CHAPTER 8

Opportunities, Challenges, and Future Trends

During the next three decades (2020 to 2050), gross domestic product (GDP) per capita is expected to increase an average of 2% to 4% per year. Because of the shifting of many manufacturing sites to Africa, South Asia, and India, non-OECD countries will experience two to four times more growth than OECD countries [1]. The oil and gas industry will continue to exhibit an era of growth. More than half of the global energy demand in 2018 was supplied by the oil and gas industry [1], and it will continue to provide up to 50% of the energy mix through 2050. These growth estimates were generated prior to COVID-19 pandemic effects of 2020.

However, three interconnected challenges are disturbing the oil and gas industry: profitability, environmental impact, and alternative energies; these challenges are imposing constraints for reserves access, production growth, and sustainability.
• As the ability to build capacity is greater than the demand increase, commodity prices and profitability tend to be limited. During periods of higher oil and gas prices (i.e., above 50 USD/bbl), more countries accelerate their potential to bring high-cost resources. Low-cost producing provinces can survive regardless of global price trends. To find, develop, and produce at lower unit costs, operating companies are expecting to get more throughput with fewer resources, both human and technical.

• The oil and gas industry is perceived as the “black sheep” of all the energy industries. The sustainability of hydrocarbon energy is jeopardized unless the industry continuously invests in the reduction of its environmental footprint, both from leaner surface operation sites and lower-pollutant processed fuels. The reuse of CO2 for enhanced oil recovery offers an option for sustainability.

• Hydrocarbons are mainly used in industrial sectors, transportation, and power generation. As the end consumption shift to electricity use, several alternate energies (i.e., solar, nuclear, and wind) are becoming more popular to fill in this demand with incentivized access for new consumers, continuously lowering unit costs and cleaner options. Additionally, environmental protection policies in OECD and non-OECD countries favor solar, nuclear, and hydraulic energies. This situation reduces the rate of increase in the hydrocarbon mix of global demand.
During the next decades, the oil and gas industry will redefine itself to consolidate its position in the long term only through innovation. The transformation of the traditional hydrocarbon industry with Oil and Gas 4.0 can be the game-changer for persisting over the next 30 to 50 years; digitalization can provide a unique foundation for innovation while enhancing general public awareness and human life quality. Automated and robotized field operations and office processes can enable cost reductions while improving people’s life and society’s quality.

The objective of this chapter is to outline the opportunities and challenges the industry has in the application of machine learning and artificial intelligence. It also outlines the expected future trends in various use cases and technologies that could shape the way the oil and gas industry navigates over the next three decades.

Challenges and Opportunities for Applying Machine Learning

Many challenges arise for the oil and gas industry to be bearable in the following decades. These can be listed from various perspectives: shareholders’ perspective (profitability and business sustainability), people’s happiness and efficiency, business process, and technology (see Figure 8-1).

From the shareholder’s perspective, profitability and sustainability are the most prevalent goals. They are ultimately influenced by price, product demand, net unit costs, safety performance, employee satisfaction, and environmental footprint. From the people’s perspective, the common challenges refer to how human goals are achieved (e.g., compensation, development, and growth) and how people contribute to the company’s goals (e.g., information sharing, innovation, continuous improvement mindset, efficiency). From the business process point of view, companies deploy efficient methods to continuously streamline product transformation from finding, developing, producing, and transforming hydrocarbons.
Process Challenges and Mitigations

The following highlights the most relevant process-related challenges and suggested mitigating options.

- **Challenge**: Companies are continuously stressed with increasing profitability, mostly by reducing cost by employing fewer human resources, while leading to longer than usual working periods and less safe working sites. Future generations will have to do more with less, hence yielding more results per unit time and less unit cost.
Mitigation Options

- Automate drilling site operations using robotized operations and leveraging advanced data analytics for event detection focusing on abnormal critical events (i.e., stuck pipe and lost circulation).

- Automate production monitoring adding continuous data analytics of wellsite parameters while enabling routine well analysis via exception-based surveillance (EBS) focusing on critical well status.

- Implement well and reservoir performance analytics for proactive opportunity identification while focusing on high-value-added activities [2].

- AI-assisted complex decision-making with an automated routine-action recommendation.

- **Challenge**: Managing downtime. One key component of the oil and gas production capacity are the time the facility is to be shut down and the instances when it is not able to deliver its intended potential. A key challenge is to maintain these periods as low-and-predictable as possible. Unintended, unplanned shutdown time may derail the unit operating costs significantly.

Mitigation Options

- Implement data analytics and business processes to predict unplanned events, track downtime, production losses (a.k.a. *production deferral*), and causes of planned vs. unplanned downtime.

- Implement event classification to enable root-cause-analysis (RCA) of all unplanned downtime events.
**Challenge:** Disconnected business processes, and difficulties in a functional organizational design due to the challenges originating from a silo mentality. For some integrated oil and gas companies, key business processes are typically disconnected across functions and within the functions.

**Mitigation Options**

- Implement KPIs across functions and share them across the multiple levels of the organization using business analytics dashboards.
- Define key roles and responsibilities that are shared across functions, and share them.

**Challenge:** At the upstream level, production operations, reservoir management, field development, and drilling are typically disconnected functions. This hinders global optimization of the opportunities for enhancing business performance. Is it better to repair a high water producing well or drill a new drain?

**Mitigation Options**

- Implement an integrated well performance enhancement opportunity identification and ranking process that involves multi-objective constrained global optimization objective functions looking at short- and long-term goals.
- Faster and reliable forecasts based on integrated right-physics approaches leveraging deep learning.
• **Challenge**: At the corporate level, upstream and downstream have very different KPIs. Although the sale of raw oil is more profitable, the potential to increase revenue is typically constrained by market size; therefore, the option to increase profit is to maximize the revenues from downstream products without jeopardizing the upstream obligations.

**Mitigation Options**

• Implement a corporate level planning and scheduling process that involves multi-objective constrained global optimization looking at short- and long-term goals. This involves using gradient-free methods with advanced evolutionary optimization techniques.

**People Challenges and Mitigations**

The following highlights the most relevant people-related challenges and suggested mitigating options.

• **Challenge**: Low availability and poor adequacy of the new workforce intensify sustainability goals. Young professionals may not have the required level of competencies to address the impending challenges and require long times to get trained.

**Mitigation Options**

• Incorporate hybrid academic syllabuses in undergraduate and graduate-level programs.
• Offer public data sets allowing students and research community to familiarize themselves with typical data sets, setting industry expectations for standard analytics and machine learning problems.

• Implement *enterprise document management* (EDM) and knowledge search leveraging *natural language processing* (NLP) to optimize resource utilization through better technical information sharing and knowledge leverage.

• Implement a robotic engineer assistant: chatbots accessing large knowledge base enabled with NLP and speech recognition.

• Educate new generations faster on what matters most (i.e., create undergraduate oil and gas programs with an emphasis on machine learning and data analytics).

• **Challenge**: Separation among subsurface and digital disciplines. Typically, most engineering and geologic disciplines, particularly those individuals with most oilfield acumen, lack digital orientation to solve problems involving data, and process automation.

**Mitigation Options**

• Implement short on-the-job training programs for new employees covering key aspects of machine learning and artificial intelligence in the oil and gas industry.

• Promote cross-posting projects between technical and digital specialties.
• **Challenge**: Managing the silo mentality across multidisciplinary teams and organizations is an old challenge across industries [3]. In such conditions, individuals’ and teams’ lack of common goals preventing them from sharing key data and information. This mentality ultimately affects efficiency and employee morale.

**Mitigation Options**

• Implement collaborative project management providing visibility to ongoing work.

• Reward teamwork, favoring those who lead new ideas, those who share lessons learned, as those who protect and share knowledge.

• Provide an environment for knowledge sharing and ideas nurturing.

• **Challenge**: Managing unplanned and ad hoc work requires people to deviate from their original responsibilities, hence derailing corporate objectives. If this becomes the normal way of working, then there is a wrong functional design and/or the available (human) resources are not enough in quantity and quality.

**Mitigation Options**

• Implement data analytics and business processes to track ad hoc work and causes of planned vs. unplanned downtime.
Technology Challenges and Mitigations

The following highlights the most relevant technology challenges and suggested mitigating options.

- **Challenge**: Requirement to continuously manage (monitor, optimize, and control) asset performance. Oil and gas production requires a continuous understanding of the reservoir, wells, and facilities; however, these need to be achieved with a limited amount of resources, which are only able to see a fraction of the operation. This is due to a lack of sensors and technologies that allow an in-depth view of the process state.

**Mitigation Options**

- Implement data analytics and business processes to automate asset *exception-based surveillance* (EBS), focusing on critical well status.

- Implement machine learning models to continuously search for optimum asset operating envelope, considering uncertainty.

- Implement an automated AI-assisted complex decision-making engine with an automated routine-action recommendation.

- **Challenge**: Demonstrating a commitment to environmental concerns while providing a maximum return to shareholders.
Mitigation Options

- Enable routine HSE inspections with permanent instrumentation processing, video surveillance with digital image processing including drone and satellite images, and robotics with human interactions, focusing on critical events.

- Implement analytics processes that involve multi-objective constrained optimization objective functions looking at better fuels and profitable products.

- **Challenge**: Delivering a safer workplace with less human-intensive actions and decision-making processes. Enable operations and processes run 24/7 with very high availability, reducing human-power requirements.

Mitigation Options

- Automate production monitoring and oilfield operations

- Enable routine HSE inspections including the use of connected wearable safety devices in critical areas

- Enable autonomous and remote control of routine actions: choke, gas-lift, frequency, and so forth

---

**Barriers to Adopting Machine Learning**

These barriers may come into play before, during, and after any machine learning and artificial intelligence project execution (see Figure 8-2). These barriers, when properly identified, will be mitigated as they jeopardize
sustainability and may kill the idea at any point in the project execution. They have been captured from experience and various references across the literature.

Knowledge and Skills Gaps

Understanding gaps in people skills is paramount for sustainable implementations of machine learning and artificial intelligence solutions. Multidisciplinary knowledge gaps, lack of machine learning and artificial intelligence skills, digital literacy, and anxieties over job elimination are some of the barriers to the broader adoption of these technologies in the industry.

The Knowledge Gap Between Data Scientists and Petroleum Engineers

Petroleum engineering is a science that is often forced to make decisions in the presence of little data availability; this has created a large body of knowledge for statistics, uncertainty management, and analytics. However, modern machine learning and advanced data analytics techniques in upstream are in their infancy stages.

In addition, individuals with advanced data science skills may not be well conversant with the engineering practices of the oil and gas industry.

The way to mitigate this challenge is to have people who are knowledgeable in both domains and pursue cross-domain training.
Lack of Machine Learning and Artificial Intelligence Skills

Oil and gas professionals are not conventionally trained to handle advanced machine learning and artificial intelligence technologies. As it is seen historically in many operators and services companies, a small fraction of professionals opt to get self-trained to address the application of new technologies. This is no different in machine learning and artificial intelligence, where only a few can understand the full application of such techniques.

Lack of machine-learning skills is a key obstacle, and it impedes organizations to fully exploit the value of their data.

Low availability and poor adequacy of the new workforce intensify industry sustainability goals. Young professionals may not have the required level of competencies to address the impending challenges and require long times to get trained.
With the pressure to reduce cost and manpower, there is a need for recruiting different types of employees or a new type or generation of the workforce that makes greater use of artificial intelligence applications.

**Lack of Digital Literacy**

Petroleum engineers and management professionals can cope with a limited amount of digital knowledge. However, when talking about machine learning and artificial intelligence, individuals need to have a broader vocabulary, a deeper understanding of computers and knowledge of digital systems. This involves general knowledge on how to build a digital solution including all its components: defining the problem objectives, use cases, algorithm, workflow, data, and hardware and software requirements.

Scaling machine learning and artificial intelligence solutions to a wider user-based production environment is a more complex task. We believe that emerging generations will have more digital literacy and abilities to absorb more data in the digital world.

New generations will adapt to and request more data-driven applications.

**Anxieties of Job Elimination**

Historically, all industrial revolutions have implied some form of workforce adaptation to other skill requirements.

As identified by the skills gap, there is a genuine concern that someday machines will get super-smart and that digital transformation lead by machine learning and artificial intelligence will massively eliminate jobs. This further creates a negative response toward machine learning and artificial intelligence applications.
Technical Challenges

On the technical side, some obstacles can be easily removed with time, which includes access to machine learning resources (data, software, and hardware), lack of best practices for data use, and IT environment alignment.

Access to Data, Software, and Hardware Resources

The oil and gas industry may not have the infrastructure needed to run advanced data analytics in most of its operations. Data is typically located in the places where it is not leveraged (i.e., in the field operations where there is little knowledge about how to use data).

Cybersecurity constraints also pose an obstacle; it brings project delays until data manipulation workflows are fully understood by corporate IT personnel. Too restrictive IT policies prevent users from collaborating and sharing knowledge about machine learning applications. These policies also block users from downloading and executing open source software and programming languages, such as R and Python.

Best Practice and Standards for Data Collection and Use

Although there are numerous open source resources for machine learning and artificial intelligence applications, there is no established best practice nor standard operating procedure for gathering and using data.

Weak Alignment with Standard IT Environment

Although many software resources are open source, the lack of corporate IT environment supporting machine learning and artificial intelligence applications has typically been a concern at the time of new initiatives.
Although there is an increasing number of commercial solutions that allow an easy transition from innovation to a software development and production environment (DevOps), there is still a concern to interface with existing legacy applications and the need for sustaining the solution from an enterprise architecture point of view [4].

Managing the Transition

Managing change properly could make us winners. These transition elements include the proper identification of the use case, shaking the status-quo, providing context on why we should embrace it, letting go of power, and embedding the solutions in the existing business process.

Poor Identification of Use Case

Identifying the problem that the new solution is attempting to solve is a key step in any new application development project. Poor identification of the required use case may later destroy the efforts in machine learning application development and bring frustration to the team.

Making the Change

Being in the comfort zone makes it difficult for new applications to get into the marketplace and displace traditional applications. Shaking the status quo makes it harder for inventive applications to enter the mainstream.

Psychological Factors: Why Should I Use It?

A set of psychological factors influence any new technology adoption. These factors include rigid mindsets, risk aversion, early-adopter hesitance, lack of trust, not-invented-here attitude, jealousy, social norms, previous experiences, and organizational level factors, such as leadership and culture [5].
Studies show that explicit propensity to trust and implicit attitude toward automation did not significantly correlate [6]. Therefore, considering the analogy with machine learning and artificial intelligence, a combination of the psychological factors prevents the adoption of new applications.

**Letting Go of Power**

Artificial intelligence applications use data in a more democratized way, including distributing data insights across the organization, which may jeopardize the power position of many individuals. Retaining control over specific datasets is common malpractice across industries.

**Embedding Change in the Normal Way of Doing Business**

One challenge is the management of change that these new applications may imply for the organization.

The management of change is of two types: (1) a new machine learning application that is changing a process that is already in place, and it is just making it more effective; and (2) a new application that creates a brand-new process. In both cases, the identified use case should clearly define the business process and governance in which the new application delivers value.

**Commercial Barriers**

Organizations face barriers on the commercial side because of not leaving some space for innovation, lacking business acumen, and lacking a proper business model and market preparedness to create a win-win situation between vendors and customers.
No Space for Innovation

Operators are typically in charge of operation and maintenance budgets, and they are pressured to keep them low and within the targets. On the other side, operators may not have any incentive in developing a new application that would dramatically change their way of working. This hinders any opportunity for innovation on machine learning/artificial intelligence technology application, which may ultimately add value to the bottom line.

Lack of Business Acumen

There is no value-added case sufficiently strong to support the capital expenditure on new applications. Often, engineers and operators lack financial acumen to formulate a business case.

In addition, it is difficult setting up proper success measurements or defining financial returns targets in terms of quantifiable production or revenue gains.

In consequence, organizations may not be prepared with proper budget line items, which allows them to pursue a machine learning project.

Business Models and Market Preparedness

Because machine learning and artificial intelligence applications come as new market offerings, not all software vendors have a full grasp on how the business models for their tools/solutions should look like.

This may include conversations about charging per seat vs. per asset basis, fixed fee vs. pro-bono basis, perpetual vs. leasing, transaction count vs. CPU/GPU count, volume discounts, and so forth.

These conversations may create conflicts between technology vendors and customers, which may embark on long discussions, sometimes damaging relationships.
Digital Transformation of the Oil and Gas Industry Enabled by Machine Learning and Artificial Intelligence

Machine learning and artificial intelligence may enable the digital transformation of the oil and gas industry if various contributing factors become a reality, including more talented people in machine learning/artificial intelligence professions, expanded wellsite sensing capabilities, increased use of wearable devices, implementation of better regulations, and increased use of artificial intelligence tools in government organizations.

People Skills

There are places in the oil and gas industry where machines could not easily replace the human contribution. The future petroleum engineer, released from traditional mundane tasks, would need to focus more on creative work, including innovative porous media recovery mechanisms, ground-breaking business models for the role of hydrocarbon in society, new uses of environmentally friendly materials, cost-effective facility life extension options, and so on.

The Talent Requirements for the Future

In the future, the hydrocarbon industry, enabled by digitization, analytics, and AI, will demand a more complex and innovative mindset and skillset. This will enable the ingestion of analytic insights from multiple domains. Collectively, it could promise the offer of a safer and more profitable industry, with fewer working hours and better work and personal life balance for employees.
In dealing with the digital world of today, energy professionals will carry a set of skills, including computing upgrades, system maintenance, and data manipulation that ranges from exploratory data analysis to programming of exception-based surveillance rules (see Figure 8-3).

**Contributing Factors to Further Advancement of Machine Learning**

Several contributing technologies and legal frameworks may change dramatically the way machine learning and artificial intelligence are adopted in the oil and gas industry. These create additional opportunities for machine learning as well as open new paradigms in well and reservoir modeling and interpretation.

**Well and Reservoir Sensing Technologies**

Future increased availability of sensing technologies, including along- and beyond-the-wellbore acoustic and electromagnetic, will enable both saturation and pressure changes to be tracked in time and space. This shall open new challenging avenues for data analytics and AI.
Massive Data Collection with Social and Human Sensors

The oil and gas industry is behind other industries (e.g., finance, medical, and marketing) regarding large-scale wireless sensors [7]. These sensors may come from various sources: connected wearable devices, social networks, multi-domain collaboration, or any network of IoT (Internet-of-Things) devices.

Policymaking in AI

As machine learning and artificial intelligence take more roles in society and corporate worlds, the need to create policies by governments and organizations becomes more obvious [8]. Government policies and global cooperation agreements could accelerate (or deaccelerate) dramatically the progress and adoption of machine learning and artificial intelligence in all levels of society, including health, food, services, energy, transport and education.

Adoption of AI by Government Organizations

Governments face numerous challenges in the adoption of AI [9], including effective use of data, people skills, AI ecosystem, legacy culture, and procurement mechanisms. However, a change in the AI adoption rate by governments, such as the UAE, could imply tremendous implications in the development of machine learning/artificial intelligence for the oil and gas industry. There is a great correlation between citizen satisfaction and government adoption rates [10].
Machine Learning and Artificial Intelligence Technology Promises

There is no doubt that machine learning and artificial intelligence have progressed exponentially over the last decade [11]. This accelerated pace suggests that the associated science and techniques will continue to grow in the next decade as well [12].

AI will take normal roles in our daily lives [13], including the oil and gas industry. AI will play a key role in solving key engineering challenges of the next decade [14]; particularly, it will solve many challenges in drilling [15], production, and reservoir engineering.

Deep Learning

The performance of machine learning models increases as data availability increases. Deep neural networks have the potential to leverage more data. The following are examples of deep learning applications.

- Automating drilling operations requires the correct event classification of time-series data. An offline model based on semantic segmentation in parallel to a CNN-based inference model can classify and predict rig states in a real-time drilling analytics system with 99% accuracy [16].

- Hydraulic fracture operations continue to improve thanks to machine learning and AI-assisted complex event detection. These events include fracture stage start and end, ball seat operation identification, and categorization of periods of pump rate. A deep learning application based on CNN and U-Net architecture provides real-time automated interpretations of hydraulic fracture events [17].
Log interpretation is frequently regarded as a time-consuming task with subjective results adding unnecessary uncertainties to reservoir studies. Automated petrophysical interpretation using multiple modeling techniques (i.e., model stacking for supervised classification) looks promising for reducing subsurface model study time-cycles and enhancing prediction quality [18].

Identifying lithology and fluids from visual inspection of drill cuttings is required for hydrocarbon detection, well placement, subsurface navigation, and ultimately optimizing field development costs. However, such a task is usually perceived as low-added-value because it relies on subjective interpretation. The use of CNN for visual recognition has become popular in recent years in this area.

Classifying cutting volume at a rig site in real time is achieved using deep-learning techniques [19]. Normalization and principal-component analyses (PCAs) are conducted before every video frame is fed into the classification model.

Drill cutting image classification is difficult because of the large similarity between the image classes. A Bayesian-optimized ensemble of CNN performs superior to other known methods, particularly given the huge parameter space [20].
Reinforcement Learning

Reinforcement learning (RL) has tremendous potential where there is a large amount of data. RL is hungry for data. An application for waterflooding optimization was presented using deep reinforcement learning based on well data [21]. AI agents can learn the reservoir behavior by using the available data as pressure and phase monitoring. Trained agents can predict how the change in policies they make, affects the objective function.

Multiphysics Models

Traditional static-based and flow-based upscaling methods to generate equivalent-continuum models from the discrete-fracture model (DFM) present both low accuracy and high computational cost. Detailed fluid flow models that can run as fast as data-driven models have always been of interest and value in the oil and gas industry. A physics-based deep learning approach for the upscaling of high-resolution images of fractured media-constructed equivalent continuum models [22].

The Future of AI

Due to the programmed ability of AI to process information, there is an agreement that, in the future, AI will provide more contextual information [23] (see Table 8-1).
Explainable AI

As machine learning/artificial intelligence models increase their performance, it becomes increasingly difficult to understand and explain them. The objective of explainable AI is to generate self-explained machine learning models that have equivalent superior performance (i.e., high accuracy in prediction) while enabling individuals to understand and trust these models [24].
Computational Linguists

Computational linguists are concerned with the statistical or rule-based modeling of natural language. Achieving superior human-level artificial intelligence depends on the ability to read documents directly in natural language text [25].

Considering the rise of AI-assisted conversational engines in the oil and gas industry (e.g., Nesh [26], Sandy [27], Willow [28], and others [29]), it is reasonable to believe that natural language processing will play a key role in the development of machine learning and artificial intelligence applications in the next decade.

Focused Initiatives

Sometimes taking a boiling-the-ocean approach leads to frustration and early disillusionment. Pursuing too many initiatives at the same time, and trying to prove value in all of them may lead to no results. It is then recommended to focus on a few initiatives and try to prove the value in a limited scope and short time frame. After rewards have been confirmed and communicated across stakeholders, there will be greater motivation to move forward with bigger chunks of work.

Data as an Asset

Without large databases, it is not easy to build strong machine learning applications. Therefore, this will be limited to a few companies unless industries decide to share publicly meaningful sets of data (e.g., Norwegian Volve field data set) to collaborate and build robust applications. Not even giant service companies nor operators have the full data set to understand the complexity of oilfield operations. This may have implications for either cost reduction of the supply chain or appearance of new lines of business in the oil patch that make money from advertising, suppliers, and companies.
Getting More Ideas Adopted

Machine learning and artificial intelligence applications are emerging as a new class of engineering or scientific method. A lot of what is done today is experimental steps to search for the perfect algorithm. Oil and gas companies have merely started to spend significant effort in developing a blueprint of data-driven applications.

There are many initiatives in the ideas and proof-of-concept stage; however, only a few ideas will be piloted on a small scale, and a small fraction will be rolled out as mainstream products.

In the meantime, the oil and gas industry needs to exercise a lot of trial and error. Without trying, the oil and gas industry will not achieve what other industries have achieved. For this, a growth mindset is needed.

Maybe some ideas are not ready for prime time, but trial and error are required.

Summary

The oil and gas industry will continue to play a key role in our society over the next decades, and its sustainability depends on our ability to address and mitigate important processes, people, and technology challenges.

The oil and gas industry’s “process” challenges include managing downtime, interconnecting its business process, and optimizing the hydrocarbon value chain to provide a sustainable industry and secure energy source for society.

People challenges include low availability and poor adequacy of the workforce to solve ongoing problems, exacerbated by separation among subsurface and digital disciplines, managing the silo mentality across multidisciplinary teams and organizations, and prioritizing unplanned and ad hoc work.
Technology-related challenges include requirements to continuously manage (monitor, optimize and control) asset performance, demonstrating a commitment to environmental concerns while providing a maximum return to shareholders and delivering a safer workplace with less human-intensive actions and decision-making processes.

Machine learning and artificial intelligence technology applications are still in the infancy stage in the oil and gas industry; therefore, tremendous opportunities exist for young professionals to perform and find ways to grow their careers. Major barriers exist in terms of knowledge skills and gaps, technical challenges including lack of standards and weak alignment with traditional IT, and changes including clear use case definitions and embedding the change into the existing processes.

On the commercial side, machine learning and artificial intelligence technologies still lack an industry framework, where there is a balance between innovation and sustainable business models. This is not only seen in the oil and gas industry but throughout many industries.

The evolution of key digital technologies will enable a better road for machine learning and artificial intelligence technologies in the oil and gas industry, including cost effective well site sensors and massive data capture through wearable devices.

The continuous progress of machine learning and artificial intelligence core technologies, including deep learning and explainable AI, is a key factor for enhancing usability in many industries, including the oil and gas industry, which will enable more transformative and value-added processes.

Policymaking toward machine learning and artificial intelligence use, in addition to increased adoption through large government organizations, will enhance the use of machine learning and artificial intelligence in all sectors. Therefore, it will provide oxygen to the oil and gas industry for navigating through the next decades.
References

[1] “Outlook for Energy,” US Energy Information Administration, September 24, 2019. [Online]. Available: https://www.eia.gov/outlooks/ieo/.

[2] G. Zang, L. Neuhofer, D. Zabel, P. Tippel, C. I. Pantazescu, V. Krcmarik, L. Krenn, and B. Hachmöller, “Smart and Automated Workover Candidate Selection,” in SPE Intelligent Energy International Conference and Exhibition, Aberdeen, Scotland, UK, 2016.

[3] B. Gleeson, “The Silo Mentality: How to Break Down the Barriers,” Forbes, October 2, 2013. [Online]. Available: https://www.forbes.com.

[4] C. Procaccini, “Application of Data Analytics Technologies to Improve Asset Operations and Maintenance: Digital Landscaping Study of the Oil and Gas Sector,” March 9, 2018. [Online]. Available: https://www.theogtc.com/media/2380/.

[5] R. Roberts and R. Flin, “Unlocking the Potential: Understanding the Psychological Factors That Influence Technology Adoption in the Upstream Oil and Gas Industry,” SPE Journal, vol. 25, no. 1, pp. 515–528, February 1, 2020.

[6] Stephanie M. Merritt, Heather Heimbaugh, Jennifer and Jennifer LaChapell, Deborah Lee, “I Trust It, but I Don’t Know Why: Effects of Implicit Attitudes Toward Automation on Trust in an Automated System,” Human Factors: The Journal of the Human Factors and Ergonomics Society, vol. 55, no. 3, pp. 520-534, 2013.

[7] T. Zhu, S. Xiao, Q. Zhang, and Y. Gu, “Emergent Technologies in Big Data Sensing: A Survey,” International Journal of Distributed Sensor Networks, vol. 11, no. 10, 2015.

[8] B. Perry and R. Uuk, “AI Governance and the Policymaking Process: Key,” Big data and Cognitive Computing, vol. 3, no. 26, p. 17, 2019.

[9] J. Torres Santeli and S. Gerdon, “World Economic Forum,” 16 August 2019. [Online]. Available: https://www.weforum.org/agenda/2019/08/artificial-intelligence-government-public-sector/.
[10] M. Carraszo, S. Mills, A. Whybrew, and A. Jura, “The Citizen’s Perspective on the Use of AI in Government,” 1 March 2019. [Online]. Available: https://www.bcg.com/publications/2019/citizen-perspective-use-artificial-intelligence-government-digital-benchmarking.aspx.

[11] J. Markoff, “Divining the future: Special Report: The Rapid Advance of Artificial Intelligence,” October 14, 2013. [Online]. Available: https://www.nytimes.com/2013/10/15/technology/the-rapid-advance-of-artificial-intelligence.html.

[12] S. Hansen, “What to Expect with The Future of AI Technology,” April 5, 2019. [Online]. Available: https://hackernoon.com/what-to-expect-with-the-future-of-ai-technology-782aec311a54.

[13] G. Templeton, “25 Examples of AI That Will Seem Normal in 2027: From Cooking to Dating to Art,” May 15, 2017. [Online]. Available: https://www.inverse.com/article/31340-ai-machine-learning-list-change-life-decade.

[14] “10 Major Engineering Challenges of the Next Decade,” Elsevier, [Online]. Available: https://www.elsevier.com/rd-solutions/industry-insights/other/10-major-engineering-challenges-of-the-next-decade.

[15] N. A. Nunoo, “Guest Editorial: How Artificial Intelligence Will Benefit Drilling?” JPT, May 1, 2018.

[16] Y. Ben, W. Han, C. James, and D. Cao, “Building a General and Sustainable Machine Learning Solution in a Real-Time Drilling System,” Society of Petroleum Engineers, February 25, 2020.

[17] Y. Shen, D. Cao, K. Ruddy, and L. F. Teixeira de Moraes, “Near Real-Time Hydraulic Fracturing Event Recognition Using Deep Learning Methods,” SPE Drilling & Completion, vol. 35, no. 1, 2020.

[18] D. Yuan, Y. Li, W. Zhang, H. Wu, and W. Wang, “Automatic Reservoir Interpretation from Conventional Well Logs Using Stacking Machine Learning Technique,” International Petroleum Technology Conference, January 2020.
[19] X. Du, Y. Jin, X. Wu, Y. Liu, X. Wu, O. Awan, and Z. Han, “Classifying Cutting Volume at Shale Shakers in Real-Time Via Video Streaming Using Deep-Learning Techniques,” Society of Petroleum Engineers. February 1, 2020.

[20] M. Kathrada and B. J. Adillah, “Visual Recognition of Drill Cuttings Lithologies Using Convolutional Neural Networks to Aid Reservoir Characterization,” Society of Petroleum Engineers Journal, September 2019.

[21] R. Miftakhov, A. Al-Qasim, and I. Efremov, “Deep Reinforcement Learning: Reservoir Optimization from Pixels,” International Petroleum Technology Conference, January 2020.

[22] X. He, R. Santoso, and H. Hoteit, “Application of Machine-Learning to Construct Equivalent Continuum Models from High-Resolution Discrete-Fracture Models,” International Petroleum Technology Conference, January 2020.

[23] J. Launchbury, “A DARPA Perspective on Artificial Intelligence,” DARPA, 15 February 2017. [Online]. Available: https://www.darpa.mil/about-us/darpa-perspective-on-ai.

[24] M. Turek, “Artificial Intelligence Colloquium: Explainable AI,” [Online]. Available: https://www.darpa.mil/program/explainable-artificial-intelligence.

[25] J. McCarthy, “What AI Needs from Computational Linguistics,” Stanford University, [Online]. Available: http://jmc.stanford.edu/index.html.

[26] hellonesh.io, “Hello Nesh,” [Online]. Available: https://hellonesh.io/.

[27] Belmont Technology Inc., Belmont Technology Inc., [Online]. Available: https://www.b15y.io/.

[28] IBM, “IBM Woodside Willow,” August 12, 2018. [Online]. Available: https://youtu.be/BocVnDrmtZo.

[29] Baker Hughes, “AI Capabilities for Oil and Gas,” June 28, 2018. [Online]. Available: https://youtu.be/X9k-gLwDJ9g.

[30] World Economic Forum, “White Paper: Digital Transformation Initiative: Oil and Gas Industry,” 2017.