
# Generative AI and foundation models in the EU: Uptake, opportunities, challenges, and a way forward

STUDY

European Economic
and Social Committee

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and Social Committee

# Generative AI and foundation models in the EU: Uptake, opportunities, challenges, and a way forward

## Final Report

## General information

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## Abstract

This report examines the burgeoning generative artificial intelligence (GenAI) and foundation models landscape within the European Union, and analyses its impact, technological advancements, and regulatory implications. It details the GenAI value chain, identifying key players and investment trends, revealing a significant US dominance. The report then explores GenAI applications across various sectors (automotive, renewable energy, and education), highlighting opportunities and challenges. A SWOT analysis assesses the EU's position as a producer and as a user of GenAI. The report concludes with policy recommendations for fostering a competitive, ethical, and inclusive European AI ecosystem, including identifying needs for increased investment, more skills development, and greater regulatory clarity, as well as a need for enhanced collaboration with civil society organisations.

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## Executive Summary

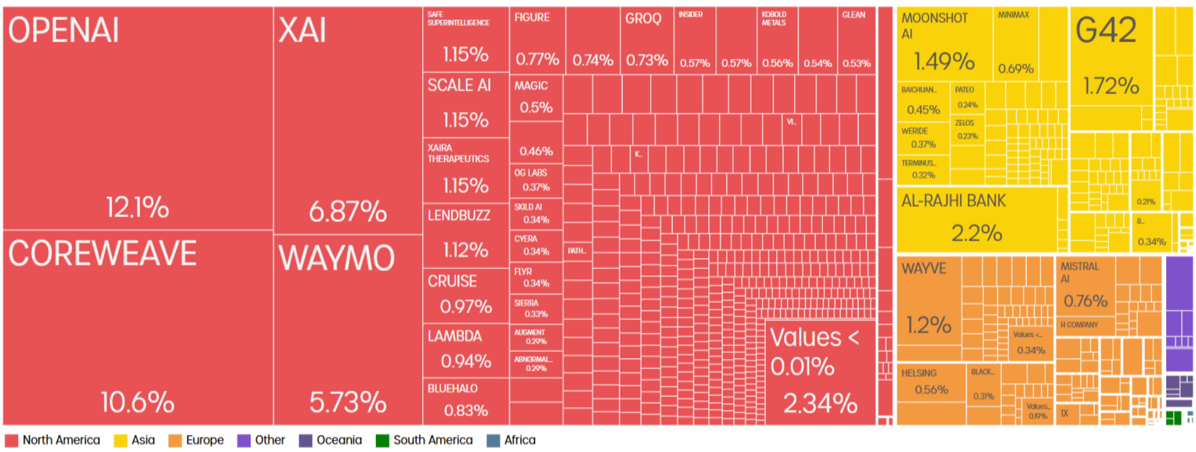
### Creating a unified AI terminology

As generative AI (GenAI) applications (such as ChatGPT and DALL-E) rapidly advance, they are transforming industries and redefining societal interactions. Therefore, there is a need to clarify essential terminology by establishing a common language which is key for effective communication among policymakers, developers and users. Understanding the distinctions between GenAI (focused on creating text, images, or other content) and foundation models (also called 'General-Purpose AI' – broadly trained systems adaptable to tasks beyond generation, such as translation and decision-making) is not merely an academic exercise; it directly influences how technologies are developed, regulated, and applied in various sectors. Misconceptions persist — equating GenAI with AI as a whole, or viewing tools like ChatGPT as representative of all GenAI, risks misaligned regulations and applications. Clarity in definitions ensures that technologies are developed, governed, and deployed effectively across sectors. For instance, foundation models underpin diverse applications, from healthcare diagnostics to financial forecasting, underscoring their broader utility compared to GenAI's content-centric focus.

### Dominance and dependency in the market for AI capabilities

The GenAI market is marked by stark imbalances. US companies dominate, securing over 80% of global funding across all the categories of GenAI value chain – from infrastructure to downstream deployment. At the same time EU entities have struggled to compete, raising concerns about market diversity and about Europe's technological sovereignty.

*Figure 1. Global distribution of Private GenAI investment recipients: 2018-2024.*



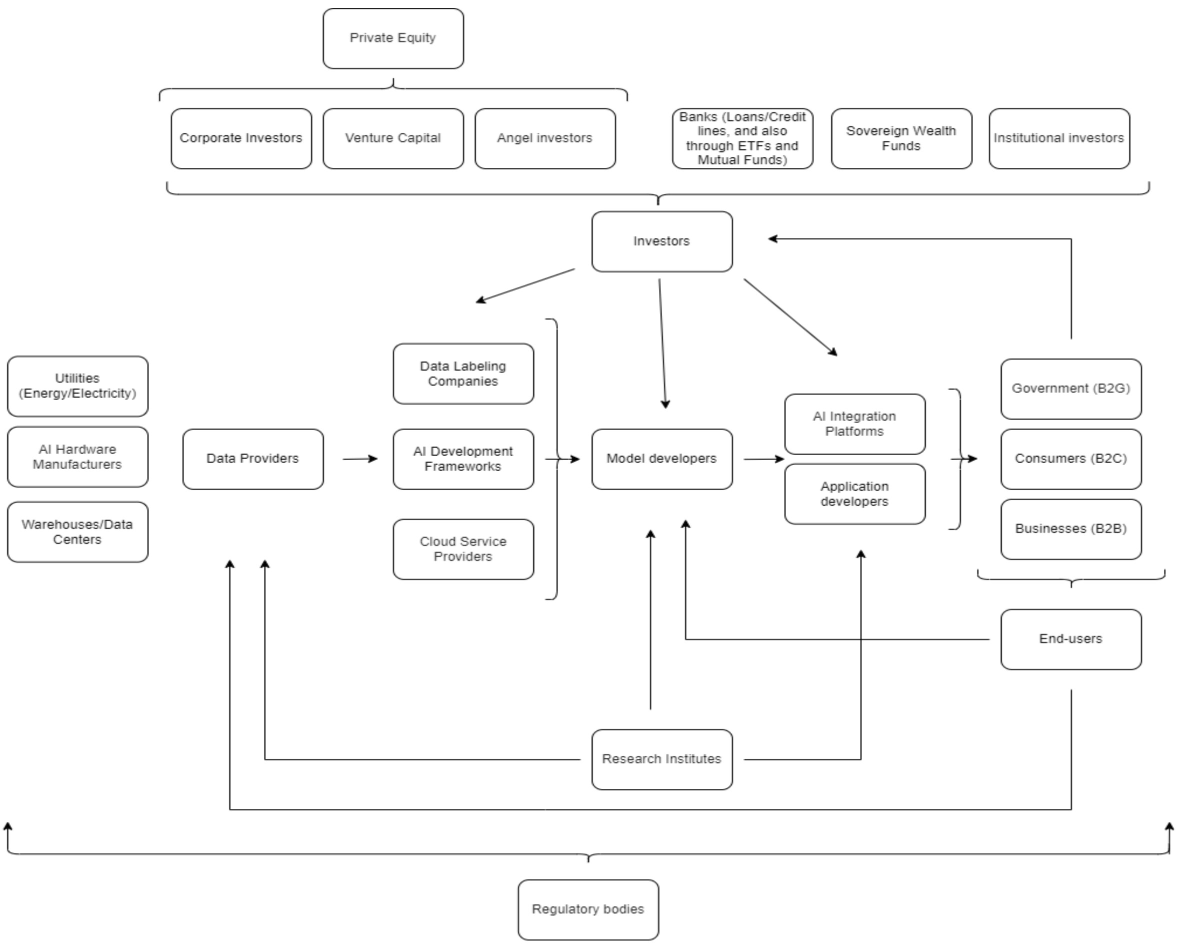

*Source: AI World, based on data from Crunchbase*

China's recent strides — such as its open-source r1 model, rivalling OpenAI at lower cost — add urgency for the EU to accelerate its AI ambitions; at the same time, they suggest that the EU might be able to follow a path similar to that of DeepSeek in order to overcome its substantial shortfalls in computing capacity and risk capital relative to the United States. Strategic initiatives like the EU's €2.1 billion AI Factories program pale in comparison with America's $500 billion Stargate Project. Addressing this critical funding gap requires bold steps: scaling up investments, streamlining cross-border collaboration within the EU and including the UK, and reducing reliance on non-EU tech giants.

## The value chain of GenAI in the EU

The GenAI value chain spans hardware, data infrastructure, model development, and application layers. A concerning trend is the vertical integration by global tech firms (e.g., Meta, Google, Microsoft with its partnership with OpenAI) which consolidates control over multiple stages of the chain, creating "one-stop-shop" ecosystems. While this boosts efficiency, it risks stifling competition and sidelining specialised EU startups. The EU must balance policies to encourage both integrated solutions and niche innovations, particularly in sectors like renewable energy and autonomous vehicles, where domain-specific expertise is irreplaceable. For example, Poland's emergence as the world's second-largest lithium-ion battery producer underscores the potential for strategic specialisation, but such successes require targeted support to thrive amid global competition.

*Figure 2. Extensive GenAI value chain based on desk research and CEPS interpretation.*




*Source: CEPS*

## The EU's *strengths, weaknesses, opportunities, and threats* as regards production and use of GenAI

An analysis of the *strengths, weaknesses, opportunities, and threats (SWOT)* of the EU's ability to benefit from GenAI production and use provides the underpinnings for recommendations to leverage the strengths and opportunities while mitigating the weaknesses and threats. SWOT analysis is a widely used management consulting tool.

*Table 1. The EU's strengths, weaknesses, opportunities, and threats (SWOT) as regards GenAI.*

| | Positive | Negative |
|---|---|---|
| **Present** | **Strengths** | **Weaknesses** |
| | • Strong base in underlying research.<br>• A capable and well-developed open source development community.<br>• Willingness to use legislation.<br>• Moderate digital infrastructure.<br>• Good ability to train AI professionals. | • Insufficient investment in production relative to global competitors (US).<br>• Fragmentation in the EU single market.<br>• Weak large scale computing infrastructure.<br>• Limitations in access to training data. |
| **Future** | **Opportunities** | **Threats** |
| | • Better education and training, increased access to skilled workers.<br>• Increased willingness to invest public and private funds.<br>• Increased focus on regulatory simplification.<br>• Increase access to training data.<br>• Focus on Green AI.<br>• Potential use of sophisticated software and open source development to offset the EU's weakness in computing infrastructure and skilled staff. | • Supply chain disruptions due to trade wars, kinetic war, natural disasters, pandemics, or general macroeconomic decline.<br>• Growing policy divergence among and within EU member states, or with key trading partners.<br>• Threats to the workplace, including job displacement, accelerated skills obsolescence, and mental health impacts.<br>• Inaction or insufficient action on the part of policymakers. |

*Source: CEPS*

## The way forward

Based on the evidence base established in this project, as reflected in the SWOT analysis, we put forward a series of recommendations to the European institutions, to civil society organisations (CSOs), and to the EESC itself. The window for action is narrow, but the stakes are high.

Our policy recommendations to the European institutions are (1) to foster the European AI ecosystem, (2) to reduce regulatory burdens, (3) to address funding challenges and deficits in computing infrastructure, (4) to ensure trustworthy AI development, and (5) to cultivate a skilled and adaptable workforce. A key aspect of fostering the EU AI ecosystem, we recommend the establishment "CERN for AI" to better integrate research and development efforts across Europe. We highlight the importance of strengthening collaboration with the UK – the UK is a powerhouse in AI research. Funding challenges need to be addressed, more by freeing up private funding than by government funding.

We see an urgent need to understand the technological, organisational, and commercial approaches that China's DeepSeek just used to achieve an important breakthrough with its r1 offering, and to consider which might profitably be employed in the EU. The ability to train with perhaps 50 times less computing power than current approaches may open doors for the EU, while DeepSeek's open source approach (in contrast to that of most US firms) may play to EU strengths.

As regards civil society organisations (CSOs), we recommend (1) empowering citizens through social dialogue and training, (2) adopting a "social by design" approach, (3) prioritising ethical and trustworthy AI systems that align with societal values, (4) increasing funding for CSOs working on AI, and (5) addressing challenges in hiring highly-skilled workers.

Our recommendations to the EESC itself are (1) to establish an AI Working Group, (2) to advocate for open source AI, (3) to promote public awareness and discourse on AI's societal impacts, (4) to promote agile regulatory responses and public engagement, and (5) to continue global collaboration.

# 1. Introduction

This final report presents the findings of the study on *Generative AI and foundation models in the EU: Uptake, opportunities, challenges, and a way forward*. As Europe begins implementing the Artificial Intelligence (AI) Act, this study offers a timely exploration of how generative AI (GenAI) and foundation models are shaping the EU's economy, technology sectors, and regulatory landscape.

GenAI, which includes technologies like ChatGPT, DALL-E, and most recently DeepSeek, has gained rapid traction due to its ability to create text, images, music, and even software code from simple user prompts. However, the true potential of these systems lies far beyond chatbots. This report dives into how general purpose AI (GPAI, also called 'foundation models' underpinning GenAI are transforming many industries, such as aerospace, where AI-driven design optimisation is enhancing fuel efficiency and flight safety; or healthcare, where AI is accelerating drug discovery through the creation of synthetic data. These innovations not only reduce costs but also improve the precision and personalisation of products and services.

## 1.1 Objectives and contribution of this study

This study seeks to contribute to an understanding of the current state of GenAI in the EU by thoroughly analysing value chain elements, and by examining specific case studies from selected industries. It provides valuable insights into defining the EU's next priority areas and actions to remain competitive in the global AI landscape. This is particularly significant given recent developments together with the rapid advancements in AI in the US and China. Notably, the US Stargate project plans to invest up to $500 billion in AI infrastructure by 2029, while the Chinese startup DeepSeek has recently disrupted the AI market with an open source model that reportedly rivals OpenAI's latest offerings at a tiny fraction of the operational cost.

Additionally, the study includes case studies on GenAI applications in renewable energy, automotive, and education, offering inspiration for future policy initiatives. These examples highlight areas where Europe may have the potential to excel, and emphasise where its focus, energy, and resources should be directed to strengthen its position in the global AI race.

## 1.2 Methodology used in this study and structure of this report

The study's methodology employs a combination of quantitative and qualitative research. For the quantitative analysis, key data sources included the Crunchbase investment database, the OECD AI Policy Observatory, and Google Patents. These sources were essential for generating the unique data visualisations on investments and patents that are presented throughout the first four chapters of the study. The qualitative research primarily involved desk research, semi-structured in-depth expert interviews, and valuable insights gathered during roundtable discussions. The evidence base built from these elements provides a robust foundation for our case studies and policy recommendations.

The study begins in Chapter 2 by establishing a clear and consistent AI terminology, which is crucial for navigating the often-confusing landscape of GenAI. Misunderstandings frequently arise when terms such as *GenAI, foundation models,* and *general-purpose AI (GPAI)* are used interchangeably, leading to confusion in both policy and technological discussions.

ChatGPT and DALL-E are prime examples of GenAI applications that have captured public attention. In contrast, foundation models such as GPT-4 or Stable Diffusion serve as a versatile underpinning for numerous AI applications, thus going far beyond mere content creation.

Having established an AI glossary and a brief explanation of the key AI terms relevant to the study, the report maps the emerging value chains within the EU in Chapter 3, identifying key players from data providers to developers, service providers, and end-users. This value chain analysis reveals how different sectors — from finance (where AI is revolutionising fraud detection) to education (where personalised learning paths are reshaping student experiences) are utilising GenAI in distinct ways.

We proceed in Chapter 4 to highlight sectoral differences within the EU single market, illustrating the unique challenges and opportunities that each industry faces as they seek to integrate these advanced AI systems.

In Chapter 5, we select three sectors — automotive, renewable energy, and education —as areas where the EU holds a potential competitive advantage in the use of GenAI. These sectors not only showcase the innovative applications of AI, but also reflect the strategic importance of promoting EU production and use of AI to enable Europe to maintain its global competitiveness.

Next comes an assessment of the EU's strengths, weaknesses, opportunities and threats (SWOT) (in Chapter 6) when it comes both to the production and to the use of generative AI.

The report concludes in Chapter 7 with policy recommendations and strategies aimed at ensuring that the EU maximises the benefits of GenAI while addressing the risks related to ethics, security, and market inequalities.

## 2. Overview of the terminology relevant to the study

### 2.1 Understanding the AI terms that matter - a short explainer of the key AI concepts

Artificial intelligence (AI) has rapidly transformed from a niche field of study into a driving force behind many of today's technological advancements. This rapid development has brought a plethora of terms — GenAI, general-purpose AI (GPAI), frontier AI, artificial general intelligence (AGI), and more — that often lead to confusion. Understanding these distinctions is not merely an academic exercise — it has practical implications for how we develop, regulate, and interact with AI technologies. Clarity in terminology helps avoid misunderstandings and sets realistic expectations for what AI can and cannot do. At its core, AI refers to the development of computer systems capable of performing tasks that typically require human intelligence[1]. This broad definition encompasses various disciplines and technologies, making it a foundational term in the field.

This study concentrates on the concept of *generative AI (GenAI)*. This term has become extremely commonly used in the last two years with the rise of chatbots like ChatGPT that have brought AI capabilities directly into the hands of the public. By clarifying the distinctions between GenAI and other forms of AI, we set the stage for a deeper exploration of GenAI's role in the current technological landscape along the value chain. It is especially relevant when exploring GenAI applications in different

[1] European Council. (2023). *ChatGPT in the public sector: Overhyped or overlooked?* Retrieved from https://www.consilium.europa.eu/media/63818/art-paper-chatgpt-in-the-public-sector-overhyped-or-overlooked-24-april-2023_ext.pdf

sectors such as automotive or aerospace because sometimes the line between AI and GenAI developments is blurred. In essence, GenAI refers to artificial intelligence systems capable of creating new content, such as text, images, music, or code in response to user prompts. While ChatGPT is a well-known example of GenAI, it is important to understand that GenAI includes a wide range of applications beyond chatbots. In sectors like automotive, energy, and education, GenAI is revolutionising how tasks are automated, how products are designed, and how services are delivered.

Misconceptions arise when GenAI is equated with AI in general or when tools like ChatGPT are assumed to represent the entirety of GenAI. For example, one might mistakenly equate GenAI with *general purpose AI* (also called *foundation models*[2]), but these are not synonymous. Unlike GenAI, foundation models go beyond content generation. These are AI systems trained on broad data at scale, adaptable to a wide array of tasks beyond content generation[3]. Models, such as BERT, GPT-4, and DALL-E serve as the underpinning for numerous applications, including translation services, decision-making tools, and more. For example, autonomous vehicles used GPAI before they started to include GenAI as well.

The concept of *frontier AI* models has recently emerged. These are cutting-edge AI systems with capabilities surpassing those of existing foundation models. These models, like GPT-o1, push the boundaries of AI performance, enabling more advanced applications and raising important discussions about the ethical and societal implications of highly capable AI systems. But the frontier could be said to be constantly in retreat. While GPT-o1 could be considered as a frontier AI model today, it is very likely that in a year or less it will no longer be considered to be a frontier model; for that matter, some would argue that it has already been overtaken by DeepSeek's r1.

Another term that often enters the conversation is *artificial general intelligence (AGI)*. AGI refers to a potential future milestone in AI development that could dramatically reshape society, economy, and human-machine interactions. AGI is a hypothetical and not yet existing type of AI that can understand, learn, and perform any intellectual task that a human can, mimicking human cognitive functions. Unlike frontier AI, which represents the leading edge of current AI capabilities, AGI remains a speculative and largely discussed concept, representing a future goal rather than a present reality.

Understanding these AI terms is crucial in the context of GenAI value chains because it allows for precise identification of where and how specific AI applications are being integrated across various industries. Each term — GenAI, GPAI, foundation models, and AGI — refers to distinct capabilities with implications for the development, deployment, and regulatory oversight of AI technologies. Given that many sectors, such as automotive, aerospace, and education, are increasingly reliant on AI for innovation and operational efficiency, understanding these distinctions is vital for assessing risks, opportunities, and policy implications along the GenAI value chain.

The selection of AI terms for the glossary in Section 2.2 reflects a deliberate effort to bridge the gap between policy discussions and the more technical vocabulary used in machine learning research. As AI continues to evolve and to play an increasingly central role across various sectors, establishing common ground between policymakers, developers, and other stakeholders is essential. The terms that

[2] the term more commonly used in research and technical communities

[3] Bommasani, R., Hudson, D. A., Adeli, E., Altman, R., Arora, S., von Arx, S., ... Liang, P. (2021). On the Opportunities and Risks of Foundation Models. ArXiv. Retrieved from https://crfm.stanford.edu/assets/report.pdf

we have selected are not only crucial for understanding the subject of this study, but also for fostering a shared language that enables clear communication across disciplines.

## 2.2 AI glossary

*Table 2. A glossary of AI terminology.*

| Concept | Definition | Category | Context |
|---|---|---|---|
| **AI Agent** | 'An autonomous software program that can act on its own to complete tasks or solve problems. Unlike simple chatbots that just respond to messages, AI agents can understand what is happening around them, make decisions based on information they gather, take real actions in the digital world, like searching the internet or controlling other programs, and learn from experience and get better over time.' (CEPS). | AI Applications and Types | Examples include robots, virtual assistants, and autonomous vehicles. |
| **API (Application Programming Interface)** | 'APIs are the behind-the-scenes connectors that allow the apps and websites we use every day to access data and functionality from other services, creating an integrated digital experience. APIs are crucial for AI deployment, especially in the context of agents. They enable AI agents to interact with a wide range of external services, databases, and tools, greatly expanding their capabilities.' (CEPS) | AI Interaction and Integration | APIs standardise interactions between different software applications, enabling developers to easily integrate advanced AI capabilities, such as GPT, into their applications. |
| **Artificial General Intelligence (AGI)** | 'Unlike narrow AI, which excels at specific tasks, Artificial General Intelligence (AGI) would possess human-like cognitive abilities across a wide range of domains. While still theoretical, AGI represents a potential future milestone in AI development that could dramatically reshape society, economy, and human-machine interactions.' (CEPS) | AI Applications and Types | AGI is distinct from current AI technologies like GenAI or Frontier AI, which focus on specific or advanced tasks rather than human-like intelligence. |
| **Artificial Intelligence (AI)** | 'The development of computer systems able to perform tasks that normally require human intelligence.' (Council of the European Union) | Core AI Concepts | AI should not be confused with terms like Generative AI (GenAI), General Purpose AI (GPAI), or Artificial General Intelligence (AGI), each representing distinct AI concepts. |
| **Big Data** | 'Refers to extremely large, complex datasets that traditional data processing methods cannot handle effectively. It includes information from various sources like social media, business | Data and Training | Traditional datasets are typically small enough to be stored and processed on a single machine. Big data, on the other hand, involves massive amounts of data that |

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| | transactions, and sensors. Big Data technologies allow organisations to collect, store, and analyse these massive datasets quickly and efficiently.' (CEPS) | | often require distributed storage and processing systems. |
| **Deep Learning (DL)** | 'A branch of Machine Learning that involves training Deep Neural Networks, composed of layers of nodes (or neurons). Each layer progressively transforms raw input data into more abstract representations, allowing the model to capture complex patterns and relationships. Unlike traditional Machine Learning algorithms, which often require hand-picking important variables, Deep Learning models can automatically learn patterns from large datasets through their layered architecture. Due to the complex transformations that occur across multiple layers, DL models are often viewed as "black boxes," making it challenging to understand the underlying decision-making process.' (CEPS) | Core AI Concepts | Unlike machine learning, which needs human input to choose data features, deep learning can figure out these features on its own, making it better for complex tasks like image or speech recognition |
| **Explainable AI (XAI)** | 'An approach to artificial intelligence that aims to make AI systems' decision-making processes understandable to humans. Unlike "black box" AI models, where the reasoning behind outputs is unclear, XAI provides insights into how and why an AI reaches its conclusions. This transparency is crucial in fields like healthcare, finance, and law, where understanding the rationale behind AI decisions is essential for trust, accountability, and regulatory compliance. XAI techniques help bridge the gap between complex AI algorithms and human comprehension, making AI more interpretable and trustworthy.' (CEPS) | AI Ethics and Transparency | For example, ChatGPT is the antithesis of explainable AI. It consequently is not a tool that should be used in situations where trust is called for. |
| **Federated Learning** | 'A machine learning method that allows models to be trained on the local data of multiple edge devices. Only the updates of the local model, not the training data itself, are sent to a central location where they are aggregated to improve the global model — a process that is iterated until the global model is fully trained.' (IAPP Key Terms for AI Governance) | Specialised AI Techniques | For example, Apple's Siri employs federated learning to enhance Siri's understanding of user queries and to improve QuickType's text predictions. By processing data on-device, Apple maintains user privacy while still benefiting from user interactions to refine their AI models. |
| **Fine-tuning** | 'A process in machine learning where a pre-trained AI model is further trained on a specific dataset to adapt it for a particular task or domain. Fine-tuning allows organisations to customise powerful AI models for their specific needs, improving performance while | Data and Training | For example, if you have a pre-trained model that understands a wide range of animal images, you can fine-tune it specifically to recognise different breeds of dogs. This process makes the model more accurate for |

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| | saving time and resources compared to training from scratch.' (CEPS) | | the new task without needing to train it from scratch, saving time and resources. |
| **Foundation model or General Purpose AI (GPAI)** | 'Foundation models (e.g., BERT, DALL-E, GPT-3) are models trained on broad data at scale and adaptable to a wide range of downstream tasks.' (Stanford University) | Advanced AI Models | *Foundation model* is often used interchangeably with *General Purpose AI (GPAI)*. While the policy and regulatory world, in particular the EU AI Act, prefers the term GPAI, *foundation model* is a term more commonly used in research and technical communities. It means the same thing as GPAI. In this study, we will stick with the term *foundation model*. Foundation models can be trained on such data sources as text, images, speech, 3D signals. Among the capabilities of foundation models are to recognise objects, analyse sentiments, answer questions, follow instructions, and caption images. |
| **Frontier models or frontier AI** | 'Cutting-edge AI models with more powerful and advanced capabilities than other foundation models.' (CEPS) | Advanced AI Models | Some foundation models are categorised as 'frontier' because they push the boundaries of current AI capabilities. The term itself is contested and lacks a universally agreed-upon definition, but one could argue that GPT-4 was an example of a frontier model until the recent launch of GPT-o1. |
| **Generative Adversarial Network (GAN)** | 'A machine learning technique that can generate data, such as realistic 'deepfake' images, that are difficult to distinguish from the data the GAN is trained on. A GAN is made up of two competing elements: a generator and a discriminator. The generator creates fake data, which the discriminator compares to real 'training' data and feeds back with instances where it has detected differences. Over time, the generator learns to create more realistic data, until the discriminator can no longer tell what is real and what is fake.' (Alan Turing Data Science and AI Glossary) | Specialised AI Techniques | GANs are distinct from models like DALL-E, which generates images based on text input. |
| **Generative AI (GenAI)** | 'Refers to artificial intelligence systems capable of creating new content, such as text, images, music, or code. These models learn patterns from vast amounts of data and use this knowledge to generate original outputs that mimic human-created content. GenAI powers applications like chatbots, text-to-image generators, | AI Applications and Types | While powerful, GenAI focuses solely on content generation. It is distinct from General Purpose AI and other broader AI categories. ChatGPT, though a form of GenAI, does not encompass all generative AI applications. |

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| | and language models, enabling tasks ranging from creative writing to software development. While offering immense potential for innovation, GenAI also raises important questions about authenticity, copyright, and ethical use.' (CEPS) | | |
| **Generative Pre-trained Transformer (GPT)** | 'GPTs are large language models trained on significant datasets of text and code, used to generate text, translate languages, and perform creative content tasks.' (Ada Lovelace Institute) | Advanced AI Models | GPTs use a neural network architecture called the Transformer, which is highly effective for understanding context in language. These GPTs are used in AI chatbots (such as ChatGPT) because of their natural language processing abilities to understand users' text inputs and generate conversational outputs. |
| **Jailbreak** | 'Attempts to bypass or circumvent the built-in safeguards, ethical constraints, or content filters that have been implemented by the model's creators. The term is borrowed from the practice of removing software restrictions on mobile devices.' (Microsoft) | AI Ethics and Transparency | Jailbreaking AI models involves creating specific prompts or instructions designed to trick the model into producing content it normally would not generate due to its safety protocols. If jailbreak is successful, the AI might then generate responses that give instructions for dangerous activities or share biased facts. |
| **Large Language Model (LLM)** | 'A type of foundation model that is trained on a vast amount of textual data in order to carry out language-related tasks. Large language models power the new generation of chatbots, and can generate text that is indistinguishable from human-written text. They are part of a broader field of research called natural language processing, and are typically much simpler in design than smaller, more traditional language models.' (Alan Turing Data Science and AI Glossary) | Advanced AI Models | LLMs are the basis for many modern AI applications, including chatbots and text generation models. They are larger and more advanced versions of neural networks specifically designed for language tasks. |
| **Machine Learning (ML)** | 'It is a subset of artificial intelligence that enables systems to learn and improve from experience without being explicitly programmed. Unlike traditional automation techniques that follows fixed, human-programmed rules, machine learning algorithms identify patterns by analysing large volumes of data. These systems refine their own models and adapt to new information without explicit reprogramming. This data-driven learning process allows machines to handle nuanced and complex tasks like voice recognition or product recommendations, where | Core AI Concepts | ML is the foundation of many AI systems, enabling predictions and automated decision-making by recognising patterns in data. It contrasts with traditional programming where explicit instructions are required. |

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| | writing explicit rules would be impractical and hard to scale.' (CEPS) | | |
| **Multimodal AI** | 'A machine learning model capable of processing information from multiple modalities (images, text, video, etc.).' (Google) | AI Applications and Types | Google's Gemini model can look at a photo of lasagna and write the recipe for it, or do the reverse. Multimodality means AI can understand and process different kinds of inputs, like images and text. This allows users to use almost any type of input to generate almost any kind of content, without being limited to just one input or output format. |
| **Natural Language Processing (NLP)** | 'The ability of a machine to process, analyse, and mimic human language, either spoken or written.' (EU-U.S. Terminology and Taxonomy for AI) | Specialised AI Techniques | NLP powers systems like Siri and Alexa, enabling machines to understand and respond to human language in a natural way. |
| **Neural Network** | 'A neural network is a system made up of layers of connected units called neurons. It takes in data, processes it through these layers to find patterns, and learns to make predictions by adjusting connections based on mistakes it makes.' (CEPS) | Core AI Concepts | Neural networks are key to modern AI, powering systems from simple tasks like pattern recognition to complex ones like deep learning, which enables breakthroughs in GenAI and LLMs. |
| **Prompt** | 'An input or instruction given to an AI model to guide its response or generate a desired output.' (CEPS) | AI Interaction and Integration | Effective prompt engineering is important when one wants to get meaningful and relevant responses from AI models like ChatGPT. |
| **Reinforcement Learning from Human Feedback (RLHF)** | 'A technique where an AI model learns to make decisions by receiving feedback from humans on its actions.' (CEPS) | Specialised AI Techniques | If a chatbot gives an unhelpful answer, one can provide feedback to guide it toward a more useful response in the future. This approach improves traditional reinforcement learning by using human guidance, making AI models like ChatGPT more accurate and reliable. |
| **Retrieval Augmented Generation (RAG)** | 'A technique that combines information retrieval with text generation to improve the accuracy and relevance of AI responses.' (CEPS) | AI Interaction and Integration | RAG enables models to fact-check or enhance their outputs by retrieving relevant information in real-time, providing more contextually accurate and up-to-date responses. |
| **Training Data** | 'Data used to train an AI model to enable it to learn the patterns necessary to perform its tasks.' (EU Artificial Intelligence Act) | Data and Training | Training data is key for machine learning as it forms the basis of the AI model's ability to identify patterns and make decisions or predictions. |

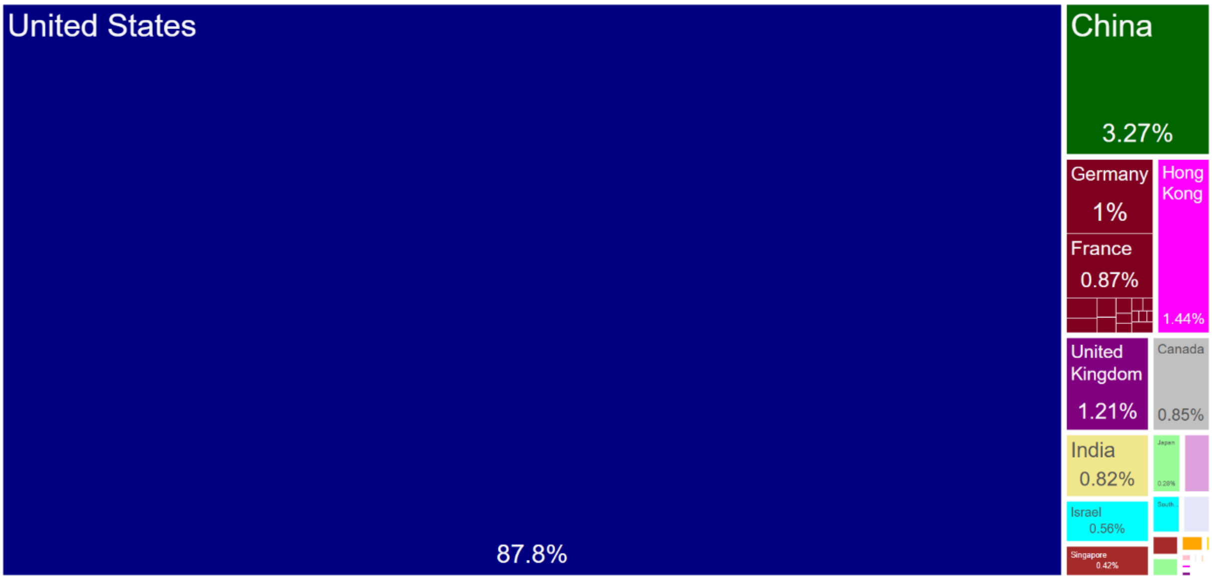
*Source: CEPS*

## 3. Initial overview of relevant actors along the value chain

### 3.1 Current state of the GenAI market

The GenAI market has been dominated to date by a few large players, primarily from the United States. This concentration of power raises concerns about market diversity and competition.

*Figure 3. Global distribution of Private GenAI investment recipients: 2016-2024.*




*Source: CEPS visualisation based on Crunchbase*

China, contrary to some expectations, has not been a dominant force in this sector *up to now*. With the emergence of DeepSeek's r1, however, this appears to have changed – DeepSeek has clearly established itself as a serious player in this space.[4]

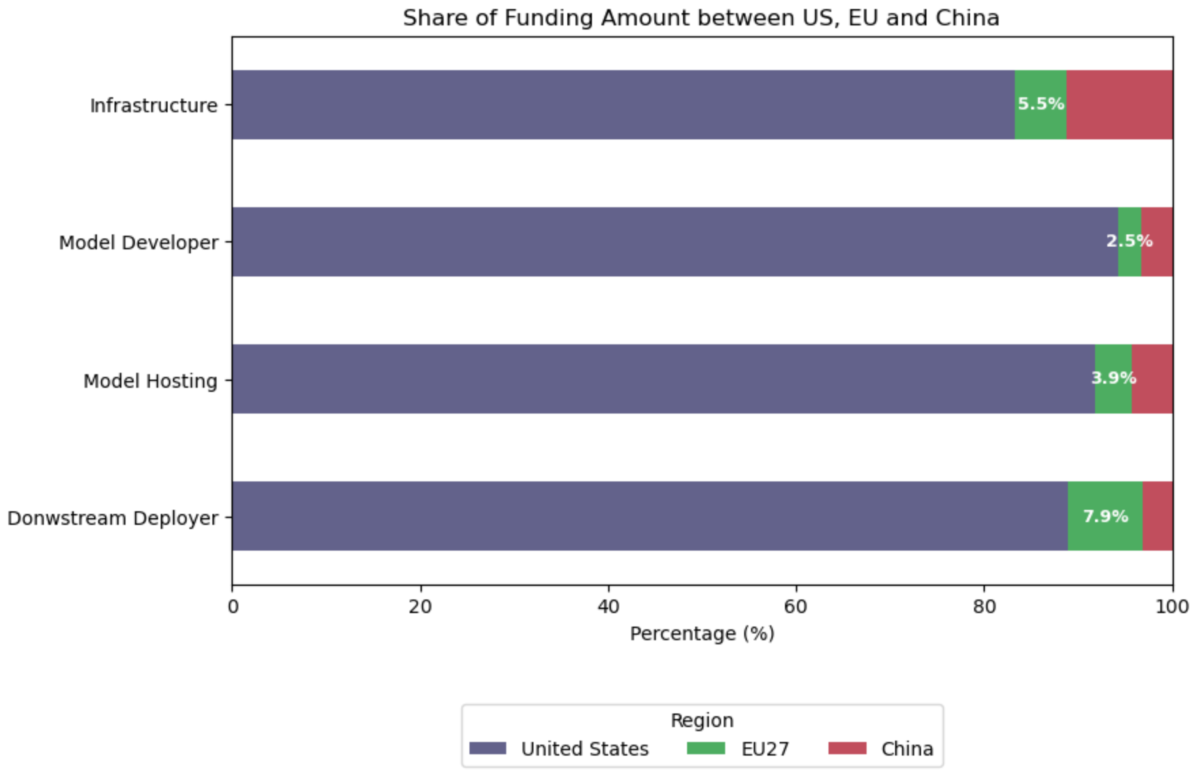
The emergence of DeepSeek might also imply that different metrics of market relevance will be needed in the future inasmuch as DeepSeek was able to produce a worthy competitor to the very best that America has been able to produce to date with a far smaller budget and less advanced hardware, thanks apparently to highly innovative software design and an open source development model. The volume and quality of the output of an AI firm might not be as closely tied to the level of investment in the future as was the case in the immediate past. Stated differently, the enormous investments made by US-based firms does not appear to have translated into a long term competitive advantage.

Key beneficiaries in the value chain up to now include hardware providers like NVIDIA and cloud infrastructure companies like CoreWeave, highlighting the importance of computational resources in this field. Also, among the largest players are model developers such as Meta, Anthropic, xAI, but OpenAI is the champion with the 4 billion USD revolving credit line that it recently received. However, with the dominance from the USA follows dependency of European companies on US infrastructure. Across different categories of the GenAI value chain, more than 85% of funding goes to US companies (Figure 3). In 2023, US investors accounted for 230 out of 559 million USD investment in EU27 GenAI

[4] As noted elsewhere in this report, charts like Figure 3 do not properly represent the share of DeepSeek in the marketplace today because its market relevance is wildly out of proportion to the investment made in DeepSeek when compared to its competitors.

companies[5]. For instance, the originally Austrian AI coding startup Magic (465 million USD funding to date) moved to San Francisco exemplifies this trend, as does the Microsoft investment into Mistral.

*Figure 4. US dominance across different value chain categories.*




*Source: CEPS visualisation based on Crunchbase, classifications by CEPS*
*Funding shares include only funding to GenAI companies in the US, EU27 and China.*

## 3.2 The GenAI value chain: Key segments

The GenAI value chain is complex, with many categories of players, as illustrated in Figure 5. This section provides a brief summary of the key segments:

- Infrastructure;
- Data services;
- Foundation models;
- GenAI applications;
- End-users; and
- Ancillary categories:
  - Research institutions;
  - Regulators; and
  - Investors.

The main players in these categories of the value chain are described in more detail in Section 4.3.

[5] OECD.AI (2024), visualisations powered by JSI using data from Preqin, accessed on 3/10/2024, www.oecd.ai .

At the base of the GenAI value chain, there are providers of GenAI *infrastructure*. Utilities provide energy that powers the computer systems the GenAI applications run on. Hardware manufacturers, first and foremost for the production of semiconductors but also for memory chips, are an essential part of the infrastructure. Various companies produce software to design the chips themselves, machines to manufacture them, or to manufacture the chips. Finally, the hardware is physically housed in specialised data centres which often are operated by parties other than the actor offering the GenAI application.

The next group in the GenAI value chain are providers of *data services*. The GenAI models need data to be trained on, which can either be openly accessible data on the internet, or proprietary data. Some companies developing GenAI models collect the data themselves, others use the services of third parties. Further, such data oftentimes need to be labelled by companies that providing labelling services. Also, both models and data are typically hosted on a cloud platform which is provided by specific actors.

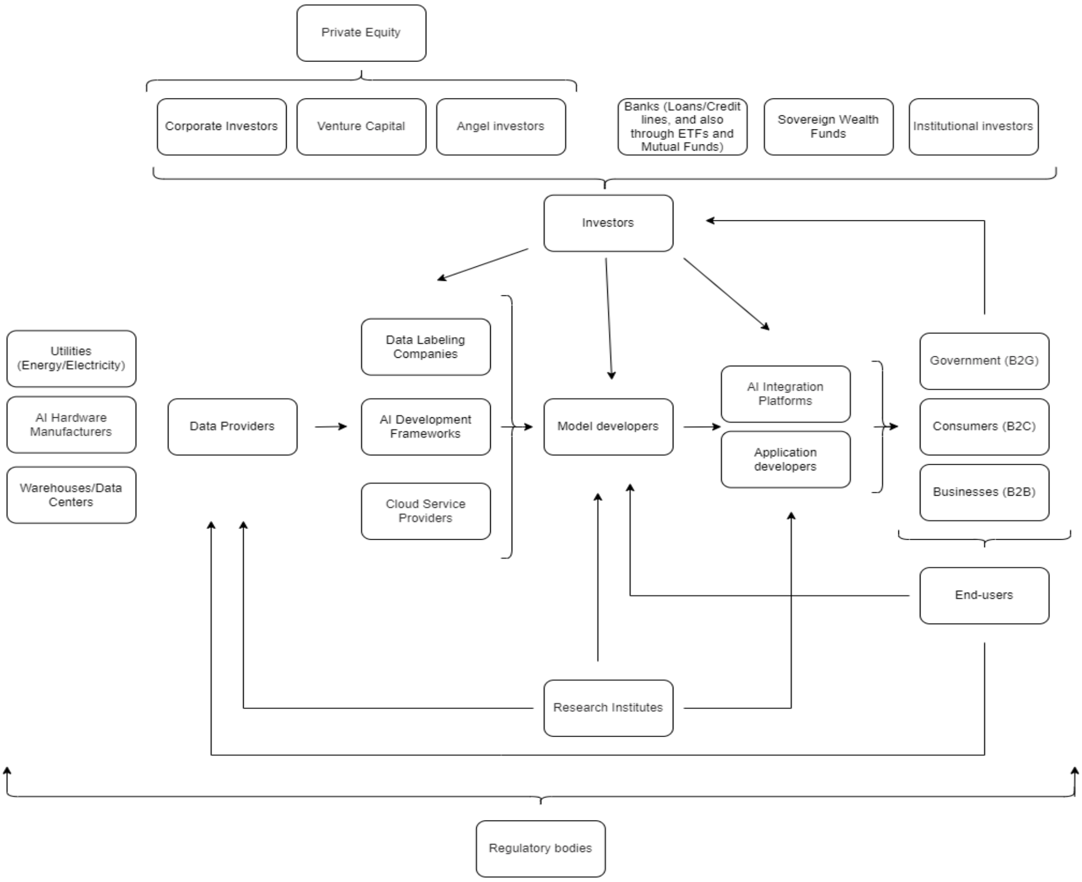
Next, there are the developers of *foundation models* underpinning GenAI. These models can be freely available, or else have to be licensed.

Building upon foundation models are the developers of GenAI *applications* that provide sector-specific solutions.

Finally, there are *end-users* – consumers and businesses – who use these applications. The end-user will, depending on the use case (see Chapters 4 and 5), typically use those applications to create text, images, videos, and computer code.

Ancillary to this are *research institutions* doing research in all aspects of the value chains. Further, *regulators* impact the value chain with rules and regulations, as well as with programmes to incentivise and develop certain aspects of the value chain; therefore, regulatory bodies are connected to all other categories. Finally, there are various types of *investors* who invest across the value chain.

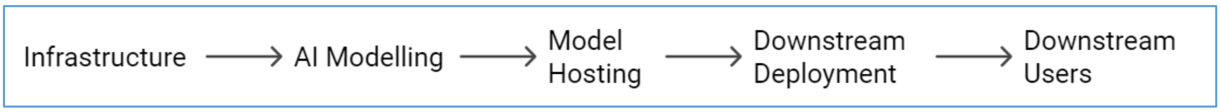
*Figure 5. Extensive GenAI value chain based on desk research and CEPS interpretation.*




*Source: CEPS*

Following G'sell (2024)[6] (Figure 6), the categories in the value chain can be simplified to just five categories (Figure 7): AI infrastructure, AI modelling, model hosting, downstream deployment and downstream users. The data providers, data labelling companies, AI development frameworks and cloud service providers depicted in Figure 5 belong to the infrastructure category in this model. Model developers do AI modelling, and AI integration platforms are mapped to model hosting. Application developers are the downstream deployers and business, government and consumers form the downstream users.

*Figure 6. A simplified value chain model.*



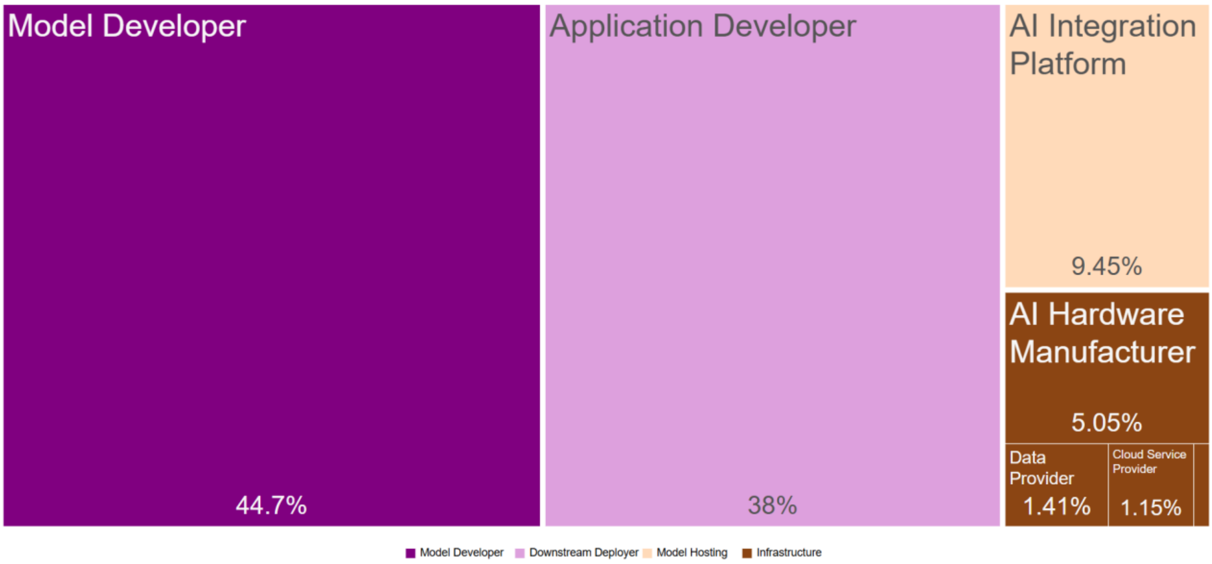

*Source: CEPS visualisation based on G'sell (2024)*

This mapping from the full-blown model of Figure 5 to the simplified model of Figure 6 makes it possible to categorise companies into different segments, where the greatest investment is currently

[6] See page 49.

found in model developers (reflecting large investments) and in application developers (reflecting many smaller investments), as seen in Figure 7.

*Figure 7. Funding among the different categories of the value chain..*




*Source: CEPS visualisation based on [Crunchbase]*

### 3.3 The GenAI value chain: The ecosystem

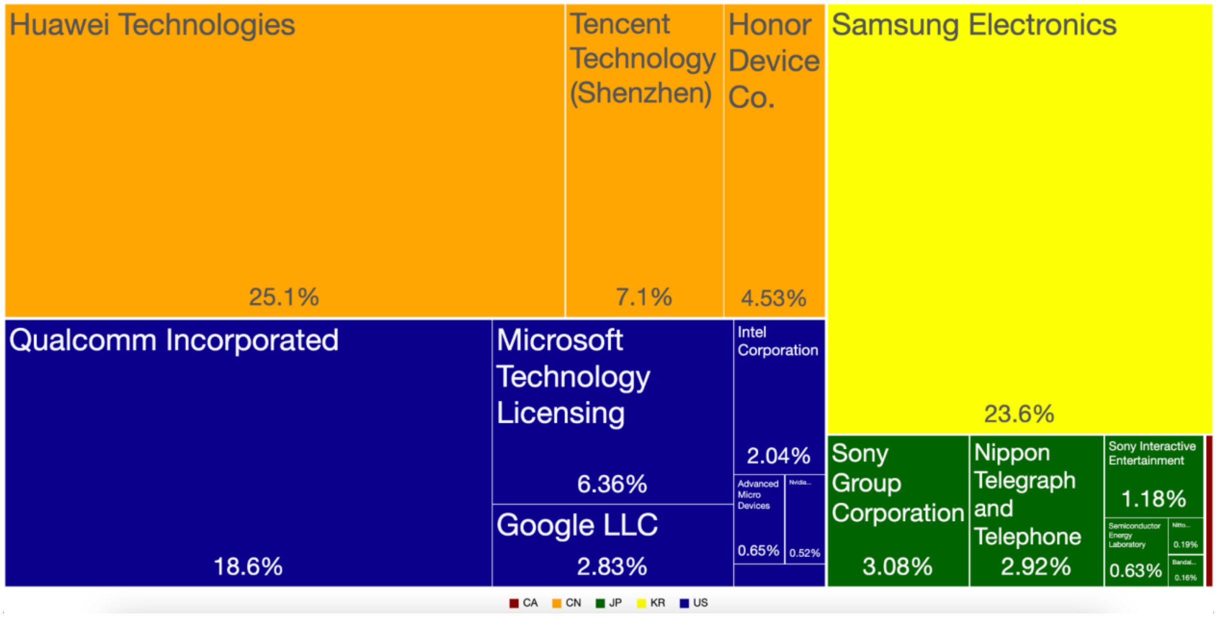
The *infrastructure* segment (Figure 8 and Figure 9) starts with AI hardware manufacturers, including NVIDIA, Coreweave, Intel, AMD, Google (TPUs), IBM, Graphcore, and Cerebras. They build the hardware and chips that are crucial for training large GenAI models. The surge in GenAI training and the complex supply chain for high-quality chips have led to sky-rocketing prices. The most important European player, ASML, produces only the machines needed for fabrication of these chips.

Another part of the infrastructure segment are data services and providers: supplying raw data for AI training, labelling, and hosting. This includes data labelling companies: they prepare and annotate data for AI model training, key players are Scale AI, Appen, Labelbox, Cloudfactory, Samasource and Gretel for synthetic data. None of them is European.

AI development frameworks provide tools for building AI models and cloud service providers: they offer scalable computing resources for AI and main services are TensorFlow (Google), PyTorch (Facebook), Keras, Microsoft Cognitive Toolkit and Apache MXNet.

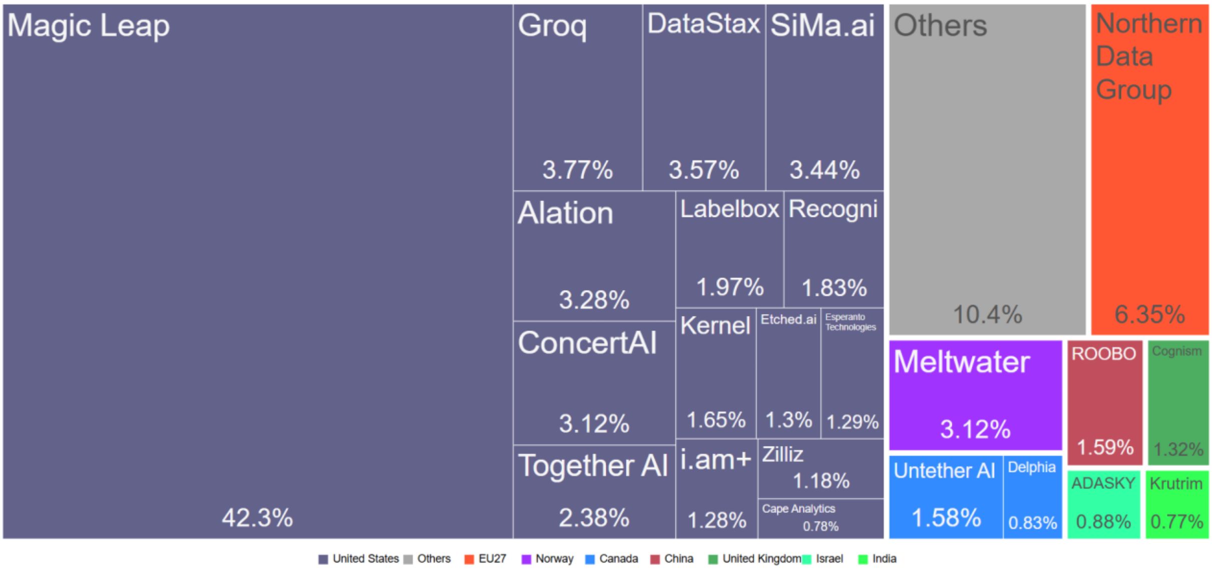
Then there are cloud service providers: Amazon Web Services (AWS), Microsoft Azure, Google Cloud Platform, IBM Cloud, Oracle Cloud, with OVHcloud as the most noteworthy European competitor.

*Figure 8. Most notable GenAI infrastructure WIPO patent assignees (2022-2024), proportions depict number of patents.*




*Source: CEPS visualisation based on Google Patents*

*Figure 9. GenAI infrastructure startups, proportions depict funding size.*



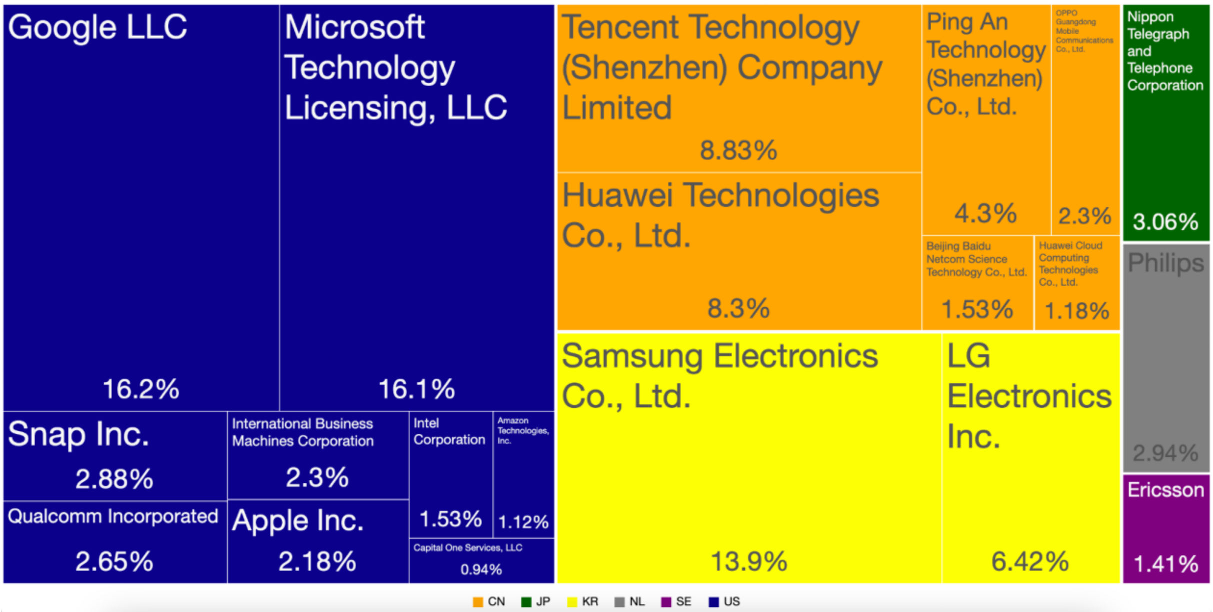

*Source: CEPS visualisation based on* [*Crunchbase*]

The *foundation model* developers create AI algorithms and models and are primarily responsible for creating the foundation models or large language models (LLMs) that form the core AI capabilities for GenAI. This is where currently the largest investments are being made (see Figure 7). OpenAI expected to lose at least 5 billion USD in 2024, which implies that they and their investors are betting on growth in the medium to long term. They have around 10 million paying ChatGPT users and more than one million third-party developers that use their models in their own services. OpenAI follows a closed model, where the details of their design are not visible to the public. With the conspicuous exception of Meta, closed models are the standard approach in the USA.

Meta publishes its models under an open and permissive license, which has the advantage of being a complement to Meta's core offerings of cloud services, hardware and advertising. Having users perform R&D on its models can effectively serve to leverage Meta's development resources, and also makes it easier for Meta to spot talent to hire.

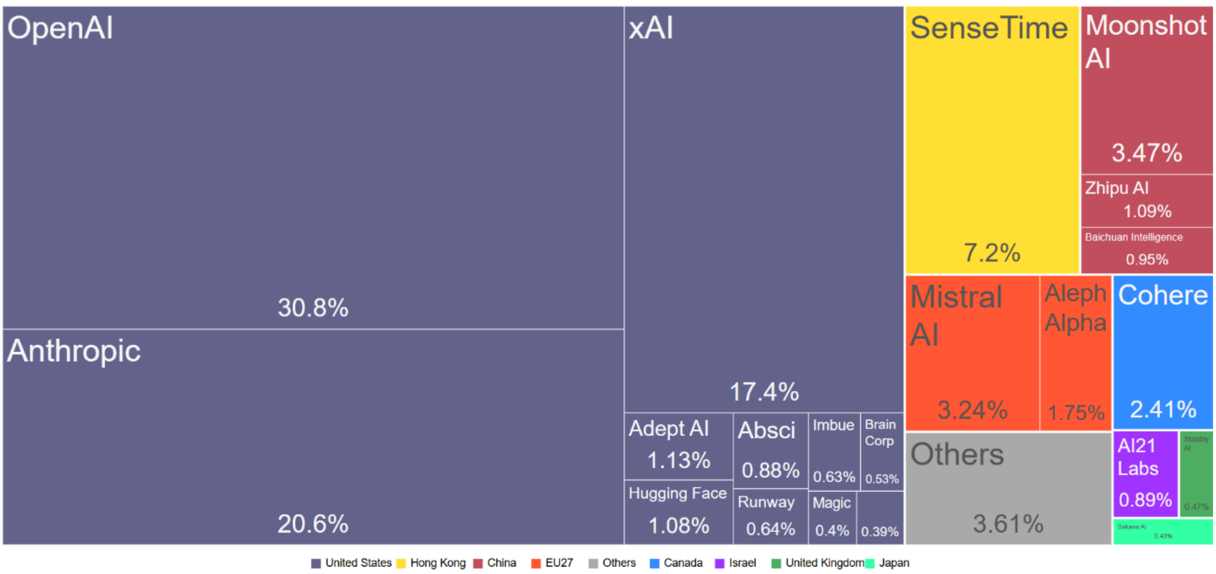
Key foundation model developers are OpenAI, Anthropic, Google AI, Meta, Microsoft Research, xAI, Mistral, and Moonshot AI (see Figure 10 and Figure 11).

*Figure 10. Most noteworthy GenAI model developer WIPO patent assignees (2022-2024), proportions depict number of patents.*




*Source: CEPS visualisation based on Google Patents*

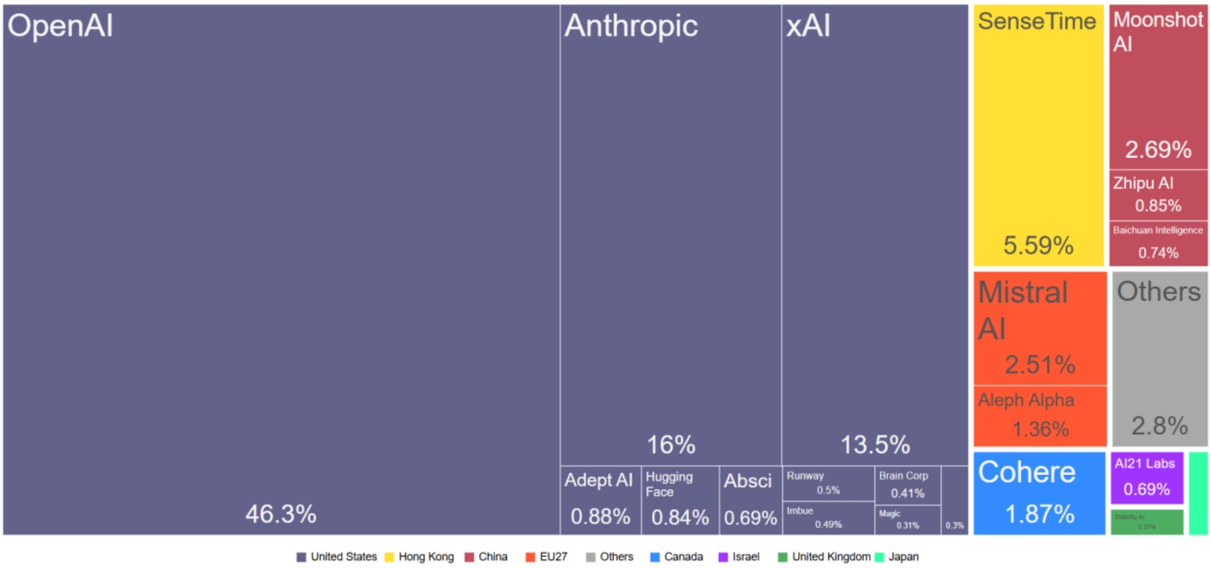
*Figure 11. Most noteworthy GenAI model developer firms, proportions depict funding size.*




*Source: CEPS visualisation based on Crunchbase*

The concentration of the market in terms of investment becomes even more obvious when OpenAI's recent 10.6 billion USD capital influx is taken into account (Figure 12). We caution, however, that the emergence of the disruptive Chinese DeepSeek r1 has the potential to upend expectations as to the degree to which investment can be expected to correspond to usage, and to financial performance.

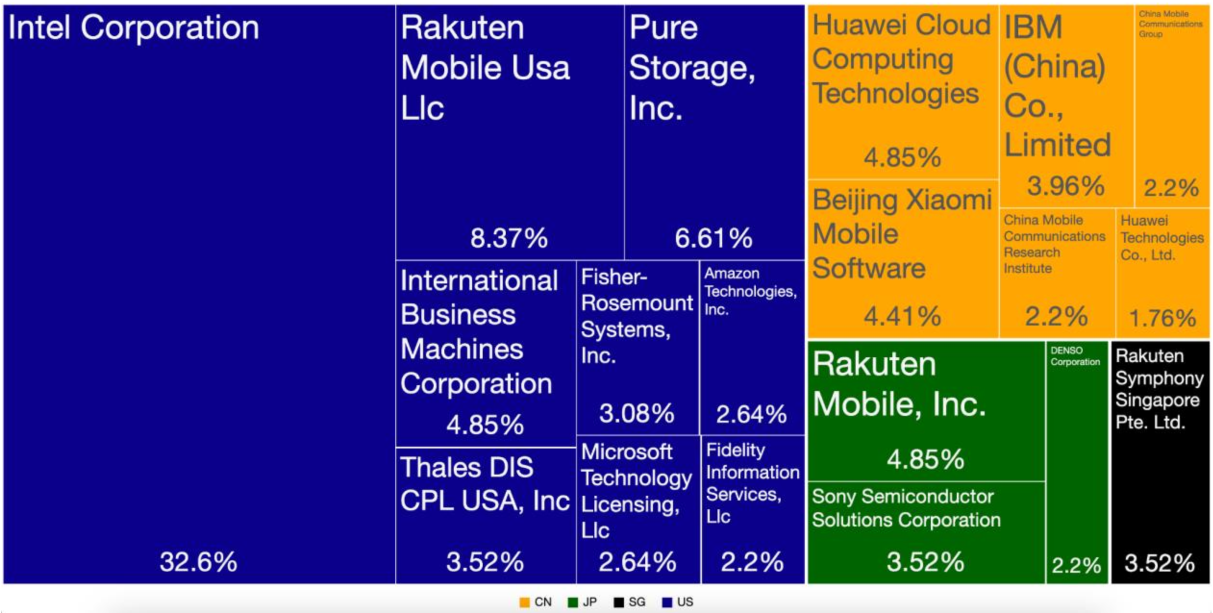
*Figure 12. Noteworthy GenAI model developer firms after OpenAI's large influx of funding, proportions depict funding size.*




*Source: CEPS visualisation based on* [*Crunchbase*]

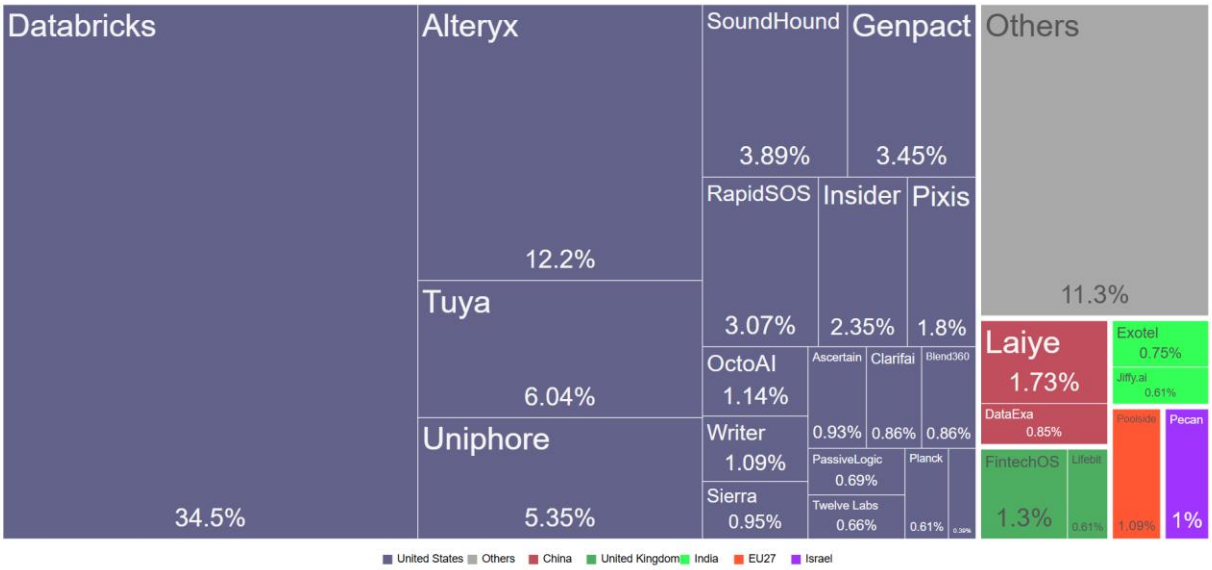
The GenAI models are inputs for AI integration platforms (model hosting). These are the bridge between the AI foundation models and the end-user applications. They provide tools, services, and infrastructure to help businesses and developers incorporate AI capabilities into their existing system. Examples beyond
Figure 13 and Figure 14 include Palantir, C3.ai, DataRobot, H2O.ai, Dataiku, and Hugging Face.

*Figure 13. Noteworthy GenAI model hosting WIPO patent assignees (2022-2024), proportions depict number of patents.*




*Source: CEPS visualisation based on Google Patent*

*Figure 14. Most noteworthy GenAI model hosting startups, proportions depict funding size.*

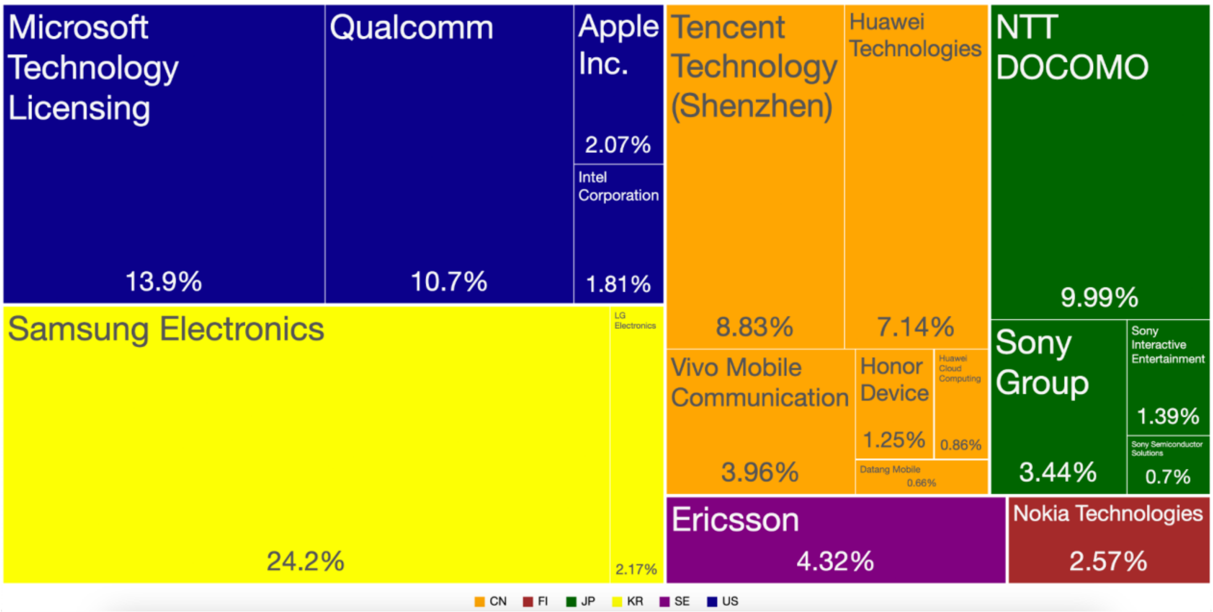



*Source: CEPS visualisation based on [Crunchbase]*
*Poolside (in orange) is a French company, Pecan (in purple) is from Israel.*

Before we turn to end-users, there are the *application developers*. They build user-facing AI products and services that do not have to be foundation models themselves, but rather function as applications on top of foundation models. In terms of patents (Figure 15), large companies such as Microsoft, Tencent and Apple dominate this segment, but there are also many giants of the tech connectivity era (Ericsson, Nokia, Huawei). Several large successful companies have arisen, including Jasper, Notion AI, Replika, Grammarly, Copy.ai, Otter.ai, Duolingo, Synthesia, Lensa, Petal, Microsoft CoPilot, and Salesforce Einstein. The EU27 contribution of largest application developers is from the companies Meero and Helsing. The large *Others* category in Figure 16 exemplifies the diversity in this area.

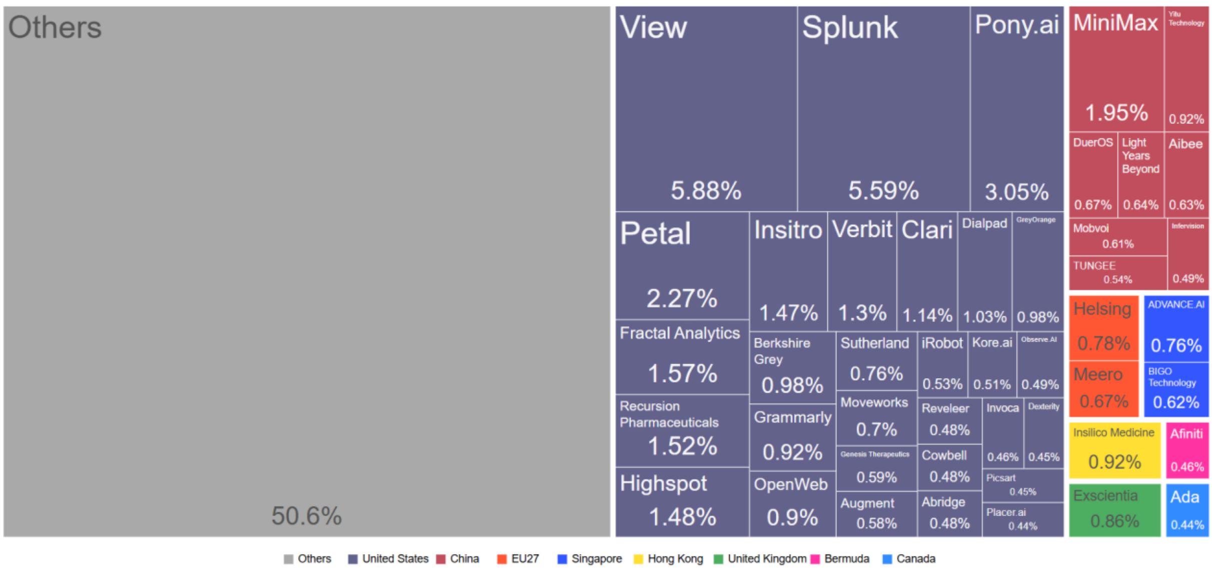
Two main categories of large downstream developers have emerged: (1) business workflow optimisation (Glean, CoPilot, and Notion AI, amongst others), and (2) creative industries (Magic Leap, Runway, Picart, Verbit, and Synthesia).

*Figure 15. A selection of GenAI application WIPO patent assignees (2022-2024), proportions depict number of patents.*




*Source: CEPS visualisation based on Google Patents*

*Figure 16. A selection of GenAI application developers.*

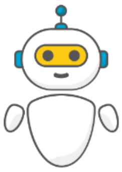



*SSource: CEPS visualisation based on Crunchbase*

*End-users* directly interact with and benefit from GenAI applications. Governments have a keen interest in using GenAI as a way of providing better services, ranging from autonomous driving in Dallas, to developing sustainable materials in Amsterdam and beyond. (Inter)national examples are DARPA, the

European Commission, the National Institute of Standards and Technology (NIST), and the US Office of Science and Technology Policy (US). Governments have started by utilising chatbots, even moving towards creating their own foundation models (the Dutch GPT-NL, the Finnish Poro or the European consortium for ALT-EDIC). Businesses implement AI solutions for operations and services. Lately, Amazon automated a large part of coding through GenAI (Figure 17), and Klarna stopped using Salesforce after implementing internal GenAI solutions. Lastly, there are the customers: individuals, educational organisations, small business and more, using ChatGPT and other AI tools. Through mining web forums researchers have learned that individuals mostly use GenAI for brainstorming, therapy and companionship, specific search, and editing text.

*Figure 17. Examples of successful GenAI deployment from government, business, and users.*



| | | |
|---|---|---|
| The chatbot of the city of Buenos Aires helps millions of citizens every month, solving 82% of their queries. | Amazon is saving 4500 years of repetitive tasks through automated coding with their Q Developer tool. | ChatGPT is helping millions of users worldwide by assisting them in tasks such as drafting emails and brainstorming creative ideas. |

*Source: CEPS*

*Investors* supply capital across all stages of AI development. GenAI is capital intensive across the entire value chain. A state-of-the-art foundry to manufacture chips relevant for GenAI costs in the billions of Euros. Further down the value chain, the cost to train foundation models has historically ranged in the hundreds of millions of Euros. Cloud services and computing GenAI models are energy intensive. Large investments have been needed, and have been regularly provided for by different types of investors who, seen in total, have invested in all stages of companies all across the value chain. The software techniques that are visible in DeepSeek r1 might possibly drive training costs and corresponding energy costs down by two orders of magnitude (i.e. a factor of 50) – a dramatic savings, but investment needs will nonetheless continue to be substantial.

There are many different kinds of investors:

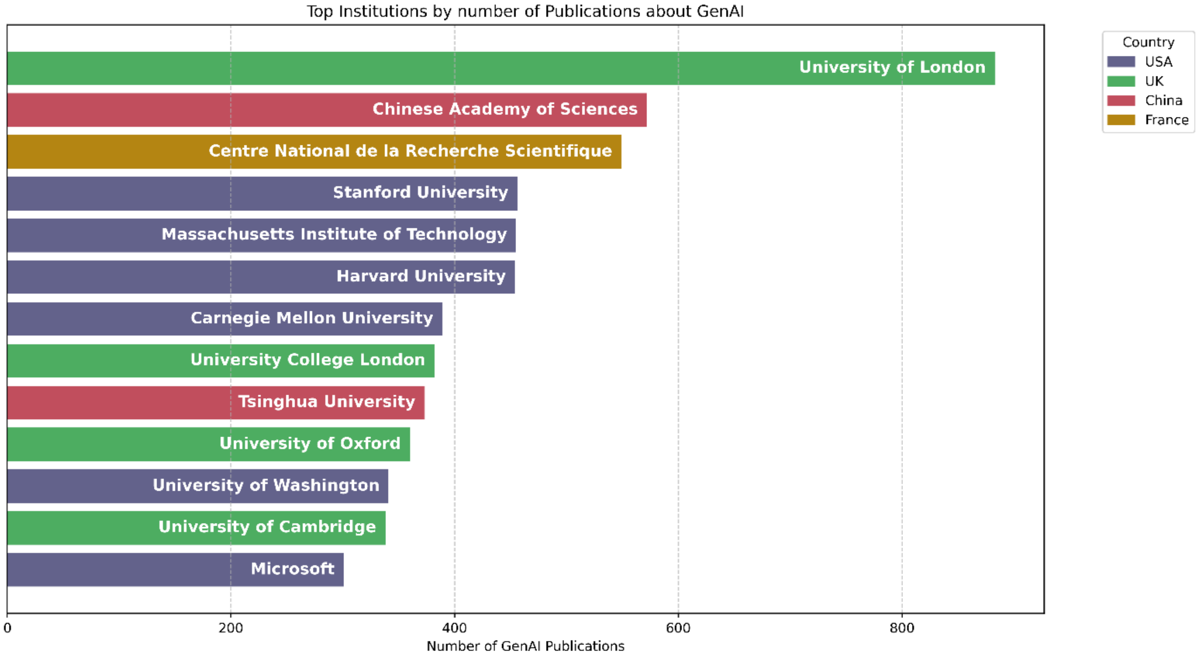
- *Private equity:* provides large-scale funding to established AI companies.
- *Venture capital*: invests in early-stage AI startups. Examples include Y Combinator, Sequoia Capital, Andreessen Horowitz, Techstars, FoundersFund, Kleiner Perkins, Greylock, Menlo Ventures.
- *Corporate investors*: often strategic, aimed at gaining access to innovative technologies. These can be large tech companies such as Google and Amazon.
- *Angel investors*: invest smaller amounts than VCs but take on higher risk by backing very early-stage AI startups.
- *Sovereign wealth funds (SWFs):* government-owned funds that invest in AI to diversify their country's investment portfolio and gain strategic technology exposure. Saudi Arabia's SWF invests heavily in GenAI, including into Mistral and Databricks. Mubadala from UAE reportedly invested in Anthropic, demonstrating that SWFs in the Middle East potentially have the power to fund the next GenAI wave. Whereas US AI funding is primarily private, in China

there is large influence of the Communist Party on the course of SWF. In the EU, the French Bpifrance was involved in 161 AI deals in the past 4 years.

- *Institutional investors:* large investment entities like pension funds, insurance companies, and university endowments (but universities typically do not directly invest in AI startup rather,, they often invest in VC or PE funds that have a focus on AI).
- *EU institutions:* the EU invests indirectly through the Horizon program, and directly through the European Investment Fund (EIF).

*Research institutes* conduct fundamental and applied AI research and include CNRS, MIT Computer Science and Artificial Intelligence Laboratory, Stanford Artificial Intelligence Laboratory, Allen Institute for AI, Max Planck Institute for Intelligent Systems, and the Chinese Academy of Sciences Institute of Automation. The leading institutions working on GenAI are displayed in Figure 18. There is also more applied AI research from institutes that work on joint industry projects such as Fraunhofer Institutes and TNO, or through state-funded initiatives.

*Figure 18. Organisations that have written the most papers with the keyword "GenAI".*




*Source: CEPS visualisation based on OpenAlex*

The UK, which is no longer part of the EU, is a major player, and continues to be aligned with the EU through for instance the Horizon research programme. When it comes to promoting European interests in artificial intelligence, EU-UK collaboration is of vital importance.

Impacting the entire value chain are *regulators*: they oversee and regulate AI development and use, and establish work programmes. Regulatory bodies include the European AI Office, US Federal Trade Commission (FTC), various AI safety institutes, and the India Ministry of Electronics & Information Technology. Among actions taken in recent years, the Italian Data Protection Authority banned ChatGPT in April 2023 over alleged misuse of personal data, and have done the same with DeepSeek. China also has a track record of blocking GenAI use.

Governments can establish work programmes to advance GenAI. In the EU, Horizon Europe is the obvious example.

### 3.4 Vertical integration trend

Another trend we observe is that major tech companies such as Meta, Google, and OpenAI (through their partnership with Microsoft) are internalising various parts of the AI value chain, creating "one-stop-shop" solutions. This trend towards vertical integration could lead to increased efficiency for consumers but may also result in market concentration and reduced competition. The EU may wish to consider policies to ensure a balanced market that allows for both integrated solutions and specialised providers.

For industry applications, especially autonomous vehicles and clean energy, there is an important layer of domain knowledge required. This need cannot be addressed by investments alone. The trend toward vertical integration may ultimately get in the way of the specialisation that is needed.

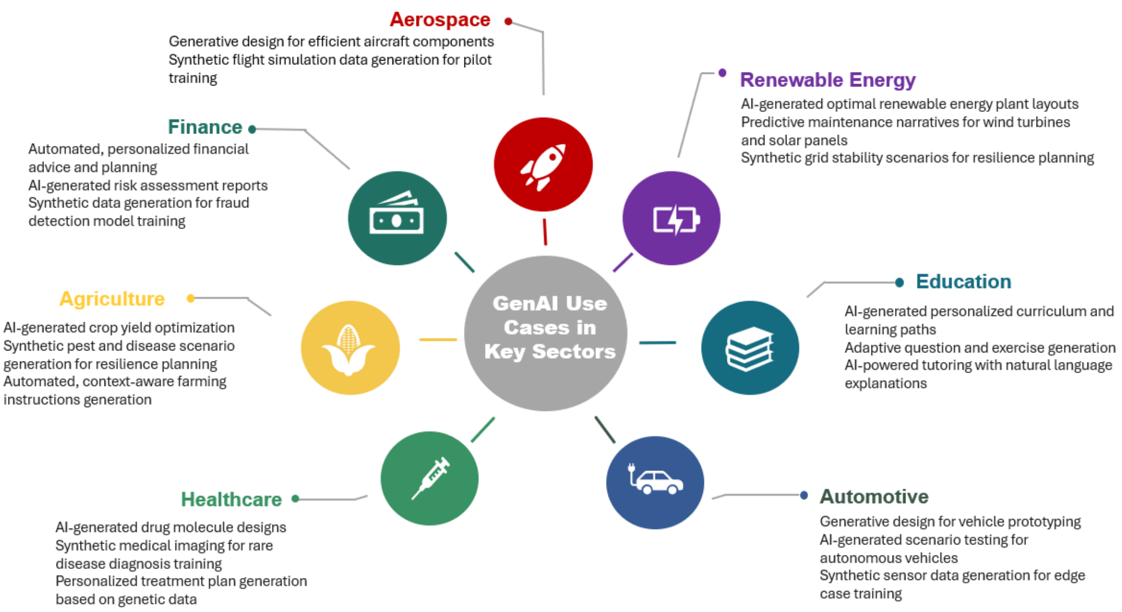
## 4. Initial overview of various sectors of the EU single market

In this chapter, we dive into the use cases, enablers, and blockers of seven key sectors in the EU single market. The analysis focuses on both common and unique elements of the use of GenAI in these sectors.

### 4.1 Use cases

Figure 19 depicts key use cases in a number of sectors that appear to offer substantial potential for the use of GenAI.

*Figure 19. The use of GenAI in seven selected sectors.*




*Source: CEPS*

In the aerospace sector, the advent of GenAI is reshaping the landscape of aircraft design and pilot training (Figure 19). By using advanced algorithms, engineers can create optimised components that enhance fuel efficiency and reduce emissions, all while pushing the boundaries of aerodynamic performance. This technology does not stop at design - it extends to pilot training through the generation of synthetic flight simulation data, allowing trainees to experience a vast array of flight scenarios without the risks associated with real-world flying. As a result, pilots gain invaluable experience in handling emergencies and complex flight conditions, ultimately leading to safer skies.

In finance, GenAI is revolutionising how individuals manage their finances by providing automated, personalised financial advice tailored to each user's unique circumstances. This sophisticated technology analyses spending habits and investment goals, generating actionable insights that empower users to make informed decisions. Furthermore, it produces comprehensive risk assessment reports that highlight potential vulnerabilities in investment portfolios. By generating synthetic data for fraud detection models, financial institutions can enhance their security measures, thereby helping to ensure that customers' assets are protected from emerging threats in an increasingly digital world.

The education sector is undergoing a transformation as GenAI introduces innovative solutions for personalised learning experiences. By creating adaptive learning paths and curricula tailored to individual student needs, this technology fosters a more engaging and effective educational environment. AI-powered tutoring systems provide natural language explanations and context-aware exercises, enabling students to grasp complex concepts at their own pace. Additionally, the ability to generate adaptive questions ensures that assessments are closely aligned with each learner's progress, promoting a deeper understanding of the material while enhancing overall academic performance.

In healthcare, GenAI is making significant strides in improving patient care and advancing medical research. The technology facilitates the design of novel drug molecules tailored to combat specific diseases, accelerating the drug discovery process, and reducing costs associated with traditional research methods. Moreover, it generates synthetic medical imaging data that trains healthcare professionals in diagnosing rare diseases, ensuring they are well-equipped to handle challenging cases. Personalised treatment plans based on genetic data further enhance patient outcomes by tailoring therapies to individual needs, marking a significant leap towards precision medicine.

The agriculture sector is embracing GenAI to optimise crop management and enhance sustainability practices. By analysing vast datasets, this technology generates automated, context-aware farming instructions that guide farmers in making data-driven decisions for irrigation and fertilisation. It also creates synthetic scenarios for pest and disease resilience planning, allowing farmers to prepare for potential threats before they arise. With AI-generated crop yield optimisation strategies, farmers can maximise their productivity while minimising resource use—ultimately fostering a more sustainable agricultural landscape.

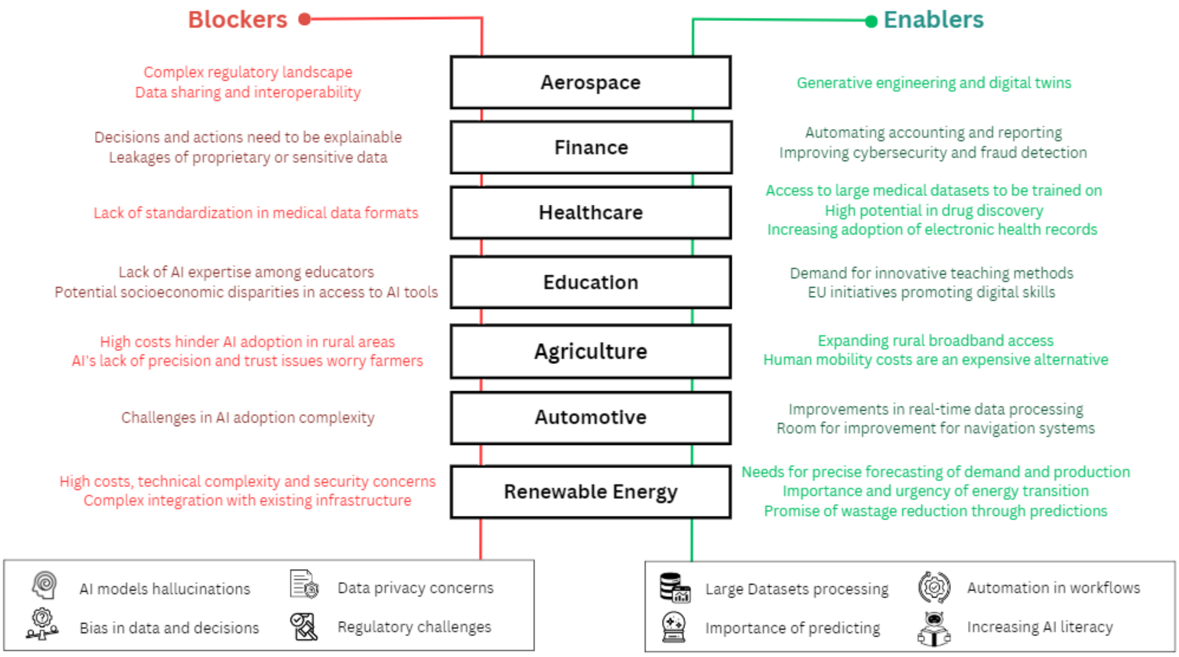
In the automotive industry, GenAI is driving innovation by streamlining vehicle design and enhancing safety features. Engineers utilise this technology for generative design processes that produce lightweight and efficient vehicle prototypes, contributing to improved fuel economy and reduced environmental impact. Additionally, AI-generated scenario testing for autonomous vehicles allows manufacturers to simulate real-world conditions and edge cases, ensuring that self-driving systems are robust and reliable.

The renewable energy sector is leveraging GenAI to optimise energy production and infrastructure development. By designing optimal layouts for renewable energy plants such as wind farms and solar arrays, this technology maximises energy capture while minimising land use. Predictive maintenance narratives generated by AI ensure that wind turbines and solar panels operate at peak efficiency by anticipating potential issues before they escalate into costly failures. Furthermore, synthetic grid stability scenarios enable energy providers to plan for fluctuations in supply and demand, ensuring a reliable energy future powered by renewable resources.

### 4.2 Common enablers and blockers in implementing GenAI

There are common enablers and blockers of GenAI in deployment that concentrate on data, infrastructure, and security. However, each sector faces unique challenges, such as the human role in medicine and education (Figure 20).

*Figure 20. GenAI Usage Enablers and Blockers.*




*Source: CEPS*

#### 4.2.1 Common enablers

First, access to large datasets is crucial for training GenAI models, leading to more accurate predictions and conclusions. For instance, healthcare benefits from extensive medical records, while finance leverages diverse financial datasets. With access to the data, AI saves costs across sectors with automation of the processing of large datasets, optimisation of workflows, and smarter scheduling.

In addition, synthetic data, created by algorithms to simulate real data, is increasingly used in AI for model training and testing in the financial sector, healthcare, and aerospace. It provides significant advantages in terms of privacy and cost.

Second, there is a growing demand for innovative solutions that enhance operational efficiency and improve customer experiences. Sectors like education and agriculture are increasingly seeking advanced tools to meet these demands.

Third, ongoing advancements in AI technology facilitate the development of new applications across sectors. For instance, improvements in natural language processing enhance capabilities in healthcare and education.

Fourth, many sectors emphasise the importance of enhancing customer interactions through personalised services. This is seen in finance with chatbots, and in aerospace with tailored travel recommendations.

#### 4.2.2 Common blockers

First, across all sectors, there are significant concerns regarding data privacy, consent, and ethical implications of AI use. Healthcare faces challenges related to patient data, while education grapples with ethical considerations surrounding AI-generated content.

Second, many sectors experience difficulties integrating GenAI into existing systems. In healthcare, for example, compatibility with current IT systems is a major hurdle.

Third, a common barrier is the lack of skilled personnel capable of implementing and managing GenAI technologies. This is particularly pronounced in finance and education, where expertise is essential for effective deployment.

Finally, often there is a resistance to change from professionals within sectors who fear job displacement or are hesitant to adopt new technologies. This resistance is especially visible in healthcare and education as professionals adapt to AI's role.

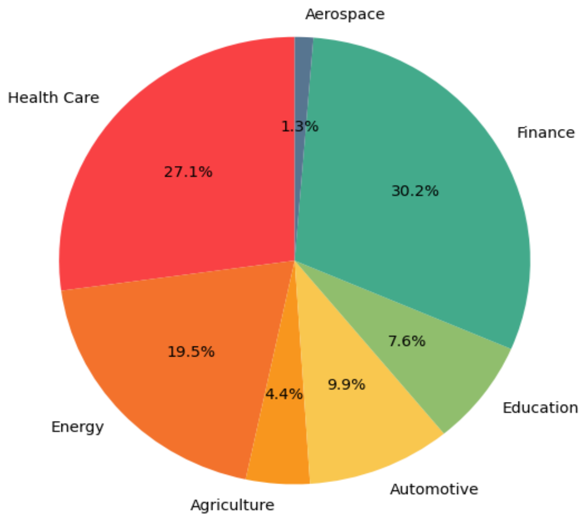
## 5. Case studies

### 5.1 Identification of the three selected sectors with justifications for their selection

While some sectors, such as finance and healthcare, have historically attracted more significant investments in GenAI (see Figure 21 below, demonstrating the shares of GenAI investments between the key sectors that we study[7]), we have identified three specific sectors where the EU would be well advised to seek to leverage GenAI as a way to foster innovation and secure a competitive position in the global landscape. Choosing sectors based purely on investment would mean basing the decision on an indication of industry size, and healthcare and finance would be natural candidates. Instead, we have chosen to include automotives and education, together with clean energy.

[7] The data is specifically about GenAI, while only for aerospace, data regarding the GenAI market share was not available, and an estimation of 1.2 billion USD was made using Market.us.

*Figure 21. Investment in GenAI across sectors.*




*Source: CEPS visualisation based on Research Precedence*

The selection of these three sectors is strategic, driven by the EU's desire to capitalise on existing strengths and address key challenges. Consider the following examples:

- Automotive: Europe has a very strong track record in automotives, hosting renowned companies and making efforts for 5G+ connectivity on highways. The rise of advanced deep learning and GenAI make autonomous vehicles "an inevitability" according to Paul Newman from the UK company Oxa. With GenAI, autonomous vehicles can partly be trained in the metaverse. Wayve (UK) uses a language model to explain and determine driving behaviour from a vision model, while EU giants Aptiv (France), Forvia (Ireland) and Einride (Sweden) are emerging. Europe saw 969 million USD in investment in autonomous vehicle startups in 2023, and over 1.1 billion USD in 2024.
- Clean energy: Europe is very ambitious with its climate goals and the regulatory effort of the Green Deal, and not without success. In 2023, the EU reported a 19% reduction in fossil fuel generation (representing a greatly reduced consumption of coal and gas). The EU hosts champions such as Iberdrola which is hosting a GenAI Centre of Excellence with the goal of optimising energy production processes.
- Education: One of the foundational strengths of the EU in education is its emphasis on cross-border collaboration and research. Initiatives like Horizon Europe exemplify this by providing substantial funding and support for AI research in education across the Member States. While Europe may not dominate the top spots in global university rankings compared to some counterparts in the USA or Asia, the widespread excellence of its educational institutions provides a solid foundation for innovation and improvement.

  Several EU-based companies are at the forefront of innovation in education technology (EdTech), making use of GenAI to transform learning experiences. Some notable examples include Lingvist, an Estonian company that has been revolutionising language learning with its AI-powered adaptive courses. Their system analyses user responses in real-time, tailoring the learning experience to each individual's needs. Lepaya, based in the Netherlands, uses GenAI to provide personalised professional skills training, adapting learning content and methods based on individual learner profiles and progress. In France, Domoscio has been pushing the boundaries of adaptive learning and knowledge retention. Their system used GenAI and cognitive science principles, particularly spaced repetition and predictive analytics, to optimise learning paths and enhance long-term memory consolidation.

The remainder of this chapter explores in greater detail the opportunities, challenges, and key applications of GenAI within these three chosen sectors. Each case study provides a deeper understanding of how the EU is navigating the integration of GenAI in the hopes of achieving its strategic objectives, and positioning itself as a global front-runner in AI-driven innovation.

## 5.2 Renewable energy sector

### 5.2.1 Opportunities in renewable energy through Generative AI

The EU is at a critical juncture in its transition to sustainable energy, with renewable sources like wind and solar central to achieving carbon neutrality by 2050. However, integrating these intermittent sources into existing grids poses significant challenges, particularly in light of the energy crisis triggered by Russia's invasion of Ukraine and the EU's ongoing efforts to reduce dependence on Russian gas.

Generative AI (GenAI) presents a transformative opportunity, offering innovative solutions to enhance grid stability, optimise renewables integration, and boost the EU's leadership in the global green economy. A key initiative in this regard is the EU's GenAI-powered *Digital Spine* framework[8]. The main goals of Digital Spine are to accelerate the EU's green transition, and to achieve climate neutrality by 2050 through advanced digital technologies. It envisions a digitally integrated energy system that optimises renewable assets, smart meters, EV charging, and smart buildings. This digital solution enables the optimal use of renewable energy sources across industries, reducing the need for enormous physical infrastructure investments.

One of the most promising opportunities lies in grid optimisation and management.

- Generative AI can provide unprecedented insights into complex energy systems, enabling predictive maintenance – AI algorithms can forecast potential equipment failures in renewable energy infrastructure, reducing downtime and maintenance costs.
- Generative AI can generate highly accurate predictions of renewable energy generation based on complex meteorological and geographical data.
- AI-powered systems can provide for smart grid intelligence – they can dynamically route and balance electricity across distributed networks, maximising the efficiency of renewable energy distribution.

The European Energy Data Space represents another groundbreaking opportunity. By creating a secure, standardised environment for data sharing across the energy sector, this initiative will enable more sophisticated AI algorithms to develop comprehensive solutions for grid management and renewable energy integration. Collaborative initiatives like GenAI4EU and projects such as ODEON and HEDGE-IoT[9] are actively developing AI-powered Internet of Things (IoT) platforms. These platforms promise

[8] Accelerating the green transition: the role of digital infrastructures in decarbonising energy and mobility sectors https://digital-strategy.ec.europa.eu/en/news/accelerating-green-transition-role-digital-infrastructures-decarbonising-energy-and-mobility https://www.enlit.world/projects-zone/unveiling-the-ai-driven-future-of-the-eus-energy-system/

[9] AI-IoT Edge-cloud and platform solutions for energy https://eucloudedgeiot.eu/wp-content/uploads/2024/09/PM-8-solutions-for-energy-HEDGE-IoT-ODEON-Svetoslav-Mihaylov.pdf

to transform energy management by enabling real-time monitoring, advanced data analysis, and intelligent control mechanisms at the network's edge. Meanwhile, the European Commission's call to establish 'AI Factories'[10] seeks to drive the development and deployment of trustworthy AI solutions across sectors, including energy. These factories could play an important role in advancing AI applications for sustainable and efficient energy systems. These initiatives seek to drive innovation, to foster collaboration, and to establish a foundation for an energy system that is both sustainable and resilient, with the aim of positioning the EU as a global leader in the application of AI-driven renewable energy innovation.

### 5.2.2 Challenges in implementing GenAI in renewable energy

Despite the many opportunities presented by generative AI, its integration into the renewable energy sector faces numerous challenges. Data-related challenges[11] emerge as a primary hurdle. The effectiveness of AI models depends critically on access to high-quality, comprehensive datasets. In the renewable energy context, this means gathering granular, real-time information about energy generation, consumption patterns, grid performance, and environmental conditions. Existing data infrastructure often remains fragmented and siloed, limiting AI's potential effectiveness.

Cybersecurity represents another critical challenge[12]. As energy systems become increasingly digital and interconnected, they become more vulnerable to potential cyber threats. The complex AI systems managing critical infrastructure must be designed with robust security protocols to prevent potential breaches that could compromise national energy security.

The energy consumption of AI models themselves presents a notable paradox. While AI aims to optimise renewable energy systems, the computational resources required to train and run sophisticated models consume substantial electricity. For instance, training large language models like GPT-3 has historically required approximately 1,287 MWh of electricity[13] — equivalent to the annual consumption of around 368 German households[14]. On the other hand, early evidence suggests that AI-driven optimisations in renewable energy could potentially generate net energy savings that far exceed the computational costs of model development[15]. Therefore, it is important to ensure that AI's energy consumption does not offset its potential environmental benefits.

Moreover, a successful implementation of AI in renewable energy demands more professionals combining expertise in data science, artificial intelligence, energy systems, and domain-specific

[10] AI Factories https://digital-strategy.ec.europa.eu/en/policies/ai-factories

[11] Unveiling the AI-driven future of the EU's energy system https://www.enlit.world/projects-zone/unveiling-the-ai-driven-future-of-the-eus-energy-system/

[12] EPRI Technical Brief. Artificial Intelligence and Generative AI in the Energy Sector. Cyber Security Use-Cases, Considerations, and Implications https://www.epri.com/research/products/000000003002029821

[13] David Patterson, Joseph Gonzalez, Quoc Le, Chen Liang, Lluis-Miquel Munguia, Daniel Rothchild, David So, Maud Texier, and Jeff Dean. Carbon emissions and large neural network training. arXiv preprint arXiv:2104.10350, 2021.

[14] Based on the estimate that EU household consumes approximately 3,500 kWh (3.5 MWh) of electricity per year https://www.cleanenergywire.org/factsheets/what-german-households-pay-electricity

[15]AI and energy: Will AI help reduce emissions or increase demand? Here's what to know https://www.weforum.org/stories/2024/07/generative-ai-energy-emissions/

knowledge. Currently, there exists a substantial skills gap that education and training institutions must urgently address[16].

A stark example of how challenges in scaling innovative technologies intersect with global competition is the recent bankruptcy of Northvolt, once a rising star in European (machine learning enabled) battery manufacturing[17]. Established to reduce dependency on Chinese battery producers, Northvolt faced enormous financial difficulties despite raising over $10 billion in funding. Challenges included fierce competition from China — controlling 85% of global battery-cell production[18] and offering significantly lower costs — coupled with operational missteps and the cancellation of key contracts. Northvolt's collapse highlights the broader risks of overambition and the need for strategic alignment in technology deployment, particularly in sectors like renewable energy where infrastructure investments are immense and geopolitical dependencies are acute.

Regulatory complexity adds another layer of challenge. In the renewable energy sector, the EU's reporting requirements for clean energy can be burdensome for SMEs. Streamlining reporting requirements would make sustainable operations more cost-effective. The European Union must develop comprehensive frameworks that balance innovation with safety, transparency, and ethical considerations. This requires creating adaptive regulatory models that can keep pace with rapid technological evolution while protecting critical infrastructure and individual privacy.

### 5.2.3 Key applications of GenAI in renewable energy

Building on these foundational efforts, generative AI is making substantial impacts in three major areas within the renewable energy sector: *grid optimisation*, *predictive maintenance*, and *battery manufacturing*. These applications demonstrate GenAI's potential to address sector-specific challenges while driving efficiency and sustainability.

#### 5.2.3.1 Grid management

Energinet, Denmark's publicly owned energy company, is responsible for operating and building the country's energy infrastructure, serving over 3.5 million electricity customers.[19]

Energinet faces the complex challenge of managing Denmark's electricity grid, particularly with the increasing reliance on fluctuating renewable energy sources like wind and solar power[20]. The company is strategically integrating GenAI to optimise grid operations and maintain a stable and reliable energy supply for consumers. AI algorithms are used to forecast electricity demand and supply in real-time, enabling Energinet to make proactive adjustments and ensure grid balance. This real-time monitoring

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[16] Labour and skills shortages in transport, energy, infrastructure and the digital sector https://www.eesc.europa.eu/en/news-media/press-summaries/labour-and-skills-shortages-transport-energy-infrastructure-and-digital-sector

[17] EV battery giant Northvolt files for bankruptcy, denting European hopes for homegrown production https://www.zerocarbonacademy.com/posts/ev-battery-giant-northvolt-files-for-bankruptcy-denting-european-hopes-for-homegrown-production

[18] Batteries are an essential part of the global energy system today and the fastest growing energy technology on the market https://www.iea.org/reports/batteries-and-secure-energy-transitions/executive-summary

[19] Presentation - AI & IoT (Thomas Wisbech - Energinet) https://ec.europa.eu/newsroom/dae/redirection/document/108696

[20] Energinet Annual Magazine 2024 https://en.energinet.dk/media/prymrbc0/aarsmagasin-2024-en-web-dobbeltsidet.pdf

and adjustment capability is critical given the unpredictable nature of renewable energy generation, which can vary significantly based on weather conditions.[21]

Furthermore, Energinet is exploring the use of AI "on the edge" of the IoT for grid management[22]. This involves deploying AI algorithms directly onto devices within the grid infrastructure. This allows for faster processing of large data streams and localised decision-making, enhancing the grid's responsiveness to changing conditions. This distributed AI approach could also offer benefits in terms of data security, as sensitive information can be processed locally. However, implementing AI on the edge necessitates a clearly defined two-way communication interface between these edge devices and the central grid management system. This interface is vital for coordinating actions, maintaining data consistency, and ensuring the overall stability of the electricity grid.

#### 5.2.3.2 Predictive maintenance

A second application area, predictive maintenance, is led by French Schneider Electric, a global leader in energy management and automation solutions. Schneider Electric has implemented AI-powered predictive maintenance across various renewable energy assets, leveraging AI algorithms to analyse data from sensors embedded within energy infrastructure[23]. These algorithms are capable of identifying anomalies and predicting potential equipment failures before they happen. By detecting issues early, Schneider Electric can conduct maintenance proactively, reducing the risk of costly system downtime and ensuring continuous energy production. This proactive maintenance strategy significantly extends the operational lifespan of renewable energy equipment, optimises maintenance costs, and enhances overall system efficiency, contributing to more reliable and cost-effective renewable energy generation.

#### 5.2.3.3 Battery manufacturing

Umicore — a leading circular materials technology company in Belgium — entered into a partnership with Microsoft to apply AI in the development of battery materials for electric vehicles[24]. This collaboration leverages Microsoft's Azure OpenAI Service, complemented by specific scientific AI models, to accelerate Umicore's R&D efforts. The AI platform will synthesise large amounts of proprietary data from Umicore's battery materials research, combined with external data, to help formulate smarter new materials more efficiently. This initiative aims to give Umicore a competitive edge in developing battery technologies, optimising time-to-market, and staying at the forefront of the rapidly evolving electric vehicle sector.

### 5.2.4 The way forward

The integration of AI and specifically Generative AI application into the EU's renewable energy sector demonstrates an opportunity in accelerating Europe's transition to sustainable energy and establishing its position as a front-runner in green technology innovation. Through initiatives like the Digital Spine

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[21] Ibid.

[22] Ibid.

[23] Schneider Electric launches AI-powered home energy management feature for Wiser Home https://www.se.com/ww/en/about-us/newsroom/news/press-releases/schneider-electric-launches-ai-powered-home-energy-management-feature-for-wiser-home-66d6bac4d6b0eff3580dc113

[24] Umicore enters AI platform agreement with Microsoft to accelerate and scale its battery materials technologies development https://www.umicore.com/en/newsroom/umicore-enters-ai-platform-agreement-with-microsoft-to-accelerate-and-scale-its-battery-materials-technologies-development/

and successful implementations at companies like Energinet, Schneider Electric, and Umicore, GenAI is already delivering benefits in grid optimisation, predictive maintenance, and advanced battery manufacturing. While the energy consumption of GenAI model usage must be carefully considered, powering AI with renewable energy can achieve net zero greenhouse gas emissions. The EU's forward-thinking approach, exemplified by programs like GenAI4EU and Battery 2030+, along with the development of the European Energy Data Space, positions Europe at the forefront of combining AI innovation with sustainable energy practices. As these technologies mature and become more energy-efficient, the EU is well-positioned to be a frontrunner in the global transformation toward an AI-driven, renewable energy future, offering a model for other regions to follow.

Europe is positioned as "partially competitive" in the "Electrification and renewables" technology domain, which encompasses renewables, batteries, hydrogen, sustainable fuels, nuclear fission, and heat pumps, according to the latest World Economic Forum analysis of Europe’s digital competitiveness[25]. This suggests having a tailored strategic approach: where Europe has partial competitiveness it should focus on scaling up and commercialising as rapidly as possible, while also defending its strategic capabilities.

The most promising opportunity for the EU lies in battery manufacturing for electric vehicles. Batteries could be key to the EU's clean energy transition and strategic autonomy. Boosting the industrial base for battery production is therefore a key task for the EU. As an example of what can be achieved, Poland has positioned itself as one of the most attractive European locations for investments in electric vehicles. It has established itself globally as a key player in battery manufacturing, becoming the world’s second-largest producer of lithium-ion batteries, after China[26]. This gives the EU a competitive advantage in clean technology supply chain, but requires more investments in the field.

The successful integration of GenAI in the energy sector not only supports the EU's 2050 carbon neutrality goals, but also strengthens the EU’s technological sovereignty and economic competitiveness.

## 5.3 Automotive sector

### 5.3.1 Opportunities in automotive through GenAI

The European Union's automotive industry is undergoing a transformation as automation and digitalisation reshape production, innovation, and competitiveness. Competition from abroad has intensified. To remain a global leader, the EU has launched the Vehicle of the Future initiative[27], a European Commission programme focused on advancing software-defined vehicles (SDVs). By improving collaboration among manufacturers, suppliers, and technology developers, the programme promotes open-source software solutions. Furthermore, it works closely with the European Chips Act[28]

[25] Europe in the Intelligent Age: From Ideas to Action https://reports.weforum.org/docs/WEF_Europe_in_the_Intelligent_Age_2025.pdf

[26] Poland, a strategic cleantech hub for Europe https://strategicperspectives.eu/wp-content/uploads/2024/12/StrategicPerpectives-Poland-strategic-cleantech-hub-for-Europe-1.pdf

[27] The Vehicle of the Future initiative https://digital-strategy.ec.europa.eu/en/policies/vehicle-future-initiative

[28] European Chips Act https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/europe-fit-digital-age/european-chips-act_en

to develop an open automotive hardware platform, underscoring the synergy between software and hardware as a driver of innovation.

A recent study by the European Commission's Joint Research Centre (JRC), *Automation in the Automotive Sector: Romania, Spain, and Germany,*[29] highlights the factors driving automation in the sector, such as the need for greater productivity, improved product quality, and reduced reliance on manual labour. However, it also identifies significant barriers, including high implementation costs, technical complexities, and the extensive training required for workers. In this context, Generative AI has emerged as a transformative force potentially capable of addressing these challenges and accelerating progress.

For instance, GenAI can mitigate the scarcity of real-world driving data, a critical bottleneck for autonomous vehicle development. By generating synthetic data that closely mirrors real-world conditions, GenAI can enable the efficient training and validation of autonomous systems[30]. This capability reduces costs and expedites innovation, allowing the EU to remain competitive in the global race for autonomous vehicles. Additionally, as digitalisation and electrification redefine manufacturing processes, GenAI-powered simulations offer immersive training tools[31], helping workers adapt to new technologies and production methods.

### 5.3.2 Challenges in implementing generative AI in automotive

Despite its potential, GenAI integration in automotive presents several challenges. One significant concern is the potential for the EU's AI Act to stifle innovation in this rapidly developing sector. This concern stems from the Act's broad definition of "safety components"[32], which, if applied too widely to AVs, could subject a vast array of AI systems within these vehicles to stringent regulatory requirements. This could lead to an excessive burden on manufacturers, potentially discouraging investment in autonomous vehicles development within the EU. To avoid stifling innovation, regular updates to the regulations are needed to ensure they keep pace with technological advancements and the evolving understanding of risks.

In addition to regulatory concerns, data security and privacy represent critical challenges for AVs powered by GenAI[33]. These vehicles essentially become mobile data centres, continuously collecting and processing an intricate web of information about their environment, passengers, and surrounding contexts. Therefore, the privacy landscape demands sophisticated protection mechanisms that go far beyond traditional cybersecurity approaches. Advanced encryption techniques, comprehensive anonymisation protocols, strict data retention policies, and transparent and efficient user consent frameworks become critical.

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[29] European Commission, Joint Research Centre, Russo, M., Simonazzi, A. and Cetrulo, A., *Automation in the automotive sector: Romania, Spain and Germany*, Publications Office of the European Union, Luxembourg, 2024, https://mpra.ub.uni-muenchen.de/121707/1/MPRA_paper_121585.pdf.

[30] For example, see this Applied Intuition solutions https://www.appliedintuition.com/

[31] For example, see solutions by Immersive Labs https://www.immersivelabs.com/

[32] The EU AI Act Article 6: Classification Rules for High-Risk AI Systems https://artificialintelligenceact.eu/article/6/

[33] Vehicle Safety and automated/connected vehicles https://single-market-economy.ec.europa.eu/sectors/automotive-industry/vehicle-safety-and-automatedconnected-vehicles_en

On top of that, integrating generative AI into automotive systems is extremely complex, where each technological component must perform seamlessly and harmoniously. Providing reliable real-time communication between sensors, managing computational complexity, maintaining system reliability, and developing robust fallback mechanisms become critical engineering challenges. Software update strategies introduce additional complexity[34]. Interoperability requirements demand standardised communication protocols, universal interfaces, and flexible, modular system architectures that can adapt to evolving technological landscapes. Product liability issues also pose noteworthy challenges.

These domains – regulatory considerations, data security, and system integration – are profoundly interconnected. Advances or challenges in one area create cascading effects across the entire ecosystem. The successful implementation of generative AI in autonomous driving will require continuous interdisciplinary collaboration, adaptive regulatory frameworks, significant research investment, and transparent communication with the public.

### 5.3.3 Key applications of GenAI in automotive

*Generative AI has an impact in three major areas within the automotive sector: autonomous driving systems training, digital twins, customer experience.*

#### 5.3.3.1 Autonomous driving systems training

Germany, a leading automotive force in the EU, is making use of GenAI to propel the development of autonomous driving functions. The nxtAIM project[35], backed by the German government, exemplifies this commitment. This initiative seeks to address a crucial bottleneck in autonomous vehicle development: the need for vast quantities of real-world driving data, especially from critical and safety-relevant scenarios. Gathering such data is costly, time-consuming, and often impractical.

Here's where GenAI steps in, offering a revolutionary solution. The nxtAIM project uses GenAI to create synthetic driving data, effectively circumventing the limitations of real-world data collection. This synthetic data, indistinguishable from real data in terms of quality, fuels the training and testing of autonomous driving systems, accelerating their development. This leap forward in data generation not only accelerates the pace of innovation but also positions the EU at the forefront of autonomous vehicle technology. The ability to rapidly develop and deploy advanced autonomous driving features is crucial for the EU's global competitiveness in the automotive sector. Moreover, the nxtAIM project underscores the collaborative spirit within the EU, bringing together major industry players like Continental and Mercedes-Benz, along with research institutions like the Jülich Research Center. This collaborative ecosystem fosters knowledge sharing and pooled resources, further strengthening the EU's position in the global race for autonomous vehicle dominance.

[34] Wu, Nan & Jiang, Rongkun & Wang, Xinyi & Yang, Lyuxiao & Zhang, Kecheng & Yi, Wenqiang & Nallanathan, Arumugam. (2024). AI-Enhanced Integrated Sensing and Communications: Advancements, Challenges, and Prospects. IEEE Communications Magazine. 62. 144 - 150. 10.1109/MCOM.001.2300724. https://www.researchgate.net/publication/379270187_AI-Enhanced_Integrated_Sensing_and_Communications_Advancements_Challenges_and_Prospects

[35] Politics and industry discuss the opportunities for the German automotive industry https://www.vda.de/en/press/press-releases/2024/241007-PM-ai-innovations-for-safe-autonomous-driving

### 5.3.3.2 Digital twins

Another potential area of GenAI applications utilisation is digital twins. For example, BMW Group is leveraging NVIDIA Omniverse as part of its digital transformation to optimise production planning, robotics, and logistics systems[36]. NVIDIA Omniverse[37] is a cutting-edge development which creates interoperability between various industrial design and engineering software, enabling seamless collaboration across teams and geographies. Omniverse acts as a digital twin environment where companies can simulate and optimise real-world processes virtually. Using the Omniverse platform, BMW has created entirely virtual factories, including a planned electric vehicle plant in Debrecen, Hungary, set to open in 2025. This virtual environment enables real-time collaboration, where teams can aggregate data into high-performance models and make adjustments to factory layouts, ensuring efficiency before actual production begins. By using AI-driven tools, BMW can simulate and test various scenarios, such as optimising robot placement in constrained spaces, ultimately reducing costs and improving operational efficiency.

The Omniverse platform allows BMW to bridge data across different software tools and collaborate globally, making it possible to streamline the planning process for new facilities while reducing risks associated with large-scale construction projects. By integrating industrial design software and developing custom applications, like Factory Explorer, BMW can more effectively plan and optimise their factories. This virtual-first approach not only accelerates time to production, but also contributes to sustainability by minimising changes during physical construction that would otherwise lead to costly delays and production downtime.

### 5.3.3.3 Enhanced customer experience

Another application area is related to AI-driven solutions that are improving customer interactions through personalised services. Volkswagen has integrated ChatGPT into its IDA voice assistant, significantly enhancing the customer experience across its new vehicle lineup, including the all-electric ID family: the Golf, Tiguan, and Passat[38]. This integration enables drivers to interact with their cars in natural language for tasks that extend beyond traditional voice control. For example, drivers can now ask questions about tourist attractions, past events, or math problems, and receive conversational responses without taking their eyes off the road. This seamless interaction not only simplifies access to information, but also reaffirms Volkswagen's commitment to making advanced technologies widely accessible.

This innovation is powered by Cerence Inc., a global leader in automotive AI solutions, known for providing cutting-edge voice and conversational AI technologies to the automotive industry. By collaborating with Cerence, Volkswagen ensures that ChatGPT operates securely, with all queries handled anonymously and deleted immediately for optimal data privacy. The system requires no additional accounts or apps and supports multiple languages, including English, Spanish, Czech, and German. This use of generative AI highlights how the automotive industry can leverage advanced technologies to enhance functionality and deliver a superior, intuitive driving experience, further cementing Volkswagen’s reputation for technological innovation and customer-centric design.

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[36] BMW Group Starts Global Rollout of NVIDIA Omniverse https://blogs.nvidia.com/blog/bmw-group-nvidia-omniverse/

[37] https://www.nvidia.com/en-us/omniverse/

[38] ChatGPT is now available in many Volkswagen models https://www.volkswagen-newsroom.com/en/press-releases/chatgpt-is-now-available-in-many-volkswagen-models-18459

### 5.3.4 The way forward

The way forward for generative AI in the EU automotive sector lies in fostering innovation while addressing key challenges through strategic initiatives. Policymakers and industry leaders must collaborate to create a regulatory environment that balances safety with innovation. A critical step is the development of clear and adaptable regulatory frameworks. Additionally, establishing “regulatory sandboxes” could provide a controlled environment for testing and refining generative AI applications in AVs before full-scale deployment.

Building and maintaining public trust is paramount for the successful integration of generative AI in the automotive industry. This requires robust investments in data security and privacy measures that go beyond traditional cybersecurity approaches. The implementation of advanced encryption techniques, comprehensive anonymisation protocols, strict data retention policies, and transparent user consent frameworks will be crucial to protect sensitive information and ensure user confidence in these systems. Furthermore, targeted upskilling programs are vital to bridge the skills gap and equip the workforce with the knowledge and expertise needed for the digital transformation of the industry. These programs should focus on equipping individuals with the skills to develop, implement, and oversee generative AI systems in a safe and responsible manner. By focusing on these strategic initiatives, the EU has the potential to establish itself as a global leader in the development and deployment of safe, ethical, and innovative generative AI applications for the automotive sector.

## 5.4 Education

### 5.4.1 Opportunities of GenAI in education

The European Union is at the forefront of integrating GenAI into education, presenting several promising opportunities. The EU's Digital Education Action Plan 2021-2027 is a key initiative aimed at enhancing digital literacy and skills across Europe[39]. This plan includes efforts to integrate GenAI in education, such as establishing expert groups to standardise terminology and quality criteria for AI-generated educational content. This standardisation is crucial for ensuring the reliability and effectiveness of GenAI tools in educational settings[40].

GenAI can significantly alleviate the administrative burden on educators by automating tasks like grading, providing feedback, and handling repetitive queries. This allows teachers to focus more on teaching and providing personalised support to students. Additionally, GenAI can personalise education by generating tailored assessment items, adapting to learners' responses, and providing real-time feedback. This can enhance learner engagement, motivation, and performance, particularly for diverse learners, including those with neurodiverse or multilingual backgrounds.

The EU's approach to AI, emphasising excellence and trust, is particularly relevant in education. The EU Artificial Intelligence Act, while categorising education-related AI applications as “high risk”, also provides a framework for collaboration between educators and policymakers to establish safeguards that

[39] Digital Education Action Plan (2021-2027) https://education.ec.europa.eu/focus-topics/digital-education/action-plan

[40] European approach to artificial intelligence https://digital-strategy.ec.europa.eu/en/policies/european-approach-artificial-intelligence

balance innovation with safety. This encourages the development of trustworthy AI that respects EU values and rules, which is essential for educational settings[41].

The EU's investment in AI research and infrastructure, such as the Horizon Europe and Digital Europe programmes, which allocate €1 billion per year for AI[42], further supports the integration of GenAI in education. These investments aim to develop safe and ethical AI applications, fostering "AI made in Europe" from the lab to the market. The creation of 'AI Factories', leveraging the supercomputing capacity of the EuroHPC Joint Undertaking, should also be beneficial for developing trustworthy generative AI models that can be applied in educational contexts.

### 5.4.2 Challenges in implementing GenAI in education

Despite the promising opportunities, the integration of GenAI in education is not without its challenges. One of the primary concerns is the ethical implications of using GenAI, particularly in areas such as plagiarism and academic integrity. The ease with which GenAI can generate content raises significant questions about the authenticity of student work, and the need for robust mechanisms to detect and prevent academic dishonesty[43]. Furthermore, there is a risk that students might rely too heavily on AI-generated content, undermining the development of essential skills such as critical thinking, problem-solving, and creativity. This necessitates a balanced approach that integrates GenAI in a way that complements, rather than replaces, traditional pedagogical practices[44]. Additionally, ensuring the seamless adaptation of all stakeholders, including teachers, administrative staff, students, and parents, to the AI developments is crucial. This requires upskilling educators not just in the functional use of GenAI but also in understanding its pedagogical implications. The cultivation of robust communities of practice and collaborative spaces for educators to exchange experiences and strategies is essential[45].

Finally, the impact of GenAI on the role of educators is a significant area of concern. While GenAI can fill gaps in disadvantaged settings where teachers are in short supply, it is crucial to maintain a balance between human and machine roles in education. Well-run, well-equipped schools with well-trained and adequately paid teachers remain essential for achieving high-quality learning outcomes. The integration of GenAI must be designed to support and enhance the teaching profession rather than replace it.

### 5.4.3 Key applications of GenAI in education

Generative AI offers numerous opportunities to enhance educational experiences. Three key applications are *personalised learning*, *content generation*, and *administrative automation.*

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[41] The EU AI Act and Responsible AI: Innovating with GenAI whilst protecting the bottom line and society https://www.cognizant.com/nl/en/insights/blog/articles/eu-ai-act-and-responsible-ai

[42] European approach to artificial intelligence https://digital-strategy.ec.europa.eu/en/policies/european-approach-artificial-intelligence

[43] Generation AI: Navigating the opportunities and risks of artificial intelligence in education https://www.unesco.org/en/articles/generation-ai-navigating-opportunities-and-risks-artificial-intelligence-education

[44] Ibid

[45] Report 11 – Generative AI and Higher Education: Challenges and Opportunities https://www.ipp-jcs.org/en/2024/09/24/report-11-generative-ai-and-higher-education-challenges-and-opportunitiesreport-11/

#### 5.4.3.1 Personalised learning

One of the most promising features of GenAI is that it can tailor educational content to meet individual learning needs, offering personalised learning paths based on student performance and preferences. This approach can improve engagement and outcomes by adapting the pace and style of instruction. An example of a company involved in this area is NOLAI[46] in the Netherlands, which uses AI tools to create adaptive learning environments. The Generative AI project launched by NOLAI and Quadraam schools in the Netherlands exemplifies the innovative integration of AI in education[47]. This initiative aims to explore how generative AI can be thoughtfully embedded within educational settings to enhance learning and teaching processes. By collecting practical cases from Quadraam's 14 secondary schools, the project seeks to understand how students and teachers are currently utilising AI tools like ChatGPT and DALL-E. These tools have been used for generating practice summaries, lesson preparation, and even creating visual aids like electrical circuit diagrams. However, the project also highlights potential risks, such as AI-generated portfolios and exams, underscoring the need for a balanced approach that leverages AI's capabilities while maintaining educational integrity.

The NOLAI project is working towards developing a toolkit for teachers and students that includes practical suggestions for effectively using AI in classrooms. This initiative reflects a broader trend where educational institutions are beginning to embrace AI's potential to transform education by providing personalised learning experiences and improving resource efficiency. However, this transformation requires careful consideration of ethical implications and the establishment of robust regulatory frameworks to guide AI's integration into education.

#### 5.4.3.2 Content generation

Generative AI can assist educators in generating educational content such as summaries, glossaries, and practice exercises. For example, developing a curriculum is a challenging task due to its ever-evolving relevance and knowledge base. On top of that, when it comes to developing a curriculum for the AI-related courses, it might need to be updated every month given the very rapid developments of AI models. The rise of generative AI provides an opportunity to create personalised lesson plans up-to-date and tailored to individual students, offering significant potential to enhance curriculums.

To illustrate, Sana Labs[48], a Swedish company, provides a platform for creating and managing learning content, powered by a range of AI capabilities designed to simplify and accelerate the content generation process. One of the key areas where Sana Labs leverages GenAI is in assisting with the creation of diverse content formats. Users can create personalised courses, complete with interactive elements such as polls, quizzes, and reflection cards. Additionally, Sana Labs supports the development of wikis and how-to guides, allowing for a centralised knowledge repository. The platform offers a drag-and-drop interface for easy content layout and an AI-powered writing assistant that functions as an “expert editor”, helping users refine their content and achieve higher quality. The AI translation feature streamlines the localisation of learning materials, eliminating the need for external agencies and reducing turnaround time. One particularly innovative feature is the ability to transform static PDF files into interactive courses using AI. This functionality enables organisations to breathe new life into existing knowledge

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[46] NOLAI https://www.ru.nl/en/nolai

[47] Generative AI Project Launched with Quadraam https://www.ru.nl/en/about-us/news/generative-ai-project-launched-with-quadraam

[48] Sana Labs https://sanalabs.com/platform-content-creation

resources, making them more engaging and accessible to learners. Finally, Sana Labs offers an AI-powered narration feature that can add voiceovers to courses, potentially enhancing engagement and accessibility for users who prefer auditory learning.

#### 5.4.3.3 University teacher preparation activities

The study, focused on university teachers at Luleå University of Technology in Sweden[49], reveals that generative AI is already being adopted by teachers at the university. Over half of the respondents (52%) reported using GenAI tools, with ChatGPT being the most popular. The most common use was for preparation activities (27%), followed by research (20%) and teaching (14%). Examples given by teachers highlight the efficiency and quality improvements brought by GenAI, such as using ChatGPT to summarise workshop content, create better visuals, and improve the clarity of their teaching materials. Interestingly, a strong positive correlation was found between the perceived impact of GenAI on teaching and the teacher's willingness to encourage students to use it ethically. This suggests that familiarity with GenAI and its potential benefits may lead to more informed and responsible adoption practices. The study concludes by advocating increased teacher knowledge about these tools to provide appropriate guidance to students who are "guaranteed to use it already".

### 5.4.4 The way forward

The EU should prioritise the finalisation of comprehensive regulatory guidelines that address both the opportunities and risks associated with AI in education. These regulations should focus on ensuring safety, transparency, and ethical use of AI technologies, while also fostering innovation. Clear standards will help educational institutions and developers navigate the complexities of integrating AI, while safeguarding against misuse and bias.

In parallel, educational institutions should create robust policies to support the integration of AI into teaching and learning practices. This includes offering professional development programs and training for educators, equipping them with the knowledge and skills to use AI tools effectively in the classroom. Institutions should also develop internal guidelines that align with EU regulations, ensuring compliance with ethical standards and promoting responsible AI usage.

Ongoing research into the educational impacts of generative AI is essential for understanding both its benefits and challenges. To maximise its potential, collaboration between governments, educational institutions, and the private sector is necessary. Joint efforts can drive innovation, improve AI tools for education, and ensure that access to these technologies is equitable across regions and socio-economic groups.

By addressing these critical areas, the EU can strategically leverage generative AI to enhance educational systems, making them more competitive globally while seeking to ensure that ethical standards and human-centric values remain at the forefront of development and implementation. This approach will help create a future-ready, inclusive educational ecosystem that benefits all learners.

[49] Pettersson, Jenny & Hult, Elias & Eriksson, Tim & Adewumi, Oluwatosin. (2024). Generative AI and Teachers - For Us or Against Us? A Case Study. Swedish Artificial Intelligence Society. 37-43. 10.3384/ecp208005. https://www.researchgate.net/publication/381455880_Generative_AI_and_Teachers_-_For_Us_or_Against_Us_A_Case_Study

## 6. The EU's strengths and weaknesses as regards GenAI

This chapter provides a *strengths, weaknesses, opportunities, and threats (SWOT)* analysis focusing on the European Union's (EU) ability to benefit from GenAI. It builds on the findings from the previous chapters, and aims to identify policy issues and thereby to provide the underpinnings for recommendations to leverage strengths and opportunities while mitigating weaknesses and threats.

SWOT analysis is a standard management consulting technique that seeks to provide a balanced view of strengths and weaknesses, both at present and going forward. The findings appears as Table 3.

*Table 3. The EU's Strengths, Weaknesses, Opportunities, and Threats (SWOT) as regards GenAI.*

| | Positive | Negative |
|---|---|---|
| **Present** | **Strengths** | **Weaknesses** |
| | • Strong base in underlying research.<br>• A capable and well-developed open source development community.<br>• Willingness to use legislation.<br>• Moderate digital infrastructure.<br>• Good ability to train AI professionals. | • Insufficient investment in production relative to global competitors (US).<br>• Fragmentation in the EU single market.<br>• Weak large scale computing infrastructure.<br>• Limitations in access to training data. |
| **Future** | **Opportunities** | **Threats** |
| | • Better education and training, increased access to skilled workers.<br>• Increased willingness to invest public and private funds.<br>• Increased focus on regulatory simplification.<br>• Increase access to training data.<br>• Focus on Green AI.<br>• Potential use of sophisticated software and open source development to offset the EU's weakness in computing infrastructure and skilled staff. | • Supply chain disruptions due to trade wars, kinetic war, natural disasters, pandemics, or general macroeconomic decline.<br>• Growing policy divergence among and within EU member states, or with key trading partners.<br>• Threats to the workplace, including job displacement, accelerated skills obsolescence, and mental health impacts.<br>• Inaction or insufficient action on the part of policymakers. |

*Source: CEPS*

### 6.1 Strengths

Firstly, the EU (together with the UK) excels in fundamental research on GenAI, including a strong focus on open-source development. This robust research foundation is crucial for future innovation and the development of new applications. The EU's scientific excellence and the presence of numerous research institutions create a fertile ground for advancing GenAI technologies.

Secondly, the EU's proactive approach to legislation is a major strength. The EU's willingness to utilise legislation to safeguard societal well-being and workers' rights sets a high standard for the ethical and responsible development and deployment of GenAI. The recent enactment of the EU AI Act, which aims to regulate AI systems based on risk levels, is a prime example of this legislative power. This act reflects a commitment to human-centric and responsible AI development, which can serve as a global benchmark.

Thirdly, the EU possesses substantial computing and network infrastructure (even if not as strong as that of some global competitors), laying the groundwork for GenAI applications.

Additionally, it boasts a world-class, cost-effective AI engineering talent pool, educating a comparable number of top AI talents as the US.

### 6.2 Weaknesses

Despite its strengths, the EU faces several weaknesses.

Firstly, a significant weakness is the insufficient investment in GenAI production compared to global competitors, particularly the United States and (to a lesser degree) China. Access to finance for GenAI startups is a serious challenge[50]. This investment gap has limited the EU's ability to compete in developing and scaling up GenAI technologies. The EU's current investment levels, while substantial, are not enough to match the scale of investments seen in other major economies.

Secondly, the EU experiences a lack of skilled workers in AI, compounded by brain drain and difficulties in attracting suitable talent. This shortage of skilled labour limits the EU's capacity both to produce and to exploit GenAI solutions effectively. On top of that, there are significant hiring barriers as hiring non-EU talent is challenging in the EU, compared to the US, which has more innovation-friendly hiring practices.

Thirdly, the incomplete EU single market, coupled with high regulatory burdens, hinders the growth and scalability of GenAI companies. These barriers restrict the flow of capital and make it difficult for startups to expand across different EU member states.

Fourth, weaknesses in infrastructure, particularly in large-scale computing, are evident, and the EU's heavy reliance on non-EU cloud providers may imply risks to the EU’s security and to the privacy of the personal data of Europeans. As this report approaches completion in January 2025, these concerns may however need some re-thinking. The apparent success of the state-of-the-art foundation model DeepSeek, from a firm with far less capitalisation than that of the US tech giants and with training costs variously estimated at only 2% of the corresponding training costs of the best models from OpenAI, might well suggest that innovative software techniques might offset to a substantial degree the EU’s weakness in computational infrastructure. Goldman Sachs has observed that “DeepSeek has demonstrated that using novel computational techniques for model inferencing … and more efficient model training make it possible to produce highly capable AI models with more limited resources and at lower costs than previously believed. This breakthrough has potentially changed the competitive landscape for generative AI by challenging the widely held view that prohibitive investment costs are a barrier to entry at the foundational model level and raising the prospect that compute costs could continue to fall in line with historical trend.” Relatedly, deficits in 5G mobile network coverage might further hamper the EU's GenAI development. These infrastructure gaps need to be addressed to support the scaling of GenAI technologies.

Finally, the strong protection of privacy and copyright in the EU limits access to training data in the EU, despite numerous laws put in place (e.g. DGA, EHDS) to try to expand re-use of non-personal data. Limited access to training data also creates barriers to the development of GenAI in the EU.

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[50] J. Scott Marcus and Maria Alessandra Rossi (2024), “Strengthening EU digital competitiveness Stoking the engine”, EUI/RSC Centre for a Digital Society, https://cadmus.eui.eu/handle/1814/76877

## 6.3 Opportunities

The EU has several opportunities to capitalise on the GenAI landscape. Firstly, there is a growing recognition of the need to increase access to skilled workers and invest in modernising the EU, particularly in AI and digital skills. Initiatives to attract experts from other regions through remote work opportunities can help bridge the skills gap. Additionally, programs like the Horizon 2020 and the Digital Europe Program, which have allocated significant funds to AI research and deployment, can be leveraged to enhance the EU's GenAI capabilities.

Secondly, completing the capital markets union (CMU) and implementing initiatives like an EU savings instrument can boost investment in GenAI. Eliminating unnecessary restrictions on investments by pension and insurance funds (as noted in the just-released *Competitiveness Compass*) could further mobilise capital, providing the necessary financial resources for GenAI startups and scale-ups.

Thirdly, increased focus on regulatory simplification and better coordination of responses to shocks at the EU level can create a more favourable environment for GenAI development. The EU's regulatory environment, while complex, can be streamlined to remove ambiguity and accelerate the adoption of GenAI. This is particularly important as European regulation can create a clear playbook for companies, both within and outside the EU, to adopt GenAI responsibly.

Fourth, standardisation, digitalisation, and initiatives to make data available (e.g., Open Data Directive, European Health Data Space) present significant opportunities.

Fifth, the focus on Green ICTs and Green AI aligns with the EU's sustainability goals and opens new avenues for GenAI application. This emphasis on sustainability can position the EU as a leader in responsible and environmentally friendly AI development.

Finally, China's just-released DeepSeek r1 may contain useful hints on ways in which to revitalise the EU's GenAI potential. The software techniques that DeepSeek has pioneered (multi-layer attention (MLA), Mixture Of Experts (MoE), and backtracking) might enable a major gain in the efficiency of model training, potentially enabling EU firms to provide good GenAI solutions with vastly less computational power and energy consumption than was previously thought to be possible. There may also be lessons to be learned from DeepSeek's mode of operation – an open source approach such as that which they have employed potentially plays to the EU's strengths in ways in which the closed source approach of most US-based GenAI champions does not.

## 6.4 Threats

The EU also faces several threats that could hinder its progress in GenAI. Firstly, the EU's reliance on US supply chains poses a significant risk, and the new US regime may be more willing to exploit those dependencies than any US regime in the previous 80 years would have considered. Trade wars, tariffs, export restrictions, kinetic war, natural disasters, pandemics, or a general global macroeconomic decline could all disrupt the flow of essential technologies and expertise. This vulnerability underscores the need for the EU to develop more diverse supply chains or greater self-sufficiency in order to reduce excessive dependence on a single external provider.

Secondly, growing policy divergence among and within EU member states could lead to fragmentation and could hinder collaborative efforts in GenAI. Harmonised policies and coordinated actions within the EU and, where possible, with our key trading partners are essential to ensure that the EU can leverage its collective strengths effectively.

Thirdly, the rapid advancement of GenAI brings potential threats to the workplace, including job displacement, accelerated skills obsolescence, and mental health impacts due to AI-driven changes. Addressing these issues through retraining programs, social support mechanisms, and ethical guidelines for AI deployment is crucial to mitigate these threats.

Finally, the threat of inaction or insufficiently effective action from policymakers could result in the EU falling behind in the global GenAI race. It is essential for policymakers to take proactive and coordinated actions to address the challenges and to capitalise on the opportunities presented by GenAI.

### 6.5 Conclusion

The SWOT analysis highlights the complex landscape the EU faces in the realm of GenAI. While the EU possesses inherent strengths in research and a proactive regulatory approach, addressing weaknesses related to investment, skills gaps, market barriers, and infrastructure is crucial.

The emergence of DeepSeek's r1 necessitates an urgent re-thinking of what we thought we knew about the evolution of this sector, and might well represent an important opportunity for the EU to re-think its overall industrial policy approach to AI foundation models. Many of the software techniques used by DeepSeek to overcome lack of capital and lack of computing resources might be profitably employed by EU firms, and the kind of open source approach taken by DeepSeek and by other Asian GenAI innovators potentially plays to the EU's strengths.

Capitalising on emerging opportunities, particularly in investment, skills development, and regulatory simplification, will be key to success. Simultaneously, mitigating risks and threats stemming from supply chain disruptions, policy divergence, and potential workplace disruptions is essential.

## 7. Policy recommendations

### 7.1 Policy recommendation for the EU institutions

This chapter explores policy recommendations for developing a robust, ethical, and inclusive AI ecosystem in Europe. The recommendations focus on strategic, structural, and human-centred actions that the European Union can take to address the challenges and opportunities that GenAI presents. In addition, it explores the critical role of civil society organisations (CSOs) in AI governance, leveraging insights from experts and roundtable discussions to identify pathways for enhancing CSO participation in implementing the EU AI Act.

The insights gained from four semi-structured interviews with Nicolas Blanc (CFE-CGC), Claire Morot-Sir (ECAS), Jimmy Farrell (Pour Demain), and Andreas Aktoudianakis (Google), combined with the discussions from a roundtable on AI organised at CEPS, provided a comprehensive understanding of the current state and future aspirations of civil society and industry regarding AI. The roundtable on the 13 November 2024 gathered a mix of participants including representatives from think tanks, academia, industry, government bodies, and policy advocacy networks, highlighting a diverse range of perspectives. Additionally, we engaged in discussions with semiconductor manufacturer IMEC to get their perspective on GenAI developments and governance. All this together forms the basis as well as a validation for the policy recommendations presented to the potential of the European Economic and Social Committee (EESC) in this chapter.

1. **Fostering the European AI ecosystem**

   The European institutions should prioritise establishing a collaborative and innovative European AI ecosystem, including creating a “CERN for AI” to better integrate research and development efforts across Europe. This initiative could involve a central hub with regional nodes to facilitate resource sharing, talent acquisition, and infrastructure development. This broader AI ecosystem would encompass specific GenAI aspects as well.

   Additionally, beyond incremental research, the Commission should focus on strategic research initiatives to address the grand challenges in AI, such as understanding the principles of intelligence, and AI's role in physical environments.

   Bridging the gap between scientific research and industry is crucial, and the Commission should continue to support initiatives like ‘AI factories’ to help businesses leverage AI. Relatedly, it will be important to develop outreach strategies to businesses on the benefits and opportunities of AI and GenAI deployment in their work – this can be done by showcasing examples of successful GenAI adoption at work.

   Strengthening collaboration within the EU is called for. Duplication of effort among the Member States, and between the Member States and the EU, needs to be reduced.

   Strengthening collaboration with the UK should be given high priority. The UK is a powerhouse in AI research. The UK has now re-joined the Horizon program, and should be treated as much as possible as “part of the EU family” relative to AI research and development.

   Strengthening international collaborations, not only with the UK but also with other AI hubs (which are rather disconnected), could strengthen the Europe’s competitive prowess in research. The EU should create strategies for the industry, academia and civil society with a shared vision for the AI future – in this way, it should be possible to ensure that everybody can benefit from AI through collaboration.

   Finally, it is essential to make it easier for companies to operate across borders within the EU by addressing regulatory inconsistencies and red tape that hinder SME participation in cross-border trade. SMEs play a huge role in the EU economy, but they have historically been slow to take up all forms of digital technology. It will be important to clear away needless burdens.

2. **Cutting regulatory burdens**

   The Commission should work on simplifying and harmonising reporting requirements across areas like cybersecurity, sustainability, and data processing, particularly for SMEs, thereby enabling them to focus on innovation. As pointed out during one of the interviews, a single EU cybersecurity reporting framework coordinated by the European Union Agency for Cybersecurity (ENISA) and streamlined requirements from the AI Act, Cyber Resilience Act, and Data Act could be beneficial. Consideration should be given to delaying the implementation of certain AI Act provisions until harmonised standards are available. Furthermore, the EU should clarify the definition of high-risk AI systems and ensure that low-risk systems are not subject to excessive burden. Experience shows that even when SMEs are nominally exempt from burdens, in practice they often have compliance obligations because they are suppliers to larger firms. A legal definition of what open source software should be included in the AI Act in order to provide more clarity on exceptions, and to continue to encourage the open-source software community to strive for innovation.

3. **Addressing compute and funding challenges**

Recognising the resource-intensive nature of AI development, the Commission should expand public compute resources significantly to meet the growing demands of AI innovation. This includes investing in initiatives like EuroHPC, which encompasses hardware, software, and energy infrastructure, and establishing a decentralised network of computing centres across Europe to ensure equitable access for researchers and small businesses. These efforts to invest in infrastructure should be coordinated at the EU-wide level, and should begin by mapping existing capabilities and identifying gaps and blockers in cloud, connectivity and computing capabilities.

Innovative funding mechanisms are also needed. Exploring options such as leveraging pension funds and insurance for AI infrastructure investment could expand available risk capital, diversify funding sources, and reduce reliance on limited public capital. In parallel with such initiatives, increasing the EU budget allocation for digitalisation, using unspent COVID recovery funds, and establishing a dedicated European critical tech investment plan with clear return-on-investment criteria are potential strategies for increasing the availability of public capital.

The Commission should also develop targeted funding strategies that prioritise projects with clear societal benefits, such as trustworthy AI and safety-focused research. Europe (including the UK) has many of the world's leading institutions and universities that could be mobilised to work on these pressing issues. However, the challenge lies in translating this research excellence into entrepreneurial ventures. The EU must overcome its struggle to convert its academic prowess into market-ready products and services.

There is an urgent need to study closely the technological, organisational, and commercial approaches that DeepSeek used to achieve an important breakthrough with its r1 offering. Goldman Sachs is upbeat: "DeepSeek's breakthrough could raise macroeconomic upside over the medium-term if its cost reductions help increase competition around the development of platforms and applications." There are downsides for existing market leaders, but these primarily impact firms based in the US, not firms based in the EU.

To the extent that DeepSeek's apparent success represents a triumph of open source technology over the closed approaches that have characterised most US-based foundation models, as suggested by in an OpEd by Eric Schmidt and Dhaval Adjodah, this is an important message for us in the EU. The EU's mature and active open source community is our "strong suit".

The technical approaches used to achieve excellent results despite limited capital and limited compute power might well be put to good use by EU firms and research institutes. Schmidt and Adjodah go on to note that the technique used by DeepSeek "…eliminates the need to expensively pretrain a new base model, and its implications for AI innovation are profound. Traditionally, even the top-funded university labs have struggled to contribute to AI research due to computing and data limitations. With DeepSeek's breakthrough, the moat surrounding large, well-funded companies might be shrinking."

4. **Ensuring responsible and trustworthy AI development**

While the AI Act promotes public trust in AI, establishing dedicated AI Safety Institutes would be crucial to ensure the development of safe and ethical AI. These institutions would play a critical role in developing and enforcing rigorous standards, guidelines, and testing methodologies to ensure that AI systems are transparent, reliable, and aligned with human values. To ensure that ethical considerations are taken into account from the outset, "Trustworthy AI" should become a core principle of EU policy, prioritising aspects such as explainability, bias mitigation, and resilience against adversarial attacks. Additionally, the Commission should prioritise fostering public understanding of AI and GenAI by demystifying the technology and addressing misconceptions through effective science communication. Public awareness initiatives should include accessible educational materials and forums to promote dialogue and understanding. Also, integration between the AI Act, GDPR, and copyright law continue to pose questions that need to be addressed.

5. **Cultivating a skilled and adaptable workforce**

The Commission should support the development of comprehensive national AI skills strategies to address the growing AI talent gap. These strategies should encompass lifelong learning, from integrating AI education into primary and secondary curricula to reskilling programs for the existing workforce. Policies are needed to help underserved communities whose jobs may be exposed to AI automation (including women) to develop the skills needed to participate in the digital transition to AI. Reskilling opportunities, transparent communication, and policies that foster trust in AI tools are essential for a smooth and equitable transition.

In addition, it is essential to increase STEM talent in the EU by encouraging EU member states to introduce programming and AI training into school curriculum. Practical training programmes should be a priority to ensure individuals can effectively use GenAI tools and critically evaluate their outputs. These initiatives will equip workers to adapt to evolving workplace demands and contribute meaningfully in an AI-driven economy. To retain the talent within the EU borders and to attract skilled talent from abroad, it will be important to make the EU more appealing to skilled workers by implementing competitive incentives, such as coordinated tax breaks for training in AI and cybersecurity.

## 7.2 Policy recommendation regarding civil society organisations (CSOs)

To effectively shape CSO involvement in AI governance policies, our interviews and workshop suggest a number of key recommendations. These suggestions prioritise inclusivity, worker empowerment, and ethical considerations, aiming to establish a balanced and forward-looking approach to AI development and deployment.

1. **Empowering citizens through social dialogue and training**

   Empowering workers through targeted training programs is a foundational step. Investing in AI literacy initiatives ensures that workers, particularly those most affected by AI-driven changes, are equipped to actively participate in discussions and decisions regarding AI adoption. One interviewee highlighted the importance of bridging the AI literacy gap, emphasising that informed workers are better positioned to contribute to meaningful dialogues about the technology's impact on their roles and industries. This should start from clarifying and explaining the key AI-related terms to the general public – the AI glossary presented in Section 2.2 of this study could represent a first step[51]. In essence, to enable the social dialogue, AI science communication should take precedence over general AI education, as it focuses on translating complex technical concepts into accessible information that empower diverse stakeholders to make informed decisions. This is particularly important for business owners, many of whom struggle to understand how to effectively use generative AI.

2. **Adopting a "Social by Design" approach**

   Worker perspectives should be integrated into the design of AI systems from the very inception of AI development by means of a "social by design" approach. This bottom-up methodology focuses on creating systems that are human-centred, inclusive, and responsive to the needs of those directly impacted. Continuous engagement between workers, employers, and policymakers fosters collaborative environments where diverse viewpoints shape ethical and practical AI solutions. Establishing structured mechanisms for ongoing consultation and feedback not only builds trust but also ensures that the development and implementation of AI systems remain aligned with societal needs and ethical principles.

3. **Prioritising ethical and trustworthy AI systems that align with societal values**

   Ensuring trust and safety in AI requires a shift from merely educating people about the technology to securing their job stability and workplace autonomy. Two interviewees advocated prioritisation of ethical and trustworthy AI systems that align with societal values rather than being solely profit-driven. Building such open-source systems not only enhances trust but also promotes the adoption of AI in ways that respect human dignity and purpose. The slow adoption of AI in the past stemmed in large part from a lack of trust in AI's trustworthiness. The EU should take a proactive stance to enhance trust in AI systems and models, and to enhance their trustworthiness.

4. **Increasing funding for CSOs working on AI**

   Increasing funding and support for organisations focused on AI can significantly enhance citizen participation in governance processes. Non-profit organisations often bear the responsibility of

[51] An accessible and clear explanation of AI terms, developed by CEPS can also be found here https://aiworld.eu/concept

ensuring that the public understands AI models, bridging the gap between complex technologies and societal needs.

At the same time, investing in research and development remains a cornerstone of responsible AI governance. Strategic focus areas – such as fostering trustworthy, ethical, explainable, and sustainable AI, along with advancing AI applications in the physical world — require consistent attention and funding. Furthermore, increasing investments in AI safety research is crucial not only to mitigate risks but also to drive innovation that aligns with the public interest and upholds ethical standards. The recommendations to enhance both public and private funding that appear elsewhere in this chapter are thus also relevant here

5. **Addressing challenges in hiring highly-skilled workers**

   Finally, addressing systemic barriers, such as challenges in hiring non-EU talent, is vital for fostering innovation. Simplifying hiring processes and improving access to financial resources for AI ventures within the EU can create a more dynamic ecosystem that supports the development of cutting-edge and socially beneficial AI technologies. The EU needs to make the business environment more supportive for career development in AI, and to offer competitive incentives, such as high salaries (and equity where appropriate) to attract and retain top talent.

## 7.3 Specific recommendations for the European Economic and Social Committee (EESC)

The EESC is well-positioned to contribute to ensuring structured involvement of civil society organisations (CSOs) in implementing the EU AI Act.

1. **Establishing an AI Working Group**

   The EESC should re-establish a dedicated working group on AI to act as a central hub for collaboration with CSOs and open-source communities. This group would host regular consultations and workshops, providing a forum for dialogue on crucial issues, such as the development of frontier AI models and addressing instances of GenAI misuse. Collaboration with the Commission's AI Office is vital to co-develop guidelines that promote open-source contributions and ethical AI practices, extending the principles of the AI Act's Code of Practice to advocate for the inclusion of open-source communities in the implementation of the EU AI Act.

2. **Advocating open-source AI**

   The EESC should advocate for open-source AI as a pillar of ethical innovation. This involves advocating for its integration into public procurement, and enabling small developers to access resources such as public data repositories and computing power. Partnerships with European institutions can further amplify this effort, helping to ensure that smaller stakeholders can compete effectively. The EESC could propose targeted funding schemes for open-source initiatives through programs like Horizon Europe, and could engage with standardisation bodies to develop frameworks that enhance interoperability across sectors such as healthcare. Collaborative initiatives like hackathons and innovation labs should also be prioritised to bring together open-source developers, academia, and the private sector.

3. **Promoting public awareness and discourse on AI's societal impacts**

   The EESC should ensure public awareness and discourse on AI's societal impacts by promoting a “social by design” approach. Integrating worker perspectives early in AI development can help to ensure that systems are more inclusive and human-centred, thus benefitting both workers and businesses. This constant dialogue between workers, employers and policymakers is fundamental to creating a robust AI ecosystem.

4. **Promoting agile regulatory responses and public engagement**

   The EESC should advocate for endorsing flexible tools like the Code of Practice to address evolving challenges posed by GPAI and GenAI. Facilitating public engagement is equally essential, and the EESC could host forums, workshops, and online platforms to demystify the AI Act and gather feedback from diverse communities, particularly those unfamiliar with AI. Partnerships with local organisations can ensure that marginalised groups have a voice in these discussions, fostering an inclusive regulatory framework.

5. **Continuing global collaboration**

   Global collaboration is critical for effective AI governance. By engaging with international bodies such as the OECD and the UN, the EESC can compare frameworks from regions like the U.S. and China, promoting alignment and consistency in addressing shared ethical and societal challenges.

In addition to these priorities, the EESC should advocate for specific actions such as creating EU-wide benchmarks for diverse datasets, developing standards for algorithmic fairness, and supporting establishing a European AI Observatory to monitor biases and promote transparency. The EESC could push for transparency requirements, including mandating plain-language explanations of AI decision-making in consumer-facing applications, and guidelines for companies to disclose how automated decisions, such as loan approvals, are made. This could include developing user-friendly guides and infographics that explain the key aspects of the AI Act in an accessible manner, focusing on how it impacts daily life, such as in education, employment, and public services.

By implementing these recommendations, the EESC can help to foster an innovative, responsible, and inclusive AI ecosystem that aligns with European values and delivers tangible benefits for society.

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