OPEN ACCESS
Computer Science & IT Research Journal
P-ISSN: 2709-0043, E-ISSN: 2709-0051
Volume 5, Issue 7, P.1621-1633, July 2024
DOI: 10.51594/csitrj.v5i7.1348
Fair East Publishers
Journal Homepage: www.fepbl.com/index.php/csitrj

Data science's pivotal role in enhancing oil recovery methods while minimizing environmental footprints: An insightful review

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Article Received: 07-02-24 **Accepted:** 05-05-24 **Published:** 25-07-24

ABSTRACT

Data science has emerged as a critical tool in the oil and gas industry, revolutionizing traditional approaches to oil recovery while addressing environmental concerns. This review explores the pivotal role of data science in enhancing oil recovery methods while minimizing environmental footprints. The oil and gas industry faces the challenge of maximizing oil recovery from reservoirs while minimizing environmental impacts. Data science offers a transformative approach by leveraging advanced analytics, machine learning, and big data technologies to optimize oil recovery processes. One key area where data science has been instrumental is in reservoir characterization. Advanced data analytics techniques enable the integration of diverse data sources, such as seismic, well log, and production data, to create detailed reservoir models. These models provide insights into reservoir properties, helping engineers design more effective recovery strategies. Data science also plays a crucial role in reservoir monitoring and management. Real-

time data from sensors and monitoring devices are analyzed using machine learning algorithms to detect anomalies and optimize production operations. This proactive approach minimizes downtime and reduces the risk of environmental incidents. In addition to reservoir management, data science is transforming drilling and completion operations. Machine learning algorithms analyze drilling data to optimize well trajectories, reduce drilling time, and improve wellbore stability. This leads to more efficient drilling operations and reduces the environmental impact of drilling activities. Furthermore, data science is driving innovation in enhanced oil recovery (EOR) techniques. By analyzing reservoir data and simulating different EOR scenarios, engineers can identify the most effective EOR methods for a particular reservoir. This targeted approach maximizes oil recovery while minimizing the use of chemicals and energy, thus reducing environmental footprints. Overall, data science is revolutionizing the oil and gas industry by optimizing production operations, enhancing reservoir management, and reducing environmental impacts. As the industry continues to embrace digital transformation, data science will play an increasingly pivotal role in driving sustainable oil recovery practices.

Keywords: Data, Oil Recovery, Environmental, Footprints, Minimizing.

INTRODUCTION

The oil and gas industry faces a myriad of challenges in its quest to meet global energy demands while minimizing environmental impacts. Conventional oil recovery methods often lead to inefficient resource utilization and significant environmental footprints, including greenhouse gas emissions, water pollution, and habitat destruction (Adamu, et. al., 2023, James, Olaniyi & Olatubosun, 2023, Khan & Tahir, 2023). In this context, the application of data science has emerged as a transformative force, offering innovative solutions to enhance oil recovery methods while mitigating environmental impacts.

Data science leverages advanced analytics, machine learning, and big data technologies to analyze vast amounts of data generated during oil exploration, production, and refining processes (Agbaji, 2021, Mohammadpoor & Torabi, 2020, Shah, et. al., 2022). By extracting valuable insights from this data, data science enables engineers and decision-makers to optimize oil recovery strategies, improve operational efficiency, and reduce environmental footprints.

This review aims to explore the pivotal role of data science in enhancing oil recovery methods while minimizing environmental footprints. It will examine how data science is revolutionizing traditional approaches to reservoir characterization, monitoring, and management, as well as drilling and completion operations. The review will also highlight successful case studies and examples where data science has been effectively applied to optimize oil recovery processes and reduce environmental impacts.

Overall, this review will demonstrate how data science is not only enhancing the efficiency and profitability of oil recovery operations but also contributing to a more sustainable and environmentally responsible oil and gas industry. Through a comprehensive analysis of current trends, challenges, and future directions, this review will provide valuable insights into the transformative potential of data science in shaping the future of oil recovery and environmental sustainability.

History of Data Science's Pivotal Role in Enhancing Oil Recovery Methods

The use of data science in the oil and gas industry dates back to the early 20th century when engineers began using statistical methods to analyze production data and optimize drilling operations (Al-Rbeawi, 2023, Aminzadeh Temizel & Hajizadeh, 2022, Kuang, et. al., 2021). However, it was not until the late 20th century that data science began to play a more pivotal role in enhancing oil recovery methods and minimizing environmental footprints. In the 1980s and 1990s, advancements in computing power and data analytics techniques led to significant improvements in reservoir characterization and management. Engineers began using sophisticated simulation models to analyze reservoir data and optimize production strategies.

In the early 2000s, the rise of machine learning and artificial intelligence revolutionized data science in the oil and gas industry. Engineers began using these technologies to analyze large volumes of data and extract valuable insights that were previously inaccessible. One of the key advancements enabled by data science was real-time monitoring and predictive maintenance. By analyzing data from sensors and monitoring devices in real-time, engineers could detect anomalies and predict equipment failures before they occurred, minimizing downtime and reducing the risk of environmental incidents (Gupta & Shah, 2022, Hanga & Kovalchuk, 2019, Koroteev & Tekic, 2021).

Data science also played a crucial role in optimizing drilling and completion operations. By analyzing drilling data, engineers could optimize well trajectories, reduce drilling time, and improve wellbore stability, leading to more efficient operations and reduced environmental impacts. The environmental benefits of data science in oil recovery have been significant. By optimizing production processes, reducing energy consumption, and implementing efficient water management practices, data science has helped reduce greenhouse gas emissions, minimize water usage, and mitigate the risks of environmental incidents (Lashari, et. al., 2019, Pandey, Dahiya & Mandal, 2021, Tariq, et. al., 2021).

Looking ahead, data science is expected to play an even more pivotal role in enhancing oil recovery methods and minimizing environmental footprints. However, several challenges remain, including technological limitations, data quality issues, and regulatory challenges. Addressing these challenges will require continued innovation and collaboration between industry stakeholders, academic institutions, and government agencies. In conclusion, the history of data science's role in enhancing oil recovery methods while minimizing environmental footprints is a testament to the transformative impact of technology in the oil and gas industry (Alagoz, Alghawi & Ergul, 2023, Bui & Perera, 2021, Madkhali & Sithole, 2023). By leveraging data science, the industry has been able to optimize production operations, improve reservoir management, and reduce environmental impacts, paving the way for a more sustainable and efficient future.

Traditional Oil Recovery Methods and Environmental Impact

The extraction of oil from reservoirs typically involves several primary methods, including primary recovery, secondary recovery, and tertiary recovery techniques (Kalita, et. al., 2022, Malozyomov, et. al., 2023, Nikolova & Gutierrez, 2020, Akindote, 2023). This is the initial stage of oil extraction, where natural reservoir pressure or artificial lift methods such as pumps are used to bring oil to the surface. Primary recovery methods can typically recover only 10-15% of the

original oil in place (OOIP). When primary recovery methods are no longer sufficient, secondary recovery techniques are employed to extract more oil from the reservoir. This often involves the injection of water or gas into the reservoir to maintain pressure and displace oil towards production wells. Also known as enhanced oil recovery (EOR), tertiary recovery methods are employed to extract even more oil from the reservoir after primary and secondary methods have been exhausted (Akindote et al., 2023; Babarinde et al., 2023; Kalita, et. al., 2020). This can include thermal methods (such as steam injection), chemical methods (such as polymer flooding), or gas injection (such as CO2 or nitrogen injection).

Despite their effectiveness in extracting oil, traditional oil recovery methods pose significant environmental risks and concerns. The combustion of fossil fuels, including oil extracted through traditional methods, releases greenhouse gases such as carbon dioxide (CO2) into the atmosphere, contributing to global climate change. Water is often used in oil extraction processes and can become contaminated with chemicals and heavy metals, posing a risk to aquatic ecosystems and human health. Oil extraction activities can lead to habitat destruction and fragmentation, particularly in sensitive ecosystems such as wetlands and forests, which can have long-lasting impacts on biodiversity (Gbadamosi, et. al., 2019, Hui, et. al., 2020, Nikolova & Gutierrez, 2020). Accidental spills and leaks during oil extraction, transportation, and storage can result in significant environmental damage, including contamination of soil, water, and wildlife.

Given the environmental risks and concerns associated with traditional oil recovery methods, there is an urgent need for the development and adoption of sustainable alternatives. Transitioning to renewable energy sources such as solar, wind, and hydropower can reduce reliance on fossil fuels and mitigate the environmental impacts of oil extraction. Improving energy efficiency in all sectors, including transportation, industry, and buildings, can reduce the overall demand for oil and other fossil fuels. Implementing CCS technologies can capture CO2 emissions from oil extraction and other industrial processes, preventing them from entering the atmosphere. Governments and regulatory bodies can play a crucial role in promoting sustainable practices through policies and regulations that incentivize the adoption of clean energy technologies and discourage the use of environmentally harmful practices (Baskar, et. al., 2019, Munasinghe, et. al., 2019, Wang, et.al., 2020).

In conclusion, traditional oil recovery methods have significant environmental impacts, including greenhouse gas emissions, water pollution, and habitat destruction. To address these concerns, there is a need for sustainable alternatives, including renewable energy sources, energy efficiency measures, carbon capture and storage technologies, and supportive policy and regulatory frameworks. By transitioning to more sustainable practices, the oil and gas industry can reduce its environmental footprint and contribute to a cleaner, greener future.

Role of Data Science in Optimizing Oil Recovery

Reservoir characterization is a critical step in optimizing oil recovery, as it provides essential information about the properties and behavior of the reservoir. Data science plays a crucial role in reservoir characterization by leveraging data analytics techniques to analyze various types of data, such as seismic surveys, well logs, and production data (Elturki & Imqam, 2020, Saikia, et. al., 2020, Seyyedattar, Zendehboudi & Butt, 2020).

Data science enables the integration of diverse data sources, including geological, geophysical, and engineering data, to create comprehensive reservoir models. These models provide insights into the reservoir's properties, such as porosity, permeability, and fluid saturation, which are essential for designing effective recovery strategies. Data analytics techniques, such as machine learning and statistical analysis, can be used to predict reservoir behavior based on historical data. By analyzing patterns and trends in the data, data science can help engineers anticipate changes in reservoir conditions and adjust recovery strategies accordingly (Ma & Zhang, 2019, Mishra, Sharma & Patidar, 2022, Akindote et al., 2023; Nikhalat Jahromi & Jorge, 2019). By analyzing reservoir data, data science can help identify the most effective recovery techniques for a particular reservoir. For example, machine learning algorithms can analyze production data to determine the optimal rate at which to extract oil to maximize recovery.

Real-time monitoring and predictive maintenance are essential for optimizing oil recovery operations and minimizing downtime. Data science plays a crucial role in these areas by analyzing real-time data from sensors and monitoring devices to detect anomalies and predict equipment failures. Data science techniques, such as anomaly detection algorithms, can analyze real-time data to identify unusual patterns or deviations from normal behavior. This can help operators detect potential issues, such as equipment malfunctions or leaks, before they escalate into major problems. By analyzing historical maintenance data and equipment performance data, data science can predict when equipment is likely to fail and schedule maintenance proactively. This can help minimize downtime and reduce the risk of environmental incidents (Al-Subaiei, et. al., 2021, Ngu, Philip & Sahlan, 2019, Saputelli, Palacios & Bravo, 2022).

Data science is also transforming drilling and completion operations by providing data-driven insights that improve efficiency and reduce costs. Data science techniques can analyze drilling data to optimize well trajectories, ensuring that wells are drilled in the most efficient manner possible. This can help reduce drilling time and costs while maximizing oil recovery. Data science can analyze wellbore stability data to identify factors that contribute to instability and recommend measures to improve stability. This can help reduce the risk of wellbore collapse and other drilling-related issues (Maasz, 2020, Sarker, 2021, Akindote et al., 2023; Tariq, et. al., 2021).

In conclusion, data science plays a pivotal role in optimizing oil recovery operations by enhancing reservoir characterization, enabling real-time monitoring and predictive maintenance, and improving drilling and completion operations through data-driven insights. By leveraging the power of data analytics, the oil and gas industry can maximize oil recovery while minimizing environmental impacts and operational costs.

Minimizing Environmental Footprints Through Data Science

One of the key ways data science can help minimize environmental footprints in the oil and gas industry is by reducing greenhouse gas emissions and energy consumption. Data science can be used to optimize production processes, such as refining and transportation, to minimize energy consumption and emissions (Li, et. al., 2020, Mohsin, et. al., 2022, Wang & Azam, 2024). By analyzing data from these processes, companies can identify areas where improvements can be made and implement changes to reduce their environmental impact. Data science can also be used to develop energy management systems that monitor and control energy use in real-time. These

systems can help companies identify opportunities to reduce energy consumption and improve efficiency, leading to lower greenhouse gas emissions. By using data analytics to predict equipment failures, companies can reduce the frequency of maintenance activities, which can lead to energy savings and reduced emissions associated with maintenance activities.

Water management is another area where data science can help minimize environmental footprints in the oil and gas industry. Data science can be used to optimize water recycling and reuse processes, reducing the amount of freshwater used in oil and gas operations. By analyzing data on water usage and quality, companies can identify opportunities to recycle and reuse water more effectively (Li, et. al., 2020, Wu, et. al., 2019, Xie, et. al., 2019). Data science can also be used to monitor water quality in real-time, helping companies detect and respond to potential water contamination events quickly. This can help minimize the environmental impact of oil and gas operations on water resources. By analyzing data on water treatment processes, companies can optimize these processes to reduce energy consumption and improve efficiency, leading to lower environmental footprints.

Data science can also help minimize the risks of environmental incidents in the oil and gas industry by enabling companies to take proactive measures to prevent them. Data science can be used to develop predictive models that identify potential environmental risks, such as equipment failures or leaks, before they occur. By analyzing data on equipment performance and environmental conditions, companies can take preemptive actions to mitigate these risks. Data science can also be used to develop more effective emergency response plans for environmental incidents. By analyzing data on past incidents and environmental conditions, companies can develop plans that are more likely to be effective in mitigating the impacts of future incidents (Desai, Pandian & Vij, 2021, Nguyen, Gosine & Warrian, 2020, Sattari, et. al., 2021).

In conclusion, data science plays a crucial role in minimizing environmental footprints in the oil and gas industry by reducing greenhouse gas emissions and energy consumption, implementing efficient water management practices, and mitigating the risks of environmental incidents through proactive measures. By leveraging the power of data analytics, companies can improve the sustainability of their operations and reduce their impact on the environment.

Case Studies and Examples

Shell has successfully implemented machine learning algorithms to optimize well placement in complex reservoirs (Chai, et. al., 2021, Jia, et. al., 2023, Akindote et al., 2024; Kor, 2019). By analyzing historical drilling data and reservoir information, Shell was able to identify optimal drilling locations that maximize oil recovery while minimizing environmental impact. Chevron has used data analytics to improve reservoir management practices. By integrating data from various sources, including seismic surveys, well logs, and production data, Chevron was able to develop more accurate reservoir models and optimize production strategies, leading to increased oil recovery and reduced environmental impact. ExxonMobil has leveraged artificial intelligence (AI) algorithms for predictive maintenance of equipment. By analyzing data from sensors and monitoring devices, ExxonMobil can predict equipment failures before they occur, reducing downtime and minimizing the risk of environmental incidents.

By optimizing production processes and reducing energy consumption, oil companies have been able to reduce their greenhouse gas emissions. For example, Shell reported a 20% reduction in emissions from its oil sands operations in Canada through the use of data-driven optimization techniques. Data science has also led to more efficient water management practices in the oil and gas industry. Companies have been able to recycle and reuse water more effectively, reducing the environmental impact of their operations on water resources (Berghout, et. al., 2019, Talaei, et. al., 2019, Wegener & Amin, 2019). By using data analytics for predictive maintenance and risk management, oil companies have been able to minimize the risk of environmental incidents, such as spills and leaks. This has helped protect ecosystems and reduce the impact on local communities.

Ensuring data quality and integrating data from diverse sources are key challenges in implementing data science in oil recovery. Companies should focus on collecting high-quality data and developing robust data integration processes to maximize the effectiveness of data-driven solutions. Successful implementation of data science in oil recovery requires collaboration between different disciplines, including geology, engineering, and data science. Companies should encourage interdisciplinary collaboration to leverage the expertise of each discipline and develop comprehensive solutions. The oil and gas industry is constantly evolving, and companies must continuously improve and adapt their data-driven solutions to changing conditions. This requires a culture of continuous improvement and a willingness to embrace new technologies and methodologies (Bhattarai, et. al., 2019, Nguyen, et. al., 2020, Ur Rehman, et. al., 2019).

In conclusion, data science has played a pivotal role in enhancing oil recovery methods while minimizing environmental footprints. Successful applications of data science in oil recovery have led to increased oil recovery, reduced greenhouse gas emissions, and more efficient water management practices. By learning from these case studies and examples, companies can develop best practices for future implementations of data science in oil recovery, leading to more sustainable and environmentally friendly operations.

Challenges and Future Directions

Oil and gas reservoirs are complex systems, and the data generated from these systems can be vast and varied (Hanga & Kovalchuk, 2019, Lu, et. al., 2019, Mohammadpoor & Torabi, 2020). One of the major challenges faced by data scientists is dealing with the complexity and diversity of this data, which can include geological, geophysical, and engineering data. Ensuring the quality of data is crucial for the success of data-driven approaches in oil recovery. Poor data quality can lead to inaccurate models and suboptimal decision-making. Data scientists must develop robust data quality assurance processes to ensure that the data used in their analyses is accurate and reliable. Integrating data from different sources can be challenging due to differences in data formats, structures, and quality. Data scientists must develop effective data integration strategies to combine data from diverse sources and create comprehensive reservoir models.

The oil and gas industry is subject to stringent regulations aimed at protecting the environment and ensuring public safety. Data-driven approaches must comply with these regulations, which can vary from region to region and impose additional constraints on oil recovery operations. Engaging with stakeholders, including local communities, government agencies, and environmental groups,

is crucial for the successful implementation of data-driven approaches in oil recovery (Acheampong & Kemp, 2022, Faturoti, Agbaitoro & Onya, 2019, Suleiman, Raimi & Sawyerr, 2019). Data scientists must work closely with stakeholders to address their concerns and ensure that their perspectives are incorporated into decision-making processes. Data scientists must also consider ethical issues related to data privacy and security when implementing data-driven approaches in oil recovery. Ensuring that data is used responsibly and in accordance with ethical guidelines is essential for maintaining trust with stakeholders.

As data science continues to evolve, new advanced analytics techniques are emerging that can provide deeper insights into reservoir behavior and improve oil recovery strategies. Machine learning, artificial intelligence, and big data analytics are expected to play an increasingly important role in optimizing oil recovery operations. Digital twins, which are digital replicas of physical assets, are being used in the oil and gas industry to simulate and optimize oil recovery processes. By creating digital twins of reservoirs, companies can test different recovery strategies and predict their outcomes, leading to more efficient and sustainable operations. Blockchain technology is being explored for its potential to improve transparency and accountability in the oil and gas industry. By using blockchain technology to track and verify data related to oil recovery operations, companies can enhance trust with stakeholders and improve regulatory compliance (Aminzadeh, Temizel & Hajizadeh, 2022, Dindoruk, Ratnakar & He, 2020, Tariq, et. al., 2021).

In conclusion, while data science has shown great promise in enhancing oil recovery methods and minimizing environmental footprints, there are several challenges that must be addressed. By overcoming these challenges and embracing emerging trends and advancements, the oil and gas industry can continue to leverage the power of data science to achieve more sustainable and efficient oil recovery operations.

CONCLUSION

In this review, we have explored the transformative impact of data science on the oil and gas industry, particularly in enhancing oil recovery methods and minimizing environmental footprints. Through the analysis of various case studies, examples, and challenges, several key points have emerged. Data science plays a pivotal role in enhancing oil recovery methods through reservoir characterization, real-time monitoring, and predictive maintenance, as well as optimizing drilling and completion operations. Environmental benefits, such as reduced greenhouse gas emissions, improved water management practices, and minimized environmental incidents, have been observed in real-world scenarios. Challenges, including technological limitations, data quality issues, regulatory compliance, and stakeholder engagement, must be addressed for the successful implementation of data-driven approaches in oil recovery. Emerging trends, such as advanced analytics, digital twins, and blockchain technology, offer new opportunities for further enhancing oil recovery methods and minimizing environmental footprints.

The review affirms the pivotal role of data science in enhancing oil recovery methods while minimizing environmental footprints. By leveraging data analytics, machine learning, and big data technologies, the oil and gas industry can optimize production operations, improve reservoir management, and reduce environmental impacts. There is a clear need for further research and collaboration in the field of data science for oil recovery. Continued innovation in advanced

analytics, data integration, and digital technologies can further enhance the efficiency and sustainability of oil recovery operations. Collaboration between industry stakeholders, academic institutions, and government agencies is essential to drive innovation and ensure the responsible use of data science in the oil and gas industry.

In conclusion, data science has the potential to revolutionize the oil and gas industry by optimizing oil recovery methods while minimizing environmental footprints. By embracing the power of data science and collaborating to address challenges and drive innovation, the industry can achieve more sustainable and efficient oil recovery operations.

Reference

Acheampong, T., & Kemp, A. G. (2022). Health, safety and environmental (HSE) regulation and outcomes in the offshore oil and gas industry: Performance review of trends in the United Kingdom Continental Shelf. *Safety Science, 148*, 105634.

Adamu, H., Bello, U., Yuguda, A. U., Tafida, U. I., Jalam, A. M., Sabo, A., & Qamar, M. (2023). Production processes, techno-economic and policy challenges of bioenergy production from fruit and vegetable wastes. *Renewable and Sustainable Energy Reviews, 186*, 113686.

Agbaji, A. L. (2021, March). An Empirical Analysis of Artificial Intelligence, Big Data and Analytics Applications in Exploration and Production Operations. In International Petroleum Technology Conference (p. D101S043R001). IPTC.

Akindote, O.J. (2023, May). Digital era: navigating vmi and supplychain for sustainable success. In *CS & IT Conference Proceedings* (Vol. 13, No. 9). CS & IT Conference Proceedings.

Akindote, O.J., Adegbite, A.O., Dawodu, S.O., Omotosho, A., & Anyanwu, A. (2023). Innovation In Data Storage Technologies: From Cloud Computing To Edge Computing. *Computer Science & IT Research Journal*, *4*(3), 273-299.

Akindote, O.J., Adegbite, A.O., Dawodu, S.O., Omotosho, A., Anyanwu, A., & Maduka, C.P. (2023). Comparative review of big data analytics and GIS in healthcare decision-making.

Akindote, O.J., Adegbite, A.O., Omotosho, A., Anyanwu, A., & Maduka, C.P., 2024. Evaluating The Effectiveness Of It Project Management In Healthcare Digitalization: A REVIEW. *International Medical Science Research Journal*, *4*(1), 37-50.

Akindote, O.J., Egieya, Z.E., Ewuga, S.K., Omotosho, A., & Adegbite, A.O. (2023). A review of data-driven business optimization strategies in the US economy. *International Journal of Management & Entrepreneurship Research, 5*(12), 1124-1138.

Alagoz, E., Alghawi, Y., & Ergul, M. S. (2023). Innovation in exploration and production: how technology is changing the oil and gas landscape. *Journal of Energy and Natural Resources*, *12*(3), 25-29.

Al-Rbeawi, S. (2023). A review of modern approaches of digitalization in oil and gas industry. *Upstream Oil and Gas Technology, 11*, 100098.

Al-Subaiei, W., Al-Herz, E., Al-Marri, W., Al-Otaibi, R., Ashyan, H., & Jaber, H. (2021). Industry 4.0 smart predictive maintenance in the oil industry to enable near-zero downtime in

operations. In International conference on industrial engineering and operations management Singapore.

Aminzadeh, F., Temizel, C., & Hajizadeh, Y. (2022). *Artificial Intelligence and Data Analytics for Energy Exploration and Production.* John Wiley & Sons.

Babarinde, A.O., Ayo-Farai, O., Maduka, C.P., Okongwu, C.C., & Sodamade, O. (2023). Data analytics in public health, A USA perspective: A review.

Baskar, G., Kalavathy, G., Aiswarya, R., & Selvakumari, I. A. (2019). Advances in bio-oil extraction from nonedible oil seeds and algal biomass. In Advances in eco-fuels for a sustainable environment (pp. 187-210). Woodhead Publishing.

Berghout, N., Meerman, H., van den Broek, M., & Faaij, A. (2019). Assessing deployment pathways for greenhouse gas emissions reductions in an industrial plant–a case study for a complex oil refinery. *Applied Energy, 236*, 354-378.

Bhattarai, B. P., Paudyal, S., Luo, Y., Mohanpurkar, M., Cheung, K., Tonkoski, R., ... & Zhang, X. (2019). Big data analytics in smart grids: state-of-the-art, challenges, opportunities, and future directions. *IET Smart Grid*, *2*(2), 141-154.

Bui, K. Q., & Perera, L. P. (2021). Advanced data analytics for ship performance monitoring under localized operational conditions. *Ocean Engineering, 235*, 109392.

Chai, Z., Nwachukwu, A., Zagayevskiy, Y., Amini, S., & Madasu, S. (2021). An integrated closed-loop solution to assisted history matching and field optimization with machine learning techniques. *Journal of Petroleum Science and Engineering, 198*, 108204.

Desai, J. N., Pandian, S., & Vij, R. K. (2021). Big data analytics in upstream oil and gas industries for sustainable exploration and development: A review. *Environmental Technology & Innovation, 21*, 101186.

Dindoruk, B., Ratnakar, R. R., & He, J. (2020). Review of recent advances in petroleum fluid properties and their representation. *Journal of Natural Gas Science and Engineering, 83,* 103541.

Elturki, M., & Imqam, A. (2020, June). Application of enhanced oil recovery methods in unconventional reservoirs: a review and data analysis. In ARMA US Rock Mechanics/Geomechanics Symposium (pp. ARMA-2020). ARMA.

Faturoti, B., Agbaitoro, G., & Onya, O. (2019). Environmental Protection in the Nigerian Oil and Gas Industry and Jonah Gbemre v. Shell PDC Nigeria Limited: Let the Plunder Continue?. *African Journal of International and Comparative Law*, *27*(2), 225-245.

Gbadamosi, A. O., Junin, R., Manan, M. A., Agi, A., & Yusuff, A. S. (2019). An overview of chemical enhanced oil recovery: recent advances and prospects. *International Nano Letters*, *9*, 171-202.

Gupta, D., & Shah, M. (2022). A comprehensive study on artificial intelligence in oil and gas sector. *Environmental Science and Pollution Research, 29*(34), 50984-50997.

Hanga, K. M., & Kovalchuk, Y. (2019). Machine learning and multi-agent systems in oil and gas industry applications: A survey. Computer Science Review, 34, 100191.

Hui, K., Tang, J., Lu, H., Xi, B., Qu, C., & Li, J. (2020). Status and prospect of oil recovery from oily sludge: A review. *Arabian Journal of Chemistry*, *13*(8), 6523-6543.

James, R. T., Olaniyi, T. K., & Olatubosun, P. (2023). Analysing the concept of environmental sustainability in oil and gas operations in the Global South: a case study of Nigeria–Niger Delta. *International Journal of Sustainable Energy Development, 11*(1), 523-532.

Jia, D., Zhang, J., Li, Y., Wu, L., & Qiao, M. (2023). Recent development of smart field deployment for mature waterflood reservoirs. *Sustainability, 15*(1), 784.

Kalita, P., Sharma, V., Pandey, L., & Tiwari, P. (2022). Secondary and tertiary oil recovery processes. *Microbial Enhanced Oil Recovery: Principles and Potential*, 23-50.

Khan, M., & Tahir, F. (2023). Assessing the economic and environmental implications of wellbore drift flow management (No. 11444). EasyChair.

Kor, P. (2019). Decision-Driven data analytics for well placement optimization in field development scenario-powered by machine learning (Master's thesis, University of Stavanger, Norway).

Koroteev, D., & Tekic, Z. (2021). Artificial intelligence in oil and gas upstream: Trends, challenges, and scenarios for the future. *Energy and AI, 3*, 100041.

Kuang, L., He, L. I. U., Yili, R. E. N., Kai, L. U. O., Mingyu, S. H. I., Jian, S. U., & Xin, L. I. (2021). Application and development trend of artificial intelligence in petroleum exploration and development. *Petroleum Exploration and Development, 48*(1), 1-14.

Lashari, S. E. Z., Takbiri-Borujeni, A., Fathi, E., Sun, T., Rahmani, R., & Khazaeli, M. (2019). Drilling performance monitoring and optimization: a data-driven approach. *Journal of Petroleum Exploration and Production Technology, 9*, 2747-2756.

Li, Z., Zhang, H., Meng, J., Long, Y., Yan, Y., Li, M., ... & Liang, Y. (2020). Reducing carbon footprint of deep-sea oil and gas field exploitation by optimization for floating production storage and offloading. *Applied Energy, 261*, 114398.

Lu, H., Guo, L., Azimi, M., & Huang, K. (2019). Oil and Gas 4.0 era: A systematic review and outlook. *Computers in Industry, 111*, 68-90.

Ma, Y. Z., & Zhang, X. (2019). *Quantitative geosciences: Data analytics, geostatistics, reservoir characterization and modeling* (p. 640). Cham: Springer International Publishing.

Maasz, G. J. (2020). Increasing overall equipment effectiveness of drilling machines by means of data driven dashboards (Doctoral dissertation, North-West University (South Africa)).

Madkhali, A., & Sithole, S. T. (2023). Exploring the role of information technology in supporting sustainability efforts in Saudi Arabia. *Sustainability, 15*(16), 12375.

Malozyomov, B. V., Martyushev, N. V., Kukartsev, V. V., Tynchenko, V. S., Bukhtoyarov, V. V., Wu, X., ... & Kukartsev, V. A. (2023). Overview of methods for enhanced oil recovery from conventional and unconventional reservoirs. *Energies, 16*(13), 4907.

Mishra, A., Sharma, A., & Patidar, A. K. (2022). Evaluation and development of a predictive model for geophysical well log data analysis and reservoir characterization: machine learning applications to lithology prediction. *Natural Resources Research, 31*(6), 3195-3222.

Mohammadpoor, M., & Torabi, F. (2020). Big Data analytics in oil and gas industry: An emerging trend. *Petroleum, 6(*4), 321-328.

Mohsin, M., Naseem, S., Sarfraz, M., & Azam, T. (2022). Assessing the effects of fuel energy consumption, foreign direct investment and GDP on CO2 emission: New data science evidence from Europe & Central Asia. *Fuel, 314,* 123098.

Munasinghe, M., Jayasinghe, P., Deraniyagala, Y., Matlaba, V. J., dos Santos, J. F., Maneschy, M. C., & Mota, J. A. (2019). Value–Supply Chain Analysis (VSCA) of crude palm oil production in Brazil, focusing on economic, environmental and social sustainability. *Sustainable Production and Consumption, 17,* 161-175.

Ngu, K. M., Philip, N., & Sahlan, S. (2019). Proactive and predictive maintenance strategies and application for instrumentation & control in oil & gas industry. *International Journal of Integrated Engineering, 11*(4).

Nguyen, T., Gosine, R. G., & Warrian, P. (2020). A systematic review of big data analytics for oil and gas industry 4.0. *IEEE Access, 8*, 61183-61201.

Nikhalat Jahromi, H., & Jorge, A. M. (2019). Data science applications in oil and gas exploration: an in-depth perspective. *Proceedings of the Institution of Civil Engineers-Energy, 172*(3), 122-133.

Nikolova, C., & Gutierrez, T. (2020). Use of microorganisms in the recovery of oil from recalcitrant oil reservoirs: Current state of knowledge, technological advances and future perspectives. *Frontiers in Microbiology, 10,* 2996.

Pandey, R. K., Dahiya, A. K., & Mandal, A. (2021). Identifying applications of machine learning and data analytics based approaches for optimization of upstream petroleum operations. *Energy Technology, 9*(1), 2000749.

Saikia, P., Baruah, R. D., Singh, S. K., & Chaudhuri, P. K. (2020). Artificial Neural Networks in the domain of reservoir characterization: A review from shallow to deep models. *Computers & Geosciences, 135*, 104357.

Saputelli, L., Palacios, C., & Bravo, C. (2022). Case Studies Involving Machine Learning for Predictive Maintenance in Oil and Gas Production Operations. In Machine Learning Applications in Subsurface Energy Resource Management (pp. 313-336). CRC Press.

Sarker, I. H. (2021). Data science and analytics: an overview from data-driven smart computing, decision-making and applications perspective. *SN Computer Science, 2*(5), 377.

Sattari, F., Macciotta, R., Kurian, D., & Lefsrud, L. (2021). Application of Bayesian network and artificial intelligence to reduce accident/incident rates in oil & gas companies. *Safety Science, 133*, 104981.

Seyyedattar, M., Zendehboudi, S., & Butt, S. (2020). Technical and non-technical challenges of development of offshore petroleum reservoirs: Characterization and production. *Natural Resources Research, 29,* 2147-2189.

Shah, V., Shah, J., Dudhat, K., Mehta, P., & Shah, M. (2022). Big data analytics in oil and gas industry. *Smart Energy*, 37-55.

Suleiman, R. M., Raimi, M. O., & Sawyerr, O. H. (2019). A deep dive into the review of national environmental standards and regulations enforcement agency (NESREA) act.

Talaei, A., Pier, D., Iyer, A. V., Ahiduzzaman, M., & Kumar, A. (2019). Assessment of long-term energy efficiency improvement and greenhouse gas emissions mitigation options for the cement industry. *Energy, 170*, 1051-1066.

Tariq, Z., Aljawad, M. S., Hasan, A., Murtaza, M., Mohammed, E., El-Husseiny, A., ... & Abdulraheem, A. (2021). A systematic review of data science and machine learning applications to the oil and gas industry. *Journal of Petroleum Exploration and Production Technology*, 1-36.

Ur Rehman, M. H., Yaqoob, I., Salah, K., Imran, M., Jayaraman, P. P., & Perera, C. (2019). The role of big data analytics in industrial Internet of Things. *Future Generation Computer Systems, 99*, 247-259.

Wang, J., & Azam, W. (2024). Natural resource scarcity, fossil fuel energy consumption, and total greenhouse gas emissions in top emitting countries. *Geoscience Frontiers, 15*(2), 101757.

Wang, S., Zhao, S., Uzoejinwa, B. B., Zheng, A., Wang, Q., Huang, J., & Abomohra, A. E. F. (2020). A state-of-the-art review on dual purpose seaweeds utilization for wastewater treatment and crude bio-oil production. *Energy Conversion and Management, 222*, 113253.

Wegener, M., & Amin, G. R. (2019). Minimizing greenhouse gas emissions using inverse DEA with an application in oil and gas. *Expert Systems with Applications, 122*, 369-375.

Wu, X., Xia, J., Guan, B., Liu, P., Ning, L., Yi, X., ... & Hu, S. (2019). Water scarcity assessment based on estimated ultimate energy recovery and water footprint framework during shale gas production in the Changning play. *Journal of Cleaner Production, 241*, 118312.

Xie, X., Zhang, T., Wang, M., & Huang, Z. (2019). Impact of shale gas development on regional water resources in China from water footprint assessment view. *Science of The Total Environment, 679*, 317-327.