HUB TECH IA

Deliverable report 4

AI and IAGEN Application Use Case

Energy Optimization in Vaca Muerta through Digital Twins and Generative Artificial Intelligence (IAGEN)

I. **Introduction.**

The Vaca Muerta formation, located in Argentina, has established itself as one of the largest shale gas and oil fields in the world, presenting a significant growth horizon for hydrocarbon production. Its relevance in the global energy landscape is increasing, especially in a context where the demand for natural gas and oil continues to be substantial.

The oil and gas industry has the opportunity to optimize its operations, driven by the need to improve economic efficiency, meet with increasingly strict environmental regulations and adopting more sustainable practices sustainable. Energy optimization becomes a critical factor to ensure the competitiveness and long-term viability of operations in Vaca Muerta.
In this context, Digital Twins, Generative Artificial Intelligence (IAGEN) and AI agents emerge as disruptive technologies with a significant potential to transform the way energy companies operate, monitor and manage their assets.

Digital Twins offer the ability to create virtual replicas of assets physical and processes, allowing real-time simulation and analysis to identify

areas for improvement and optimization.

On the other hand, Generative Artificial Intelligence, with its ability to generate models, analyze large volumes of unstructured data and optimize complex processes, presents new avenues for innovation and efficiency in the industry energy. The strategic combination of these two technologies has the potential to Unlock unprecedented levels of energy optimization in the Vaca region Dead, contributing to more efficient, safe and sustainable production.

II. **Digital Twins: A Virtual Model for Optimization in Vaca Muerta**

Digital Twin technology consists of creating a representation dynamic virtual replica of a physical asset, process, or system. This virtual replica is powered of real-time data from sensors in the physical world, allowing for a continuous monitoring of its performance, health status and environmental impact. The Key components of a Digital Twin include a network of sensors and IoT devices for data collection, connectivity platforms for data integration data, analytical capabilities for interpreting information and tools of modeling and simulation for behavior prediction.
In the oil and gas industry, Digital Twins offer a wide range of applications relevant to operations in Vaca Muerta.

One of them is the monitoring and management of asset and infrastructure integrity. critical, such as pipelines, production platforms and refineries. By providing a virtual copy of these assets, operators can monitor their status, detect early signs of failure and opportunities for improvement. This leads to the implementation of predictive maintenance strategies, which allows reducing costs associated with unplanned downtime and increase the uptime of the teams .

Simulation of reservoirs and processes using Digital Twins also facilitates production optimization. When creating virtual environments to test new

systems and refine operational workflows with minimal risk, businesses can maximize efficiency, increase productivity and reduce costs in all the stages of the oil and gas value chain.

Security is another area where Digital Twins bring significant value. ability to simulate risk scenarios and provide virtual training in a secure environment allows companies to improve security procedures and emergency preparedness.

In addition, Digital Twins play a crucial role in optimizing the energy consumption and resource management. By analyzing production patterns and consumption in virtual models, companies can identify inefficiencies, minimize waste and optimize energy use.

The implementation of Digital Twins has already proven to be successful in various case studies within the energy industry.

III. Generative Artificial Intelligence: Driving Optimization and Innovation in Dead Cow

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 content and original that is often indistinguishable from that created by humans. In the industry oil and gas, IAGEN presents enormous potential for optimization and innovation in Vaca Muerta.

Technological Synergy: The Integration of Digital Twins and IAGEN for a Advanced Optimization in Vaca Muerta

1. Prediction and optimization of energy consumption in real time

How does IAGEN help?

Uses large volumes of historical and current data (temperature, pressure, flow, pump usage, etc.) to generate predictive models and recommendations

customized solutions that optimize energy use in wells and treatment plants.

Role of the digital twin:
The digital twin of each well or plant receives this data, simulates scenarios and allows Validate recommendations before applying them in the real world, with adjustments automatic in real time.

2. Reengineering of extraction and compression processes

How does IAGEN help?
Analyze operational logs and generate optimized workflows, eliminating redundant or poorly synchronized steps that waste energy (e.g.,
frequent starts/stops of equipment).

Role of the digital twin:
Simulate new processes before their actual implementation, estimating savings energy and the efficiency achieved, and allows testing edge or failure conditions.

3. Predictive energy maintenance

How does IAGEN help?
Analyzes sensor logs and fault history and suggests interventions right away before the equipment becomes energy inefficient or deteriorates.

Role of the digital twin:
Simulates the behavior of equipment with different levels of wear and allows anticipate how it would affect their energy efficiency.

4. Evaluation and recommendation of carbon footprint reduction strategies

How does IAGEN help?
It automatically generates reports on the main sources of consumption and emissions at each stage (extraction, processing, transportation) and proposes mitigation or compensation measures (use of renewable energy, carbon capture, etc.).

Role of the digital twin:
Calculates the estimated impact of each strategy before its implementation, and allows virtually monitor the energy and decarbonization plan.

5. Identification of invisible energy leaks

- Activity: The entire chain (production, midstream, internal distribution)
- IAGEN + digital twin:
  - IAGEN analyzes historical data and generates hypotheses about non-financial losses. detected. For example, thermal leaks, miscalibrated valves and electrical losses.
  - The digital twin can test these hypotheses virtually without stopping the operation.

6. Additional use cases:

The combination of Digital Twins and Generative Artificial Intelligence represents a Powerful synergy that can unlock new frontiers in optimization energy in Vaca Muerte. The integration of these two technologies allows for a more advanced and holistic optimization of operations in the oil and gas industry gas.
One of the ways in which this synergy manifests itself is through the use of real-time data from Digital Twins to train and improve the IAGEN models. Digital Twins provide a constant stream of up-to-date information on the status and performance of assets and processes physicists. This information can be used by IAGEN's algorithms to learn and adapt to changing conditions in Vaca Muerta operations, which results in more accurate predictive models and more efficient optimization strategies

effective.

On the other hand, IAGEN can generate optimized operating scenarios that then can be simulated and evaluated within the virtual environment provided by Digital Twins. This allows companies to test different strategies and configurations with minimal risk, identifying the most efficient solutions for improve performance and reduce costs in Vaca Muerta.

The combination of both technologies also leads to predictive analysis. advanced fault detection and maintenance optimization. Digital Twins continuously monitor the status of the equipment, while IAGEN analyzes This data to predict with high accuracy when failures are likely to occur. This capability allows companies to schedule maintenance in a proactive, minimizing downtime and reducing costs associated with unplanned repairs.

Finally, IAGEN can analyze the large volumes of data collected by Digital Twins and generate useful information in real time for operators in Vaca Muerta. This facilitates faster and more informed decision-making, which leads to to greater efficiency and productivity in operations. The ability to achieve a closed-loop optimization, where data from the Digital Twin feeds the IAGEN model, which in turn generates recommendations to optimize the system physicist, exemplifies the power of this integration [9].

Area of Application	Focus of the Twin Digital	Focus of the Intelligence Artificial Generative	Benefits Synergistic
Management of the Integrity of	Monitoring in real time	Analysis of data of	ID early of

Assets	of the health of the infrastructure a, simulation of stress and wear.	sensors for detection of anomalies, prediction of possible faults.	possible issues, programming proactive of the maintenance or, useful life extended from the assets.
Optimization of the Production	Simulation of the behavior nt of the deposit, optimization of the rates and processes of extraction.	Generation of strategies optimal of drilling, analysis advanced of data of production.	Rates of recovery improved, productivity improved from the wells, assignment optimized from resources.
Maintenance or Predictive	Monitoring continuous of the performance of the teams, prediction of needs of maintenance	Generation of programs of maintenance or, diagnosis of failures of teams and guide of repair.	Prediction highly precise of faults, programs of maintenance either optimized, reduction of time of

	either.		inactivity and the costs of maintenance either.
Management of the Security and Risks	Simulation of scenarios of emergency, training virtual for procedure you of security.	Analysis of data operatives for the ID of dangers, generation of strategies of mitigation of risks.	Protocols of security improved capabilities response to emergencies improved, reduction of accidents and incidents.
Management of the Energy and Resources	Monitoring of the consumption of energy, simulation of strategies of saving of energy.	ID of patterns of waste of energy, optimization from the use of energy.	Consumption of energy reduced, minimization of waste, efficiency improved from the resources, contribution to the objectives of sustainability

			.
Optimization of the Chain Supply	Follow-up of the flow of materials and teams, simulation of scenarios logistics.	Prediction of interruptions s in the chain of supply, optimization of routes of transport.	Logistics improved, costs of transport reduced, availability timely of resources, minimization of interruptions s.

IV. AI Agents and Agentic Flows for Implementation

1. Concept of IAGEN agents

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 tasks high-demand cognitive skills. From this capacity, a new architecture emerges Technological: IAGen-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 around.

An IAGen agent combines large language models with components

additional features such as external tools, memory, planning and autonomous execution. This allows them to operate in complex environments, with the ability to break down objectives in steps, coordinate multiple actions, interact with digital systems (such as databases, APIs or documents) and adapt to changes in context in real time. These qualities distinguish them from traditional chatbots, and open up a spectrum 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 assume human resources, legal, financial or logistical tasks, and even those 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 your operations without losing quality or control.

In addition, agentic workflows—structures where multiple agents collaborate with each other to solve complex problems—allow responsibilities to be distributed between different agent profiles, each with specific functions. This generates Hybrid work environments where humans and agents coexist, optimizing times, costs, and results. The ability to connect agents with tools such as Google Drive, CRMs or document management platforms further expands its capabilities.

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

Among the benefits of authentic workflows driven by business models generative artificial intelligence, the possibility of automating processes is found complete, end-to-end production systems, and even add value from the leveraging the skills of language models based on these technologies.

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

2. Agent design proposal for energy optimization with twins digital

a. **Look what's happening**

The agent receives data from the well or plant: temperature, pressure, how much energy is using bombs, etc.

b. **Remember what happened before**

You also have access to historical data, for example, when the most energy was spent or when it was produced most efficiently.

c. **Imagine different possible scenarios**

It uses an “artificial brain” type model to ***generate*** different ways of operating (for example, example, changing the speed of a pump).

d. **Pretend before acting**

He asks the digital twin: “If I operate like this, do I use less energy?” The twin is like a virtual well or plant that simulates what would happen.

e. **Choose the best option and apply it**

When it finds the most efficient way, **it sends that instruction to the real system** (or suggests to the human operator that it be applied).

f. **Learn all the time**

If the decision was good, he learns from it. If not, he adjusts to do better next time.

3. Hypothetical example:

At a gas compression plant in Vaca Muerta, a digital twin integrated with IAGEN predicts energy consumption based on demand and adjusts operation to avoid overloads, resulting in an 18% saving in energy costs annual.

4. Detailed description of the phases, techniques and different strategies for Implement AI agents and agentic workflows powered by IAGEN in combination with digital twins.

1. AI Agent Workflow powered by IAGEN

a. Energy forecasting

- Uses generative models such as *LLM + Time Series Forecaster* to estimate the future consumption based on current variables. A "Time Series Forecaster" is a tool that uses data from the past to predict what will happen in the future future. For example: there is a record of how much energy was used each day in a plant. The "Time Series Forecaster" analyzes that data and tries to predict how much energy will be used tomorrow or next week. In the context of this report, it is used in conjunction with a "LLM" (Large Language Model) to estimate future energy consumption in different parts of a operation, such as a well, a pump, or a plant, based on the variables current.
- Creates reports of expected consumption by operating unit (well, pump, plant, etc.).

b. Generative optimization

This section addresses "Generative Optimization," a key system function that uses Generative Artificial Intelligence (GENI) to identify and propose optimal operating configurations. This includes optimizing flow rates, pump speed and frequency, and valve pressures, all with the goal of maximizing energy efficiency in Vaca Muerta's operations.

Generates optimal operating configurations for:

- Flow rates. Refers to the volume of fluid (whether oil, gas or water) that flows through a point in a given period of time. Flow optimization involves finding the right balance to maximize production without overloading the system or wasting energy. This may include adjusting the pumping speed or opening of valves to maintain a constant and efficient flow.
- Pump speed and frequency. The speed of a pump refers to to the speed at which the impeller rotates, while the frequency is related to the number of times the pump is turned on and off in a period. Optimizing these parameters involves finding the configuration that allows pumping the necessary fluid with the least possible energy consumption. This may include varying the speed of the pump on demand or program on/off cycles to avoid unnecessary power spikes.
- Valve pressures. Valves control the flow of fluids in a system when it opens or closes. In turn, the pressure at which they operate is crucial. Optimizing valve pressures involves adjusting the opening of the valves to maintain the desired pressure at different points in the system. This helps reduce or avoid pressure fluctuations that can damage equipment or reduce efficiency, and can also contribute to minimizing energy leaks and waste.

• Generates prompts to digital twin simulators to test each configuration.

The IAGEN model or an AI agent automatically creates "prompts" or specific instructions for the digital twin simulators. These "Prompts" are essentially questions or requests designed to test different operational configurations proposed by IAGEN. For example, the IAGEN could generate a prompt that says: "simulate the impact on consumption energy if we increase the flow rate of pump X by 15% and reduce the

Y valve pressure by 10%". The digital twin then executes this simulation, providing data on the resulting energy consumption, the efficiency and other relevant factors.

In the context of Vaca Muerta, this could mean that IAGEN analyzes data historical and current data of an oil well and generates a prompt for the twin digital that simulates how it would affect energy production and consumption change the pumping speed at certain times of the day. The digital twin, which It is a virtual replica of the well, runs this simulation and provides detailed results, allowing operators to evaluate whether the proposed configuration is viable and efficient before implementing it in the real world.

c. Automatic simulation

After the "Generative Optimization" phase where IAGEN proposes configurations operational, "Automatic Simulation" is activated as a validation mechanism crucial. This stage uses the digital twin to virtually test the proposed scenarios, focusing on the evaluation of energy performance without the need for physical interventions in the real system.

Description of the scenarios:

Scenario transfer to the digital twin: IAGEN sends to the digital twin multiple alternative configurations, each with specific settings on variables operational. The digital twin, acting as an isolated test environment, simulates the system behavior under each of these configurations.

Comparative analysis of energy results: The digital twin processes each scenario, generating detailed data on energy consumption and efficiency.

These results are analyzed comparatively to identify the configuration that offers the best balance between efficiency and performance.

Selection and recommendation of the optimal configuration: Once the simulations are complete, the system selects the configuration that has demonstrated the best energy performance. This optimal configuration is presented as the recommendation for implementation in the real system, based on the virtual validation performed.

d. Real-time decision-making and adjustments

It is key to develop and implement the integrated Digital Twin system capability and Generative Artificial Intelligence (IAGEN) to react dynamically to variations in operating conditions. For example, variations such as weather, pressure and demand, update the operational plan. Here, real-time information collected by sensors and the Digital Twin, so that IAGEN or an AI agent can automatically adjust the parameters operating to maintain energy efficiency. Hypothetical scenario: if there is a change sudden change in demand for gas or oil, the system can modify the speed of the pumps or valve pressure to optimize energy consumption. In addition, the agent AI can suggest adjustments to the human operator, providing an additional layer of control and supervision. This ensures that operations at Vaca Muerta continually adapt to changing conditions, maximizing efficiency and minimizing waste energy.

Continuous learning

The Digital Twins and Generative Artificial Intelligence (IAGEN) system also should incorporate dynamic learning and continuous improvement. This learning process continuous is essential to maintain the efficiency and adaptability of the system over the long term term. Adjustments to the models can be made weekly or monthly, considering the following factors:

- Deviations between prediction and reality":
    - The AI agent or IAGEN constantly compares the predictions of energy consumption and performance with the real data observed in the operations. If there are significant differences between the predicted and actual results, the system adjusts its models to reduce these deviations in the future. For example, If the model underestimated energy consumption by 10% in the last week, will be recalibrated to account for this error and improve accuracy in the upcoming predictions.
- Feedback from the real system or the digital twin:

- The system receives feedback from both the real system (through the sensors and operational data) and the digital twin (through the simulations and tests). This feedback includes information about the actual performance of the implemented configurations, the observed efficiency and any problems or anomalies detected. The system uses this information to adjust their models and improve their prediction and optimization capabilities. For example, if the digital twin detects a spike in energy consumption, it will not predicted during a simulation, this information is used to refine the model and avoid similar situations in the future.

- New configurations that emerged spontaneously:
  - Sometimes, human operators or the recommendations of the operators themselves AI agents can implement new or unintended operational configurations. planned. These configurations can arise as a response to situations unforeseen or as a result of experimentation and the search for improvements. The system records these new configurations and analyzes their impact on the energy efficiency. If a new configuration proves to be more efficient than the previous ones, the system incorporates it into its models and considers it in future recommendations. For example, if an operator manually adjusts the speed of a pump and observes a significant improvement in efficiency, this new settings are recorded and used to tune the model optimization.

5. Concrete examples of software and systems with necessary integrations

System	**Function**
SCADA / IoT	Real-time data entry real

Historian / DWH	Historical data for training
Digital twin platform (e.g. Siemens, Cognite, AspenTech)	Scenario simulation
Recommendation Engine / Control API	Applying settings suggested
Visualization platform (e.g. Grafana, Power BI, Custom Panel)	Show insights and decisions

V. Challenges and Opportunities for Implementation in Vaca Muerta

Challenges

The implementation of Digital Twins, IAGEN, and AI agents in Vaca Muerta presents significant challenges and opportunities. In the technical field, the integration of These technologies with existing infrastructure and legacy systems can be complex .

The management and quality of the large volumes of data generated also represent a significant challenge, requiring specialized expertise.

Cybersecurity and the protection of sensitive information are crucial, given the interconnection of virtual and physical systems.

In addition, the scalability of technological solutions to cover all the operations in Vaca Muerta is an aspect that must be carefully considered. From an economic perspective, the high initial investment costs in hardware,

software and infrastructure can be a barrier to adoption. Therefore, it is
It is essential that companies can demonstrate a clear return on investment and
tangible to justify these expenses.

Regarding regulatory and talent challenges, the specific regulatory framework in
Argentina for the adoption of Digital Twins and IAGEN in the oil and gas industry
gas is still in a very embryonic stage, which can be a barrier to
additional adoption . The level of complexity we see suggests the participation of
companies or laboratories specialized in this type of developments, which reduce the
initial learning cost.

Likewise, the availability of human talent with specialized skills in
data science, artificial intelligence and digital technologies applied to the sector
energy is a critical factor for the success of the implementation.

Opportunities

Despite these challenges, the opportunities offered by Digital Twins and
IAGEN for energy optimization in Vaca Muerta are considerable.

These technologies have the potential to generate a significant increase in
operational efficiency and productivity.

Reducing operating and maintenance costs through maintenance
predictive and process optimization, is another key benefit.

Improving safety and reducing operational risks are also aspects
fundamental areas where these technologies can add value.

Finally, the implementation of Digital Twins combined with IAGEN and agents
AI can contribute to sustainability and reducing the carbon footprint of
operations in Vaca Muerta, aligning with the growing environmental demands and
regulatory .

VI. Strategic Recommendations and Conclusions

For operating companies in Vaca Muerta that wish to address the implementation

of Digital Twins and IAGEN for energy optimization, it is recommended
focus on pilot projects to demonstrate value and develop internal expertise.

It is crucial to establish robust data governance frameworks to ensure the quality and
security of information. Investing in training and improvement programs
skills for existing staff is essential to overcome the talent gap.

Before large-scale implementation, clear objectives must be defined and identified
specific use cases. Fostering collaboration between information technology (IT) and
operational technology (OT) teams is critical for effective integration.
successful.

It is suggested to adopt a phased implementation approach, starting with
high-value applications.

Finally, collaborate with technology providers and partners with relevant experience
can facilitate the adoption process.

It is recommended to analyze the possibility of investing, in the short term, in equipment
implementation of AI agents in technology and training.

Investment in proof of concept and pilot testing is required. The focus here is on
be the training of talent to implement, since a trend is verified
cost reduction in systems that enable “no code” and “low code” automation.
For the first stage, it is also recommended to use teams with experience in
design and implementation of AI agents. Finally, it is key to form an “in” team
house” for the accompaniment and appropriation of an agentic culture that redefines
human-machine interaction.

For the Argentine government and regulatory bodies, it is recommended to develop
clear regulatory guidelines for the use of Digital Twins and AI in operations
of oil and gas can foster investment and innovation. Promoting programs
educational programs to develop talent in data science, AI and digital technologies
relevant to the energy sector is a long-term measure that can ensure the
success of digital transformation.

In conclusion, the strategic implementation of Digital Twins and Intelligence Generative Artificial Intelligence and AI agents in Vaca Muerta offer transformative potential significant for energy optimization. Key benefits include gains substantial improvements in operational efficiency and productivity, a considerable reduction in operating and maintenance costs , a notable improvement in safety and reduction of operational risks, an importantcontribution to sustainability and reduction of carbon footprint, and improved decision-making capabilities and strategic planning.

Despite the challenges, the synergy between these technologies presents an opportunity unique to drive efficiency, safety and sustainability in the industry oil and gas in the Vaca Muerta region.

Sources cited

1. Argentina oil and gas | Deloitte Insights, accessed March 4, 2025, https://www2.deloitte.com/us/en/insights/economy/americas/vaca-muerta-argentina-energy-sector-boom.html

2. An Overview of Recent Developments and Understandings of Unconventionals in the Vaca Muerta Formation, Argentina - MDPI, accessed: March 4, 2025, https://www.mdpi.com/2076-3417/14/4/1366

3. Unlocking the Potential of Digital Twins in Oil & Gas: A Leap..., accessed: March 4, 2025, https://energiesmedia.com/unlocking-the-potential-of-digital-twins-in-oil-gas-a-leap-forward-in-optimization-and-efficiency/

4. Efficient use of energy in oil and gas upstream facilities | IOGP Publications library, access: March 4, 2025, https://www.iogp.org/bookstore/product/efficient-use-of-energy-in-oil-and-gas-upstream-facilities/

5. Digital Twins in Oil and Gas, access: March 4, 2025, https://www.futureoilgas.com/news/digital-twins-oil-and-gas

6. AWS Energy & Utilities Generative AI, accessed: March 4, 2025, https://aws.amazon.com/energy-utilities/generative-ai/

7. Generative AI is poised to reshape the global energy landscape - SLB, accessed: March 4, 2025, https://www.slb.com/resource-library/insights-articles/generative-ai-is-poised-to-reshape-the-global-energy-landscape

8. Digital Twins in the Energy Industry: Transforming Operations in North America, access: March 4, 2025, https://www.vistaprojects.com/digital-twins-in-the-energy-industry-transforming-operations-in-north-america/

9. Oil and Gas Digital Twin Technology and Generative AI - Safety Services Company, access: March 4, 2025, https://www.safetyservicescompany.com/blog/oil-and-gas-digital-twins-ai/

10. 10 Applications of Digital Twins in the Oil and Gas Industry - RemSense, access: March 4, 2025, https://remsense.com.au/10-applications-of-digital-twins-in-the-oil-and-gas-industry

11. Digital Twin for Oil and Gas - Future-proof with VEERUM, accessed: March 4, 2025, https://veerum.com/industrial-digital-twin-software/oil-and-gas/

12. Digital Twin for the Oil & Gas Industry - IBM, accessed: March 4, 2025, https://www.ibm.com/think/topics/digital-twin-for-oil-gas

13. Digital Twin in Oil and Gas Industry: Benefits, Use Cases and Challenges - Toobler, Accessed: March 4, 2025, https://www.toobler.com/blog/digital-twin-oil-and-gas

14. Digital Twin in Oil and Gas: Benefits and Use Cases - Appinventiv, accessed: March 4, 2025, https://appinventiv.com/blog/digital-twin-in-oil-and-gas/

15. Digital Twin in the Energy Sector: Benefits, Use Cases, and Examples - Appinventiv, Accessed: March 10, 2025, https://appinventiv.com/blog/digital-twin-in-energy-sector/

16. Digital Twins in Energy Industry: Use Cases and Challenges Explained - Toobler, Accessed: March 10, 2025, https://www.toobler.com/blog/digital-twins-in-energy

17. Oil and Gas Industry Digital Twin Case Study | Prevu3D, accessed: March 10, 2025, https://www.prevu3d.com/digital-twin-case-studies/oil-gas/

18. Kongsberg To Build Digital Twin for Shell's Nyhamna Gas Facility - JPT, access: March 10, 2025, https://jpt.spe.org/kongsberg-build-digital-twin-shells-nyhamna-gas-facility

19. Digital Trends Disrupting the Oil and Gas Sector | Shale Magazine, accessed: March 10, 2025, https://shalemag.com/digital-trends-oil-and-gas/

20. Digital Twins in the Energy Industry: Transforming Operations in North America - EnergyNow.com, access: March 10, 2025, https://energynow.com/2024/12/digital-twins-in-the-energy-industry-transforming-operations-in-north-america/

21. The Future of Oil & Gas: AI-Powered Exploration & Production - DTskill, access: March 10, 2025, https://dtskill.com/blog/generative-ai-in-oil-and-gas/

22. www.alpha-sense.com, access: March 10, 2025, https://www.alpha-sense.com/blog/trends/generative-ai-in-energy/#:~:text=Generative%20AI%20can%20be%20used,about%20drilling%20and%20production%20strategies.

23. Generative AI in Energy: Use Cases, Risks, and Future Outlook - AlphaSense, access: March 10, 2025, https://www.alpha-sense.com/blog/trends/generative-ai-in-energy/

24. Generative AI for Oil and Gas | Enhanced Efficiency | 7P - 7Puentes, access: March 10, 2025, https://www.7puentes.com/generative-ai-for-oil-and-gas/

25. Generative AI in Oil and Gas: Optimize Production, Safety, and Sustainability | SoftServe, access: March 10, 2025, https://www.softserveinc.com/en-us/generative-ai/energy

26. AI in Oil and Gas: Future Trends & Use Cases - Moon Technolabs, accessed: March 10, 2025, https://www.moontechnolabs.com/blog/ai-in-oil-and-gas/

27. How Generative AI Can Fuel Oil and Gas Data Analytics | Publicis Sapient, access: March 10, 2025, https://www.publicissapient.com/insights/maintenance-co-pilot

28. Guide to Gen AI for Predictive Maintenance - Encora, accessed: March 10, 2025, https://insights.encora.com/insights/guide-to-gen-ai-for-predictive-maintenance

29. Generative AI for Oil & Gas: Using Data Agent for Enhanced Data Search | by Alexandra Khomenok | Tovie AI | Medium, accessed: March 18, 2025, https://medium.com/tovieai/generative-ai-for-oil-gas-using-data-agent-for-enhanced-dat

a-search-2d500f5cddbb

30. Oil & Gas: the Future with Generative AI - - Datategy, accessed: March 18, 2025, https://www.dacategy.net/2024/01/05/oil-gas-the-future-with-generative-ai/

31. Top Generative AI Use Cases by Industry - InData Labs, accessed: March 18, 2025, https://indatalabs.com/blog/generative-ai-use-cases-by-industry

32. Point of View: The Impact of Generative AI on the Oil and Energy Sector - Prioriti AI, access: March 18, 2025, http://prioriti.ai/point-of-view/point-of-view-the-impact-of-generative-ai-on-the-oil-and-en energy-sector/

33. The oil industry adopts generative AI to optimize its operations - energynews, access: March 18, 2025, https://energynews.pro/en/the-oil-industry-adopts-generative-ai-to-optimize-its-operatio ns/

34. Optimizing Oil & Gas Production: Innovative Strategies for Maximizing Efficiency - Signicent, accessed March 18, 2025, https://signicent.com/optimizing-oil-gas-production/

35. Digital Transformation Market in Oil and Gas to Grow by USD 56.4 Billion from 2025-2029, Fueled by Investments and Partnerships, with AI Driving Market Evolution - Technavio - PR Newswire, access: March 18, 2025, https://www.prnewswire.com/news-releases/digital-transformation-market-in-oil-and-ga s-to-grow-by-usd-56-4-billion-from-2025-2029--fueled-by-investments-and-partnerships- with-ai-driving-market-evolution---technavio-302371299.html

36. Powering the Future: How Digital Twins Are Revolutionizing the Energy Sector - Cigniti, access: March 18, 2025, https://www.cigniti.com/blog/energy-sector-innovation-digital-twins/

37. Digital Twin Implementation - Challenges & Practices - Toobler, accessed: March 18, 2025, https://www.toobler.com/blog/challenges-in-digital-twin-implementation

38. What Market Data Says About the Oil and Energy Industry | TalentNeuron Blog, access: March 18, 2025, https://www.talentneuron.com/blog/what-market-data-says-about-the-oil-and-energy-in dustry

39. Cybersecurity challenges of digital twins: threats and security measures | INCIBE-CERT, access: March 18, 2025, https://www.incibe.es/en/incibe-cert/blog/cybersecurity-challenges-digital-twins-threats-and-security-measures

40. Quality assurance of digital twins - DNV, accessed: March 18, 2025, https://www.dnv.com/oilgas/digital-twins/

41. Argentina Moves to Boost Renewable Energy Market with New Regulations, access: March 18, 2025, https://www.netzerocircle.org/news/argentina-moves-to-boost-renewable-energy-market-with-new-regulations

42. Argentina introduces new regulatory framework for stringent crypto oversight - CryptoSlate, access: March 18, 2025, https://cryptoslate.com/argentina-introduces-new-regulatory-framework-for-stringent-crypto-oversight/

43. Renewable energy in Argentina: a utopia for the global south? | EnergyTransition.org, access: March 18, 2025, https://energytransition.org/2024/12/renewable-energy-in-argentina-a-utopia-for-the-global-south/

44. Oil And Gas Industry Overview: Three Key Trends to Watch in 2025 - Lathrop GPM, access: March 22, 2025, https://www.lathropgpm.com/insights/oil-and-gas-industry-overview-three-key-trends-to-watch-in-2025/

45. Top 8 Oil and Gas Industry Technology Trends for 2025 - Kissflow, accessed: March 22, 2025, https://kissflow.com/solutions/oil-and-gas/oil-and-gas-technology-trends/

46. Digital twins in the energy sector: transforming hype into action - Faculty AI, access: March 22, 2025, https://faculty.ai/insights/articles/digital-twins-in-the-energy-sector-transforming-hype-into-action

47. Digital transformation in oil and gas companies - Deloitte, accessed: March 22, 2025, https://www2.deloitte.com/us/en/pages/consulting/articles/digital-transformation-in-oi

l-and-gas.html

48. Accelerating Success in Oil and Gas Industry with Digital Twins - Wipro, access: March 22, 2025, https://www.wipro.com/engineering/industry-4-0-digital-twins-accelerate-oil-and-gas-success-4-steps-to-maximize-benefits/

49. Efficiency Technologies in Oil and Gas Industry Reduces Energy Use - The Pew Charitable Trusts, access: March 22, 2025, https://www.pewtrusts.org/~/media/assets/2014/08/chpefficiencyoil.pdf

50. Energy transition in Argentina: Challenges and opportunities on the road to a sustainable future - BBVA CIB, access: March 22, 2025, https://www.bbvacib.com/insights/news/energy-transition-in-argentina-challenges-and-opportunities-on-the-road-to-a-sustainable-future/

51. Decreasing costs of renewables – Analysis of energy sector planning and climate policy in Argentina - Fraunhofer ISI, accessed: March 22, 2025, https://www.isi.fraunhofer.de/content/dam/isi/dokumente/ccx/NDCUpdate/Impact-of-Cost-Progressions-on-Argentinas-NDC-Governance-Report-1.pdf