a first analysis of the ERC's funding portfolio on AI and will be followed by further in-depth studies in specific domains.

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Annex I - Methodology

Our portfolio analysis was built through several stages and tools:

- A comprehensive list of **14,829 ERC projects, as of 31 March 2023**, was extracted from the Commission's internal CORDA database. This list spans all ERC scientific domains covering projects funded under the FP7, Horizon 2020, and Horizon Europe framework programmes, as well as all ERC grant schemes (Starting, Consolidator, Advanced, Synergy and Proof of Concept). To be noted there were no PoC 2021 and SyG 2021 calls (due to the transition from the 2014-2020 Framework Programme for Research and Innovation to the 2021-2027 Framework Programme).
- To identify projects related to AI, a keyword search was performed on projects' titles, abstracts and keywords, resulting in approximately 1,453 projects. The set of keywords and phrases used to identify ERC-funded AI projects was primarily based on the work developed by OECD (Baruffaldi et al. 2020, OECD 2022a) and Australia's National Science Agency CSIRO (Hajkowicz et al. 2022), which was conducted for bibliometric analysis of AI patents and scholarly publications.
- Additional ERC-funded AI projects were identified through insights from ERCEA Scientific and Ethics Officers and the internal ERCEA classification exercise Mapping Frontier Research (MFR), which included policy factsheets on ERC frontier research contribution to the European Green Deal, Europe fit for a digital age, and EU4Health. A re-check through analysis of abstracts, reporting and results (CORDIS), along with grant agreement information (CORTEX), **grant status as of 21 September 2023**, resulted in a **consolidated list of 1,048 projects**.
- Within this identified list, a **keyword search was conducted in a subset of policy areas: health, green transition, agrifood and other ecosystems, democracy, justice and law, workplace and employment, and education**. The areas and relevant keywords were selected through a policy scoping at European and international level (relevant documents included in the references) and are indicative of key present debates (although not exhaustive). All projects were manually linked to policy areas or labelled as contributing to knowledge and solutions in other areas, based on the information available in the projects abstracts, grant agreements, and results.
- As for the exploration of **ethics issues related to AI**, the analysis focused only on projects funded by the ERC under Horizon Europe (2021-2022) when the systematic review of ethics issues pertaining to the development or use of AI was first introduced. The analysis was based on information extracted from the Ethics Summary Reports compiled by ethics experts and shared with ERC beneficiaries before the beginning of research activities. Serious and/or complex ethics issues[11] pertaining to AI were identified in 92 projects. Ethics issues raised by research activities can be considered as serious or complex when they have the potential to violate fundamental rights, to result in significant harm or to call into question the integrity of the proposed activities. Complexity may also be related to technologies that have not been sufficiently tested, or raise ethics issues at scale, or raise multiple, intersectional ethics issues.

As a final remark, the report highlights a number of ERC projects in each section to illustrate the specific issues or areas under focus. The selection was based on several factors, including high relevance to the topic, recommendations from ERCEA Scientific and Ethics Officers, insights from qualitative evaluation studies of completed projects, and comprehensive overview of domains and organisations.

Endnotes

1 - To note that our analysis covered only the first two years of Horizon Europe (2021 and 2022).

2 - The evaluation of applications to ERC grants is conducted by peer review panels organised in three domains: Life Sciences (LS), Physical sciences and engineering (PE) and Social sciences and humanities (SH) described in ERC panel structure: https://erc.europa.eu/sites/default/files/2023-03/ERC_panel_structure_2024_calls.pdf

3 - To note that projects from 2022 ERC calls were not included for the analysis of the year-on-year evolution due to the need to recheck the final grant status of such projects (that could not be included in the current analysis as of 21 September 2023).

4 - To note that projects from 2022 ERC calls were not included for the analysis of the incidence per domain per year due to the need to recheck the final grant status of such projects (that could not be included in the current analysis as of 21 September 2023).

5 - To note that FP7, PoC and 2022 calls are not included.

6 - Also to note that the AI Act will not be applied to any research, testing and development regarding AI systems or models prior to being placed on the market or put into service.

7 - Additional insights can be found in the Mapping ERC Frontier Research report on Sustainable food production and consumption (prepared as input to the scientific opinion of the European Commission's Group of Chief Scientific Advisors (GCSA), which highlighted around 100 ERC-funded projects relevant to the Food 2030 strategy objectives.

8 - Broader insights on biodiversity can be found in the Mapping ERC Frontier Research report on Biodiversity, which showcased 230 projects and their links to EU Biodiversity Strategy 2030.

9 - The topic of democracy is the focus of the recent Mapping ERC Frontier Research report on Democracy: Confronting Challenges and Building Resilience.

10 - The European Commission will also publish additional guidance notes on AI ethics in research for applicants and beneficiaries of Horizon Europe in areas like informed consent, explainable AI, AI bias, and ethics audits.

11 - For a definition of complex and serious ethics issues in research, see the Horizon Europe guidance document "Identifying serious and complex ethics issues in EU-funded research".

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