



Smart Energy: The Impact Of AI On The Energy Business

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Energy Industry Report



The Abdullah Bin Hamad Al-Attiyah International Foundation for
Energy & Sustainable Development





INTRODUCTION

SMART ENERGY: THE IMPACT OF AI ON THE ENERGY BUSINESS

Artificial intelligence (AI) is increasingly emerging as the central node in a range of digitalisation technologies encompassing big data, machine learnings, the internet of things (IoT), automation, and remote sensing. It already offers improved efficiency, lower costs, and better environmental performance. It is critical to unlocking the full potential of the renewable electricity revolution. Over the next decade and beyond, it will be the key competitive differentiator beyond simple resource endowments. But to make the most of it, companies have to rethink their business models, partnerships, and people, radically.



Energy Industry Report

This research paper is part of a 12-month series published by the Al-Attiyah Foundation every year. Each in-depth research paper focuses on a prevalent energy topic that is of interest to the Foundation's members and partners. The 12 technical papers are distributed in hard copy to members, partners, and universities, as well as made available online to all Foundation members.

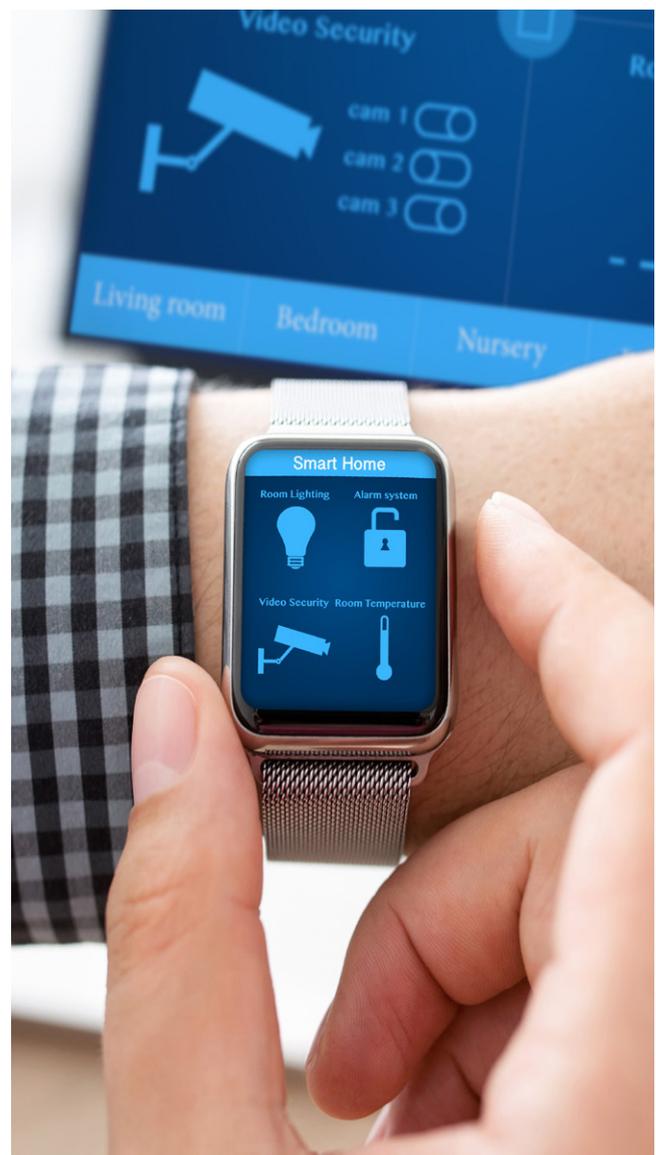


EXECUTIVE SUMMARY

- Artificial intelligence (AI) is the core part of digitalisation, the developing suite of techniques that acquires, interprets, and decides on digital data.
- AI is increasingly being employed in the energy sector, in a wide range of applications in petroleum and electricity.
- However, at the moment, it is primarily used in isolated applications, instead of systematically integrated into an entire company's business model and operations.
- Intelligent, networked systems will become the norm across energy company operations, and power grids, with the integration of 'smart homes' and the 'IoT'.
- The growing use of AI raises concerns about cybersecurity, transparency, and control, which have to be planned into systems in widespread adoption.
- However, AI will also improve the performance and cost of renewables and other non-hydrocarbon technologies, eventually boosting them versus oil and gas.
- There is the potential for AI to catalyse breakthroughs in areas such as self-driving vehicles, advanced nuclear, batteries, bio-energy or carbon capture and storage (CCS); transforming the energy industry beyond simple projections based on incremental improvements in today's technologies.

IMPLICATIONS FOR LEADING OIL AND GAS PRODUCERS

- The successful and comprehensive application of AI will be increasingly essential for oil and gas companies, whether international or national.
- Oil and gas firms will have to retool their recruiting, training, project management, and operational practices to make the best use of AI.
- AI will enable oil and gas firms to produce more complex, challenging, remote, and mature resources at low costs and with better environmental performance. These improvements will extend the competitiveness of oil and gas and tend to keep hydrocarbon prices relatively low while sustaining demand for them.



WHAT IS ARTIFICIAL INTELLIGENCE IN THE ENERGY SECTOR?

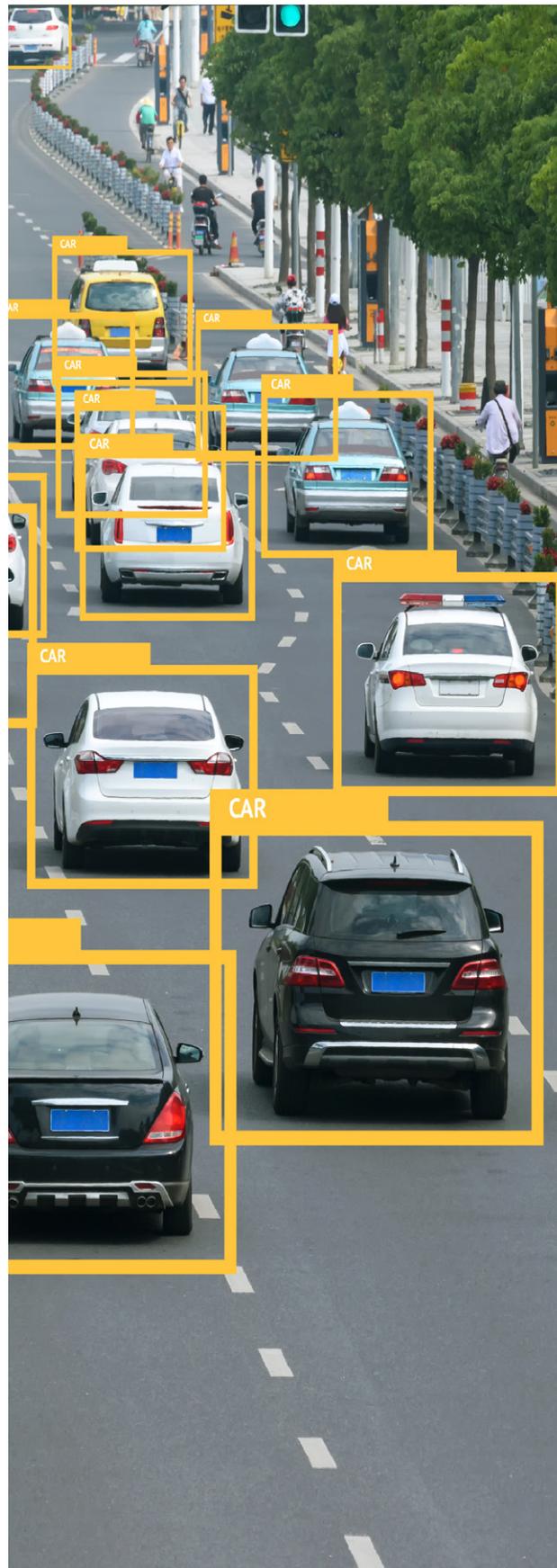
AI can be defined, broadly speaking, as intelligence distinguished from “natural” or “human” intelligence, that independently makes and implements decisions based on data concerning a set of goals in sectors critical to the economy: agriculture, energy, transport, and food. AI, therefore, is intelligence that learns from experience and makes new decisions.

AI promises to catalyse a radical transformation of the global economy through the fusion of two disruptive and powerful megatrends—digitalisation and decarbonisation. Even though not explicitly developed for the energy sector, artificial intelligence can offer gains in efficiency, productivity, and maximise returns both for traditional and renewable energy systems. To attain its full potential, AI has to be embodied in new business models and operated by highly-skilled and differently-skilled employees.

AI is not a single technology or tool—it is a system.

AI is not a single technology or tool—it is a system. It encompasses three capabilities ¹:

1. Sensing: tools that gather data, some of it obtained by humans, some equivalent to human senses (for instance, video footage), some from locations inaccessible to humans (e.g. drones, satellites, in well-bores, inside furnaces), and some from senses not available to humans (for instance, measuring electric charges, high temperatures, radioactivity or chemical concentrations);



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2. **Analysing:** all the information gathered has to be combined, converted to consistent formats, and made available. Then AI tools, often working together with human input or supervision, identify patterns, make predictions, and otherwise derive useful conclusions and outputs from the information. Unlike a simple automated system, and like humans, AI is capable of learning, and of changing its own 'thought' processes through experience; and
3. **Acting:** the system acts, either through a human operator or increasingly, autonomously. Autonomous operation is particularly relevant for complex but automatable tasks; those that are repetitive, boring or dangerous for a human operator, such as fine-tuning the operating temperature of a furnace; or that require particular precision or high speed. But AI combines this with the ability to synthesise vast datasets and update them constantly, finding patterns that a human would miss.

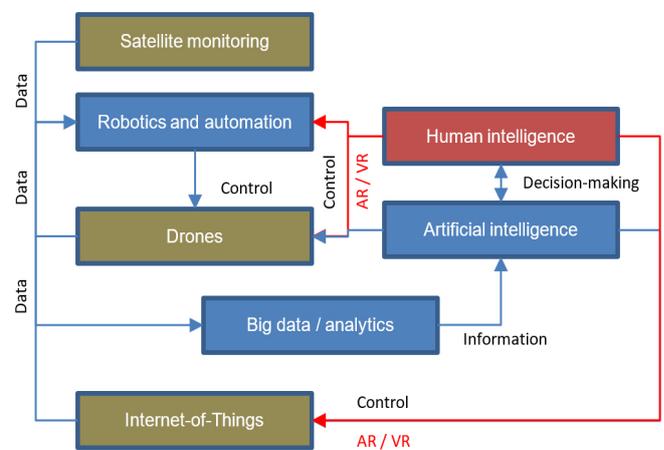
'Weak' AI specialises in narrow, well-defined tasks.

'Strong' AI can generalise to unfamiliar tasks.

In the energy sector, AI is the crucial central component of the broader theme of digitalisation. The term "AI" is often used synonymously with digitalisation, even though digitalisation itself is a cluster of technologies that lowers the costs of storing, sharing, and analysing data, by converting such data into digital bits. AI exists alongside, and is related to, areas including information

and communication technology (ICT) systems, "big data" / machine learning / advanced analytics, IoT, augmented and virtual reality (AR / VR), drones, robotics, and automation (Figure 1 and Figure 2). These subsets collect information and react flexibly to the changes in the environment.

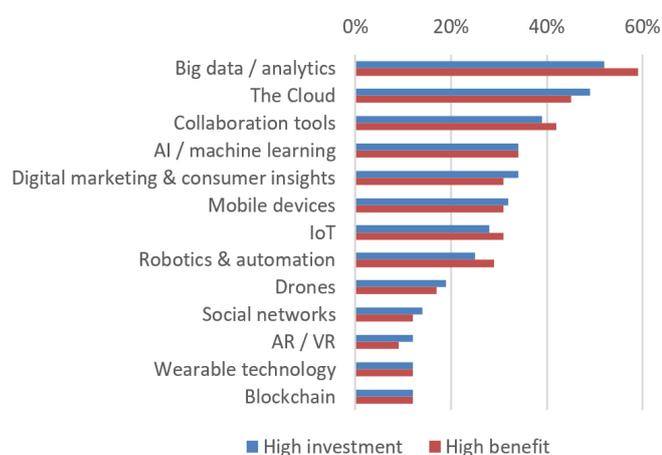
FIGURE 1 INTERACTION OF DIGITALISATION TECHNOLOGIES



AI can be calibrated to many areas of the energy business, such as upstream oil and gas exploration and operations; monitoring pipelines and grids via remote sensing (drones and satellites) for leaks, faults, and sabotage; remote energy operations (such as renewables and offshore) with no personnel on-site; predictive maintenance optimising downstream margins; and electrifying transport systems. In future, a low-carbon, sustainable economy will be driven by the increasing cost-competitiveness of low-carbon alternatives as well as technologies that support and maintain such options. Big data and analytics are the top current focus areas for petroleum companies, with AI also ranked highly (Figure 2).

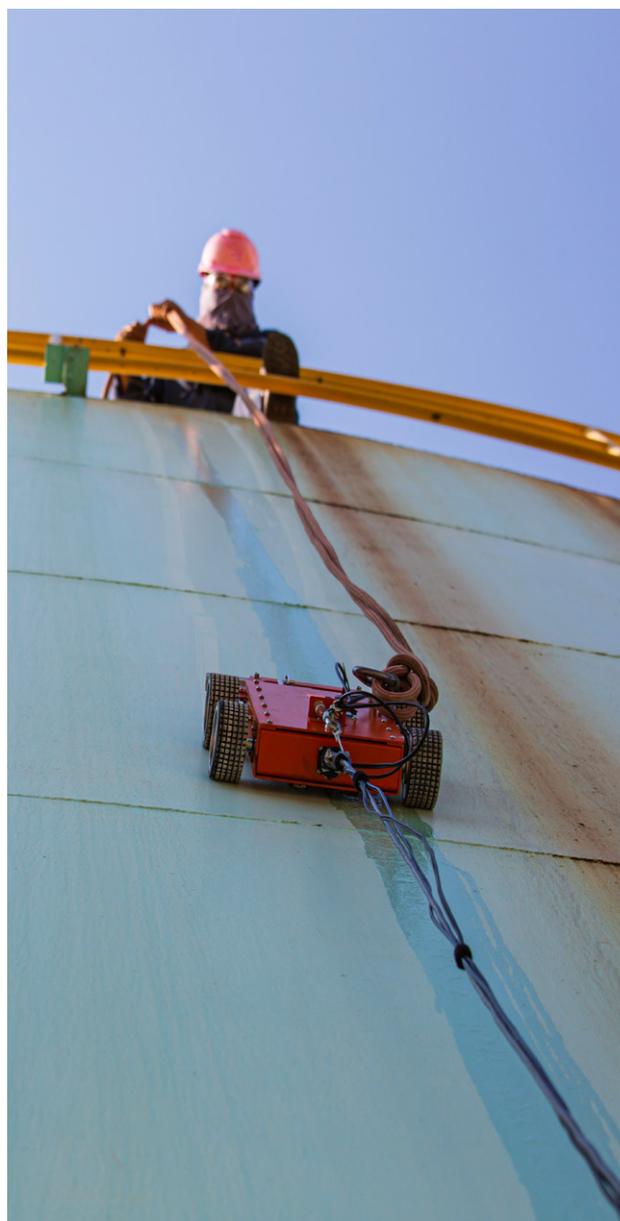
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FIGURE 2 OIL & GAS COMPANIES' EXPECTED FOCUS AREAS OVER THE NEXT 18 MONTHS ⁱⁱ



Application of digitalisation in the oil & gas industry varies by region, with North America a strong leader, Europe a little ahead of Asia-Pacific, and the Middle East somewhat behind. Big data and analytics are the critical technologies for most regions, followed by the Cloud, and then by collaboration tools. But in the Middle East, digital marketing is the most popular area ⁱⁱⁱ.

AI is also a key contributor to the theme of decarbonisation. Businesses are facing growing pressures (regulatory, reputational, and market-driven) to shift to a low-carbon future. This shift involves both improved efficiency and greater use of renewable and other low-carbon energy sources. AI is a vital enabler of both, particularly as it relates to electrification as a clean energy carrier. However, many AI applications use additional electricity, raising the importance of low-carbon generation.

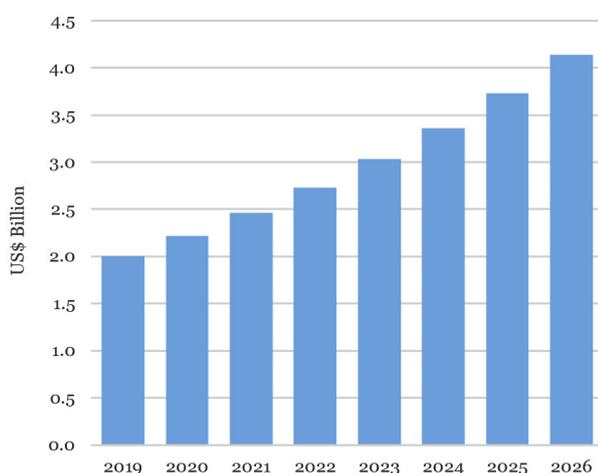


AI IS A KEY PART OF MAINTAINING THE PETROLEUM INDUSTRY'S ECONOMIC COMPETITIVENESS

The oil and gas industry is witnessing its worst downturn in history, driven by the Covid-19 pandemic-induced economic crisis, and associated collapse in oil demand. Just as some early signs of recovery have emerged, second wave, and in some cases, third-wave infections have gripped major economies, further dampening demand. Such disruptions will continue exerting downward pressure on hydrocarbon prices, forcing energy companies to focus more intensely on reforming their portfolios.

Against this backdrop, proactive digitalisation is expected to create around US\$ 1 trillion in value for the oil and gas market according to the World Economic Forum, of which US\$ 580-600 million is expected to accrue to upstream companies, US\$ 100 billion to midstream firms, and US\$ 260-275 billion to downstream companies. In turn, this would result in US\$ 640 billion of overall savings: US\$ 170 billion for customers, US\$ 10 billion in productivity improvements, US\$ 30 billion from reducing water usage, and US\$ 430 billion from reducing CO₂-equivalent emissions by 1.3 billion tCO₂e, saving about 800 million m³ of water and avoiding ~230-kilo barrels (kbbbl) of oil spills.

FIGURE 3 OIL & GAS AI MARKET ^{iv}



In 2019, spending on AI in the oil and gas market was valued at US\$ 2 billion. It is expected to reach US\$ 3.8 billion by 2025, at a compound annual growth rate (CAGR) of 11%, with significant benefits for the wider society (Figure 3).

Key drivers for the uptake of digitalisation come on the supply and demand sides. On the supply side, factors include much greater computing power and bandwidth, improved AI algorithms and methodologies derived from general research, the greater familiarity of employees with digital technologies, and the availability of cheap and highly functional digital devices.

On the demand side, key drivers include:

- The attraction of remote working in the Covid-19 pandemic;
- Low oil and gas prices, making cost reductions, higher asset uptime, and lower staffing levels essential;
- A turn to more complex resources, including shale / tight reservoirs, ultra-deepwater, small and mature fields, with cost pressures, more benefits of optimisation, thinner margins, and more complexity of decision-making;
- An ageing and retiring petroleum workforce, with the danger of losing accumulated knowledge and experience;
- Health, safety, and environmental reasons to limit workforce exposure in the field; and
- Greater societal and regulatory pressure for greater energy and environmental efficiency.

The Covid-19 pandemic has accelerated the shift to remote working. Staff movements to and from work sites, and internationally, have been severely constrained. Operational sites, including in Mexico and Mozambique, have been affected by pandemic outbreaks. Office work and in-person meetings have been discouraged by social distancing measures. In this environment, the ability to monitor, operate, and troubleshoot fields and facilities remotely, and for teams to collaborate virtually, has been essential. This shift has been facilitated by digitalisation, automation, and the remote gathering of data by technologies like IoT and drones.

A significant concern among emerging oil producers is extending the life of producing wells through improved drilling and extraction or tapping unconventional resources in challenging terrains. AI surveillance systems such as cloud and high-performance computing (HPC) can aid in identifying recoverable reserves while decreasing labour and capital costs of traditional surveillance instrumentation (for example reservoir "sensors", which are expensive, disconnected, and static). Large amounts of data are manipulated in models which supports decision-making for optimal oil recovery and a holistic approach to production and reservoir management.

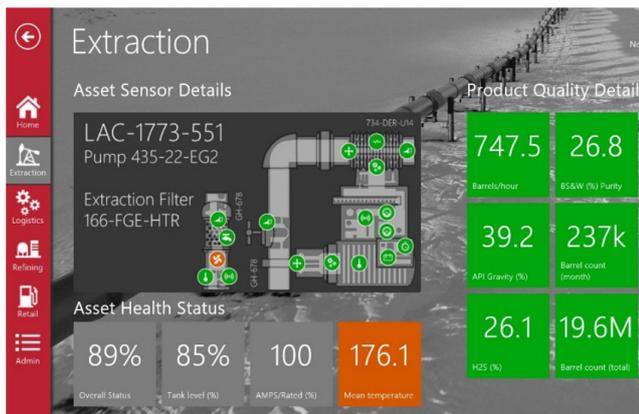
This applies particularly to shale and tight reservoirs, widely exploited in North America. These lend themselves to the complicated but repeatable operations that machine learning can optimise⁹. This is in contrast to projects such as a deep-water field or remote liquefied natural gas facility, which are more "one-off", and are better suited to approaches such as the 'digital twin'.



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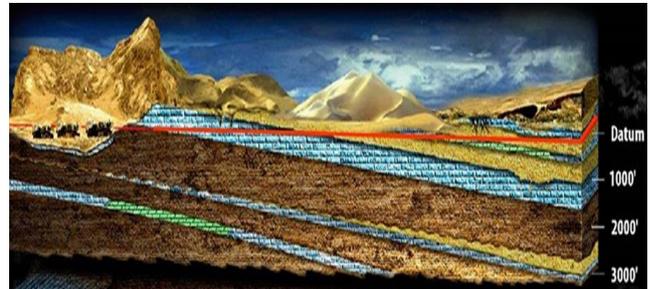
New hydrocarbon finds in the Middle East, are increasingly concentrated in technically challenging and complex geological structures. This requires efficient resource appraisal, particularly for tight, sour gas and oil. Major countries with a plethora of such resources include the UAE, Oman, Saudi Arabia's offshore, northern Iraq, and Bahrain. AI can provide accurate reservoir descriptions and geo-mechanical characterisations and the best-suited hydraulic fracture modelling and designs through advanced numerical simulation capabilities and highly sophisticated sensor systems.

FIGURE 4 A DEMO OF AZURE'S AI (IOT) PREDICTIVE MAINTENANCE SUITE FOR OIL AND GAS, MICROSOFT



Deep-water drilling is less attractive in regions with low gas prices, requiring higher efficiency in capital allocation and labour costs. Big data and other AI can enable cost-effective deep-water drilling that can minimise costs by automating repeatable, traditional processes through "virtual instructors" and "smart agents" that capture the knowledge of seasoned professionals.

FIGURE 5 IMAGE OF ARAMCO'S GEOPHYSICAL SEISMIC RESEARCH USING AI (BIG DATA ANALYTICS)



Case Study: Saudi Aramco's Big Data Technology

The Saudi Aramco R&D Center has managed to make major strides to address key oil and gas challenges, including seismic processing and analysis, increasing the effectiveness and efficiency of gas exploration, optimising enhanced crude oil recovery methods, enhancing well productivity, and reducing Capex.

Aramco has introduced GigaPowers, an oil and water enhanced reservoir simulator, and TeraPowers, a next-generation reservoir and basin simulator to improve computational modelling, to give its petroleum engineers a better understanding of reservoir mechanics. This understanding enables maximum recovery and sustainable production for the long term.

Aramco's Geophysical Data Acquisition Division (GDAD) is responsible for imaging, velocity analysis, and noise suppression in complex, arid land environments, subsalt deep-water and transition zone environments.

It characterises reservoirs and monitors oil and gas in both carbonate and clastic reservoirs, identifying faults and fracture fairways.

Benefits

- Hidden insights into cost-cutting
- Optimising artificial lift systems
- Data on weather patterns, topography challenges
- Boost operational efficiency by 20%
- Compression of large data

AI also has broad applicability in the midstream (pipelines, tankers, and storage) and downstream (refining, petrochemicals, and retail) petroleum sectors. Predictive maintenance has emerged as a key area to avoid unplanned downtime while reducing expenditure and unnecessary checks and replacements. Big data systems scan performance data from equipment to spot signs of imminent breakdown.

The 'digital twin' of an oilfield or facility aims to replicate it digitally and virtually, with a real-time link to data gathered from the field. This approach has already been used by NASA and Formula One racing. The digital twin allows operators to test "what-if" scenarios and practice operations such as plant shutdowns and maintenance campaigns. Staff can be trained in virtual reality to improve safety. Digital twins can exist even before the construction phase, allowing optimisation of design and build. BP uses a digital twin system called APEX ^{vi}. Equinor's giant new Johan Sverdrup field is its first to have been made with a digital twin from the outset.



NEW GEOGRAPHIES OFFER GROWTH WITH CHALLENGES

Refineries and petrochemicals have the flexibility to run different slates of feedstock and produce different outputs dependent on market conditions. Machine learning models on markets, combined with digital twins, can 'operate' such a refinery virtually to test how inputs and outputs can be practically varied in real-time to meet market shifts.

It is an interesting question as to how well such models would perform in the case of an unprecedented situation such as the Covid-19 pandemic when price and demand relations are well outside historical experience. This emphasises the need for integration of AI systems with intelligent, experienced human oversight.

Finally, in the area of energy trading and retail, AI is already very widely used. For instance, in algorithmic and high-frequency trading, and in understanding consumer behaviour for purchasers of fuels (see the AI- Attiyah Foundation energy industry report for September 2020, 'Pressure on the Pump: The Future of Fuel Retail' ^{vii}).



AI IS COMPATIBLE WITH TRADITIONAL & NEW ENERGY

AI is often seen as less compatible with the traditional energy systems of oil and gas, and more synonymous with emerging and sustainable energy forms like renewables, nuclear, smart grids, and electrified transport. This perception is not least because current definitions see AI as a branch of machine learning (and subdiscipline of computer science) that can enable new energy forms to produce and transmit intelligently, while reacting flexibly to changes and the environment (such as firming, grid stabilisation, peak shaving, and remote power).



In these areas, AI can be expected to increase the performance and competitiveness of new energy sources and improve energy efficiency, reducing the demand for oil, gas, and coal.

However, AI in the traditional industries of oil, gas, and power has already transformed how those industries function and can facilitate the attainment of a wide variety of sustainability goals, including meeting the Paris Agreement's target for limiting greenhouse gas emissions (GHG), and so, climate change.

Traditional oil and gas industries are characterised by three significant environmental challenges: local impacts, water use, and GHG emissions (fuel combustion, flaring, methane leakage). According to the World Economic Forum, up to 1.3 billion tCO₂e could be saved globally from upstream activity through the implementation of AI and other information and communication technologies (ICT).

These challenges are primarily environmental, but their mitigation does not rely on ecological approaches alone. For example, addressing water scarcity due to high enhanced oil recovery (EOR) demand in oil brownfields cannot be mitigated solely by recycling and reusing discharged water. The introduction of AI streamlines and helps optimise the efficiency and viability of oil and gas operations, as well as the mitigation of a wide variety of challenges plaguing them. Then, it aids and improves management decision-making to strengthen energy companies' competitive positions in a rapidly changing environment.

AI IS INTEGRAL TO A LOW-CARBON, RENEWABLE-POWERED FUTURE

The International Renewable Agency's (IRENA) "Innovation landscape for a renewable-powered future" project identifies four solutions to drive the uptake of low-carbon, renewable sources in an era of digitalisation. These include enabling technologies, the right business models, market design and reform, and systems operation.

AI applies to some renewable energy systems in a similar way to the petroleum sector, for instance, managing biofuel refineries, diagnosing grid failures in real-time, or predictive maintenance of offshore wind turbines. But it has wider and more valuable applications.

For the power sector, AI essentially converts data into value, and is a key contributor to renewable energy integration as a result of two other innovation trends: decentralisation and rising electrification.

The increasing use of non-dispatchable electricity generation, particularly solar and wind power, creates more need for flexible grid operations^{viii}. Matching supply and demand requires fine control of imports and exports, scheduling plant and grid maintenance, the deployment of storage resources, demand-side response (flexible users, who can shut down for a price, such as some industries), and prediction of demand in response to factors such as weather, holidays, sporting events, and even pandemics. 'Smart grids' will interface with 'smart homes' to manage energy use and save on consumer bills^{ix}.

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Generation resources are increasingly distributed, particularly with widespread 'rooftop' solar installations in areas such as Germany and California. Storage resources are also likely to become distributed, as electric vehicles achieve mainstream sales, and are connected to chargers at home or work, with the ability to discharge into the grid at times of peak demand. The "virtual power plant"^x is a networked system of generation, storage, and demand resources that can replicate the reliability and 'dispatchability' of a traditional centralised power plant such as a gas-fired turbine or nuclear reactor. Such a system can bid its capacity and earn the operator revenues far beyond the simple sale of intermittent electrons from a solar or wind farm.

AI systems are also used to improve energy efficiency by managing heating and cooling loads, motor speeds, and other systems. Google's Deep Mind AI, for instance, was able to lower energy consumption at one of its data centres by 15%, mostly by cutting cooling demand by 40%^{xi}. Applying AI and digital twins to design and efficiency retrofits could likely yield more significant savings.

Increasing electrification involves personal transport, heating, and some industrial processes. This can raise the flexibility of electricity demand—for instance, storing heat in water or building frameworks just before a cold snap. But it increases the complexity of the grid, the need for timely response and prediction, and automated systems. AI will be essential for coordinating millions of 'prosumers' (a person who buys high-standard electronic goods) who at various times generate, store, supply, or use electricity.

Such users will have their own optimisation functions, for instance, an industry that shuts down temporarily when electricity prices rise too high. Market designs have to align such incentives to ensure that AI can optimise operations profitably.

Companies using AI systems will respond very well to incentives. However, those incentives have to exist and be well thought through. This applies, particularly to climate change. To maximise the contribution of AI to reducing GHG emissions, a price or cap on emissions, or equivalent regulations, will have to be in place^{xii}.

AI REQUIRES NEW BUSINESS MODELS AND WAYS OF WORKING

The full take-up of AI still faces barriers. These include:

- A reactive attitude to new developments;
- 'Not invented here' mindset to innovations arising outside the energy sector;
- Legacy assets and data systems;
- Unfamiliarity and resistance of existing staff to new technologies and ways of working;
- Conservative managerial mindset which is wary of innovation;
- Concerns over cybersecurity; and
- Worries about sharing proprietary data and systems with outside companies.

One major conceptual challenge with AI is its alien nature. AI is largely a black box^{xiii}. It may make many fewer mistakes than a human, but the mistakes it does make can be of an unexpected nature completely unlike human error. Its outputs also depend on the data in

the training sets, which may contain hidden biases or errors, or recurrent features that the AI does not know to discard as irrelevant to the deeper problem. The AI's operations also rely on the optimisation function chosen for it, which may miss considerations of practicality, human relationships, or ethics. An AI cannot explain why it reached a particular decision. This will be particularly important in the case of fully autonomous systems, that may have an enormous responsibility for safety, environmental or financial exposure. Therefore, AIs are increasingly being developed to give explanation and feedback about their decisions and to operate to empower or augment human intelligence rather than replacing it.

Though highly networked systems may be more vulnerable to cyberattacks, AI is also capable of learning to recognise and respond to attacks.

Incorporating specific AI techniques into the energy business brings little rewards. Realising its full potential requires reconfiguring organisations.

Novel partnerships are a significant element of this. For instance, BP has worked with Microsoft to incorporate the Azure AI platform into its operations; Google has cooperated with Total and Schlumberger on subsurface data modelling. Shell has used Amazon Web Services to integrate several terabytes of legacy and new data and improve cybersecurity ^{xiv}.

Energy companies will also have to work actively to recruit digitally-skilled employees, particularly given the negative image of the petroleum industry among many younger people in Western countries. Studies show 44% of millennials (born 1981-96) and 62% of Generation Z (born 1997-2012) find oil and gas jobs unappealing ^{xv}.

The rise of AI will permit more energy to be produced, transported, and consumed by fewer people, lowering its cost. It will also shift the nature of energy work: less manual work and hands-on operators, more data scientists, programmers, analysts, and robot designers. New jobs will be created; these are likely to be higher-paid, safer, and more enjoyable than in the past. But, despite comfortable talk about digital employment, it's all but certain that the number of employees required per barrel of oil or kilowatt-hour of electricity will continue its historic decline.

THE IMPLICATIONS OF AI FOR ENERGY GO FAR BEYOND PETROLEUM AND POWER OPERATIONS

This discussion has focused mostly on the applications of AI within the oil, gas, and power sectors, to optimise operations, reduce costs, and improve environmental outcomes. But increasingly powerful AI promises to reshape society in various ways, that would have significant implications for the energy sector.

Perhaps the most obvious such area is autonomous (self-driving) vehicles, already available with limited functionality. True self-driving vehicles would be highly safe and efficient, able to park, to come when summoned, to avoid congestion, and to recharge themselves. But the ability to make journeys at high speed over long distances, while the passengers sleep, work, or enjoy entertainment, would likely considerably raise the demand for transport and the size of individual vehicles, and thus its energy consumption (in the form of electricity).

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Energy research and development is another area where AI may crack critical problems. The design of complex advanced nuclear fission and fusion reactors, and CCS, would be greatly facilitated by digital twins. AI systems can search through thousands of combinations of materials to develop tailored batteries for specific applications, or to find room-temperature superconductors. A similar approach might yield results in genetic engineering to produce bio-synthetic fuels and plastics. Such breakthroughs would upset business models and energy forecasts to 2050 and beyond based on the simple extrapolation of existing technology performance.

CONCLUSIONS

In the short and medium term, AI and its associated digitalisation technologies will be crucial for the traditional energy industries, particularly petroleum, to remain competitive and improve their environmental acceptability.

Oil companies, whether state-owned or private, will be differentiated by whether and how well they adopt AI and the related



digital technologies. This is partly a question of policies, technology purchases, and organisational matters. Still, it will evermore be reliant on having the right business model and the right people—likely a very different skill-set from the traditional energy industry.

At the same time, and increasingly as time goes on, AI will also boost the performance of new energy systems, including renewables, batteries, and hydrogen. This could lead to the emergence of breakthrough technologies and systems that dramatically reshape the energy landscape.

Energy companies and their host countries need a comprehensive AI strategy to survive and flourish in the new era. This will involve collaborations with existing service partners, and also with non-traditional partners, such as Microsoft, Google, and Apple but likely with emerging firms too. But finding and executing the right strategy in the asset-heavy, relatively slow-moving energy business is far from straightforward in the fast-evolving field of AI.



APPENDIX

- i. https://www.ey.com/en_ro/oil-gas/is-ai-the-fuel-oil-and-gas-needs
- ii. Data from <https://www.petroleum-economist.com/media/9189/accelerating-digital-transformation-in-oil-and-gas-dps.pdf>
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- xv. https://assets.ey.com/content/dam/ey-sites/ey-com/en_gl/topics/oil-and-gas/ey-how-do-we-regenerate-this-generations-view-of-oil-and-gas.pdf

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