The AI-Energy Nexus: A Mapping of Trends and Applications for Oil and Gas Companies

by Pier Paolo Raimondi

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Introduction

In humanity's history, energy and innovation have been two powerful factors for socioeconomic growth. Within the last two hundred years societies have moved from biomass to coal and then oil, natural gas and other sources in an ongoing energy transformation. Over the centuries, innovation and technological breakthroughs have allowed countries and communities to thrive, while also influencing energy markets (for instance, consider the combustion engine and oil).[1] In this way, energy and innovation feed and transform each other.

Now, the advent and rise of artificial intelligence (AI) is expected to redefine global economies. Indeed, AI is expected to be one of the most disruptive technologies in our history. The growing market and political interests around AI are motivated by its increasing capabilities due to a combination of falling computation costs, widespread data availability, technical breakthroughs and global competition among countries and companies. As AI is a general-purpose technology, like electricity, its application can transform multiple sectors and activities. Its expansion has been remarkable since 2022 following the release of Open AI's ChatGPT. In February 2025, ChatGPT had 400 million weekly active users globally. Furthermore, other private companies have decided to release their AI products to the public, stimulating adoption and expansion.

1 Smil, Vaclav, *Energy and Civilization. A History*, Cambridge/London, MIT Press, 2017; Yergin, Daniel, *The Prize. The Epic Quest for Oil, Money, and Power*, New York, Free Press, 2003.

Thanks to its integration into economies and sectors, AI could have multiple, positive macroeconomic outcomes.[2] For example, Goldman Sachs expects that generative AI could raise global GDP by 7 per cent (equal to 7 trillion US dollars).[3] The IMF estimated AI could contribute to increasing global GDP by nearly 4 per cent over the next decade, although warning about uneven distribution depending on preparedness and access among countries (especially advanced and emerging economies).[4] Such enthusiasm has sparked a wave of private investments, although real return is yet to be seen.[5]

In this quest, the nexus between AI and energy has recently become even more salient. As with any other (digital) activity, AI demands energy – more specifically electricity – and, simultaneously, AI can significantly shape the energy sector. This latter element has been acknowledged by Mario Draghi in his report on the future of European Competitiveness: the "energy sector is one of the sectors with the greatest potential to benefit from the capacity of AI to boost efficiency and accelerate innovation".[6]

Given the great implications, it is crucial to assess first the geopolitical context of AI development and then the impacts on electricity demand trends and energy policies. Then, it is noteworthy to analyse how AI can transform the energy sector with a focus on private and national oil companies' AI strategies and applications.

2 Acemoglu, Daron, "The Simple Macroeconomics of AI", in *Economic Policy*, Vol. 40, No. 121 (January 2025), p. 13-58, DOI 10.1093/epolic/eiae042.

3 Goldman Sachs, "Generative AI Could Raise Global GDP by 7%", in *Goldman Sachs Insights*, 5 April 2023, https://www.goldmansachs.com/insights/articles/generative-ai-could-raise-global-gdp-by-7-percent.

4 Cerutti, Eugenio et al., "The Global Impact of AI: Mind the Gap", in *IMF Working Papers*, No. 25/76 (April 2025), https://doi.org/10.5089/9798229008570.001.

5 Goldman Sachs, "Gen AI: Too Much Spend, Too Little Benefit?", in *Global Macro Research*, No. 129 (25 June 2024), https://www.goldmansachs.com/insights/top-of-mind/gen-ai-too-much-spend-too-little-benefit.

6 Draghi, Mario, *The Future of European Competitiveness. Part B*, September 2024, p. 22, https://commission.europa.eu/node/32880_en.

1. AI in a geopolitical world

The high transformational potential of AI for society and economies has spurred a global race among countries and companies to strengthen comparative advantages. This global competition has commercial and geopolitical dimensions. Policymakers have been working to attract private investment to unleash AI developments for economic benefit as well as enhanced economic and national security. Private companies are competing for market share in the global AI value chain. Competition is related to investments and technological know-how concerning both data centres and AI models. Data centres provide the computational power needed by AI as they are used to train and run AI models. Investments in data centres have expanded significantly over the past years as state competition rises. Indeed, governments are pouring massive amounts into investments: China launched a 47.5 billion US dollars semiconductor fund, India pledged 1.25 billion and Canada 2.4 billion.[7]

At the national level, the main two players are the United States and China. The two superpowers can leverage on their tech sector, capital availability, energy resources and industrial policy. These two countries host 45 per cent and 25 per cent of world data centre capacity, respectively. The US leads the world in data centres and AI computation, thanks to its tech giants and investments. Over the past decade, the US has been the source of more machine learning models than any other country. Seventy-three per cent of large language models (LLM) are being developed in the US, and US institutions still lead in terms of AI model production. In 2024, 40 AI models were produced in the US compared to China's 15 and Europe's 3.[8] The US has also seen a massive amount of private investment, reaching 109.1 billion US dollars in 2024. To put this into perspective, this figure is nearly 12 times China's 9.3 billion US dollars and 24 times the UK's 4.5 billion. Among the top 20 countries by private investment in AI in 2024 are other countries like Sweden, the United Arab Emirates (UAE), the Netherlands and Italy (figure 1), while the picture is slightly different if total investment AI over 2013-24 is taken into account (figure 2).

7 Stanford Institute for Human-Centered AI (HAI), *Artificial Intelligence Index Report 2025*, April 2025, https://hai.stanford.edu/ai-index/2025-ai-index-report.

8 Ibid.

Figure 1 | Top 20 countries by private investment in AI, 2024 (billion US dollars)

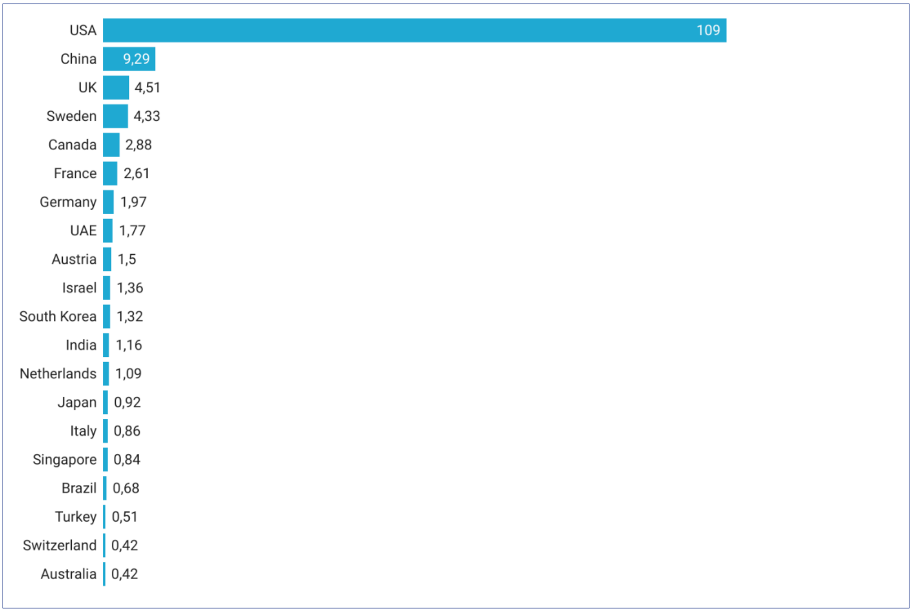
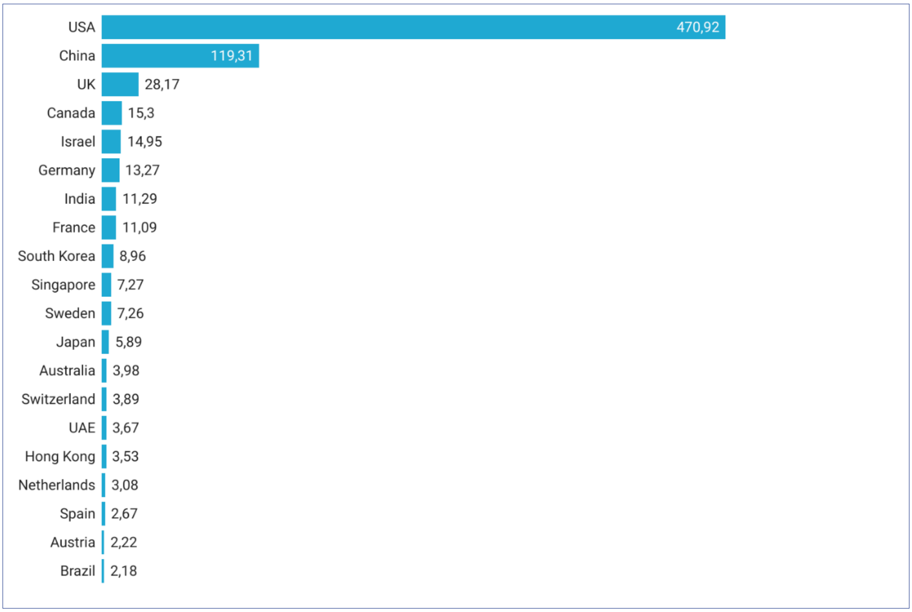


Figure 2 | Top 20 country by total investment in AI, 2013-2024 (billion US dollars)



Source: Author's elaboration on Stanford HAI, *Artificial Intelligence Index Report 2025*, cit.

In this flood of private investment, the Trump administration has worked to merge major players, such as OpenAI, Oracle and SoftBank, to form a new joint venture announcing a 100 billion US dollars investment in the US.[9] In 2024, US federal agencies doubled AI-related regulations compared to the previous year. The integration of AI into official strategies is also motivated by growing competition with the main contender, China. In November 2024, the bipartisan US-China Economic and Security Review Commission called for a Manhattan Project–style initiative to retain US leadership in advanced technologies.[10]

China has increasingly climbed the ladder of AI leadership. In 2017, China presented its ambition to become the global AI leader by 2030 in its official document "A New Generation Artificial Intelligence Development Plan".[11] China has developed a remarkable industrial policy for AI development over the past decade.[12] Nonetheless, AI requires more flexibility in terms of industrial policy compared to more traditional sectors given the fast-changing scenario and the role of innovation. Although the US still leads AI model production quantity-wise, China is closing the quality gap. Moreover, Chinese private companies may gain relevance in the achievement of Chinese goals. Nonetheless, the US retains a comparative advantage in advanced AI chips.[13]

What is clear is that AI has fuelled great power rivalry as both countries seek to gain and protect comparative advantages in key technologies. Countries have increasingly considered the technology competition as a zero-sum game despite calls for cooperative frameworks.[14] For example, the US has deployed

9 Metz, Cade and Cecilia Kang, "Trump Announces $100 billion A.I. Initiative", in *The New York Times*, 21 January 2025, https://www.nytimes.com/2025/01/21/technology/trump-openai-stargate-artificial-intelligence.html.

10 Tong, Anna and Michael Martina, "US Government Commission Pushes Manhattan Project-Style AI initiative", in *Reuters*, 20 November 2024, https://www.reuters.com/technology/artificial-intelligence/us-government-commission-pushes-manhattan-project-style-ai-initiative-2024-11-19.

11 Webster, Graham et al., "Full Translation: China's 'New Generation Artificial Intelligence Development Plan'", in *DigiChina*, 1 August 2017, https://digichina.stanford.edu/?p=826.

12 Chan, Kyle et al, "Full Stack: China's Evolving Industrial Policy for AI", in *RAND Experts Insights*, 26 June 2025, https://www.rand.org/pubs/perspectives/PEA4012-1.html.

13 Heim, Lennart, "China's AI Models Are Closing the Gap – But America's Real Advantage Lies Elsewhere", in *RAND Commentaries*, 2 May 2025, https://www.rand.org/pubs/commentary/2025/05/chinas-ai-models-are-closing-the-gap-but-americas-real.html.

14 Goujon, Reva, "The Real Stakes of the AI Race", in *Foreign Affairs*, 27 December 2024, https://www.foreignaffairs.com/node/1132520; Aziz Huq, "A World Divided Over Artificial Intelligence", in *Foreign Affairs*, 11 March 2024, https://www.foreignaffairs.com/node/1131513.

a regulatory framework to prevent China's acquisition of key technological development in order to remain technological leadership. A key case study involves the export restrictions on chips and semiconductors.[15]

Europe accounts for 15 per cent of global data-centre electricity consumption;[16] however, the EU is lagging behind in the AI race due to limited number of companies operating in the field, smaller capital markets and skills shortages.[17] Initially, the EU focused on a regulatory framework for safe AI development characterised by a precautionary and ethics-driven approach. As result, in June 2024 the bloc adopted the EU AI Act, which is the first-ever comprehensive legal framework on AI worldwide and lays out a clear set of risk-based rules for developers. In April 2025, the European Commission presented the AI Continent Action Plan, which launched the InvestAI initiative.[18] The initiative is expected to mobilise 200 billion euro for AI investment in the EU. The Plan seeks to set up at least 13 AI factories across Europe and establish up to five AI gigafactories. However, European ambitions face several hurdles. A key barrier is the ability to raise capital vis-à-vis its competitors. Moreover, higher energy and real estate prices (two crucial components of operating costs) in Europe compared to the US or the Middle East represent a serious disadvantage for EU-based providers. These challenges have led to considerations about the EU regulatory approach.[19] Nonetheless, some member states have increasingly joined the race – starting with France. In February 2025 the country released its AI strategy entitled "Make France an AI Powerhouse", presenting a 109 billion euros infrastructure investment plan to unleash AI developments in France.[20]

15 Harithas, Barath, "Wired for Resilience: Transatlantic Approaches to Semiconductor Supply Chain Security", in *IAI Papers*, No. 25|12 (June 2025), https://www.iai.it/en/node/20281; Allen, Gregory C., "DeepSeek, Huawei, Export Controls, and the Future of the U.S.-China AI Race", in CSIS Reports, March 2025, https://www.csis.org/node/115070.

16 International Energy Agency (IEA), *Energy and AI*, April 2025, p. 14, https://www.iea.org/reports/energy-and-ai.

17 Draghi, Mario, *The Future of European Competitiveness. Part B*, cit.

18 European Commission website: *Shaping Europe's Leadership in Artificial Intelligence with the AI Continent Action Plan*, https://commission.europa.eu/node/38607_en.

19 Csernatoni, Raluca, "The EU's AI Power Play: Between Deregulation and Innovation", in *Carnegie Europe Papers*, May 2025, https://carnegieendowment.org/research/2025/05/the-eus-ai-power-play-between-deregulation-and-innovation.

20 French Presidency, *Make France an AI Powerhouse*, 11 February 2025, https://www.elysee.fr/en/emmanuel-macron/2025/02/11/make-france-an-ai-powerhouse.

Globally, AI has gained political attention not only from major economies. Legislative mentions of AI have increased 21.3 per cent across 75 countries since 2023, corresponding to a ninefold increase since 2016. This trend shows that major economies aren't the only ones to have embarked on the AI race, but also middle powers and emerging economies. Among those countries the Middle Eastern states – especially in the Gulf – stand out.[21] Within GCC countries, Saudi Arabia and the UAE are particularly eager to leverage their large financial capabilities, vast energy reserves, land availability and strong political commitment to become AI hubs.[22] As they are attempting to move away from fossil fuels, the new mantra is "data is the new oil". Indeed, these countries have increasingly integrated AI into their ambitious economic diversification plans.[23] Both Saudi Arabia and the UAE have launched different strategies, like the UAE Strategy for Artificial Intelligence in 2017 and the Saudi National Strategy for Data and AI in 2020.[24] These strategies have been followed by the announcement of multi-billion investment in AI projects. The UAE's G42 has teamed up with major tech companies in the Stargate UAE project, aiming to create a major AI hub in the Emirates.[25] Saudi Arabia launched the 100 billion US dollars Project Transcendence initiative and established a new national AI champion, HUMAIN, backed by the Public Investment Fund.[26] To achieve these goals, however, Gulf countries need to address several hurdles, notably human capital and skills; dependency on imported technology; trusted and transparent data regulation; a harsh and hotter climate; and geopolitical instability.

21 Cornish, Chloe et al., "Can the Gulf Really Become an AI Superpower?", in *Financial Times*, 1 June 2025, https://www.ft.com/content/509e1b95-9fe9-4402-b97a-7c2c9ba9a2f6.

22 Alexander, Kristian, "Digital Infrastructure, Strategic Power: The Gulf's Data Centre Boom", in *ORF Middle East Expert Speaks*, 26 June 2025, https://orfme.org/?p=2331.

23 Hacid, Hakim, "The Gulf Pushes for AI Independence", in *Nature*, 21 May 2025, https://doi.org/10.1038/d44148-025-00142-0.

24 Berglind, Niklas et al., "The Potential Value of AI: And How Governments Could Look to Capture It", in *McKinsey Articles*, 25 July 2022, https://www.mckinsey.com/industries/public-sector/our-insights/the-potential-value-of-ai-and-how-governments-could-look-to-capture-it.

25 G42, *Global Tech Alliance Launches Stargate UAE*, 22 May 2025, https://www.g42.ai/resources/news/global-tech-alliance-launches-stargate-uae.

26 "Saudis Plan $100 Billion AI Powerhouse to Rival UAE Tech Hub", in *Bloomberg*, 6 November 2024, https://www.bloomberg.com/news/articles/2024-11-06/saudis-plan-100-billion-ai-powerhouse-to-rival-uae-s-tech-hub; Public Investment Fund, *HRH Crown Prince Launches HUMAIN as Global AI Powerhouse*, 12 May 2025, https://www.pif.gov.sa/en/news-and-insights/press-releases/2025/hrh-crown-prince-launches-humain-as-global-ai-powerhouse.

Furthermore, the regional sovereign wealth funds and other companies have also become precious partners in expanding and ensuring investments also abroad – especially in the US.[27] Furthermore, the Gulf countries have gained a new economic and strategic relevance in light of the US-China rivalry. Indeed, the current Trump administration has tried to promise American technological know-how in a bid to encourage the Gulf states to distance themselves from China.[28] Although the UAE's G42 has shown some willingness in this regard,[29] the deep economic and energy ties between Gulf countries and China remain a source of concern in the long-term as Gulf countries are increasingly preferring to hedge and balance rather than choosing between Washington and Beijing.[30]

Another region that has embraced AI and the data centre boom is Southeast Asia. Countries in the area have increasingly built favourable AI regulations, leveraging on growing digital economies and favourable populations as well as competitive costs.[31] Indeed, ASEAN countries offer 20 per cent lower costs for data centre construction and operation than the global average.[32] However, ASEAN countries will need to boost clean energy to prevent an unsustainable emission growth.[33]

The key enablers for AI expansion, such as capital, stable and affordable energy, and technological know-how, explain the geographic concentration of global data centres in a small number of countries. Furthermore, features like proximity to vital infrastructure, energy resources and large amounts of customers have been critical in defining the global map until now. Another important aspect is climate and weather. Cooler regions have attracted higher

27 UAE Embassy in Washington, *The UAE and US: Forging the Future of AI and Advanced Tech*, 24 July 2025, https://www.uae-embassy.org/node/12153.

28 Winter-Levy, Sam, "The Emerging Age of AI Diplomacy", in *Foreign Affairs*, 28 October 2024, https://www.foreignaffairs.com/node/1132353.

29 Maccioni, Federico et al., "UAE to Build Biggest AI Campus Outside US in Trump Deal, Bypassing Past China Worries", in *Reuters*, 15 May 2025, https://www.reuters.com/world/china/uae-set-deepen-ai-links-with-united-states-after-past-curbs-over-china-2025-05-15.

30 Winter-Levy, Sam, "The Emerging Age of AI Diplomacy", cit.

31 Chadha, Sapna, "Why AI Is Southeast Asia's New Engine for Profitable Growth", in *World Economic Forum Stories*, 21 November 2024, https://www.weforum.org/stories/2024/11/ai-report-southeast-asia-economic-growth.

32 Azalia, Nathania, "The Rise of Data Centres, Artificial Intelligence, and ASEAN's Decarbonisation Goal", in *Accept Perspective Blog*, 24 June 2025, https://accept.aseanenergy.org/?p=26432.

33 Ember website: *Energy Efficient Data Centres Powered by Clean Electricity Are Key for Sustainable Growth*, https://ember-energy.org/?p=12308.

investments in data centres due to lower cooling costs.[34] For example, a survey discovered that cooling accounts for over 40 per cent of total energy consumption in UAE data centres.[35] Hotter temperature and higher cooling needs lead also to higher energy consumption – ultimately affecting costs despite fossil fuel subsidies. This may become an even more relevant factor as global and local temperatures rise. In a more geopolitical and advanced world, decisions on location will depend more on sovereignty and national security, also influencing AI diplomacy and partnerships among countries and companies.

2. The AI-energy nexus

AI models are powered by data centres, which ensure sufficient computational power for their application. Therefore, it is crucial to analyse data centres' electricity consumption to evaluate the impact of AI on energy systems. From an energy perspective, it is important to differentiate between average and large data centres. The former require small power volumes (5-10 megawatts, MW), while large hyperscale data centres have power demands of 100 MW or more. This last type is increasingly becoming more common.

Data centres' electricity consumption has increased at 12 per cent per year since 2017, outpacing total electricity consumption by a factor of four. In 2024, data centres' electricity consumption was 415 terawatt hours (TWh), equal to 1.5 per cent of global electricity demand.[36] It is noteworthy that AI is currently responsible only for a relatively modest share of global data centres' electricity consumption, and that there are relevant differences at the national level (table 1). The US, Europe and China account for around 85 per cent of global electricity consumption from data centres today. More specifically, data centres correspond to more than 4 per cent of electricity consumption in the US, but less than 2 per cent of Europe's and 1.1 per cent in China.

34 Keller, Christian et al., "AI Revolution: Meeting Massive AI Infrastructure Demands", in *Barclays Impact Series*, 16 January 2025, https://www.ib.barclays/our-insights/ai-revolution-meeting-massive-infrastructure-demand.html.

35 Credence Research website: *UAE Data Center Market*, https://www.credenceresearch.com/report/uae-data-center-market.

36 IEA, *Energy and AI*, cit.

Table 1 | Electricity consumption of data centres, by share and in absolute terms, by countries in 2024 and consumption increase by 2030

	Data centres' share of electricity consumption in 2024 (%)	Data centres' electricity consumption in 2024 (TWh)	Consumption increase by 2030 (TWh)
US	>4	180	240
China	1.1	100	175
Europe	<2	70	>45
Japan	~2	<20	~15
India	~0.5	~9	n.a.

Source: Author's elaboration on IEA, *Energy and AI*, cit.

2.1 Forecasts of power consumption

Technological developments and new investments are expected to drive electricity consumption upward. From today until 2030, data centre consumption is expected to grow by around 15 per cent annually. Based on the Base Case of the IEA, global electricity consumption by data centre is projected to more than double, reaching 945 TWh by 2030. To put this figure into perspective, this would be slightly more than Japan's total electricity consumption in 2024. At the same time, data centres' power consumption will remain limited overall as it is expected to account for 3 per cent of total global electricity consumption in 2030. Despite the limited share at the global level, the growth will have a high impact at the national and local level. For example, data centres are expected to be responsible for about half of electricity demand growth to 2030 in countries like the US and Japan. These trends appear to reinforce the highly local feature of data centres. Indeed, these are characterised by a highly geographic concentration at both the national and the subnational level. Therefore, the expected growth in demand will have profound local consequences.

The rise of electricity consumption accompanying expansion of AI use yields environmental concerns as well. Indeed, it is estimated that a single AI-powered query consumes about 10 times the energy of a typical Google search. This is both a public and private concern as tech companies have set several climate targets. Indeed, a report on 200 digital companies assessed that those companies that are heavily investing in AI saw their operational emissions in 2023 rise to 150 per cent of their 2020 levels.[37] Furthermore, companies need to navigate through different energy mixes at the regional and national level – affecting their performance. Although grids' emission intensity may be reduced by the expansion of renewables, the speed and pace may not be in line with tech companies' targets, highlighting a mismatch between tech and energy timelines.

Despite the general expectation of higher power consumption driven by AI, a high degree of uncertainty remains. Precise data availability, efficiency gains and real pace of AI adoption are only some of the key factors that will affect demand trends. For example, trends of efficiency improvements provide a good sense of hope for lower demand than what is currently expected. The efficiency of AI-related computer chips has doubled roughly every three years. As result, a modern AI-related computer chip consumes 99 per cent less power to perform the same calculations as a predecessor from 2008.[38] Moreover, efficiency gains can be provided by technological providers in order to reduce emission intensity. For example, the workload demand for data centres nearly tripled over the 2015–2019 period; however, power consumption remained flat due to improvements in energy efficiency.[39] Additionally, recent technological breakthroughs, such as the release of a large reasoning model made by the Chinese DeepSeek in early 2025, have reinforced the belief in future improvements.[40] Another potential efficiency-related improvement could come from progress on distributed data centre training capabilities.[41] However, it is equally valid to consider that efficiency does not yield lower consumption

37 ITU-International Telecommunication Union and WBA-World Benchmarking Alliance, *Greening Digital Companies 2025. Monitoring Emissions and Climate Commitments*, June 2025, https://www.itu.int/en/ITU-D/Environment/Pages/Publications/GDC-25.aspx.

38 Spencer, Thomas and Siddharth Singh, "What the Data Centre and AI Boom Could Mean for the Energy Sector", in *IEA Commentaries*, 18 October 2024, https://www.iea.org/commentaries/what-the-data-centre-and-ai-boom-could-mean-for-the-energy-sector.

39 Goldman Sachs, "Is Nuclear Energy the Answer to AI Data Centers' Power Consumption?", in *Goldman Sachs Insights*, 23 January 2025, https://www.goldmansachs.com/insights/articles/is-nuclear-energy-the-answer-to-ai-data-centers-power-consumption.

40 Wiggers, Kyle, "DeepSeek Claims Its 'Reasoning' Model Beats OpenAI's o1 on Certain Benchmarks", in *TechCrunch*, 27 January 2025, https://techcrunch.com/?p=2949475; Amodei, Dario, *On DeepSeek and Export Controls*, January 2025, https://www.darioamodei.com/post/on-deepseek-and-export-controls.

41 Patel, Dylan et al., "Multi-Datacenter Training: OpenAI's Ambitious Plan to Beat Google's Infrastructure", in *SemiAnalysis*, 4 September 2024, https://semianalysis.com/?p=148471080.

per se – as made visible also by the decoupling between global emissions, energy consumption and emission intensity.[42] Reduced costs and efficiency improvements increase AI usage, potentially resulting in a net positive effect on electricity demand based on the Jevons paradox.[43] Lastly, the real pace of AI adoption will depend on key bottlenecks, such as grids and other components of the AI value chain as well as social acceptance.

2.2 Reliable mix of energy and offtakes

Despite different demand scenarios, a reliable mix of energy is needed to meet current and future demand from AI (figure 3). Global electricity generation to supply data centres is expected to grow from 460 TWh in 2024 to over 1,000 TWh in 2030 and 1,300 TWh in 2035. Renewables meet half of the additional demand to 2030, followed by natural gas and coal. Energy storage is expected to play a key role as a buffer to address renewables' intermittency and grid expansion while ensuring sustainable energy supplies. Therefore, a combination of natural gas and renewables is foreseen as taking the lead due to cost-competitiveness and availability in key markets. Although renewables will play a role in meeting rising demand also due to environmental concerns, natural gas could be the best option to ensure adequate and affordable energy for AI growth in the short term – especially in the US.[44] It is undeniable that the presence of vast and relatively cheap gas resources could be a key advantage to power AI developments. This option appears to be supported by Trump's energy policy although it could be at odds with other elements of the energy dominance objective. Indeed, the Trump administration seeks to provide cheap energy to domestic consumers and at the same time increase US LNG exports as an economic and strategic objective. However, the US may soon face conflict between its domestic and international goals.[45] Furthermore, the

42 Keller, Christian et al., "AI Revolution", cit.

43 In 1985, William Stanley Jevons analysed coal consumption in England and the impact of technological innovation, namely James Watt's steam engine. He noted that gains in efficiency led to a much greater range of applications, across sectors and end-users, although the fuel input needed for each application fell. This effect contributed to a paradoxical result: growth of total coal consumption.

44 Bazilian, Morgan, "The Smart Bet: Natural Gas for AI", in *The National Interest Blog*, 16 April 2025, https://nationalinterest.org/?p=442052.

45 Joseph, Ira, "US Exports and Domestic Gas Use Face Off for Incremental Supply", in *SIPA Energy Explained Blog*, 2 April 2025, https://www.energypolicy.columbia.edu/?p=22734.

gas industry faces some challenges in terms of delivery time for gas turbines, a potential slow-down in near-term supply-side growth,[46] and (methane) emissions, potentially undermining its acceptability for tech companies. Indeed, addressing the environmental footprint of gas supplies by monitoring and cutting methane emissions is pivotal to ensure sustainability of AI projects. Moreover, AI power consumption may lead to a nuclear renaissance – as illustrated by Microsoft's 20-year deal to reopen the Three Mile Island nuclear facility.[47] Some large US tech companies, like Amazon, Microsoft, Google and Meta, have announced nuclear energy deals to power their operations and their data centres.[48] While some of these agreements rely on existing plants, others concern future and innovative technologies, such as small modular reactors (SMRs). However, such an option faces a major constraint: timing. Indeed, the commercial deployment of SMRs may not align with data centre timelines, given regulatory and commercial developments.[49]

Another energy source that may emerge prominently is geothermal energy. Thanks to recent technological advances, such as horizontal drilling and hydraulic fracturing taken from the US oil industry, this energy option is experiencing a new momentum.[50] There have been some relevant agreements, such as between Google and Fervo Energy in Nevada or the 1 billion US dollars investment made by Microsoft and G42 in Kenya.[51]

46 Wood Mackenzie, *Despite Surging Power Demand, Gas-Fired Power Faces Manufacturing Constraints That Could Limit Near-Term Growth*, 14 May 2025, https://www.woodmac.com/press-releases/despite-surging-power-demand-gas-fired-power-faces-manufacturing-constraints-that-could-limit-near-term-growth.

47 McCormick, Myles and Jamie Smyth, "Microsoft in Deal for Three Mile Island Nuclear Power to Meet AI Demand", in *Financial Times*, 20 September 2024, https://www.ft.com/content/ddcb5ab6-965f-4034-96e1-7f668bad1801.

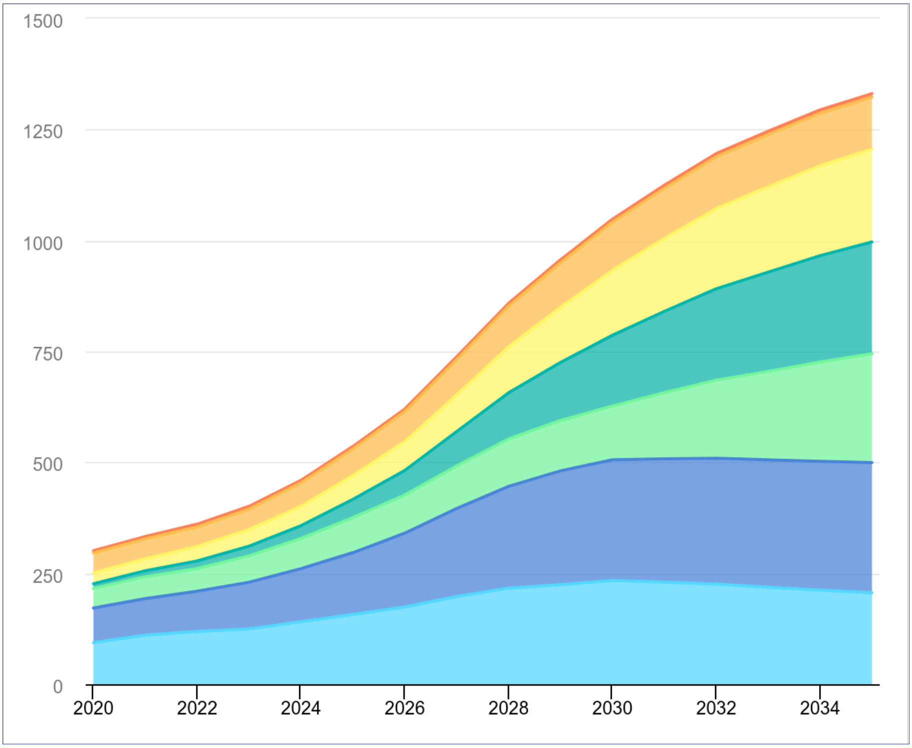
48 Smyth, Jamie, "Amazon Buys Stake in Nuclear Energy Developer in Push to Power Data Centres", in *Financial Times*, 16 October 2024, https://www.ft.com/content/00776191-b010-4104-add4-8dc430386911.

49 Crownhart, Casey, "Can Nuclear Power Really Fuel the Rise of AI?", in *MIT Technology Review*, 20 May 2025, https://www.technologyreview.com/2025/05/20/1116339.

50 IEA, *The Future of Geothermal Energy*, December 2024, https://www.iea.org/reports/the-future-of-geothermal-energy.

51 Terrell, Michael, "A First-of-Its-Kind Geothermal Project Is Now Operational", in *The Keyword Blog*, 28 November 2023, https://blog.google/outreach-initiatives/sustainability/google-fervo-geothermal-energy-partnership; Microsoft, *Microsoft and G42 Announce $1 Billion Comprehensive Digital Ecosystem Initiative for Kenya*, 22 May 2024, https://news.microsoft.com/source/?p=7378.

Figure 3 | Sources of global electricity generation for data centres, IEA's Base Case Scenario, 2020-2035



Source: IEA website: *Sources of Global Electricity Generation for Data Centres, Base Case, 2020-2035*, last updated 4 April 2025, https://www.iea.org/data-and-statistics/charts/sources-of-global-electricity-generation-for-data-centres-base-case-2020-2035.

From the corporate perspective, companies are considering a variety of energy sources to meet data centres' rising electricity demand. This trend is due to hyperscalers'[52] need of uninterrupted energy supply 24 hours a day, every day. Therefore, several tech companies have worked on expanding offtake models to ensure sufficient energy supply for current and future data centres. As result, companies have signed several power purchase agreements (PPAs), with a relevant share of them for clean energy sources to ensure stronger sustainability. The IEA warns however of a mismatch between physical and "financial" electricity mixes as most clean PPAs are financial agreements for

52 Hyperscalers are large-scale cloud service providers, such as Google, Amazon, Meta and Microsoft.

annual volumes and not tied to hour-to-hour consumption. To overcome this issue, some companies have concluded PPAs with hourly matching.[53]

2.3 National energy policies

From a national perspective, political commitment and energy resource availability shape national energy policy and strategies for meeting current electricity consumption by data centres. The US has increasingly powered its AI capacities with natural gas (40 per cent of electricity for data centres), followed by renewables (24 per cent), nuclear (15 per cent) and coal (20 per cent). By contrast, coal plays a larger role in Chinese AI energy supply (70 per cent) followed by renewables (20 per cent). Since the return of Donald Trump to the White House, the two countries have had different energy policies. The US is committed to exploit its current fossil fuels endowment to power its economy, while China is integrating its clean energy technologies into other sectors – including AI.

China remains heavily dependent on coal (58 per cent of power generation), but at the same time it is massively and rapidly deploying solar and wind energy as well as expanding its nuclear capacity to ensure energy security and affordability.[54] Therefore, Beijing has coupled data centres with renewables already since 2021, when it announced a three-year action plan to build new data centres defined as "efficient, clean, optimised and circular".[55] By contrast, Donald Trump has focused on unleashing US fossil fuel resources to achieve energy dominance and provide cheap energy prices to consumers. This approach however comes at the expense of clean energy as Trump put forward a bill that cuts green spending, originally ensured in the Inflation Reduction Act passed in August 2022.[56] This decision may result in preventing new energy sources to supply and satisfy rising AI energy demand – alongside the attempt to reindustrialise the US economy.

53 IEA, *Energy and AI*, cit.
54 US Energy Information Administration (EIA), "China Continues Rapid Growth of Nuclear Power Capacity", in *EIA In-Brief Analysis*, 6 May 2024, https://www.eia.gov/todayinenergy/detail.php?id=61927.
55 Ye, Yuan, "Explainer: How China Is Managing the Rising Energy Demand from Data Centres", in *Carbon Brief China Energy*, 16 April 2025, https://www.carbonbrief.org/explainer-how-china-is-managing-the-rising-energy-demand-from-data-centres.
56 Beattie, Alan, "The US Is Failing Its Green Tech 'Sputnik Moment'", in *Financial Times*, 26 June 2025, https://www.ft.com/content/01585423-bb60-4906-8322-6c76a08a2791.

Countries like France, the UAE and ideally Japan are eager to leverage their nuclear power fleet. Among them, France has the lead given its historically large nuclear fleet. In its AI strategy, France outlines its multiple advantages to attract AI projects, starting from its decarbonised, abundant and stable energy supply. Sixty-eight per cent of France's electricity generation came from nuclear in 2024.[57] As of today, the country is also a major net electricity exporter (89 TWh in 2024). Nuclear provides consumers with stable, cheap energy with lower carbon intensity. This valid argument has induced France to reconsider its approach towards nuclear energy following the energy crisis. Before the crisis, previous governments had committed to reducing the share of nuclear in the country's electricity generation. However, in 2022, President Macron announced the building of six nuclear reactors to expand power generation and renew the current nuclear fleet.[58] The average age of French reactors is 37 years.[59] France's ambition therefore faces some challenges. Firstly, the country's nuclear fleet has experienced some operational issues that have reduced output. Secondly, should France allocate its generation surplus to domestic AI projects, neighbouring countries may face a significant energy crunch. Lastly, energy is only a (key) component of the equation for successful AI development. The country should work on improving skills, enhancing industrial capacity in other AI segments and improving the regulatory framework.[60]

Among countries that produce and use nuclear energy, the UAE and Japan have shown a different approach. The UAE has been a success story for nuclear developments. Nuclear will provide 25 per cent of UAE power needs. By contrast, Japan decided to halt its nuclear capacity following the 2011 Fukushima disaster. The expected growth in demand has, however, generated a relevant policy U-turn.[61]

57 Ember Electricity Data Explorer website: *Share of Electricity Generation in France*, https://ember-energy.org/data/electricity-data-explorer/?entity=France&metric=pct_share.

58 Leali, Giorgio, "France to Build Six New Nuclear Reactors", in *Politico*, 10 February 2022, https://www.politico.eu/?p=1984214.

59 World Nuclear Association, "Nuclear Power in France", in *Country Profiles*, updated 14 July 2025, https://world-nuclear.org/information-library/country-profiles/countries-a-f/france.

60 McGeady, Cy and Rebecca Riess, "Great Power Competition: Surveying Global Electricity Strategies for AI", in *CSIS Commentaries*, 8 May 2025, https://www.csis.org/node/116210.

61 Geddie, John and Katya Golubkova, "Resource-Poor Japan Was Girding for an AI Energy Surge. Deepseek Raised the Stakes", in *Reuters*, 31 January 2025, https://www.reuters.com/business/energy/resource-poor-japan-was-girding-an-ai-energy-surge-deepseek-raised-stakes-2025-01-30.

2.4 Ancillary factors

Along with energy supply, policymakers and companies need to put in place other actions to build and enhance ancillary factors that are indispensable for AI expansion. Firstly, governments will need to strengthen the energy infrastructure that will transport energy to data centres. The growing relevance of power grids has returned as a top political priority as countries and companies have increasingly integrated renewables and electrification into their energy systems.[62] Grid constraints are indeed a significant barrier for traditional data centre hubs in Europe.[63] To overcome such obstacles, countries need to streamline and accelerate permitting procedures. For example, connection queues for new data centres can reach up to seven years in North Virginia, a major data centre hub, and in Germany.[64]

Moreover, building adequate power infrastructure requires a steep increase in investments. According to the IEA, grid investments should nearly double to over 600 billion US dollars per year by 2030 to meet national climate targets. According to Goldman Sachs Research, about 720 billion US dollars of grid spending through 2030 may be needed.[65] According to the Draghi report, the EU should allocate 0.9 euro in grid investment for every euro spent on clean power during the 2022-2040 period to achieve EU climate targets. The report assesses that grid investments alone will require around 90 billion euros each year over the 2031-2040 period, with a potential increase in energy bills for households and companies.

Furthermore, policymakers need to address any potential regressive economic consequences of the surge in AI-related electricity demand and infrastructure investment. Firstly, some trade-offs in terms of allocation of resources

62 IEA, *Electricity Grids and Secure Energy Transitions*, October 2023, https://www.iea.org/reports/electricity-grids-and-secure-energy-transitions.

63 Cremona, Elisabeth and Pawel Czyzak (eds), *Grids for Data Centres: Ambitious Grid Planning Can Win Europe's AI Race*, Ember, 19 June 2025, https://ember-energy.org/?p=12538.

64 IEA, Energy and AI, cit.; Green, Alastair et al., "How Data Centers and the Energy Sector Can Sate AI's Hunger for Power", in *McKinsey Articles*, 17 September 2024, https://www.mckinsey.com/industries/private-capital/our-insights/how-data-centers-and-the-energy-sector-can-sate-ais-hunger-for-power.

65 Goldman Sachs, "AI to Drive 165% Increase in Data Center Power Demand by 2030", in *Goldman Sachs Insights*, 4 February 2025, https://www.goldmansachs.com/insights/articles/ai-to-drive-165-increase-in-data-center-power-demand-by-2030.

between households and data centres may emerge. Furthermore, planning the distribution of grid expansion costs should be addressed in order to prevent additional costs for final consumers. Otherwise, such issues may enflame social opposition (e.g., Not In My Back Yard, NYMB) to data centres due to economic and social concerns; something that could ultimately slow AI projects. For example, the Irish grid operator imposed a moratorium on new data centres until 2028 in the Dublin area due to concerns over blackouts.[66] Irish data centres consumed 21 per cent of total country electricity in 2023 and almost 80 per cent in Dublin. In short, grid availability will be a key factor in attracting data centre investments. Given grid issues and different national energy mixes, Europe could see a shift in data centre investments from traditional hubs to Nordic countries and Southern countries, which are powered by high hydro and renewable energy potential. In 2022, China unveiled its national project "East Data, West Computing", whose objective is to process data produced in the eastern provinces of Western China.[67] Most data centres are indeed located in the more populous south-eastern parts of China, while Chinese renewable resources are mainly generated in the western provinces, requiring long-distance transmission.[68] The initiative is estimated to produce a positive reduction in emissions.[69]

Despite challenges and lengthy time frames, traditional hubs remain quite attractive as the top ten largest data centre markets by installed capacity still account for more than 15 per cent of data centre capacity under development.[70] This is due to some key factors, such as skills and human capital, large share of customers, regulation and taxation as well as energy prices, that together shape investment decisions.

66 O'Brien, Matt, "Ireland Embraced Data Centers that the AI Boom Needs. Now They're Consuming Too Much of Its Energy", in *AP News*, 19 December 2024, https://apnews.com/article/6c0d63cbda3df740cd9bf2829ad62058.

67 Ye, Yuan, "Explainer: How China Is Managing the Rising Energy Demand from Data Centres", cit.

68 Kemp, John, "China's Rapid Renewables Rollout Hits Grid Limits", in *Reuters*, 5 July 2024, https://www.reuters.com/markets/commodities/chinas-rapid-renewables-rollout-hits-grid-limits-2024-07-04.

69 Xie, Xuemei et al., "Greening China's Digital Economy: Exploring the Contribution of the East–West Computing Resources Transmission Project to CO_2 Reduction", in *Humanities and Social Sciences Communications*, Vol. 11 (2024), Article 466, https://doi.org/10.1057/s41599-024-02963-0.

70 IEA, *Energy and AI*, cit.

3. National and international oil companies

Energy markets comprise multiple players, notably governments, regulators, energy companies, utilities, transmission and distribution operators, as well as consumers. In international energy markets, oil and gas companies are crucial stakeholders. Although there are thousands of such companies, they can be divided into two major groups: international oil companies (IOCs) or majors, and national oil companies (NOCs). In the popular imagination, IOCs are the most powerful actors in the international markets. These majors are the main heirs of the "Seven Sisters" that had shaped and dominated international oil markets until the 1970s.[71] Their share of production dropped from 93 per cent in 1972 to less than 50 per cent in modern times.[72] They have been operating at the international level, focusing on large, capital-intensive projects. For these companies, the upstream division plays a crucial role both financially and strategically. Indeed, the upstream yields most of their financial value and revenue. This group includes both Western and European companies, like ExxonMobil, Chevron, BP, Shell, TotalEnergies and Eni.

Despite IOCs' legacy, another group of companies is far more relevant in the oil markets: national oil companies. These companies have been entitled by their home governments to manage and exploit national resources. Although the advent of NOCs goes back 100 years, their significant expansion and growth was the result of political and economic independence in the aftermath of World War II. Given their institutional role, these companies are responsible for a range of diverse political-economic and energy issues, from managing resources to ensuring revenues, providing energy supply, supporting industrialisation, providing jobs for national citizens and increasing national technological innovation and capacity building.[73] In most countries, NOCs are a

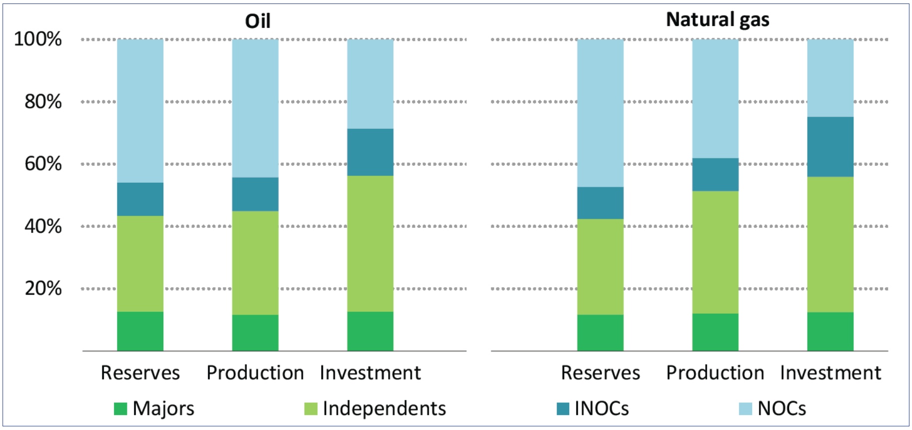
71 Yergin, Daniel, *The Prize*, cit.

72 Abbas, Abubakar Jibrin, "Navigating Energy Transitions: A Comparative Analysis of NOCs' Operational Performance", in *GECF Expert Commentaries*, March 2024, https://www.gecf.org/Events-Conferences/Events-HH/ArticleID/156.

73 Noreng, Øystein, *The Oil Business and the State. National Energy Companies and Government Ownership*, London/New York, Routledge, 2022.

key source of resources generated by exports in the international markets. These companies account for more than half of global production and hold close to 60 per cent of the world's oil and gas reserves (figure 4).[74] They mainly operate in their home country's upstream operation – although there are also NOCs with significant upstream investments outside their home country. Among this group, there are companies such as Saudi Aramco, Abu Dhabi National Oil Company, Qatar Energy, Equinor, PETRONAS and China National Petroleum Corporation. Most of these companies are located in emerging economies, with the clear exception of Equinor. At the same time, there are differences regarding resource endowment among NOCs. For example, given more limited oil and gas reserves compared to its Gulf peers, Malaysia's PETRONAS has more incentives than other NOCs to diversify its business.[75]

Figure 4 | Ownership of reserves, production and upstream investment by company type in 2022



Source: IEA, *The Role of Oil and Gas Industry in Net Zero Transitions*, cit., p. 22.

Over the past decade, the role and relevance of NOCs has further expanded as major companies cut back their capital investment due to low global oil prices

74 IEA, *The Role of Oil and Gas Industry in Net Zero Transitions*, November 2023, https://www.iea.org/reports/the-oil-and-gas-industry-in-net-zero-transitions.

75 Cahill, Ben and Kjersti Swanson, "National Oil Companies, Climate Commitments, and Methane", in *CSIS Briefs*, December 2023, https://www.csis.org/node/108591.

and rising climate targets.[76] These companies account for around 45 per cent of global capital investment in upstream fossil fuel projects. This figure is partly motivated by lower cost production compared to their competitors. Indeed, they generally own resources with lower-than-average development costs and their assets tend to have slower decline rates.

The main difference between IOCs and NOCs is probably related to priorities. Whereas IOCs are generally more focused on maximising profits and shareholder returns, NOCs are focused on managing national reserves to ensure energy supply to the domestic markets and national economic development.

Besides different political-economic objectives and governance structure, these two different groups are far from being homogeneous in terms of governance, climate commitment and energy standpoint. For example, among major companies, the US companies have been generally more prudent regarding climate commitments and targets compared to their European peers.[77] Furthermore, US companies have been committed to leverage their capital and energy advantages by strengthening their role. A clear example is also illustrated by large acquisitions in 2023. In that year, ExxonMobil purchased the US company Pioneer in a 60 billion US dollars all-share acquisition, while Chevron absorbed Hess in a 53 billion US dollars share-based deal. By contrast, European companies have pivoted towards sustainable energy more explicitly. Companies like BP and Shell took the lead in renewables investment, announcing very ambitious strategies to move away from oil. However, many European oil companies have weakened their climate targets (both emission cuts and renewables targets) due to lower financial returns and a different political environment following the energy crisis.[78]

By contrast, NOCs have generally been seen as climate obstructionists due to their political-economic relevance for their home countries. Given their

76 Hafner, Manfred et al., *The Energy Sector and Energy Geopolitics in the MENA Region at a Crossroad. Towards a Great Transformation?*, Cham, Springer, 2023, https://doi.org/10.1007/978-3-031-30705-8.

77 Krauss, Clifford, "U.S. and European Oil Giants Go Different Ways on Climate Change", in *The New York Times*, 21 September 2020, https://www.nytimes.com/2020/09/21/business/energy-environment/oil-climate-change-us-europe.html.

78 Bousso, Ron, "European Oil Giants Step Back from Renewables Path", in *Reuters*, 18 November 2024, https://www.reuters.com/business/energy/european-oil-giants-step-back-renewables-path-2024-11-18.

relevance in the international energy markets, NOCs' contribution in the fight against climate change is not only welcomed, but necessary. However, climate ambitions vary greatly among NOCs. Different ambitions, targets and investment depend on climate ambition within the country's leadership, governance stability, resources availability, access to capital and the degree of national economic diversification.[79] For example, NOCs of large, fragile states with limited financial reserves, like Iraq or Algeria, may be tempted to maximise their revenues in order to preserve the status quo. On the other hand, NOCs of stable, rich and technical equipped countries, like those in the Gulf, may enhance their role in ensuring energy security, while investing in new business, like renewables, hydrogen and carbon capture and storage (CCS), in order to position themselves in a demand-constrained scenario. They have indeed the most ambitious transition plans considering new business models to ensure energy, economic and national objectives. Meanwhile, Gulf NOCs have committed to remaining the "last barrel standing" as they hold comparative advantages and do not consider net-zero targets to be the goal of petrostate and oil companies.[80] However, the different pathways and strategies will depend on their governments' preferences and ambitions. Outlining companies' climate ambitions, for both NOCs and IOCs, is possible although it is difficult to make direct comparisons of different oil companies' climate targets due to different approaches and terminologies. Nonetheless, differences in drivers and objectives emerge in different climate and operational targets. Both NOCs and IOCs (and their upstream sector) need to navigate major uncertainties, namely price volatility and expected demand reductions due to climate policies and technological developments, which affect capital-intensive decisions. Therefore, there are clear arguments for pursuing business transformation (or at least adjustments), while improving efficiency and reducing costs in order to ensure capital returns in volatile markets.[81]

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79 Cahill, Ben, "Pathways for National Oil Companies in the Energy Transition", in *CSIS Commentaries*, 15 July 2021, https://www.csis.org/node/61583.

80 Hafner, Manfred and Pier Paolo Raimondi, "Energy Transition and Prospects for Producing Countries in the MENA Region", in *IEMed Mediterranean Yearbook 2023*, p. 69-75, https://www.iemed.org/publication/energy-transition-and-prospects-for-producing-countries-in-the-mena-region.

81 Alkadiri, Raad and Björn Ewers, "Preparing National Oil Companies for a New Energy Landscape", in *BCG Articles*, 23 November 2020, https://www.bcg.com/publications/2020/strategies-for-being-an-environmentally-conscious-oil-company.

4. AI applied to key operations and NOC/IOC strategies

Oil companies have a long history of innovation. Indeed, the industry has been tirelessly working on developing technological capabilities that are essential in lowering costs and expanding reserves. Most of efforts towards technological innovation have been dedicated to the upstream sector (exploration and production activities) as this is the most remunerative business unit. Technology has contributed to lowered costs of exploration and operations. An example is the development of deep-water offshore fields.[82] Thanks to technological improvements, the industry has largely outpaced depletion concerns, which also resulted in reduced costs. However, global energy markets have been drastically changing as climate policy and technological developments have transformed the paradigm (from "peak oil supply" to "peak oil demand").[83] It is noteworthy that AI and its implications for energy demand may change the pace in the new scenario. Thus, the supply-side of the AI story induces energy companies to reassess their investment portfolios and explore how to meet rising energy demand.[84] Investments in projects and key technologies, as well as new commercial strategies, will be considered to respond energy security, affordability and sustainability concerns of the tech industry. For example, companies like Chevron and ExxonMobil have announced plans to begin power generation, mainly from natural gas, for data centres, marking a change in strategy.[85] At the same time, many hyperscalers and tech companies have set climate targets and are demanding decarbonised energy for their plans. There is therefore a call for IOCs and NOCs to expand their technological portfolio to meet these needs. ExxonMobil is keen to leverage its CCS potential to ensure

82 IEA, *Digitalization and Energy*, November 2017, https://www.iea.org/reports/digitalisation-and-energy.

83 Dale, Spencer and Bassam Fattouh, "Peak Oil Demand and Long-Run Oil Prices", in *OIES Energy Insights*, No. 25 (January 2018), https://www.oxfordenergy.org/?p=30822.

84 Moore, Malcolm, "AI's Huge Power Needs Give Oil Majors Incentive to Invest in Renewables, Says Adnoc Boss", in *Financial Times*, 4 November 2024, https://www.ft.com/content/b12367a3-c07c-4180-90fe-8ddf358f7952.

85 Kearney, Laila, "Exclusive: Chevron Advances Plans to Develop US Data Centers with Power Generation", in *Reuters*, 14 March 2025, https://www.reuters.com/business/energy/ceraweek-chevron-advances-plans-develop-us-data-centers-with-power-generation-2025-03-14.

low-carbon energy.[86] Another example is the deal signed between Eni and the UAE's Khazna Data Centers for the development of an "AI Data Center Campus" with a total IT capacity of 500 MW in Italy.[87] The Italian company is expected to supply energy through a new high-efficiency gas power plant coupled with CCS.

With the surge of AI, the oil and gas industry has been evaluating how to integrate the new technology into their business models. The complexity of energy systems can create a valuable ecosystem for AI to thrive. According to some estimates, the global market for AI applications in hydrocarbon value chains is around 3 billion US dollars in 2024 and is expected to increase up to 5.2 billion in 2029.[88] Although it is difficult to assess the real contribution of AI, it is reasonable to think that it will support businesses' decisions and improve some of their operations. Nonetheless, its actual (and successful) deployment depends on multiple key criteria, starting from the alignment of objectives and incentives. Therefore, companies will be eager to deploy AI in areas like operational improvements, such as exploration and production (E&P) activities, maintenance of assets, accelerating emission abatement and enhancing resilience.

From a corporate perspective, there could be two different types of AI application: in simpler and more complex use cases (mainly related to the core business of the company). The simpler use cases include standard back-office functions or "copilots" that can boost productivity. This kind of application does not require significant technical expertise, specialisation and training to be deployed. For example, companies like BP and TotalEnergies have launched partnerships with Microsoft to integrate the use of Copilot.[89]

86 ExxonMobil, *Powering the AI Revolution with Reliable Energy*, 24 July 2025, https://corporate.exxonmobil.com/news/corporate-news/powering-the-ai-revolution-with-reliable-energy.

87 Eni, *Khazna Data Centers and Eni Partner to Develop 500 MW AI Data Center Campus near Milan*, 11 July 2025, https://www.eni.com/en-IT/media/press-release/2025/07/pr-khazna-data-centers-eni-partner-develop-i-data-center-campus.html.

88 DNV, *AI Spells Opportunity and Manageable Risk for the Oil and Gas Industry*, 1 October 2024, https://www.dnv.com/article/ai-spells-opportunity-and-manageable-risk-for-the-oil-and-gas-industry.

89 BP, *BP Looks to Leverage Power of Generative AI with Copilot for Microsoft 365*, 15 November 2023, https://www.bp.com/en/global/corporate/news-and-insights/press-releases/bp-looks-to-leverage-power-of-generative-ai-with-copilot-for-microsoft-365.html; TotalEnergies, *TotalEnergies Unlocks the Potential of Generative Artificial Intelligence for Its Employees*, 27 February 2024, https://totalenergies.com/node/23866.

By contrast, the more complex use cases are far more innovative and require more customisation based on company needs. For this kind of solution, companies will require trained-from-scratch LLM. Companies have certainly looked at integrating AI into support functions (e.g., HR, legal and IT), but those that are harnessing the most value are focusing also on adjusting their core business processes. Using machine learning to analyse and learn from extensive datasets collected from the company can bring benefits across the value chain and asset lifecycles.[90] For example, by using over 30 AI tools across the entire value chain, ADNOC generated 500 million US dollars of additional value in 2023.[91] Among companies, some have explicitly embraced AI in their corporate strategy and invested heavily in developing capacity and partnering with major tech providers. For example, PETRONAS established an Artificial Intelligence Centre of Excellence in Malaysia with the goal of accelerating advancement of AI solutions useful for the energy system and its operational activities.[92] Saudi Aramco launched its generative AI model, Aramco Metabrain AI, which can analyse drilling plans, geological data and historical information (leveraging 50 years of company data) to optimise operations and decision-making processes.[93] Moreover, ADNOC, together with AIQ, launched ENERGYai, an agentic AI solution that leverages decades of data and expertise to integrate LLM in solutions tailored for ADNOC's upstream.[94] Although companies need to grow in-house AI teams, there is a growing materialisation of strategic partnerships and collaborations between technology providers and oil and gas companies, such as the one between C3 AI and Shell in October 2023.[95]

90 DNV, *AI Spells Opportunity and Manageable Risk for the Oil and Gas Industry*, cit.

91 ADNOC, *$500 Million in Value Generated by ADNOC through Deployment of AI Solutions in 2023*, 5 March 2024, https://www.adnoc.ae/en/news-and-media/press-releases/2023/$500-million-in-value-generated-by-adnoc-through-deployment-of-ai-solutions-in-2023.

92 PETRONAS, *PETRONAS Establishes AI Centre of Excellence through Collaboration with Global Partners*, 3 November 2022, https://www.petronas.com/node/1135.

93 Saudi Aramco, *How AI Helps Aramco Turn Oil Data into New Opportunity*, 12 March 2025, https://europe.aramco.com/en/news-media/news/2025/aramco-deploys-ai.

94 ADNOC, *ADNOC and AIQ Developing First-of-Kind Agentic AI Solution for Global Energy Transformation*, 4 November 2024, https://www.adnoc.ae/en/news-and-media/press-releases/2024/adnoc-and-aiq-developing-first-of-a-kind-agentic-ai-solution-for-global-energy-transformation.

95 C3 AI, *C3 AI and Shell Expand Collaboration for Asset Monitoring and Predictive Maintenance*, 11 October 2023, https://c3.ai/?p=61378.

4.1 Applications in the upstream sector

One of the most crucial activities for AI integration within oil and gas companies concerns exploration and production activities. For every single company, be it NOC or IOC, these activities represent the main area of business. One of the first steps in this regard is a seismic analysis through seismic imaging technology, which has been a cornerstone of the industry for decades. High-resolution 3D seismic imaging techniques, coupled with AI algorithms, provide more precise imaging, reducing exploration risks and time, and increasing the success rate of drilling operations. Some leading companies have already been using AI-powered solutions to produce oil faster, at lower cost and resource intensity. This has been for instance the case for Shell, which partnered with SparkCognition in its deep-sea exploration and production to boost offshore oil output.[96]

Furthermore, some oil companies have developed and adopted supercomputers to boost their exploration activities and improve efficiency. For example, in 2000, oil and gas companies used 11 supercomputers, which were ranked among the world's 500 fastest. By 2024 the figure had increased to 24, and total computing capacity has grown at almost 70 per cent annually outpacing the broader supercomputing industry.[97] In this field, several companies have either developed their own capabilities or collaborated with partners to integrate such technology. In Europe, in 2024 Eni launched its supercomputer, HPC6, located in northern Italy, which was ranked as the world's fifth fastest computer[98] behind three US research computers and Microsoft's Eagle computer.[99] The HPC6 contains almost 14,000 graphics processing units (GPU) and can perform complex calculations and run AI processes. Clearly, this technology will be devoted to improving efficiency along the company's business, starting from E&P activities. Other companies, like Exxon, Shell and Chevron, have

96 Kelly, Stephanie, "Shell to Use New AI Technology in Deep Sea Oil Exploration", in *Reuters*, 17 May 2023, https://www.reuters.com/business/energy/shell-use-new-ai-technology-deep-sea-oil-exploration-2023-05-17.
97 IEA, Energy and AI, cit.
98 As of July 2025, it is the sixth largest in the world.
99 Moore, Malcolm, "Eni Fires Up €100mn Supercomputer in Race to Find Oil and Gas Reservoirs", in *Financial Times*, 25 December 2024, https://www.ft.com/content/4d8f9ce3-4fb2-4560-bbf3-7ac0d3fb2872.

instead used supercomputers at the US National Center for Supercomputing Applications and the Los Alamos National Laboratory as they consider it more efficient to rent someone else's supercomputer. Indeed, Eni's HPC6 was built at a cost of more than 100 million euros and must face speed innovation from other giant computing systems. However, building private computing power can be a new kind of business as Eni expressed its availability to sell to other players.[100] Among other companies, only TotalEnergies and Saudi Aramco have supercomputers ranked in the first 100 in the world.[101] TotalEnergies holds the Pangea supercomputer (ranked 92nd), while Saudi Aramco owns Dammam-7 (ranked 71st).

Furthermore, AI can enhance planning, automate drilling, predict conditions and streamline workflows. By partnering with IBM, ExxonMobil has deployed AI allowing the company to reduce well planning and design time from nine to seven months, and cutting data preparation time by 40 per cent.[102] Digitalisation has also transformed oilfields into much more interconnected assets, contributing to cost reduction and security improvements. Concerning the optimisation of production, the IEA estimated in 2017 that a cost reduction of 10-20 per cent could have been achieved by the widespread use of then-existing digital technologies.[103] Regarding security, AI-powered systems can enhance safety measures, improve maintenance operations and prevent major equipment failures with direct economic benefits, such as the case of Chevron's partnership with Microsoft's Azure platform, or Shell and BP.

4.2 Monitoring and mitigating methane emissions

Despite the expected decline of demand for fossil fuels, they will remain in the energy picture. Based on IEA scenarios, oil and gas supply is still expected to account for 14 per cent of energy supply in 2050. At the same time, it is crucial to increase efforts to reduce emissions related to the remaining supply through

100 Moore, Malcolm, "Oil Major Eni Opts for Carbon Capture and Data Centres in Boost to Transition Strategy", in *Financial Times*, 27 February 2025, https://www.ft.com/content/06fefe46-29de-40e5-8119-2c7b6f930270.

101 TOP500 List, June 2025, https://www.top500.org/lists/top500/list/2025/06.

102 DeNittis, Nicholas, "Artificial Intelligence at ExxonMobil: Two Applications at the Largest Western Oil Company", in *Emerj Articles*, 30 January 2023, https://emerj.com/?p=42795.

103 IEA, *Digitalization and Energy*, cit.

addressing production emissions. AI and machine learning, powered by data from sensors and on-site, aerial and satellite cameras, can help companies to identify, quantify and address emissions and oil spills. In this sense, a relevant AI application to the energy sector is that of monitoring and mitigating emissions – especially methane emissions. Methane emissions are the second largest contributor to climate change after carbon dioxide (CO_2) and are responsible for around 30 per cent of total warming since the Industrial Revolution. This is because methane is a powerful greenhouse gas with more than 80 times the warming power of CO_2 in the first 20 years after release. From the oil and gas industry perspective, methane emission is quite relevant. The extraction of fossil fuels accounts for around 120 million tonnes of methane emissions – equal to one-third of current total methane emissions from human activity. Capturing methane emissions has multiple benefits from the energy, environmental and economic standpoints. By capturing these emissions, companies and countries can monetise what was otherwise lost and wasted. They also can enhance market liquidity and energy security with tangible positive consequences for consumers and industries – especially in countries with rising demand. Finally, cutting methane emissions represents the most cost-effective and impactful action in the short term to address global warming.

Methane emissions are becoming a political and a business concern. Politically, countries have increasingly put methane under the spotlight (after decades of focusing mainly on CO_2) as the lowest-hanging fruit to significantly fight global warming due to availability of technologies. Indeed, existing technologies can reduce around 70 per cent of methane emissions, and about 40 per cent of methane emissions from oil and gas operations could be avoided at no net cost[104] according to IEA estimates. At COP26, more than 100 countries, led by the US and the EU, launched the Global Methane Pledge, which aims at a joint reduction of at least 30 per cent by 2030. According to the IEA, methane emissions from oil and gas operations need to fall by more than 75 per cent by 2030 to avoid exceeding the Paris Agreement target.[105]

104 Based on the average gas prices from 2017 and 2021.

105 IEA, *Net Zero by 2050. A Roadmap for the Global Energy Sector*, May 2021, https://www.iea.org/reports/net-zero-by-2050.

Given this higher scrutiny, companies have steadily joined the effort. A growing number of oil and gas companies have set methane targets and launched initiatives to address the issue, such as the Oil and Gas Methane Partnership 2.0 (OGMP 2.0), the Oil and Gas Climate Initiative (OGCI) and the Oil and Gas Decarbonization Charter (OGDC). The OGDC was launched at COP28 and gathers 30 NOCs and 20 IOCs which commit to achieving near-zero methane emissions by 2030 from their upstream operations. At the company level, the growing focus on methane emission is dictated by the need to certify and ensure adequate standards for future commercialisation of their production. Importing regions have increasingly addressed methane emissions from oil and gas imports, starting from the first-ever regulation in the EU[106] and the "Coalition for LNG Emission Abatement toward Net-Zero" (CLEAN) launched by Japan and South Korea to reduce methane emissions in the LNG value chain.

Existing technologies, powered by AI, can boost data processing techniques to detect and quantify total emissions caused by large and smaller leaks. The expansion of satellites, including methane-focused satellites, provides robust and transparent data, including fugitive emissions (responsible for 20 per cent of methane emissions from oil and gas operations). For example, AI and deep learning approaches can track emissions and detect leaks in real time, predicting future emissions to prevent leaks.[107] Indeed, AI helps in several key actions, such as processing data from sensors at scale, combining input from multiple satellites to overcome specific limitations, and integrating satellite information with data from other types of sensors.[108] An emblematic case in this sense is Chevron, which deployed AI to enhance methane emissions abatement in its upstream operations, helping cut emissions intensity by 60 per cent.[109]

106 European Commission DG for Energy website: *Methane Emissions*, https://energy.ec.europa.eu/node/5573_en.

107 IEA, *Energy and AI*, cit.

108 Sandalow, David et al., *Artificial Intelligence for Climate Change Mitigation Roadmap*, 2nd ed., ICEF, November 2024, https://doi.org/10.7916/2j4p-nw61.

109 Salzman, Avi, "AI Is Changing Oil Country – and Pumping Up Profits", in *Barron's*, 26 November 2024, https://www.barrons.com/articles/ai-oil-industry-profit-permian-basin-8adcacdd.

4.3 Carbon capture, utilisation and storage

To further drive emissions downward and enhance resilience, oil and gas companies are eager to develop carbon capture and storage (CCS) projects. According to the IEA scenario, global CCS capacity needs to increase by more than 40 times today's capacity by 2030. There is also a growing momentum on CCS due to industrial competitiveness concerns as well as higher political acceptability, as highlighted also by the Global Stocktake promoting a technologically neutral approach. Most companies have set CCS targets and projects as a way to leverage their know-how and contribute to emissions reduction. However, efficiency and scale improvements are needed to achieve targets. For example, capture rates should be improved from 90 per cent to 98 per cent. Another major barrier is represented by cost – making its reduction a primary need for the technology. AI can ideally be integrated into CCS projects. Firstly, effective CCS depends on subsurface knowledge and reservoir simulation. Therefore, AI and additional computing power can be deployed for rapid screening of potential CCS locations and for assessing trap and seal integrity. Additionally, AI tools can also assist companies in identifying the optimal pathways between sequestration sites and emissions sources taking into account aspects such as distance, transportation options and volume. Integration is possible thanks to the emergence of new companies like Geoteric, which aims at identifying suitable storage sites,[110] or Cerebras, which has partnered with TotalEnergies to improve carbon storage simulations.[111] Equinor, which has been committed to CCS development, has collaborated with TGS to advance digitalisation of CCS, especially in Northern Lights project.[112]

110 Geoteric, *The Role of AI in Accelerating CCUS to Support Net-Zero. Case Study*, 27 May 2021, https://www.geoteric.com/hubfs/Geoteric%20-%20CCUS%20case%20study.pdf.

111 Cerebras website: "TotalEnergies", in *Customer Spotlights*, https://www.cerebras.ai/customer-spotlights/totalenergies.

112 TGS, *TGS and Equinor Collaborate to Drive Digital Transformation in CCS Operations*, 7 July 2025, https://www.tgs.com/press-releases/tgs-and-equinor-collaborate-to-drive-digital-transformation-in-ccs-operations.

5. Challenges for AI applications

AI's potential in the oil and gas industry is clear. Many companies have already integrated AI projects into their operations to improve efficiency, enhance resilience in a demand-constrained world and accelerate mitigation strategies. Such integration is expected to grow as AI applications become as available as current software. To fully harness AI's potential, all companies – and countries – need to address and overcome certain challenges.[113] Firstly, data quality. The risk of flawed data influencing AI outputs is real. Therefore, companies need to improve both quality and quantity of their data. Indeed, large and patchy datasets hinder accuracy and consistency. To address this issue, companies will need to further streamline and integrate data sources by reducing fragmented sources and silos (also within the same organisation). The long and complex value chain of oil and gas industries may result in siloed data within different business units and geographies. Furthermore, cooperative and open-source data have been key features of the rise of AI. However, corporate data and strategies may hinder cooperative AI initiatives in the oil and gas industry. Thirdly, the long lifecycle of many energy assets may represent a barrier as older assets lack compatibility with modern AI technologies. Fourthly, expanding digitalisation entails some security risks, notably related to critical infrastructure, data management and safety. Therefore, companies need to enhance their security checks and measures to keep sensitive operational data safe. Fifthly, AI adoption by businesses requires an adequate management culture and well-trained workforce.[114] Indeed, integrating new technologies will require new skills and processes, and change long-standing work procedures. To do so, incentives and support will be essential. Last but not least, growing geopolitical and technological competition may lead to further fragmentation, including through export restrictions, that may ultimately hinder companies' AI strategies and ability to obtain technologies and capital efficiently.

113 Sircar, Anirbid et al., "Application of Machine Learning and Artificial Intelligence in Oil and Gas Industry", in *Petroleum Research*, Vol. 6, No. 4 (December 2021), p. 379-391, https://doi.org/10.1016/j.ptlrs.2021.05.009.

114 Bhadauria, Swapnil, "Scaling AI for Maximum Impact in Oil and Gas", in *EY Insights*, 6 January 2025, https://www.ey.com/en_us/insights/oil-gas/maximizing-the-impact-of-ai-in-the-oil-and-gas-sector.

Conclusions

The great transformative potential of AI has led to a rise of private investments, underpinned by geopolitical competition further exacerbated by the zero-sum game approach towards technological competition. While there are two major players (US and China) with their peculiarities, other countries have expressed the ambition to play a role in this race leveraging on different advantages (e.g., cheap energy, vast land, strong financial and political commitment). Besides investments and political will, the success and speed of AI is deeply tied to the energy sector as it is expected to drive electricity demand upwards, forcing governments to reconsider their energy policies.

In this scenario, oil and gas companies are expected to play a key role in both the supply and demand of the AI revolution. On one side, they will need to revise their investment portfolio to ensure affordable and energy supplies to data centres. At the same time, AI can be integrated along the value chain to ensure efficiency and enhance resilience.

Although we are still in the early stages of AI innovation and its fast-evolving development, this paper has identified clear areas where companies have decided to integrate AI models into their business, primarily the upstream sector. Indeed, despite a range of priorities, they share the same challenges and objectives as members of the same industry. Nonetheless, some NOCs have expressed their ambitions more explicitly than others. This is mainly motivated by the convergence of national and corporate objectives. Most of these are NOCs of petrostates that are eager to remain highly competitive in the oil and gas business due to monetisation goals, but also are more committed to a general diversification. Furthermore, these companies can benefit from collaborating with other national institutions (e.g., sovereign wealth funds) to enhance their AI capabilities, while achieving national targets. At the same time, AI integration and strategy tend to reflect the company's business, structure and characteristics. Lastly, there is a growing integration between oil companies and technology providers through strategic partnerships and collaborations. However, due to sensitive information and value creation, oil companies are expected to become (partially) data-driven companies as they aim at growing in-house AI teams to harness the technology's full potential.

The AI-Energy Nexus: A Mapping of Trends and Applications for Oil and Gas Companies

The great transformative potential of artificial intelligence (AI) has sparked massive investments, drawn the interest of governments and enflamed global competition. As with any other technology, energy will be essential to power such developments. The AI-energy nexus is therefore quite relevant. In this picture, oil and gas companies are key players not only in providing affordable and stable energy supplies and contributing to national targets, but also as potential consumers and developers of AI. Both international and national oil companies have started to integrating AI into their operations. As of today, most of the announced applications are in line with companies' objectives: enhance resilience and reduce costs. This paper seeks to analyse a range of applications and corporate decisions regarding AI in both national and international oil companies.

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