Cloud Computing in the Oil and Gas Industry

[1]Matthew N. O. Sadiku, [2]Philip O. Adebo and [3]Janet O. Sadiku,
[1,2]Roy G. Perry College of Engineering, Prairie View A&M University, Prairie View, TX, USA
[3]Juliana King University, Houston, TX, USA

Abstract: Cloud computing has become a key technology in the oil and gas industry, enabling companies to streamline processes, reduce costs, and drive innovation. It not only simplifies data analytics but also sets the stage for enhanced operational efficiency, thereby directly influencing the bottom line. With cloud computing, companies can essentially "rent" supercomputers as needed, without the upfront spend and maintenance associated with computers of that magnitude. For oil and gas professionals, cloud solutions allow more accurate modeling, data-backed drilling strategies, and optimized production. This paper delves into the integration of cloud computing within the oil and gas sector and how it has revolutionized the sector.

Keywords: Cloud Computing, Oil And Gas Industry, Petroleum Industry

I. INTRODUCTION

Digital transformation of oil and gas (O&G) companies is the integration of emerging technologies like artificial intelligence, machine learning, cloud services, automation, IoT, and data analytics across business functions. The goals of digitalization include improving efficiency, driving employee productivity, promoting sustainability, mitigating risks, and providing better customer and partner experiences. Figure 1 shows digitalization of the O&G industry [1].
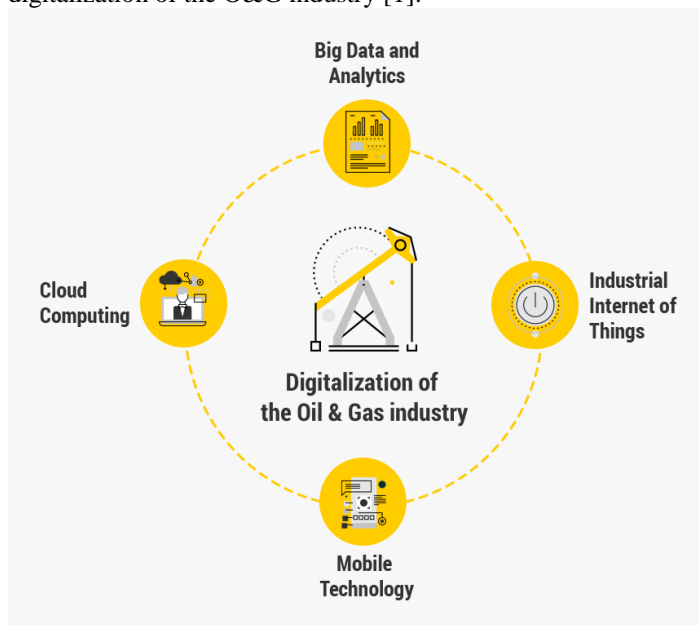

Figure 1: Digitalization of the O&G industry [1].

Cloud computing is a means of pooling and sharing hardware and software resources on a massive scale. Users and businesses can access applications from anywhere in the world at any time. Companies offering these computing services are called cloud providers and typically charge for cloud computing services based on usage [2]. Some features of cloud computing are displayed in Figure 2 [3]. The goal of cloud engineering is to create a highly scalable, flexible, and secure computing environment that can support the needs of modern businesses.
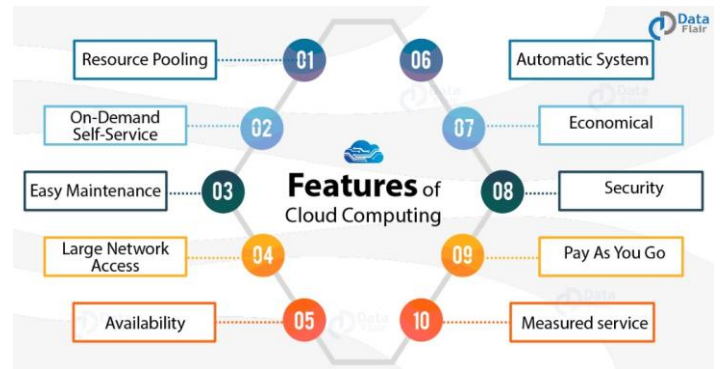

Figure 2: Some features of cloud computing [3].

Oil and gas (O&G) companies are businesses that explore, produce, refine, distribute, and sell oil and natural gas products. They have been around for over a century, but they have evolved dramatically in recent years. They operate in the energy sector and play a crucial role in meeting the world's energy demands. It is estimated that there are around 5,500 oil and gas companies globally. One of the major changes has been the integration of cloud computing technology into the O&G companies. These companies vary in size, from small local enterprises to large multinational corporations. Industry giants like Saudi Aramco, ExxonMobil, Shell, BP, and Chevron are at the forefront of adopting cloud technologies to streamline operations. The share of voice of top 10 O&G companies in 2022 is depicted in Figure 3 [4].
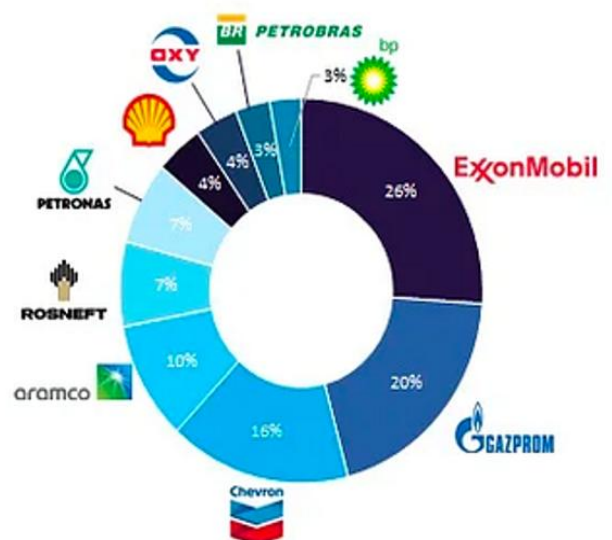

Figure 3: The share of voice of top 10 O&G companies in 2022 [4].

II. CLOUD COMPUTING BASICS

Cloud computing represents a newly emerging service-oriented computing technology. It is the provision of scalable computing resources as a service over the Internet. It allows manufacturers to use many forms of new production systems

such as 3D printing, high-performance computing (HPC), industrial Internet of things (IIoT), and industrial robots. It is transforming virtually every facet of modern manufacturing. It is innovating, reducing cost, and bolstering the competitiveness of American manufacturing [5].

The key characteristic of cloud computing is the virtualization of computing resources and services. Cloud computing is implemented in one of three major formats: software as a service (SAAS), platform as a service (PAAS), or infrastructure as a service (IAAS). These services are illustrated in Figure 4 [6] and explained as follows:
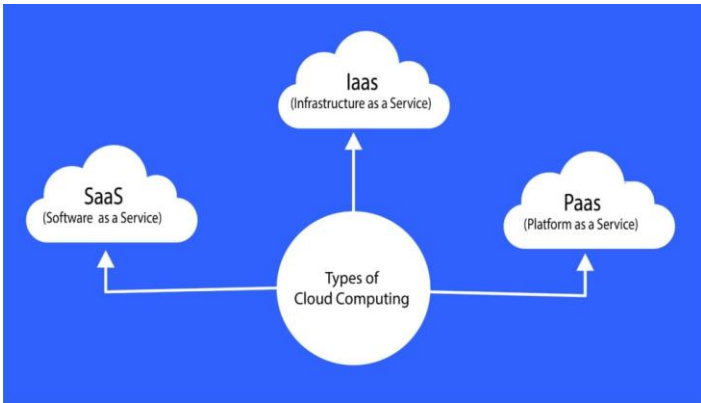

Figure 4: Three types of cloud computing [6].

SaaS: This is a software delivery model in which software and associated data are hosted on the cloud. In this model, cloud service providers offer on-demand access to computing resources such as virtual machines and cloud storage. Nowadays oil & gas companies transition to cloud computing and implement SaaS solutions for operations.

PaaS allows the end-user to create a software solution using tools or libraries from the platform service provider. In this model, cloud service providers deliver computing platforms such as programming and execution.

In the IaaS model, cloud service providers can rent manufacturing equipment such as 3D printers.

Just like cloud computing, CM services can be categorized into three major deployment models (public, private, and hybrid clouds) [7]:

- Private cloud refers to a centralized management effort in which manufacturing services are shared within one company or its subsidiaries. A private cloud is often used exclusively by one organization, possibly with multiple business units.

- Public cloud realizes the key concept of sharing services with the general public. Public clouds are commonly implemented through data centers operated by providers such as Amazon, Google, IBM, and Microsoft.

- Hybrid cloud that spans multiple configurations. and is composed of two or more clouds (private, community or public), offering the benefits of multiple deployment modes.

These models are shown in Figure 5 [8]. Cloud computing finds application in almost every field.
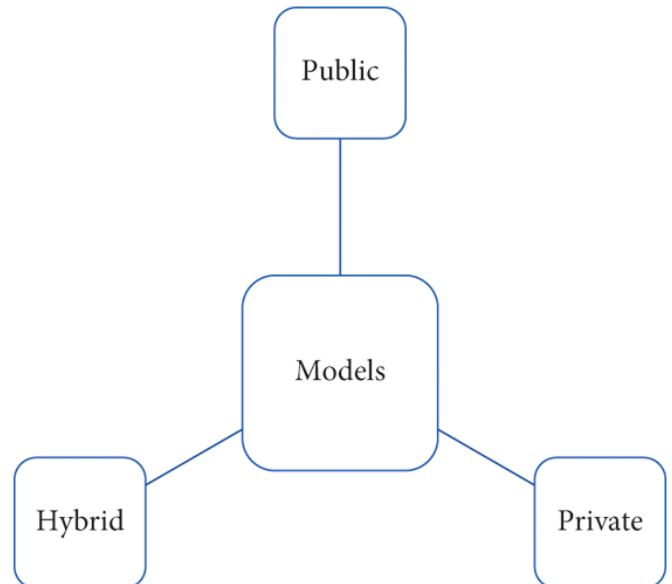

Figure 5: Cloud computing models [8].

III. CLOUD COMPUTING IN OIL AND GAS

The oil and gas sector encompasses a wide spectrum of activities ranging from exploration, extraction, refining to the distribution of petroleum products. From upstream to downstream, oil and gas companies are turning to the cloud to reduce operating cost and streamline processes. If there is one commonality throughout the value chain of the O&G industry, it is the existence of unstructured operations, disparate eco-systems, disconnected processes, and disjointed efforts, and massive wastage of resources. The oil industry is habitually alienated into three foremost components (upstream, midstream, and downstream), illustrated in Figure 6 [4] and explained as follows:
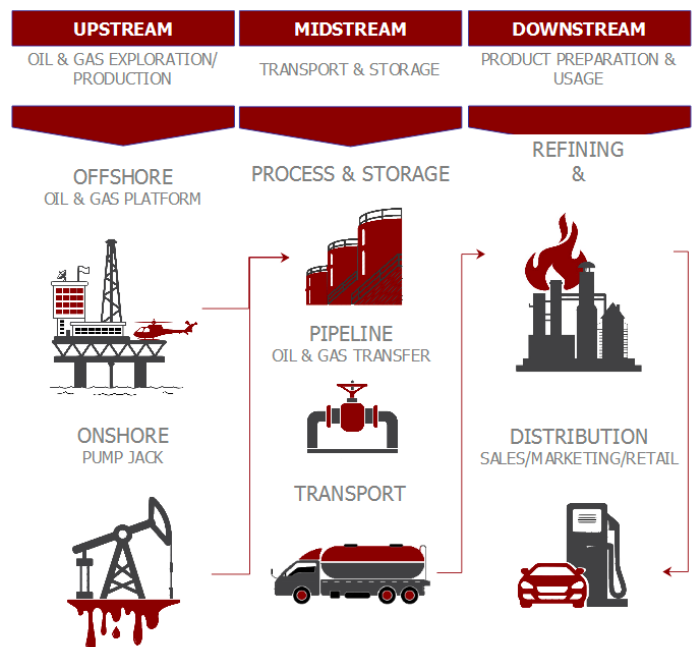

Figure 6: The oil industry has three components [4].

- *Upstream Sector:* The capital-intensive operations found in the upstream sector do not lend well to the trial-and-error approach typically used with new digital technologies. Upstream operators have collaborated with oilfield service companies for years to design products and processes to achieve drilling

gains and obtain operational efficiencies. Machine-learning and automation have applications across the upstream industry that can lead to percentage gains in production. In spite of compelling cases for cloud computing, the upstream petroleum industry faces technical challenges, notably reliance on massive datasets, ongoing legacy investments in IT, data security, and most of all, expertise.

- *Midstream Sector:* Midstream amenities follow gathering lines and transmission lines incorporating pumping station, control valve station, dehydration, fractionation, stockpiling and other requirements based on the necessity of transportation on that location to carry oil to the consumers. The nature of pipeline transportation fills in as a national system to move the oil-based vitality assets from production regions or distribution ports to consumers, airplane terminals, military bases, and industry consistently. A pumping station is shown in Figure 7 [9].

- *Downstream Sector:* Big data and cloud computing could affect the industry downstream, where hydrocarbon planning and marketing depend on supply, demand and consumer behavior. SaaS applications are useful throughout the oilwell lifecycle and also in downstream business applications.
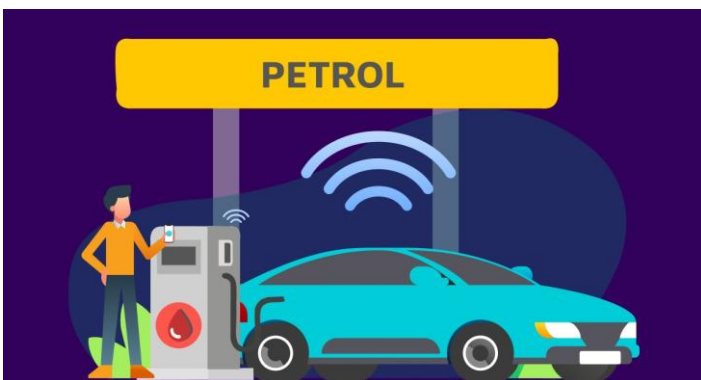
IV. APPLICATION OF CLOUD COMPUTING IN OIL AND GAS

Figure 7: A pumping station [9].

The O&G industry plays a major role in the energy market and continues to influence the global economy as it produces the world's primary fuel. Cloud is one of the key technologies in this industry and remains the backbone for digital transformation. Technology enables O&G companies to move rapidly, show more agility and drive innovation. Cloud computing has impacted the oil and gas industry in several ways, including the following [10]:

- *Efficient Data Analysis* The oil and gas industry produces large volumes of data through its day-to-day exploration and production activities. The industry is gathering, storing, and analyzing their data on the cloud. Efficient analysis and timely insights on data can improve production by over 10%. The oil and gas industry is using cloud computing supercomputers to analyze all of the data being collected through devices and sensors. Supercomputers are faster and more powerful than standard computers and can analyze the massive amount of data coming in from oil and gas operations at record speeds. Cloud computing in the oil and gas industry allows companies to process this information quickly without spending the money

upfront to purchase and manage these devices. More data analysis means more efficiency and less waste because it dampens the need for guesswork and roots out what does not work. The importance of real-time processing of data is shown in Figure 8 [11].

- *Data Storage:* Storage hardware must evolve at a rapid pace to keep up with the incredible accumulation of data in today's world. Private servers used to be the answer for data storage, but private servers are extremely expensive to host and maintain. By contrast, cloud storage is scalable on the fly. Cloud computing allows oil and gas companies to scale their data management and storage, driving greater flexibility in infrastructure costs. The amount of data determines how much you spend on data storage. If the need for more storage arises, the cloud expands accordingly. A cloud company knows how to store, maintain, and expand their own storage locations better than a gas company. Outsourcing data storage to the cloud saves oil and gas companies the IT overhead cost they do not want to eat.

- *Automation:* Combining robotics with the cloud allows companies to establish the concept of "Robots-as-a-Service," or RaaS. Companies like BP, ExxonMobil, TotalEnergies, and even Ouro Negro deploy robotics regularly throughout their operations. From inspection to maintenance, detection, construction, cleaning, and heavy labor, robots are found on every level of energy production. Industrial robots are efficient; they can repeat a task thousands of times without changing or needing breaks, and they can operate in locations that may be unsafe for humans. Cloud programming and mechanized robotic technology allow companies to scale production to meet peak demands. Cloud robotics uses a rental business model but still allows firms to access the cloud to program, manipulate, and maintain robots—all remotely.

- *Remote Monitoring:* Cloud computing can enable remote monitoring and control of oil and gas assets, including wells, pipelines, and refineries. This can help improve oil and gas efficiency by reducing the need for manual intervention and enabling companies to monitor and optimize operations in real time. Remote monitoring and automated operations can significantly reduce safety risks associated with traditional oil and gas operations. By leveraging remote monitoring solutions, you can enhance safety protocols, minimize human intervention, and mitigate operational risks.

- *Collaboration:* Digital transformation relies on the collaboration between people, processes, and technology. Oil and gas companies often work with geographically dispersed teams and must collaborate effectively. Companies must establish strong communication and collaboration between all team members in the cloud. Cloud-based collaboration tools can help improve communication and collaboration across the sector. Cloud computing allows for effective collaboration between stakeholders across departments through collaborative platforms for communication, reviews, and approvals. This simplifies workflow, documentation, process management, compliance, and decision-making, resulting in transparency, speed, and business growth. With today's complex energy assets, no single

engineer can design an entire system alone. Collaboration with others is required.

- *Cost Reduction*: The pay-as-you-go model of cloud services eliminates the need for large upfront investments in on-premises hardware, leading to significant cost reductions. Cloud computing can reduce IT costs by up to 50%. In the oil and gas industry, cloud computing can help companies save costs by reducing the need for on-premises infrastructure, hardware, and software maintenance, as well as providing access to pay-as-you-go models that allow companies to pay only for the resources they use. Exploratory services rely heavily on data analysis and calculations. Storing and managing this data on-premises requires significant capital investment in hardware procurement, maintenance, upgrades, and IT personnel. Cloud technology significantly reduces these costs by allowing companies to pay only for the data storage space they use.

V. BENEFITS

The benefits derived from cloud computing are multifaceted. From boosting safety through robotics to facilitating precise drilling operations with real-time data analytics, the horizon of possibilities is expansive. Cloud computing has become a key technology in the oil and gas industry, enabling companies to reduce costs, improve efficiency, and drive innovation. Other benefits of cloud computing in O&G industry include the following [4]:

- *Security:* The journey towards cloud adoption is not devoid of skepticism, often rooted in concerns around data security and vendor lock-ins. Separate teams sharing responsibility for different parts of the cloud can create security risks if the information is not transferred between them correctly. In the oil and gas industry, data connectivity and security are crucial for safer and more successful drilling. Data connectivity and security make dangerous operations safer. The oil and gas industry is highly regulated and has numerous safety and security risks. Cloud computing can help improve safety and security by providing secure and compliant cloud infrastructure, disaster recovery solutions, and advanced security measures such as encryption and access controls.

- *Improved Efficiency*: The bottom line is that enhancing operational efficiency in the oil and gas industry by implementing automation technology and process optimization with the cloud will reduce risks but also help improve safety and lower overall costs. Cloud computing can help companies optimize operations from exploration to production. It can also help reduce downtime and improve asset utilization. Cloud computing in the oil and gas industry allows companies to create a more efficient and scalable structure. By monitoring and managing assets remotely through cloud-based systems, companies can identify potential problems early, minimize downtime, and improve overall operational efficiency.

- *Innovation:* Cloud computing can help companies accelerate their ability to innovate by enabling them to adopt the latest technologies, such as big data, IoT, AI, and machine learning.

- *Safety:* Cloud computing and robotics offer the oil and gas industry a chance to boost safety and efficiency by performing dangerous tasks remotely.

- *Real-time Insights:* Cloud computing is revolutionizing the oil and gas industry by turning vast data into actionable insights. It can help companies make smarter decisions in real-time.

- *Predictive Maintenance:* Cloud computing can help companies enable predictive maintenance and automate "smart" pipeline monitoring.

- *Predictive Analytics:* This enables oil and gas analysts to blend multiple data types and determine causes of failures. It can help operators recognize that a piece of equipment has a problem. Analysts are also able to scrutinize performance data to compare actual-versus-estimated costs.

- *Connected Operations*: Inefficiencies often arise as a result of complex processes and siloed operations. In the O&G industry, capital projects are executed by various stakeholders and functions, including suppliers, vendors, contractors, sub-contractors, and internal functions such as finance, procurement, and engineering.

- *Better Reliability:* Unplanned outages and downtime result in significant losses for O&G companies. Downtime can be caused by equipment failure, security breaches, or unidentified problems. Cloud computing can improve infrastructure reliability for O&G companies by offering predictive maintenance through data insights.

- *Lower Carbon Footprint:* Scientists and the UN have both stated that global emissions will need to drop by 7.8% per year in the next 10 years to prevent further temperature increases across the globe. Oil and gas companies are constantly under pressure to reduce their carbon dioxide and other greenhouse gas emissions. Virtualization can significantly increase server efficiency, resulting in less energy and electricity consumption. Additionally, cloud computing allows for servers to be utilized more efficiently and with less energy consumption.

- *Scalability:* The most significant benefit of the cloud computing eco-system is its ability to provide flexibility and scalability to adapt to the storage needs of the O&G company with agility and speed. With cloud computing, companies can scale their infrastructure up or down as needed, reducing costs and improving efficiency. Cloud infrastructure can be easily scaled up or down based on operational needs, providing flexibility to handle fluctuating data volumes during exploration, drilling, and production phases.

- *Monitoring*: Real-time monitoring also allows process design engineers and the operational teams to study usage patterns and predict potential failures.

VI. CHALLENGES

The road to digital transformation is laden with challenges. The environmental impact of operations, marked by greenhouse gas emissions and pollution, along with the social implications, is a pressing concern. Oil and gas companies are facing several long-term challenges, including climate change and the scarcity of easily recoverable hydrocarbons. Amidst the challenges, cloud computing emerges as a beacon of solutions, which not only augment operational efficiency but also drive a substantial reduction in environmental footprint. Other

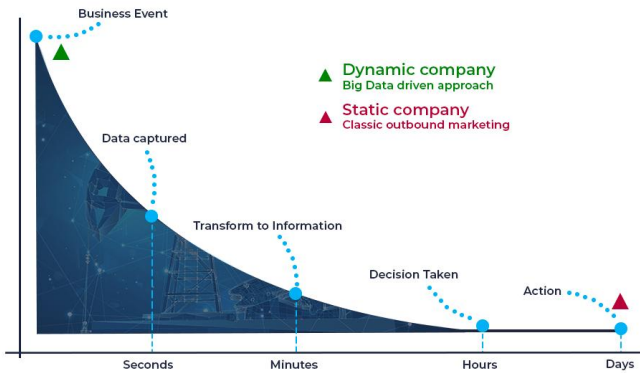challenges of cloud computing in O&G industry include the following [4]:

Figure 8: The importance of real-time processing [11].

Figure 9: A typical air pollution due to oil and gas [4].

- *Air Pollution:* The extraction and processing of oil and gas release harmful pollutants like sulfur dioxide and nitrogen oxides into the air, which can have negative impacts on human health and the environment. Figure 9 shows a typical air pollution due to oil and gas [4]. Cloud computing's potential to significantly reduce greenhouse gas emissions underscores its role as a cornerstone for a sustainable oil and gas industry. Cloud computing and advances in AI enable oil and gas companies to locate and prevent natural gas flare-ups and leaks which produce enormous amounts of carbon emissions.
- *Climate Change*: The burning of fossil fuels like oil and gas releases carbon dioxide into the atmosphere, which is a major contributor to climate change.
- *Water Pollution:* Oil spills and leaks from pipelines and offshore drilling rigs can contaminate water sources, which can harm aquatic life and negatively impact the ecosystem.
- *Habitat Destruction:* The exploration and development of oil and gas reserves can lead to the destruction of natural habitats and the displacement of wildlife.
- *Land Use:* Oil and gas drilling requires significant land use, which can lead to deforestation, soil erosion, and disruption of natural ecosystems.
- *Social Impacts:* The oil and gas industry can have negative social impacts on local communities, including displacement, land rights violations, and environmental injustice.

- *Increased Costs:* Multiple teams working on different parts of the cloud for oil and gas can increase costs. With so many people involved in various aspects of the cloud, it can be challenging to streamline processes and ensure everyone is working efficiently.
- *Integration Complexity:* O&G companies must confront the aging legacy systems still powering too many assets. Cloud-based platforms integrate IoT sensors, hardware, and software to enable remote, real-time asset monitoring. Integrating existing legacy systems with cloud-based platforms can be complex and require careful planning. Process industries like oil and gas are quite complex, with several types of equipment to track and manage in a facility.
- *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 can be challenging.
- *Change Management:* The oil and gas industry constantly shifts as markets, politics, and technology evolve. Transitioning to a cloud-based environment may require significant changes in workflows and employee training.
- *Compliance:* 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.

CONCLUSION

Cloud computing is a substantial lever propelling the O&G sector towards a future marked by sustainability, efficiency, and growth. The potential benefits of cloud computing in the O&G industry far outweigh the challenges, making it a crucial tool for driving innovation, cost reduction, and operational excellence in the industry. The industry can no longer afford to delay cloud adoption. In today's fast-paced digital landscape, the oil and gas industry is undergoing a profound transformation to stay competitive globally. This shift is affecting every aspect of the business, from exploration to distribution. It is a strategic move to thrive in the fourth industrial revolution. Today, cloud computing makes sense for small- to medium-sized oil and gas producers looking to develop a broader strategy toward effective digital innovation. It has become a vital component of the oil and gas industry, and its importance is only increasing. More information about cloud computing in the O&G sector can be found in the books in [12-14] and the following related journals:

- *Petroleum*
- *Petroleum Research*
- *Energy Reports*
- *Oil & Gas Journal*

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ABOUT THE AUTHORS

Matthew N.O. Sadiku is a professor emeritus in the Department of Electrical and Computer Engineering at Prairie View A&M University, Prairie View, Texas. He is the author of several books and papers. His areas of research interest include computational electromagnetics, computer networks, and marriage counseling. He is a life fellow of IEEE.

Philip O. Adebo is an instructor at Texas Southern University. He completed his PhD in Electrical and Computer Engineering, Prairie View A&M University with emphasis on power systems. His research interests include power systems, renewable energy, microgrids, smart-grid systems, restructuring power systems, and optimization of power systems.

Janet O. Sadiku holds bachelor's degree in nursing science in 1980 at the University of Ife, now known as Obafemi Awolowo University, Nigeria and master's degree from Juliana King University, Houston, TX in December 2022. She has worked as a nurse, educator, and church minister in Nigeria, United Kingdom, Canada, and United States. She is a co-author of some papers and books.