HUB TECH IA

Deliverable report 39

AI and IAGEN Application Use Case

Environmental Management in Minimizing Resource Use for Water and Energy Optimization in Hydraulic Fracturing in Vaca Muerta, Neuquén, Argentina, through IAGEN

1. Introduction

The growing demand for unconventional hydrocarbons has driven hydraulic fracturing activity in formations like Vaca Muerta in Argentina. However, this resource-intensive technique poses significant challenges in terms of environmental sustainability, particularly in terms of water and energy use.

Generative Artificial Intelligence (GENI) is emerging as a promising technology for optimizing the consumption of these resources, offering innovative solutions for environmental management. Generative Artificial Intelligence (GENI) is a branch of artificial intelligence that focuses on the creation of new content, such as models, images, code, or text, from existing data. This technology uses advanced algorithms to analyze large amounts of information, identify patterns, and generate new and original content that is often indistinguishable from human-created content.

This report analyzes the potential of AI in minimizing water and energy use in hydraulic fracturing operations in Vaca Muerta, considering recent research, current technologies, the current regulatory framework, global case studies, economic and environmental benefits, challenges and limitations, as well as the latest trends in the field of AI applied to sustainability in the energy industry. Key findings suggest that AI has considerable potential to improve the efficiency and reduce the environmental

impact of hydraulic fracturing in Vaca Muerta, although its effective implementation requires addressing significant challenges related to data infrastructure, technical expertise, and the regulatory framework. Specific recommendations are presented for the adoption and implementation of AI in the region, with the aim of fostering more sustainable exploitation of hydrocarbon resources.

II. Background of Hydraulic Fracturing in Vaca Muerta

The Vaca Muerta formation, located in the Neuquén basin of Argentina, represents one of the most important reserves of unconventional hydrocarbons worldwide, boasting the second largest reserve of shale gas and the fourth largest reserve of shale oil globally.

Hydraulic fracturing is an essential process for the commercial production of hydrocarbons in low-permeability formations such as Vaca Muerta. This technique involves the high-pressure injection of a mixture composed primarily of water, sand, and chemical additives into shale rock, generating a network of fractures that facilitates the release and extraction of trapped oil and gas.

The development of Vaca Muerta is of strategic importance to Argentina as the country seeks to achieve energy self-sufficiency and become a significant exporter of oil and liquefied natural gas (LNG), thereby reducing its dependence on imports. 1 The development of this formation is anticipated to significantly boost the Argentine economy, with the potential to overtake the agricultural sector as the main foreign exchange earner. 15

The magnitude of the reserves and Argentina's ambition to become a key player in the global energy market underscore the need to adopt sustainable practices in the development of Vaca Muerta to ensure its long-term viability and the social acceptance of these operations. Optimizing resource use and minimizing environmental impact are crucial considerations for achieving these goals.

III. Importance of Water and Energy Optimization in Fracking

Hydraulic fracturing is characterized by high water consumption, requiring millions of gallons per well, which can put considerable pressure on local water resources in the

Neuquén region, an area with limited water availability. Water demand in Vaca Muerta is expected to increase significantly as its development intensifies.
Fracking operations also present substantial energy demands, contributing to operating costs and the carbon footprint .

There is growing environmental concern and regulatory pressure surrounding resource use in the oil and gas industry, with increasing scrutiny on water consumption, wastewater disposal, and greenhouse gas emissions from fracking operations.
The environmental and economic sustainability of hydraulic fracturing critically depends on significantly reducing the intensity of water and energy use. Optimizing these resources is not only crucial to minimize environmental impacts in terms of water scarcity, ecosystem degradation, and climate change, but also to improve operational efficiency and reduce costs for the industry. The potential water shortage in the Neuquén region further underscores the urgency of water optimization.

IV. Potential of Generative Artificial Intelligence (IAGEN)

Generative Artificial Intelligence (GEN) is presented as a promising technology for analyzing complex data and generating innovative solutions for resource optimization in various industries, including the energy sector. GEN's ability to learn from multimodal data sources, including visual, textual, and sensor data, offers unique opportunities for sustainability solutions .
Its capabilities in predictive modeling for equipment failure and demand forecasting, process and logistics optimization, and real-time decision support are relevant to environmental management in oil and gas operations.
The objective of this report is to explore the application of GEN in minimizing water and energy use in hydraulic fracturing operations in Vaca Muerta, ultimately contributing to more sustainable and efficient hydrocarbon extraction.

V. Specific Focus on Water and Energy Optimization Using IAGEN

The use of IAGEN can be useful in simulating reservoir extraction scenarios and identifying optimal well configurations to improve recovery rates and streamline production through predictive maintenance and real-time operational data integration,

which indirectly impacts energy efficiency by optimizing resource extraction and reducing unnecessary operations.

IAGEN can facilitate predictive maintenance of equipment such as ESPs by diagnosing faults and providing repair instructions, potentially reducing energy consumption of faulty equipment and preventing environmentally harmful leaks or spills. Generative AI can act as a digital assistant for technicians, optimizing maintenance scheduling and providing information on impending failures.

The role of IAGEN in analyzing real-time emissions data to forecast patterns, automate source identification, and streamline reporting for better management of methane emissions, ensuring regulatory compliance, and optimizing operational efficiency is explored.

The potential of IAGEN in fuel-efficient logistics route optimization is highlighted by analyzing weather conditions, route hazards, and other data to plan cost-effective and fuel-efficient routes for tanker trucks, reducing energy consumption in transportation. IAGEN's demonstrated

capabilities in related areas such as production optimization, emissions management, and logistics suggest significant potential for water-related use cases.

IAGEN's ability to process large data sets and identify patterns could be leveraged to optimize water use in hydraulic fracturing, predict water needs, and improve water recycling processes. IAGEN's core capabilities in data analysis, simulation, and predictive modeling are highly relevant to water management. For example, if IAGEN can simulate reservoir extraction and optimize drilling strategies, it could also be used to model water flow and optimize water injection and recovery processes in hydraulic fracturing. Similarly, its success in emissions management indicates its potential to analyze water use patterns and identify areas for efficiency reduction or improvement.

VI. Application of agents driven by IAGEN in the activity

1. **IAGEN Agents Concept**

In recent years, generative artificial intelligence (GAI) has revolutionized the way we

interact with technology, enabling the development of systems capable of generating content, answering complex questions, and assisting with highly demanding cognitive tasks. From this capability, a new technological architecture has emerged: GAI-powered agents. These agents are not simple conversational interfaces, but autonomous systems that can interpret instructions, make decisions, execute tasks, and learn from their interactions with the environment.

An IAGen agent combines large language models with additional components such as external tools, memory, planning, and autonomous execution. This allows them to operate in complex environments, with the ability to break down objectives into steps, coordinate multiple actions, interact with digital systems (such as databases, APIs, or documents), and adapt to context changes in real time. These qualities distinguish them from traditional chatbots and open up a range of more sophisticated and customizable applications.

At the organizational level, these agents are being used to automate processes, generate data analysis, assist in decision-making, and improve the user experience, both internally and externally. For example, they can take on human resources, legal, financial, or logistics tasks, and even tasks linked to the technical areas of production processes, acting as intelligent assistants that collaborate with human teams. This ability to integrate knowledge and execute tasks autonomously transforms the way organizations can scale their operations without losing quality or control.

Furthermore, agentic workflows—structures where multiple agents collaborate to solve complex problems—allow responsibilities to be distributed among different agent profiles, each with specific functions. This creates hybrid work environments where humans and agents coexist, optimizing time, costs, and results. The ability to connect agents with tools such as Google Drive, CRMs, or document management platforms further expands their capabilities.

The development of IAGen-powered agents represents a crucial step toward a new era of intelligent automation.

Among the benefits of authentic workflows powered by generative AI models is the ability to automate entire production processes, end-to-end, and even add value by leveraging the capabilities of language models based on these technologies.

However, its implementation also poses technical, ethical, and legal challenges, ranging from responsible design to human oversight. Therefore, understanding its architecture, operational logic, and potential impacts is critical for its effective and safe adoption in diverse professional contexts.

2. Agentic Flow Design Proposal for Implementation

Phase 1: Data Collection

- *Sensor Agents* : Sensors are installed in fracking wells and power stations to collect real-time data on water consumption, energy, and well conditions.

Phase 2: Predictive Analysis

- *Analytical Agents* : Using machine learning models, agents analyze collected data and predict water and energy consumption in future operations, adapting to variables such as temperature, pressure, and soil characteristics.

Phase 3: Operational Optimization

- *Autonomous Agents* : Automatically adjust operational parameters (pressure, water flow, etc.) to reduce resource consumption while maintaining fracturing efficiency.

Phase 4: Execution of Changes

- *Executive Agents* : Implement the recommendations of the optimization system, adjusting machinery and workflow in real time.

Phase 5: Evaluation and Feedback

- *Evaluating Agents* : After the operation, the agents carry out an evaluation of the efficiency achieved, adjusting the predictive and operational models for future fractures.

Concrete Hypothetical Example: In a real-life scenario, a fracking well may experience fluctuations in water temperature due to weather conditions. IAGEN would adjust the energy required to maintain the appropriate temperature and ensure optimal pressure, using only the amount of energy needed, resulting in significant savings.

VII. Benefits of Adopting IAGEN in Vaca Muerta

- Potential Economic Benefits

IAGEN can lead to reduced operating costs in Vaca Muerta through the optimization of AI-identified drilling parameters, predictive maintenance that minimizes downtime and repair expenses, and efficient allocation of resources such as water and proppant based on AI-driven insights.

There is potential to increase production and improve recovery rates in Vaca Muerta through AI-driven optimization of hydraulic fracturing techniques, such as determining optimal fracturing fluid compositions and injection protocols based on reservoir conditions, as well as improved well placement and reservoir management strategies. AI can generate detailed production forecasts by simulating complex reservoir behavior.

The possibility of improved supply chain management and logistics optimization in Vaca Muerta is highlighted through AI's ability to forecast demand, optimize inventory levels, and streamline transportation routes for materials such as water and proppant, leading to significant cost savings and increased efficiency.

The potential to improve decision-making and reduce risks in exploration and drilling in Vaca Muerta is mentioned by using AI to analyze geological data and predict potential drilling hazards, thereby reducing the risk of unsuccessful drilling operations and

associated financial losses.

The adoption of AIGEN in Vaca Muerta has the potential to generate significant economic advantages by optimizing operations across the entire hydraulic fracturing lifecycle, leading to lower costs and increased productivity. The excerpts provide numerous examples of how AI leads to cost reductions and efficiency gains in various aspects of oil and gas operations, suggesting a strong economic case for adopting AIGEN in Vaca Muerta.

- Potential Environmental Benefits:

IAGEN can contribute to minimizing water consumption at Vaca Muerta through optimized water management strategies informed by AI's predictive capabilities for water demand and use patterns, increased efficiency in water recycling processes by analyzing flowback water characteristics, and potentially by assisting in the design of fracturing fluids that require less water.

There is potential to reduce energy consumption at Vaca Muerta through optimized drilling operations identified by AI to minimize unproductive drilling time, predictive maintenance to ensure rigs are operating efficiently, and optimized production processes that reduce energy waste.

IAGEN's role in improving emissions management at Vaca Muerta by analyzing real-time sensor data to detect and locate methane and hydrocarbon leaks, optimizing processes to reduce gas venting and flaring, and streamlining emissions reporting for improved regulatory compliance is highlighted.

The potential to improve safety protocols and reduce environmental risks at Vaca Muerta through AI-powered real-time monitoring of operating parameters and environmental conditions to detect potential hazards such as leaks or spills is mentioned, enabling timely interventions and preventing accidents.

The adoption of AIGEN at Vaca Muerta offers significant environmental benefits by enabling more efficient resource management, reducing water and energy intensity, minimizing emissions, and improving safety, contributing to more sustainable fracturing

operations. The excerpts provide numerous examples of how AI can be applied to various aspects of oil and gas to mitigate environmental impacts, suggesting significant potential for similar benefits in Vaca Muerta's hydraulic fracturing activities.

VIII. Challenges and Possible Limitations of IAGEN Implementation in Vaca Muerta:

Data Infrastructure and Integration Challenges

Accessing and integrating large amounts of heterogeneous data generated at different stages of oil and gas operations in Vaca Muerta, which often exist in silos and legacy systems, hampers the development and implementation of IAGEN solutions.

Ensuring the quality, accuracy, and consistency of data across these diverse sources is critical for training reliable and effective IAGEN models.

The presence of old and legacy IT systems within oil and gas companies can limit compatibility with modern AI analytics tools, hindering the seamless integration of IAGEN solutions.

The fragmented and often outdated nature of the data infrastructure prevalent in the oil and gas industry, including Vaca Muerta, represents a significant barrier to the effective implementation of IAGEN. Integrating data from diverse sources and ensuring its quality are prerequisites for leveraging the full potential of AI in environmental management.

Technical Expertise and Skills Gaps

A workforce with specialized skills in artificial intelligence, machine learning, data science, and domain-specific knowledge of oil and gas operations is required for the successful development, deployment, and maintenance of IAGEN solutions in Vaca Muerta.

There may be challenges in attracting and retaining talent with these highly in-demand skills, as oil and gas companies in Argentina may face competition from other industries, including the technology sector, both locally and globally.

It is important to invest in comprehensive training and upskilling programs for the existing workforce to enable them to effectively use and manage IAGEN tools and integrate them into their workflows.

A shortage of professionals with the necessary interdisciplinary expertise in both AI

technologies and oil and gas operations could significantly hamper the effective implementation of IAGEN solutions for environmental management in Vaca Muerta. Overcoming this skills gap through targeted efforts in education, training, and recruitment is essential.

Regulatory and Ethical Considerations

The regulatory landscape for artificial intelligence in Argentina is evolving, currently nascent, and lacking specific and binding regulations, which could create uncertainty for companies seeking to implement AI solutions in the oil and gas sector.

A comprehensive and forward-looking regulatory framework is needed that balances the promotion of technological innovation with crucial data protection, privacy, and ethical considerations in the development and deployment of AI technologies such as AI.

There is a potential for bias in AI algorithms, which can lead to discriminatory results or inaccurate predictions if not carefully addressed during the development and training of AI models, emphasizing the importance of ensuring fairness, transparency, and accountability in their applications within the oil and gas industry.

The absence of specific AI regulations in Argentina, while offering some flexibility, also creates a degree of uncertainty for the oil and gas industry regarding compliance and potential future restrictions on the use of AI. Furthermore, ethical considerations related to data privacy, algorithmic bias, and potential impact on the workforce must be proactively addressed to ensure responsible and reliable implementation of AI in Vaca Muerta.

Initial Investment and Return on Investment

Oil and gas companies in Vaca Muerta could require a potentially high initial investment to develop and deploy IAGEN solutions, including costs associated with upgrading data infrastructure, acquiring specialized software and hardware, and hiring or training skilled personnel110.

The return on investment (ROI) of IAGEN projects needs to be clearly understood and demonstrated, including the quantification of the economic benefits derived from

improved efficiency, reduced costs, and increased production, as well as environmental benefits such as reduced water and energy consumption and decreased emissions .

Demonstrating the tangible value and significant cost savings achieved through IAGEN implementation is critical to drive widespread adoption and secure further investment within the oil and gas industry in Vaca Muerta.

The significant initial investment often associated with the adoption of advanced technologies such as IAGEN requires a compelling business case for oil and gas companies in Vaca Muerta. Demonstrating a clear and measurable return on investment, encompassing both economic and environmental benefits, is crucial to justifying these expenditures and gaining stakeholder support.

Adoption Resistance and Cultural Barriers

There is potential for resistance to the adoption of new AI-driven technologies by a workforce in the oil and gas industry, including Vaca Muerta, who may be more accustomed to traditional operating methods and may have concerns about job displacement or the reliability of AI systems.

It is important to implement effective change management strategies, clearly communicate the benefits of AI, and provide appropriate employee training and support to overcome cultural barriers and encourage acceptance of these new tools.

It is necessary to build trust in the accuracy and reliability of AI-generated information and recommendations, ensuring that users trust decision-making based on AI results.

Overcoming inherent resistance to change and addressing potential cultural barriers within oil and gas organizations in Vaca Muerta is critical to the successful integration and widespread utilization of AI technologies. Building trust through transparency, demonstrating tangible benefits, and engaging the workforce in the adoption process are essential to fostering a culture that embraces AI-driven innovation.

Recommendation:

Short-term investment in AI agent implementation teams in technology and training: Investment is required in proofs of concept and pilot testing. The focus here must be on

developing the talent needed to implement these solutions, as there is a trend toward cost reduction in systems that enable "no-code" and "low-code" automation. For the first stage, it is also recommended to recruit teams with experience in AI agent design and implementation. Finally, it is key to form an in-house team to support and foster an agentic culture that redefines human-machine interaction.

IX. Conclusion

The application of Generative Artificial Intelligence (GENA) in the Vaca Muerta hydraulic fracturing industry represents a strategic opportunity to transform environmental management in the energy sector. Through the use of intelligent agents, predictive modeling, and real-time analytics, it is possible to significantly optimize water and energy use, reduce emissions, and improve operational efficiency. While the economic and environmental benefits are compelling, its implementation requires overcoming technical, regulatory, and cultural challenges. Investing in the training of local talent, responsible system design, and initial investment in agentic solutions will allow us to move toward more sustainable and competitive exploitation of hydrocarbon resources in Argentina. The integration of GENA not only boosts energy development but also redefines the sustainability paradigm in the industry.

Sources cited

1. Argentina's Vaca Muerta: 10 Years of Fracking and Local Resistance - NACLA |, accessed February 1, 2025, https://nacla.org/argentina-vaca-muerta-fracking-resistance
2. Vaca Muerta - Global Energy Monitor, access date: February 1, 2025, https://www.gem.wiki/Vaca_Muerta
3. Vaca Muerta play - AAPG Wiki, access date: February 1, 2025, https://wiki.aapg.org/Vaca_Muerta_play

4. An Overview of Recent Developments and Understandings of Unconventionals in the Vaca Muerta Formation, Argentina - MDPI, access date: February 1, 2025, https://www.mdpi.com/2076-3417/14/4/1366
5. Balancing energy security and a healthy environment | SEI, accessed February 1, 2025, https://www.sei.org/publications/energy-environment-vaca-muerta-fracking/
6. Vaca Muerta Challenge, access date: February 1, 2025, https://vacamuertachallenge.ypf.com/
7. Energy Connects Us | Tecpetrol, accessed February 1, 2025, https://www.tecpetrol.com/en/experience-at-fortin-de-piedra
8. Argentina's oil and gas sector: Vaca Muerta shale can drive near-term growth and fuel medium-term opportunities - Deloitte, accessed February 1, 2025, https://www2.deloitte.com/us/en/insights/economy/americas/vaca-muerta-argentina-energy-sector-boom.html
9. Vaca Muerta Shale Drives Argentina's LNG Export Ambitions - JPT - SPE, accessed February 1, 2025, https://jpt.spe.org/vaca-muerta-shale-drives-argentinas-lng-export-ambitions-restricted
10. Argentina | Energy Outlook 2025: Oil and Gas - BBVA Research, accessed February 1, 2025, https://www.bbvaresearch.com/en/publicaciones/argentina-energy-outlook-2025-oil-and-gas/
11. Rystad Energy: Vaca Muerta smashes crude output record in 3Q24, on track to meet 1 million bpd in 2030 - Oilfield Technology, access date: February 1, 2025, https://www.oilfieldtechnology.com/drilling-and-production/29112024/vaca-muerta-smashes-crude-output-record-in-3q24-on-track-to-meet-1-million-bpd-in-2030/
12. “To develop Vaca Muerta we need innovation, scale, productivity and management control”, access date: February 1, 2025, https://www.tecpetrol.com/en/news/2022/markus-virtual-chat-young-engineering
13. Oil & Gas Laws and Regulations Report 2025 Argentina - ICLG.com,

accessed February 1, 2025, https://iclg.com/practice-areas/oil-and-gas-laws-and-regulations/argentina

14. Argentina's Oil and Gas Policies (2016-2024): A Deep Dive into Vaca Muerta, accessed February 1, 2025, https://www.researchgate.net/publication/387172576_Argentina's_Oil_and_Gas_Policies_2016-2024_A_Deep_Dive_into_Vaca_Muerta

15. of Argentina Vaca Muerta: the future, access date: February 3, 2025, https://www.pwc.com.ar/es/assets/document/invest-in-vaca-muerta.pdf

16. Argentina's Vaca Muerta is fueling the country's shale oil boom dream | The National, accessed February 3, 2025, https://www.thenationalnews.com/business/energy/2025/02/03/argentina-shale-oil/

17. The Vaca Muerta Tribunal Delegation, access date: February 3, 2025, https://www.rightsofnaturetribunal.org/vaca-muerta/

18. Watershed implications of shale oil and gas production in Vaca Muerta, Argentina - Stockholm Environment Institute, access date: February 3, 2025, https://www.sei.org/wp-content/uploads/2021/05/watershed-implications-of-shale-oil-and-gas-production-in-vaca-muerta.pdf

19. Defending communities from fracking's advance in Argentina - Aida-americas.org, accessed February 3, 2025, https://aida-americas.org/en/blog/defending-communities-fracking-s-advance-argentina

20. The Environmental Impact of Fracking on Water Resources - Landgate, accessed February 3, 2025, https://www.landgate.com/news/the-environmental-impact-of-fracking-on-water-resources

21. How Generative AI Can Drive Fuel Oil and Gas Data Analytics | Publicis Sapient, accessed February 3, 2025, https://www.publicissapient.com/insights/maintenance-co-pilot

22. Generative AI in Oil and Gas: Optimize Production, Safety, and Sustainability

| SoftServe, access date: February 3, 2025, https://www.softserveinc.com/en-us/generative-ai/energy

23. The Future of Oil & Gas: AI-Powered Exploration & Production - DTskill, accessed February 3, 2025, https://dtskill.com/blog/generative-ai-in-oil-and-gas/

24. Generative AI for Oil and Gas: Unleashing the Potential Through..., access date: February 3, 2025, https://tovie.ai/blog/generative-ai-for-oil-and-gas-unleashing-the-potential-through-digital-transformation

25. Generative AI for Oil and Gas | Enhanced Efficiency | 7P - 7Puentes, accessed February 3, 2025, https://www.7puentes.com/generative-ai-for-oil-and-gas/

26. Point of View: The Impact of Generative AI on the Oil and Energy Sector - Prioriti AI, access date: February 3, 2025, http://prioriti.ai/point-of-view/point-of-view-the-impact-of-generative-ai-on-the-oil-and-energy-sector/

27. Energy Efficiency - Energy System - IEA, access date: February 3, 2025, https://www.iea.org/energy-system/energy-efficiency-and-demand/energy-efficiency

28. Efficient use of energy in oil and gas upstream facilities | IOGP Publications library, access date: February 3, 2025, https://www.iogp.org/bookstore/product/efficient-use-of-energy-in-oil-and-gas-upstream-facilities/

29. Electric Heat Tracing Market Size, Growth and Forecast 2032, access date: February 3, 2025, https://www.credenceresearch.com/report/electric-heat-tracing-market

30. World Energy Actor | ENGIE, accessed February 10, 2025, https://www.engie.com/en

31. AES | Global Energy Companies, accessed February 10, 2025, https://www.aes.com/

32. Earthjustice Supports Fracking Challenge in Mendoza, Argentina, accessed

February 10, 2025, https://earthjustice.org/press/2021/earthjustice-supports-fracking-challenge-in-mendoza-argentina

33. UN Committee recommends Argentina “reconsider” the use of fracking - Aida-americas.org, accessed February 10, 2025, https://aida-americas.org/en/press/un-committee-recommends-argentina-reconsider-use-fracking

34. Organizations Concerned by Mendoza Supreme Court Rejecting their Participation Fracking Litigation Case | Center for International Environmental Law, access date: February 10, 2025, https://www.ciel.org/news/mendoza-supreme-court-rejects-organizations-participation-fracking-case/

35. “Water is worth more than gold”: Mendoza, Argentina rejects advance of extractive industry, access date: February 10, 2025, https://peoplesdispatch.org/2019/12/24/water-is-worth-more-than-gold-mendoza-argentina-rejects-advance-of-extractive-industry/

36. “Condemned to Sacrifice” in the Shadow of Argentina's Vaca Muerta | NACLA, accessed February 10, 2025, https://nacla.org/condemned-sacrifice-argentina-vaca-muerta

37. Can oil and gas companies reduce their emissions at Vaca Muerta? - Dialogue Earth, accessed February 10, 2025, https://dialogue.earth/en/business/can-oil-and-gas-companies-reduce-their-emissions-at-vaca-muerta/

38. Argentina | ieexi - World Bank, accessed February 10, 2025, https://flaringventingregulations.worldbank.org/argentina

39. Oil and gas regulation in Argentina: overview - Beccar Varela, access date: February 10, 2025, https://www.beccarvarela.com/images/publicaciones/plcoilgasreg.pdf

40. Empowering Drilling and Optimization with Generative AI - SLB AI, access date: February 10, 2025, https://ai.slb.com/blog/drilling-genai-optimization

41. AI in Oil and Gas: Future Trends & Use Cases - Moon Technolabs, accessed February 10, 2025, https://www.moontechnolabs.com/blog/ai-in-oil-and-gas/
42. Generative AI is poised to reshape the global energy landscape - SLB, access date: February 10, 2025, https://www.slb.com/resource-library/insights-articles/generative-ai-is-poised-to-reshape-the-global-energy-landscape
43. Application of Generative AI to Derive Insight from Supply Chain & Logistics Contracts, access date: February 10, 2025, https://www.researchgate.net/publication/385520476_Application_of_Generative_AI_to_Derive_Insight_from_Supply_Chain_Logistics_Contracts
44. Design and Implementation of a Virtual Experimental Teaching System for Deep Energy Exploitation Based on Digital Twin Technology - MDPI, access date: February 10, 2025, https://www.mdpi.com/2079-8954/12/10/386
45. Broadening the Gains from Generative AI in: Staff Discussion Notes Volume 2024 Issue 002 (2024), access date: February 12, 2025, https://www.elibrary.imf.org/view/journals/006/2024/002/article-A001-en.xml
46. Gen AI: Unlocking Natural Gas's Full Potential - Accenture, accessed February 12, 2025, https://www.accenture.com/ie-en/blogs/energy/gen-ai-key-unlocking-natural-gas-full-potential
47. Energy and AI: the power couple that could usher in a net-zero world, access date: February 12, 2025, https://www.weforum.org/stories/2025/01/energy-ai-net-zero/
48. Explained: Generative AI's Environmental Impact | MIT News, accessed February 12, 2025, https://news.mit.edu/2025/explained-generative-ai-environmental-impact-0117
49. How generative AI can accelerate value-led sustainability | EY Vietnam, accessed February 12, 2025, https://www.ey.com/en_vn/insights/climate-change-sustainability-services/how-generative-ai-can-accelerate-value-led-sustainability

50. Powering the future: The energy shift for sustainable AI - The World Economic Forum, access date: February 12, 2025, https://www.weforum.org/stories/2025/01/the-essential-energy-shift-for-sustainable-genai/
51. As generative AI asks for more power, data centers seek more reliable, cleaner energy solutions - Deloitte, access date: February 12, 2025, https://www2.deloitte.com/us/en/insights/industry/technology/technology-media-and-telecom-predictions/2025/genai-power-consumption-creates-need-for-more-sustainable-data-centers.html
52. The Hidden Costs of AI | Sustainability | Washington University in St. Louis, access date: February 12, 2025, https://sustainability.wustl.edu/the-hidden-costs-of-ai/
53. Generative AI in Energy: Use Cases, Risks, and Future Outlook - AlphaSense, access date: February 12, 2025, https://www.alpha-sense.com/blog/trends/generative-ai-in-energy/
54. AWS Energy & Utilities Generative AI, accessed February 12, 2025, https://aws.amazon.com/energy-utilities/generative-ai/
55. Generative AI in Clean Energy Transformation | by Nishnat Bijani - Medium, access date: February 12, 2025, https://medium.com/@nishantbj/generative-ai-in-clean-energy-transformation-1dc8a0f14f8c
56. Generative AI for smart grid modeling | MITNews | Massachusetts Institute of Technology, access date: February 12, 2025, https://news.mit.edu/2024/generative-ai-smart-grid-modeling-0226
57. Generative AI: Power Consumption and Grid Evolution - Rackmount Solutions, access date: February 12, 2025, https://www.rackmountsolutions.net/news/?p=generative-ai-and-power-grids
58. ChatGrid – a generative AI tool for power grid visualization - Renewable Energy World, access date: February 12, 2025, https://www.renewableenergyworld.com/power-grid/smart-grids/chatgrid-to-assis

t-power-grid-operators-with-generative-ai-grid-visualisation/

59. AI Is Everywhere Now—and It's Sucking Up a Lot of Water - Inside Climate News, accessed February 12, 2025, https://insideclimatenews.org/news/28092024/ai-water-usage/

60. The Environmental Impact of AI: A Case Study of Water Consumption by Chat GPT, access date: February 20, 2025, https://www.researchgate.net/publication/370202417_The_Environmental_Impact_of_AI_A_Case_Study_of_Water_Consumption_by_Chat_GPT

61. A Brief Guide to Water Management in the Oil and Gas Industry - Kimray, access date: February 20, 2025, https://kimray.com/training/brief-guide-water-management-oil-and-gas-industry

62. Water Management for Oil and Gas - WSP, access date: February 20, 2025, https://www.wsp.com/en-us/services/water-management-for-oil-and-gas

63. Shale Production and Water Reuse: A Look at Adoption and Barriers - JPT, access date: February 20, 2025, https://jpt.spe.org/shale-production-and-water-reuse-a-look-at-adoption-and-barriers

64. Green Technologies for a Sustainable Oil and Gas Industry Future - GET Global Group, access date: February 20, 2025, https://getglobalgroup.com/ksa/green-technologies-sustainable-future-oil-gas-industry/

65. Vaca Muerta Will Have Its First Gas Fracture by 2024, accessed February 20, 2025, https://www.signalpowergroup.com/vaca-muerta-will-have-its-first-gas-fracture-by-2024

66. Tenaris increases its capabilities in Vaca Muerta with third fracking set, access date: February 20, 2025, https://www.tenaris.com/en/news/2025/tenaris-increases-its-capabilities-in-vaca-muerta-with-third-fracking-set

67. Digital Twins in Smart Oilfields: Simulating and Optimizing Oilfield

Performance, access date: February 20, 2025, https://energiesmedia.com/digital-twins-in-smart-oilfields-simulating-and-optimizing-oilfield-performance/

68. 26 Real-Time Decision Support in Optimizing Well Production and Hydraulic Fracturing Operations using Digital Twins - Earthdoc, access date: February 20, 2025, https://www.earthdoc.org/content/papers/10.3997/2214-4609.202477026?crawler=true&mimetype=application/pdf

69. Real-Time Decision Support in Optimizing Well Production and Hydraulic Fracturing Operations using Digital Twins | Earthdoc, access date: February 20, 2025, https://www.earthdoc.org/content/papers/10.3997/2214-4609.202477026

70. Drilling Down: How AI is Changing the Future of Oil and Gas - Sand Technologies, access date: February 20, 2025, https://www.sandtech.com/insight/drilling-down-how-ai-is-changing-the-future-of-oil-and-gas/

71. AI and Machine Learning: Transforming Energy Operations - GET Global Group, access date: February 20, 2025, https://getglobalgroup.com/role-of-ai-and-machine-learning-in-energy-operations-and-management-2/

72. Energy Laws and Regulations 2025 | Argentina - Global Legal Insights, accessed February 20, 2025, https://www.globallegalinsights.com/practice-areas/energy-laws-and-regulations/argentina/

73. Argentina - International - US Energy Information Administration (EIA), access date: February 20, 2025, https://www.eia.gov/international/analysis/country/ARG

74. Argentina: Energy – Oil & Gas – Country Comparative Guides - Legal 500, accessed February 20, 2025, https://www.legal500.com/guides/chapter/argentina-energy-oil-gas/

75. Renewable energy in Argentina: a utopia for the global south? |

EnergyTransition.org, accessed February 21, 2025, https://energytransition.org/2024/12/renewable-energy-in-argentina-a-utopia-for-the-global-south/

76. AI Case Study: AI for Drilling and Exploration Optimization at Shell - Redress Compliance, access date: February 21, 2025, https://redresscompliance.com/ai-case-study-ai-for-drilling-and-exploration-optimization-at-shell/

77. A Review of AI Applications in Unconventional Oil and Gas Exploration and Development, access date: February 21, 2025, https://www.mdpi.com/1996-1073/18/2/391

78. AI in the Oil & Gas Industry: From drilling optimization to market prediction | HCLTech, access date: February 21, 2025, https://www.hcltech.com/blogs/ai-in-the-oil-and-gas-industry-from-drilling-optimization-to-market-prediction

79. AI in Oil and Gas: Preventing Equipment Failures Before They Cost Millions, access date: February 21, 2025, https://energiesmedia.com/ai-in-oil-and-gas-preventing-equipment-failures-before-they-cost-millions/

80. AI in Oil and Gas: AI solutions for the Energy Industry - 7Puentes, access date: March 25, 2025, https://www.7puentes.com/ai-solutions-for-oil-and-gas/

81. AI spells opportunity and manageable risk for the oil and gas industry - DNV, access date: February 21, 2025, https://www.dnv.com/article/ai-spells-opportunity-and-manageable-risk-for-the-oil-and-gas-industry/

82. Oil and gas can be slow to change. Can AI be a disruptor? | GlobalSpec, access date: February 21, 2025, https://insights.globalspec.com/article/23508/oil-and-gas-can-be-slow-to-change-can-ai-be-a-disruptor

83. From exploration to refining: how AI is transforming oil and gas - ADI Analytics, access date: February 21, 2025,

https://adi-analytics.com/2024/05/08/from-exploration-to-refining-how-ai-is-transforming-oil-and-gas/

84. Intelligent Water, Improved Systems: The AI Blueprint | Arcadis, accessed February 21, 2025, https://www.arcadis.com/en/insights/blog/global/celine-hyer/2024/intelligent-water-improved-systems-the-ai-blueprint

85. The Role of Generative AI (GenAI) for the Global Water Sector, accessed February 21, 2025, https://www.waterrf.org/research/projects/role-generative-ai-genai-global-water-sector

86. Engineered AI: Unapologetically optimized for the energy industry - SLB, access date: February 21, 2025, https://www.slb.com/resource-library/insights-articles/engineered-ai-unapologetically-optimized-for-the-energy-industry

87. Can AI make waves in your water utility? - Arcadis, accessed February 21, 2025, https://www.arcadis.com/en-us/insights/blog/global/esteban-azagra/2024/can-ai-make-waves-in-your-water-utility

88. Sustainable water management in the oil and gas industry: Harnessing the power of AI and data-driven solutions for efficient water use - AWS, access date: February 21, 2025, https://aws.amazon.com/blogs/industries/sustainable-water-management-in-the-oil-and-gas-industry-harnessing-the-power-of-ai-and-data-driven-solutions-for-efficient-water-use/

89. AI for process optimization for water treatment - Global Infrastructure Hub, accessed February 21, 2025, https://www.gihub.org/infrastructure-technology-use-cases/case-studies/ai-for-process-optimization-for-water-treatment/

90. Digitized Workflow Aids Water Management for Hydraulic Fracturing - JPT, access date: March 2, 2025,

https://jpt.spe.org/digitized-workflow-aids-water-management-for-hydraulic-fracturing

91. Five key areas in which AI is set to transform water management in 2025, access date: March 2, 2025, https://smartwatermagazine.com/news/xylem-vue/five-key-areas-which-ai-set-transform-water-management-2025

92. AI for Water Management: Smart Solutions for Conservation, access date: March 2, 2025, https://www.signitysolutions.com/tech-insights/ai-for-water-management

93. Veolia takes artificial intelligence deployment to the next level to drive sustainable water management, access date: March 2, 2025, https://www.watertechnologies.com/about-us/newsroom/veolia-takes-artificial-intelligence-deployment-next-level-drive-sustainable

94. Enhancing Water Management in Shale Gas Extraction through Rectangular Pulse Hydraulic Fracturing - MDPI, access date: March 2, 2025, https://www.mdpi.com/2071-1050/15/14/10795

95. Natural Gas Use in Power Generation Saves Water and Reduces Drought Vulnerability, access date: March 2, 2025, https://www.jsg.utexas.edu/news/2013/12/natural-gas-saves-water-and-reduces-drought-vulnerability-even-when-factoring-in-water-lost-to-hydraulic-fracturing/

96. Applications of AI in oil and gas projects towards sustainable development: a systematic literature review - PubMed Central, access date: March 2, 2025, https://pmc.ncbi.nlm.nih.gov/articles/PMC10034239/

97. Understanding the Fate of Non-recovered Fracturing Water and the Source of Produced Salts for Optimizing Fracking Operations - Natural Resources Canada, date accessed: March 2, 2025, https://natural-resources.canada.ca/funding-partnerships/understanding-fate-recovered-fracturing-water-source-produced-salts-optimizing-fracking-operations

98. Unlocking the power of data for sustainable water management with AWS, access date: March 2, 2025,

https://aws.amazon.com/blogs/industries/unlocking-the-power-of-data-for-sustainable-water-management-with-aws/

99. Sustainable Practices Enabled by Technology in Oil and Gas - FAT FINGER, access date: March 2, 2025, https://fatfinger.io/sustainable-practices-enabled-by-technology-in-oil-and-gas/

100. Efficient Use of Data Analytics in Optimization of Hydraulic Fracturing in Unconventional Reservoirs | Request PDF - ResearchGate, access date: March 2, 2025, https://www.researchgate.net/publication/301464704_Efficient_Use_of_Data_Analytics_in_Optimization_of_Hydraulic_Fracturing_in_Unconventional_Reservoirs

101. AI on big field data helps make hydraulic fracturing more economically viable - Skoltech, access date: March 2, 2025, https://www.skoltech.ru/en/2022/07/ai-on-big-field-data-helps-make-hydraulic-fracturing-more-economically-viable/

102. AI in Oil and Gas Industry - Benefits, Use Cases, and Examples - Oyelabs, accessed March 2, 2025, https://oyelabs.com/ai-in-oil-and-gas-industry-use-cases-and-examples/

103. An Artificial Intelligence-Based Model for Performance Prediction of Acid Fracturing in Naturally Fractured Reservoirs - PMC, access date: March 2,2025, https://pmc.ncbi.nlm.nih.gov/articles/PMC8173587/

104. htt.io, access date: March 2, 2025, https://htt.io/learning-center/understanding-the-role-of-technology-in-gas-and-oil-safety-management#:~:text=Modern%20drones%20can%20carry%20light,damage%20while%20keeping%20workers%20safe.

105. Understanding the Role of Technology in Gas and Oil Safety Management - Htt.io, access date: March 5, 2025, https://www.htt.io/learning-center/understanding-the-role-of-technology-in-gas-and-oil-safety-management

106. Innovating Energy: Emerging Technologies in Oil and Gas Production, access date: March 5, 2025,

https://www.dwenergygroup.com/innovating-energy-emerging-technologies-in-oil-and-gas-production/

107. Emerging Technology Trends in Oil and Gas Operations - Travelers Insurance, access date: March 5, 2025, https://www.travelers.com/resources/business-industries/oil-gas/digital-transformations-in-oil-and-gas-operations

108. Half of Argentine companies are already seeing results from their investments in artificial intelligence - BNamericas, access date: March 5,2025, https://www.bnamericas.com/en/news/half-of-argentine-companies-are-already-seeing-results-from-their-investments-in-artificial-intelligence

109. (PDF) Argentina's Potential in Artificial Intelligence - ResearchGate, access date: March 5, 2025, https://www.researchgate.net/publication/387172794_Argentina's_Potential_in_Artificial_Intelligence

110. Artificial Intelligence could unlock efficiency and safety gains for oil and gas sector, access date: March 5, 2025, https://www.worldpipelines.com/special-reports/23092024/artificial-intelligence-could-unlock-efficiency-and-safety-gains-for-oil-and-gas-sector/

111. Regulating Artificial Intelligence in Argentina - WSC Legal, accessed March 5, 2025, https://wsclegal.com/regulating-artificial-intelligence-in-argentina/

112. Foster innovation or mitigate risk? AI regulation in Latin America | White & Case LLP, access date: March 5, 2025, https://www.whitecase.com/insight-our-thinking/latin-america-focus-2024-ai-regulation

113. Argentina's approach to AI: 'Let's not overregulate ourselves' - BNamericas, accessed March 5, 2025, https://www.bnamericas.com/en/interviews/argentinas-approach-to-ai-lets-not-regulate-ourselves

114. Maximizing the impact of AI in the oil and gas sector | EY - US, access date: March 5, 2025,

https://www.ey.com/en_us/insights/oil-gas/maximizing-the-impact-of-ai-in-the-oil-and-gas-sector

115. The great AI debate in the oil and gas industry: balancing job loss concerns with the thriving potential of AI applications - Kent, access date: March 5, 2025, https://kentplc.com/news-insights/the-great-ai-debate-in-the-oil-and-gas-industry-balancing-job-loss-concerns-with-the-thriving-potential-of-ai-applications

116. AI and risk in Norway's petroleum industry - Havtil, access date: March 5, 2025, https://www.havtil.no/en/explore-technical-subjects2/technical-competence/news/2024/ai-and-risk-in-norways-petroleum-industry/

117. Generative Artificial Intelligence for the Power Grid - NREL, access date: March 5, 2025, https://www.nrel.gov/grid/generative-artificial-intelligence-for-the-power-grid.html

118. Generative AI for Power Grid Operations - NREL, access date: March 5, 2025, https://www.nrel.gov/docs/fy25osti/91176.pdf

119. carbonherald.com, access date: March 5, 2025, https://carbonherald.com/researchers-try-to-find-new-carbon-capture-materials-using-the-power-of-ai/#:~:text=The%20AI%20model%20created%20by,it%20assembled%20120%2C000%20potential%20structures.

120. Researchers Try To Find New Carbon Capture Materials Using The Power Of AI, access date: March 28, 2025, https://carbonherald.com/researchers-try-to-find-new-carbon-capture-materials-using-the-power-of-ai/

121. Argonne scientists use AI to identify new materials for carbon capture, access date: March 28, 2025, https://www.anl.gov/article/argonne-scientists-use-ai-to-identify-new-materials-for-carbon-capture

122. Beckman scientists use AI to identify new materials for carbon capture, access date: March 29, 2025, https://beckman.illinois.edu/about/news/article/2024/02/14/beckman-scientists-

use-ai-to-identify-new-materials-for-carbon-capture

123. Researchers generate a carbon capture breakthrough using AI, physics and supercomputers - UIC today - University of Illinois Chicago, access date: March 29, 2025, https://today.uic.edu/researchers-generate-a-carbon-capture-breakthrough-using-ai-physics-and-supercomputers/

124. From capture to storage: AI transforming the carbon cycle - Energy Tech Summit, access date: March 29, 2025, https://energytechsummit.com/from-capture-to-storage-ai-transforming-the-carbon-cycle/

125. How Generative AI is Transforming the Energy Sector: A Practical Guide - Lyzr AI, accessed March 29, 2025, https://www.lyzr.ai/blog/ai-in-energy-sector/

126. Artificial Intelligence for Energy, access date: March 29, 2025, https://www.energy.gov/topics/artificial-intelligence-energy