Emerging Technologies in Oil and Gas Industry

Matthew N. O. Sadiku[1], Paul A. Adekunte[2], Janet O. Sadiku[3]

[1]Roy G. Perry College of Engineering, Prairie View A&M University, Prairie View, TX, USA
[2]International Institute of Professional Security, Lagos, Nigeria
[3]Juliana King University, Houston, TX, USA

ABSTRACT

In the fast-paced world of oil and natural gas industry, staying ahead means embracing the new. To boost efficiency, cut costs, and lessen environmental harm, the oil and gas industry is adopting new technologies. This is becoming more achievable with the rise of emerging technologies like artificial intelligence, machine learning, robotic automaton, big data analytics, the Internet of things, and drones. Emerging technologies are finding their way into the oil, gas, and petrochemical industry where they provide a wide range of benefits. The integration of these technologies into the oil and gas sector is a strategic move towards a more sustainable, safer, and cost-effective future. This paper explores the use of emerging technologies in the oil and gas industry.

KEYWORDS: emerging technologies, oil & gas industry, petrochemical industry, artificial intelligence, big data, robotics, drones, blockchain

INTRODUCTION

For over a century, oil and gas has played a vital role in the economic transformation of the world. The oil and natural gas industry provides the world with reliable and affordable energy. The industry is the largest and most diverse one, with operations spanning a wide range of conditions in several countries. It is illustrated in Figure 1 [1]. It includes large networks of equipment sourcing, trading, and transport. It uses cloud computing, data analytics, artificial intelligence, and machine learning to optimize production. Oil and natural gas technologies have dramatically altered the energy landscape over the past decade, particularly in North America.

Technology is constantly changing, and oil and gas (O&G) companies must keep up to stay competitive. The oil and gas industry has always been at the forefront of technological advancements, constantly pushing the boundaries of innovation to enhance efficiency, safety, and sustainability. The O&G sector is undergoing rapid and significant transformation. Digital transformation of oil and gas companies is the integration of emerging technologies like cloud services, automation, IoT, big data, and data analytics across business functions.

WHAT ARE EMERGING TECHNOLOGIES?

Technology may be regarded as a collection of systems designed to perform some function. It can help alleviate some of the challenges facing business today. Emerging technology is a term generally used to describe new technology. The term often refers to technologies currently developing or expected to be available within the next five to ten years. Any imminent, but not fully realized, technological innovations will have some impact on the status quo.

Emerging technologies are shaping our societies. They continue to affect the way we live, work, and interact with one another. Emerging technology (ET) lacks a consensus on what classifies them as "emergent." It is a relative term because one may see a technology as emerging and others may not see it the same way. It is a term that is often used to describe a new technology. A technology is still emerging if it is not yet a "must-have" [2]. An emerging technology is the one that holds the promise

of creating a new economic engine and is trans-industrial. ET is used in different areas such as media, healthcare, business, science, education, or defense.

The characteristics of emerging technologies include the following [3]:

➢ *Novelty:* Emerging technologies are typically new or novel, meaning they have yet to be widely adopted or used. They often represent a significant departure from existing technologies or processes.

➢ *Potential for Disruption:* Emerging technologies have the potential to disrupt existing markets, industries, or ways of doing things. They may also displace existing businesses or industries.

➢ *Uncertainty:* Because emerging technologies are still in the early stages of development, there is often a high uncertainty surrounding their future potential and impact. It can be challenging to predict how they will evolve.

➢ *Rapid Change:* Emerging technologies often evolve rapidly, with new developments and innovations emerging frequently. It can make keeping up with the latest trends and advancements challenging.

➢ *Interdisciplinary*: Emerging technologies often involve multiple disciplines or fields of study, such as computer science, engineering, and biology. They may require collaboration across different fields and industries to develop their potential fully.

Emerging technologies are worth investigating. They are responsible for developing new products or devices. The military often looks to emerging technologies for new services or tools that will help them create a competitive business advantage.

EMERGING TECHNOLOGIES IN OIL & GAS

As the energy demand continues to grow, the oil and gas companies have embraced various technological advancements to extract, refine, and distribute oil and natural gas resources more effectively. These technological advancements have revolutionized the O&G industry. Emerging technologies used in the oil and gas industry include the following [4,5]:

➢ *Artificial Intelligence (*AI): This is changing the game across various industry facets. AI provides powerful benefits across the value chain in energy production. Oil and gas companies use the technology to assess the value of reservoirs and customize drilling plans according to an area's geology. AI is also used during location search for oil drilling to analyze seismic data and provide risk insights. By applying AI, firms can now evaluate oil reservoirs with higher precision, monitor machinery conditions in real time, and even devise drilling plans tailored to specific geological conditions. This leads to enhanced operational efficiency, reduced chances of human error, and significant cost reductions. The oil and gas industry is also embracing the power of artificial intelligence and data science to tackle intricate challenges across all stages of their operations. Artificial Intelligence's primary goal in the oil and gas upstream, midstream, and downstream operations is to reduce risks, improve efficiency, and extract more value from resources by using advanced technology.

➢ *Machine Learning*: This tool gives oil and gas companies powerful insights from the data generated during oil and gas operations. They can use the data to improve operational efficiency and decision-making. Machine learning models look at sensors to help you find opportunities for improvement.

➢ *Robotic Automation*: Engineers have found ways to automate tasks and overcome sub-surface challenges using the latest technology. Emerging technologies in robotics and automation have the potential to improve operations in the oil and gas industry by reducing costs, and increasing safety, efficiency, and speed of the processes. One of the highly adopted automation technologies is robotic process automation (RPA). The technology automates repetitive and rule-based tasks such as document processing, data entry, and reporting. When an oil and gas well is being closed, RPA significantly reduces closing time and minimizes human errors. Robotic systems can perform tasks such as pipeline inspection, maintenance, and repairs, minimizing the need for human intervention in potentially dangerous situations. Most of the robots designed for the oil, gas, and petrochemical industry can withstand extreme weathers, temperatures and other harsh conditions usually present in the oil and gas industry.

➢ *Big Data and Analytics*: This is another tool in the tech arsenal that is making waves. It is all about using the vast amounts of data generated daily to make smarter decisions. The oil and gas industries generate large volumes of data every day. Using analytics, data scientists can find trends and patterns in the data. The oil and gas industry has been collecting data for decades, so it is no surprise that companies in the sector are adept at using big data and data analytics. By analyzing data from diverse sources, companies can identify the best locations for drilling, anticipate when

machinery might need maintenance and much more. With the use of advanced analytics, companies turn this raw data into actionable insights in real-time so executives and managers can decide how best to operate their business. The oil and gas industry is now using big data and analytics to achieve higher efficiency levels. It will use the two to customize predictive models and optimize drilling processes. Predictive analytics like variable analysis and condition-based monitoring allows oil and gas companies to design scenario-based simulations and predict future maintenance requirements. That way, they can perform required maintenance before equipment gets damaged.

➤ *Internet of Things* (IoT): This is essentially a network of smart devices that talk to each other. IoT has created a new era of connectivity; devices and machines now communicate easily to create a more efficient and productive environment. In the oil and gas industry, IoT enables the real-time monitoring and data collection of various operations. This connectivity leads to more efficient operations management, better communication in the field, and minimized equipment downtime. More oil and gas companies will use IoT devices to monitor pumps, pipes, and filters to avoid costly leaks. Industrial IoT technology can also help oil and gas companies reduce their overall costs. In modern oil and gas operations, small smart sensors play a big role in maintaining smooth and safe production. These devices can gather data on temperature, pressure, gas levels, and more.

➤ *Drones:* These are proving to be invaluable in the industry, especially for monitoring oil wells, storage sites, and other facilities. They provide a bird's-eye view that not only speeds up inspections but also enhances the accuracy of assessments. Their simple flight interfaces, flexibility, and ease of adding sensors and accessibility make them a must have for the oil and gas industry. Drones can safely reach places that are difficult or dangerous for humans, gathering important data without risking lives. Intelligent and flexible tools such as robots and drones reduce the human intervention while improving safety and operational efficiency in the oil rigs, production facilities, and pipelines. Figure 2 shows the use of drone in oil and gas [6].

➤ *Cloud Computing*: This puts data control in the hands of oil and gas companies. They have better analytic insights, more efficient production, and safer drilling. The technology enables companies to scale at speed and accelerate innovation, streamline operations, and become agile. Many oil and gas companies are turning to cloud solutions for data storage, analysis, and management due to their many benefits. The decentralized nature of the cloud makes it much easier for those in the gas and oil industry to perform complex analyses and make decisions. Cloud solutions can assist oil and gas companies in enhancing their sustainability efforts. Large portion of emissions can be avoided by switching from the traditional mode of locally deployed data centers and servers to cloud infrastructure. Cloud computing helps overcome many technical challenges in the oil and gas industry. Cloud-native tools create a functional IT environment online, and we no longer have to invest in hardware or space.

➤ *Blockchain:* This secures and simplifies complex oil and gas supply chain processes and introduces transparency. Processes such as oil and gas trading, inventory control, shipment tracking, and billing and payments become easier to manage. By logging every deal from parts orders to routes on decentralized, encrypted blocks, blockchain creates a single source of truth. Timestamped records also verify regulatory compliance permanently. This makes it easier for everyone to be on the same page. Blockchain technology increases transparency, accountability, and prevents supply chain disruptions through decentralized payments, cross-chain, and innovative contracts within the oil and gas industry. Figure 3 shows the use of blockchain in oil and gas industry [1].

➤ *Augmented Reality:* AR's popularity in the O&G sector is growing because it can cut down on waste and expenses while improving employee safety. On-site technicians can use AR to instantly connect with off-site specialists, significantly reducing travel costs for flying expert to remote facilities. With this use of AR technology, experts can guide technicians through tasks with audio and video - decreasing the possibility of costly or dangerous errors on-site. AR can also be used to overlay relevant data on the field. Virtual platforms can help employees get up to speed and test their knowledge about what to do in times of crisis.

➤ *Virtual Reality* (VR): This differs from AR in that it brings users into an entirely digital world, instead of just overlaying images on top of our own reality. Virtual reality enhances training, simulation, visualization, inspections, and remote

assistance. Like AR, VR's popularity in enterprise organizations is steadily increasing. Oil and gas companies can cut costs by up to 25 percent per barrel if they use digital solutions like augmented reality and virtual reality. Immersive technology solutions, such as augmented reality (AR), virtual reality (VR), and mixed reality (MR) combine real and virtual environments to increase efficiency and reduce errors. Like digital twins, mixed reality tools merge digital and physical worlds in real-time. They are becoming increasingly useful for companies that manage complex machines and field-based services. Figure 4 shows AR, VR, and MR [1].

➢ *3D Printing:* Additive manufacturing (or 3D printing) facilitates the production of parts on-site to reduce traditional supply chain costs and time massively. This is revolutionizing parts prototyping in the O&G industry and providing cost savings while developing more efficient ways to develop and maintain equipment. For example, Shell used a 3D printed scale model to validate structure design and avoid potential construction issues and cost overruns.

➢ *Cybersecurity:* Cybersecurity solutions are indispensable for enhancing the safety of upstream, midstream, and downstream oil and gas operations because cybersecurity attacks can result in the loss of confidential information or disruption. It centers around a three-level approach of assessing, protecting, and responding in the event of a cyber threat to improve an O&G company's cyber readiness.

BENEFITS

By employing a variety of cutting-edge technologies, businesses can benefit from data-led insights, respond in real-time to new challenges, and boost efficiency and productivity. With the right systems and technologies in place, oil and gas industry can tap into their data to gain efficiency, boost resilience, and gain the competitive advantages they need to thrive. Other benefits of emerging technology in O&G sector include the following [1]:

➢ *Environmental Concern:* Environmental considerations play an increasingly important role in oil and gas production. Increasing supplies of reliable energy and decreasing emissions is not an either-or proposition. We want to do both, strengthen energy security and help advance the energy transition. For example, advanced sensors do not just boost efficiency, they can also have a significant environmental impact. They provide the visibility required for cutting emissions and can reveal where reductions are possible. As

environmental concerns grow, regulatory bodies are tightening their grip on O&G operations, particularly regarding emissions and waste management. Figure 5 shows pollution in oil and gas industry [7].

➢ *Automation:* One of the most significant advancements in the oil and gas industry is the automation of various processes. Tasks that previously exposed workers to hazardous manual labor can now be automated to limit risk. Through process automation, oil and gas companies can enhance operational efficiency and achieve competitive advantage. Automated drilling systems have revolutionized drilling operations. Automation and robotics are playing pivotal roles in reducing human error, improving safety, and enhancing operational efficiency, particularly in hazardous environments. Automation in the oil and gas industry creates safer work environments by removing manual work processes and accelerating operations. For example, automating drilling processes such as pressure drilling and pipe handling reduces costs and improves safety.

➢ *Renewable Energy Integration:* To remain competitive, O&G companies must innovate in alternative energy production while continuing to optimize traditional methods. The oil and gas industry is undergoing a significant transformation with the integration of renewable energy sources. The industry is investing in renewable technologies such as solar power, wind energy, and geothermal energy to reduce carbon emissions and improve sustainability. Renewable energy technologies are sufficiently being used to generate electricity for offshore platforms, replacing the need for diesel generators.

➢ *Price Volatility:* Oil and gas companies face considerable price fluctuations driven by many forces. Digital tools can help firms better predict and respond to this volatility. The key is using data with artificial intelligence to model potential pricing scenarios. This allows companies to forecast supply and demand to make strategic moves.

➢ *Change Management:* The oil and gas industry constantly shifts as markets, politics, and technology evolve. Digital tools can help companies be ready to adapt quickly. Predictive analytics track early signals in the wider landscape, like new policies or industry conversations. This heads-up lets leaders avoid big changes by implementing new training programs or adjusting strategies.

➢ *Predictive Maintenance:* Replacing equipment too early or too late can wreak havoc on your business and budget. With modern technology, clear dashboards can help you recognize deteriorating conditions days or weeks early, allowing targeted repairs before failures. Predictive algorithms with big data also optimize budgets by precisely allocating spending. This predictive maintenance can protect your bottom line from the costs of penalties and incidents. Sustaining consistent output and minimizing downtime also provides more reliability in a traditionally unstable industry.

➢ *Efficiency:* By leveraging real-time analytics and AI-powered tools, companies can streamline production processes and make informed decisions that enhance operational efficiency. Integrating tech tools to reduce emissions helps a business grow and prosper and be more efficient and competitive in the highly volatile O&G industry.

➢ *Sustainability:* This is no longer a choice but a necessity. Both consumers and investors are demanding that companies reduce their environmental footprint and adopt greener practices. Sustainability is within reach for the oil and gas industry. And it is clearer than ever that modernizing business models and workflows with disruptive tech is an important step.

➢ *Expanded Productivity:* Digitization enables easy access to critical industry information right from exploration and production to environmental monitoring and safety. This information helps enhance productivity, reduce risks, and improve all aspects of oil and gas operations.

➢ *Increased Safety*: Tools like automation and robotics are now an integral part of the drilling process. Connecting and disconnecting drill pipes are perilous operations for humans. Technologies such as iron roughneck robotics and snake-arm robots have completely automated this process, removing all forms of human life risks.

➢ *Improved Performance*: Gas and oil producers are now harnessing industry tech tools that integrate AI technologies to improve performance, predict trends, and reduce costs. They also use the tools for resource exploration to map and identify petroleum deposits and detect equipment failure and gas leaks.

CHALLENGES

The oil and gas industry is currently facing many challenges, such as geopolitical implications, unstable crude oil and gas prices, the need to address global climate change, the need to find new sources of oil and gas, and the need to lower emissions. Digital transformation is challenging, costly, resource-intensive, and has lengthy implementation and migration cycles. Other challenges of emerging technology in oil and gas sector include the following [1]:

➢ *Fears:* Policymakers worry that a significant reduction of US petroleum imports will have geopolitical implications beyond increased US energy security and could alter diplomatic relationships with oil-producing countries. However, these fears are unfounded due to a popular mis-characterization of the role of oil in shaping diplomatic relationships.

➢ *Old Machinery:* Much of the industry was built on machinery designed for the previous century. While they were reliable, these aging systems lack the connectivity and visibility needed to detect and adapt to today's increasingly dynamic conditions. Outdated monitoring puts safety at risk if threats go unnoticed.

➢ *Cost:* Investing in new digital technologies can modernize operations, but upgrades often come with big price tags. Leaders must strike the right balance between funding cutting-edge innovations and fixing aging infrastructure. Some companies postpone digital investments, but cutting costs today by delaying technology improvements will eventually backfire.

➢ *Training:* Employees who are used to old ways of working may need help adopting new software and digital processes. Training programs should fit specific teams like offshore crews, engineers, project managers, and field technicians. You can customize your training to meet the needs of your specific workforce and customers.

➢ *Regulation:* As oil and gas operations go digital, companies need strategies to follow regulations and protect against hacking. With sites worldwide, companies must follow different rules, depending on their location and the work being done. For example, offshore drilling has many environmental regulations companies must follow. Oil and gas companies are increasingly embracing ESG (environmental, social, and governance) strategies as a way to comply with regulations and appeal to a growing base of environmentally conscious investors.

➢ *Data Management:* Collecting and managing more data can provide insights to improve efficiency and guide better decisions across

operations. However, making the most of this data presents a set of challenges.

➢ *Complexity:* With today's complex energy assets, no single engineer can design an entire system alone. While technological advancements play a crucial role, other factors such as sustainability initiatives, regulatory pressures, and market demands are also significantly influencing the sector. As companies navigate these complexities, they are finding innovative ways to adapt and thrive in an ever-evolving landscape.

CONCLUSION

The oil and gas business continues to witness remarkable technological advancements that enhance efficiency, productivity, and sustainability. There is a need for O&G companies to invest in emerging technologies to reduce risks, increase productivity, and reduce costs. Some of these include artificial intelligence, robotics, machine learning, IoT, drones, big data, data analytics, augmented reality, virtual reality, and blockchain. The new technologies in the oil and natural gas sector have enabled the explosion of production growth in the United States. They reinvent how the oil and gas sector operates. As emerging technologies continue to evolve, the oil and gas industry will undoubtedly embrace technologies to address future challenges and contribute to global energy security. The oil and gas industry is still miles behind digital transformation. The gradual adoption of these emerging technologies may lead to new challenges, but over time their adoption will lead to a safer workplace. More information on emerging O&G technologies is available from the books in [8-12].

REFERENCES

[1] A. Dennis, "Digital transformation of the oil & gas industry (2024)," July 2024, https://whatfix.com/blog/oil-gas-digital-transformation/

[2] M. Halaweh, "Emerging technology: What is it?" *Journal of Technology Management & Innovation*, vol. 8, no. 3, 2013, pp. 108-115.

[3] N. Duggal, "Top 18 new technology trends for 2023," July 2023, https://www.simplilearn.com/top-technology-trends-and-jobs-article

[4] "Innovating energy: Emerging technologies in oil and gas production," March 2024, https://www.dwenergygroup.com/innovating-energy-emerging-technologies-in-oil-and-gas-production/

[5] "Top 8 oil and gas industry trends for 2024," September 2024, https://kissflow.com/solutions/energy/oil-and-gas-technology-trends/

[6] D. Evans, "4 Emerging technologies disrupting the oil & gas industry in 2019," https://irisblog.thewild.com/4-emerging-technologies-disrupting-oil-gas-industry-2019#:~:text=Drones%2C%20augmented%20reality%20(AR),technologies%20influencing%20the%20industry%20today.

[7] "Top 10 trends shaping the oil and gas industry," Unknown Source

[8] J. S. Gomes (ed.), *New Technologies in the Oil and Gas Industry*. IntechOpen, 2012.

[9] Institute for Improved Oil Recovery, Society of Petroleum Engineers (U.S.), *Emerging Technologies for Improved Oil and Gas Recovery: A Technical/economic Assessment: Proceeding*. Institute for Improved Oil Recovery, 1990.

[10] H. Al-Megren and R. Altamimi (eds.), *Advances in Natural Gas Emerging Technologies*. IntechOpen, 2017.

[11] N. K. Mitra, *AI and Digital Technology for Oil and Gas Fields*. Boca Raton, FL: CRC Press, 2024.

[12] D. Dwivedi, A. Ranjan, and J. S. Sangwai (eds.), *Functional Materials for the Oil and Gas Industry (Emerging Trends and Technologies in Petroleum Engineering)*. Boca Raton, FL: CRC Press, 2023.

Figure 1 Representation of the oil and gas [1].
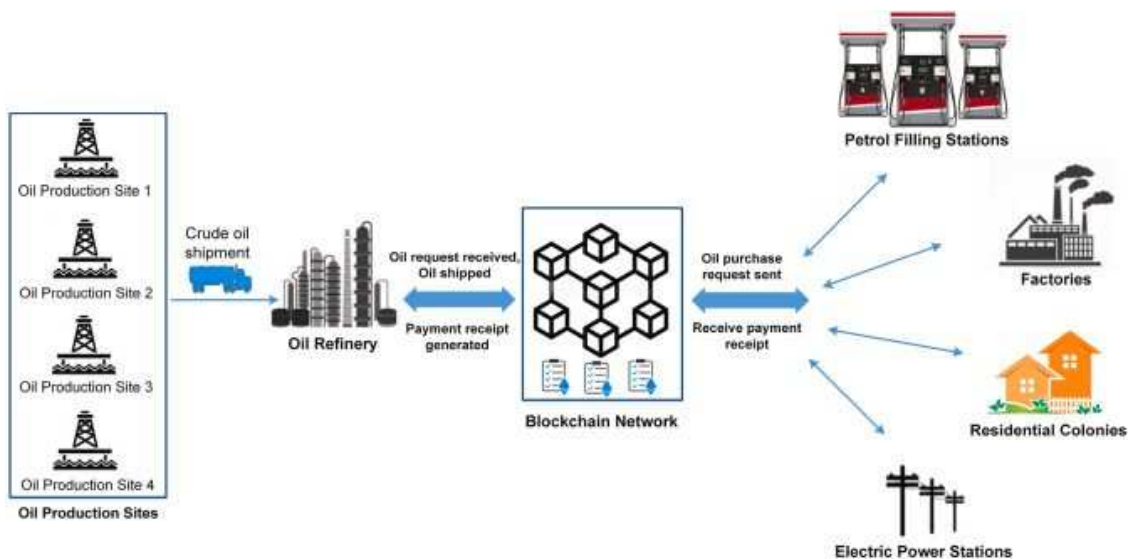

Figure 2 Use of drone in oil and gas [6].

Figure 3 Use of blockchain in oil and gas industry [1].

Figure 4 Augmented, virtual, and mixed realities [1].

Figure 5 Pollution in oil and gas industry [7].