HUB TECH IA

Deliverable report 41

AI and IAGEN Application Use Case

Predictive Asset Maintenance with AI for optimization and prediction of equipment failures by analyzing operational data in real time

I. Introduction

This report delves into the transformative application of computer vision and generative artificial intelligence (CVI) in the energy sector, with a particular focus on its potential within Vaca Muerta, Neuquén, Argentina. The analysis reveals that the adoption of these cutting-edge technologies offers substantial benefits, including increased operational efficiency, improved safety protocols, and significant cost reductions.

Machine vision enables real-time monitoring and predictive maintenance of energy infrastructure, while IAGEN facilitates advanced reservoir simulation, production optimization, and the discovery of new resources.

Despite the technical, regulatory, and skills challenges that accompany its implementation, the future for the integration of artificial intelligence into the Vaca Muerta energy sector looks promising, heralding an era of increased productivity and sustainability.

Strategic recommendations are presented for energy companies operating in the region, emphasizing the importance of data quality, skills development, and strategic collaboration to unlock the full potential of these technologies.

1. **The Convergence of AI and Energy Production.**

The Growing Importance of AI in the Energy Sector: The energy sector has embraced artificial intelligence (AI) as a fundamental tool for improving productivity and decision-making, with companies of all sizes investing significant resources in the development and implementation of AI tools.

There is growing industry confidence in AI's ability to generate significant impact across various areas of the energy value chain.

2. **The Specific Relevance of Computer Vision and Generative Artificial Intelligence .**

Generative Artificial Intelligence (GENI) is a branch of artificial intelligence that focuses on creating 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.

Within the broad field of AI, computer vision and generative artificial intelligence (GENAI) stand out for their unique capabilities in addressing specific challenges in energy production.

Machine vision, which uses deep learning algorithms to analyze visual input from cameras and sensors, enables real-time insights and the automation of complex processes. This technology has proven its worth in many important areas, from improving safety and compliance to optimizing asset management and maintenance.

On the other hand, AIGEN refers to AI systems that can create new data, models, or insights based on existing information to improve decision-making, efficiency, and innovation. With the ability to generate new content, code, and even understand and respond to complex queries in a human-like manner, AIGEN presents significant potential to transform the way energy is discovered, accessed, and produced. These two branches of AI, while distinct in their approach, offer complementary capabilities that can be applied to address a wide range of challenges within the energy sector.

3. Focus on Vaca Muerta, Neuquén, Argentina:

Vaca Muerta, located in Neuquén Province, Argentina, represents one of the world's largest unconventional oil and gas reserves. The development of this vast resource has the potential to redefine Argentina's role in the global energy market, positioning the country to become a key exporter. In fact, Vaca Muerta's oil and gas production is expected to grow steadily through 2030, driven by large projected investments and supportive government policies.

Given the scale and strategic importance of Vaca Muerta to the Argentine economy, optimizing its production processes is crucial. The application of advanced technologies such as machine vision and AIGEN presents a significant opportunity to maximize resource extraction, improve operational efficiency, and ensure safety and sustainability in this key region.

II . The Role of Machine Vision in Energy Production

1. Machine Vision Technology Overview:

Computer vision technology leverages deep learning algorithms to interpret and analyze visual data captured by cameras and sensors. This capability goes beyond simple image recognition, allowing computers to "see" and interpret the visual world in a way that mimics human vision.

In the context of energy production, machine vision can process large amounts of visual data in real time, providing valuable insights and automating complex processes that would traditionally require human inspection.

This automation not only increases efficiency but also improves accuracy and consistency in various operational tasks.

2. Specific Use Cases in the Oil and Gas Industry (Global):

- **Improved Safety and Compliance:** Machine vision plays a critical role in improving safety and compliance within the oil and gas industry. Machine vision systems can automatically monitor “red zones” to detect unauthorized personnel

entering heavy machinery, significantly reducing the risk of accidents. Additionally, AI-powered cameras can verify that workers are wearing the appropriate personal protective equipment (PPE), significantly improving safety standards. This continuous, automated monitoring ensures compliance with safety protocols and minimizes the potential for human error in hazardous environments.

- **Improved Asset Management and Maintenance:** Machine vision is revolutionizing asset management and maintenance in the oil and gas industry. Unmanned aerial vehicles (drones) equipped with high-resolution cameras and machine vision algorithms can identify early signs of corrosion in pipelines and structures, enabling proactive maintenance before problems become serious. By analyzing visual data from equipment over time, machine vision systems can also predict potential failures before they occur, minimizing costly downtime. Additionally, machine vision is used to inspect drilling rigs and subsea pipelines for defects such as misalignment and corrosion, as well as to monitor storage tanks for signs of corrosion or fatigue.
- **Optimized Production and Operations:** Machine vision enables real-time monitoring of production processes in the oil and gas industry, providing accurate data on flow rates, pressure, and other critical parameters. This technology can also automatically read and digitize data from legacy analog instruments, integrating older equipment into modern digital systems. On drilling rigs, machine vision systems can monitor the proper closure of mast latches, improving safety and efficiency in drilling operations. By analyzing complex operations, machine vision-powered systems can identify bottlenecks and suggest improvements to increase overall efficiency.
- **Enhanced Exploration and Environmental Protection:** Machine vision is playing an increasingly important role in enhancing exploration and environmental protection within the oil and gas industry. By analyzing aerial and satellite imagery, machine vision can identify geological features for exploration, improving the efficiency of prospecting activities. Advanced imaging techniques

combined with AI can detect even tiny leaks in pipelines or storage facilities, preventing environmental damage. Furthermore, machine vision and machine learning can better identify and quantify oil spills and methane emissions into the air, enabling more timely and appropriate responses.

3. Potential Applications of Artificial Vision in Renewable Energy Production Processes:

While the application of machine vision is often highlighted in the context of oil and gas, its potential to improve renewable energy production processes is equally significant. For example, machine vision can be used to inspect wind turbine blades for damage, monitor the condition of solar panels for defects or dirt, and inspect power lines and substations for anomalies. These applications can lead to more efficient maintenance, increased reliability, and reduced downtime at renewable energy facilities.

III . Generative Artificial Intelligence in Energy Production

1. **Understanding Generative Artificial Intelligence (GENAI):**

   Generative artificial intelligence (GENA) encompasses AI models that can generate new data, models, or insights by learning patterns in the data they are trained on. These models, which include large language models (LLMs) like ChatGPT, have the ability to create new content, such as text, videos, images, and audio. In the context of energy production, GENA offers a paradigm shift from analysis and prediction to creation and innovation, enabling the generation of new ideas, code, and solutions to complex challenges within the industry.

2. **Applications of Generative Artificial Intelligence in the Oil and Gas Sector:**
   - **Enhanced Reservoir Simulation:** IAGEN has the potential to significantly improve the efficiency and accuracy of reservoir management in the oil and gas industry. By analyzing large amounts of geological data, seismic surveys, and historical production data, IAGEN can create accurate models of underground reservoirs. These models can simulate reservoir behavior under various conditions, helping

operators optimize drilling strategies, well locations, and production schedules. Furthermore, IAGEN can generate multiple scenarios based on different variables, such as oil prices and drilling techniques, allowing for a more thorough evaluation of potential development strategies. IAGEN can also enhance images to create detailed 3D models and generate subsurface images with limited seismic data, addressing upstream data acquisition challenges.

- **Predictive Maintenance Optimization:** AIGEN can play a crucial role in optimizing predictive maintenance strategies in the oil and gas sector. By generating new data and improving simulations, AIGEN can increase the predictive capabilities of operating assets. It can also analyze historical maintenance records and real-time operational data to predict equipment failures before they occur.
- **New Oilfield Exploration:** IAGEN has the potential to revolutionize the exploration process for new oil and gas fields. By enhancing subsurface images with limited seismic data and analyzing vast amounts of geospatial data, IAGEN can help identify promising exploration areas. It can also generate multiple geological structures to improve the interpretation of seismic data, allowing companies to make more informed drilling decisions. By processing large amounts of data, uncovering patterns, and creating simulations, IAGEN can help find new oil and gas deposits and offer the most rewarding exploration activities.
- **Other Potential Applications:** In addition to the areas mentioned above, IAGEN has a wide range of other potential applications in the oil and gas sector. These include using Enterprise Chat (GPT) for business leaders to access crucial information from unstructured data, optimizing drilling processes, improving safety protocols, streamlining logistics, drafting legal documents and analyzing contracts, generating code for programmable logic controllers, and creating synthetic data to train AI models.

IV. Opportunities to Leverage Generative Artificial Intelligence to Optimize Operations and Drive Innovation in Vaca Muerta:

Generative artificial intelligence (GENA) presents numerous opportunities to optimize

operations and drive innovation within the Vaca Muerta region. Given the complexity of the region's geological formations, GENA can significantly improve reservoir simulation. It also has the potential to optimize drilling parameters and completion designs based on historical data and real-time sensor information. Furthermore, GENA can be used for predictive maintenance in the harsh operating conditions and remote locations characteristic of Vaca Muerta. GENA's ability to analyze large data sets and generate insights can be particularly valuable in optimizing the complex and challenging operations associated with unconventional resource extraction in this key region.

IV. AI Agents and Agentic Workflows. The Evolution of Generative AI.

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

The agentic flow for the implementation of artificial vision in production processes is described in the following phases:

Image and Data Capture

High-resolution sensors and cameras capture real-time images of the infrastructure under inspection.

Image Analysis and Processing

The images are processed by machine vision algorithms, which identify and classify defects according to predefined criteria.

Generation of Alerts and Decisions

IAGEN systems generate automatic alerts that are sent to operators so they can make informed decisions about the need for intervention.

Implementation of Preventive Maintenance

Based on the alerts generated, preventive maintenance interventions are scheduled, reducing the possibility of unexpected failures and improving operational efficiency.

V. Benefits of Implementing Artificial Vision and Generative Artificial Intelligence

1. Quantifiable Benefits:

- **Increased Operational Efficiency:** AI adoption in the oil and gas industry has the potential to create a paradigm shift with cost savings of 10-20% by 2025. Predictive maintenance, enabled by AI, can reduce unplanned downtime by 20% and maintenance costs by 15% . In the renewable energy sector, AI-powered predictive maintenance can decrease water utilities' operating costs by 25%. This data suggests that AI, including computer vision and generative AI, can lead to significant improvements in operational efficiency and substantial cost savings through optimized processes and reduced downtime.
- **Cost Reduction:** AI can contribute to cost reduction in the energy sector in several ways. In the area of energy efficiency, AI has the potential to reduce energy consumption in buildings by up to 25%.

- **Enhanced Safety:** AI plays a crucial role in improving safety within the oil and gas industry. According to research, AI can help identify and predict potential safety incidents up to 80% earlier than traditional methods. Computer vision, in particular, improves safety management by analyzing operational data and ensuring compliance with safety regulations. AI-powered systems can predict industrial problems, enabling proactive repairs that reduce accidents. These capabilities highlight the potential of AI to create safer working environments and protect the environment.
- **Reduced Downtime:** Predictive maintenance, enabled by AI, has a significant impact on reducing downtime in the energy sector.

2. Potential for Improved Decision-Making and Optimized Resource Management:

AI offers the ability to provide data-driven projections and enables faster, more informed decision-making in the oil and gas industry. Generative AI can optimize resource extraction and management through AI-driven insights. Furthermore, AI facilitates better resource allocation and waste reduction. By analyzing large amounts of data and identifying patterns, AI enables energy companies to make more strategic decisions and optimize resource allocation, leading to improved overall performance.

VI . Challenges and Considerations for Implementing AI in Vaca Muerta

1. **Technical Challenges**
   - **Data Quality and Integration:** Successful AI implementation in Vaca Muerta relies heavily on the availability of large amounts of high-quality data. However, the oil and gas industry often faces inconsistent data quality and accuracy. Furthermore, integrating AI solutions with legacy systems and siloed data represents a significant technical challenge. Overcoming these obstacles requires robust data management strategies and solutions that enable seamless integration across diverse platforms.
   - **Infrastructure Limitations:** The deployment of AI technologies in Vaca Muerta could be limited by a potential shortage of computing centers and the need for

improved data management. Securing suitable locations with sufficient power availability for AI infrastructure is also a critical consideration. While connectivity issues are improving with the expansion of 5G and satellite technology, the availability of robust computing and power infrastructure remains essential to support the energy-intensive nature of AI applications.

- **Specific Challenges at Vaca Muerta:** Operations at Vaca Muerta present unique technical challenges, including challenging subsurface conditions such as high pore pressures/fracture gradients, casing collapse incidents, and fluid losses. Lithological severity has also exceeded initial projections. These specific challenges may require customized AI solutions and careful consideration during the implementation process to ensure the accuracy and effectiveness of the AI models.

2. **Regulatory Overview:**

Argentina is actively promoting the use of AI, emphasizing the need for a framework that encourages its application without incurring excessive regulation. While several AI-related bills are being discussed, a common regulatory vision does not yet exist. The current focus is on incorporating ethical principles, transparency, and data protection in the use of AI. Argentina's Personal Data Protection Law (PDPL) aligns with international standards. In the context of computer vision, regulations exist for the use of drones for both hobbyist and commercial purposes. Importantly, there is currently no specific, binding regulation on AI in Argentina. This evolving regulatory landscape presents both opportunities and uncertainties for the energy sector in Vaca Muerta, requiring companies to stay informed and prioritize ethical considerations and data privacy.

3. Workforce Skills and Training Gap:

Argentina faces a shortage of skilled labor in the field of AI . To successfully implement AI solutions in Vaca Muerta, it is crucial to invest in training existing personnel to operate these tools effectively. Training programs should cover specific technical aspects of AI tools, knowledge of oil and gas processes, cybersecurity

awareness, and data quality management protocols. However, AI also has the potential to help bridge the skills gap in the energy sector by democratizing knowledge and facilitating learning.

4. Economic and Investment Considerations:

Adopting AI technologies in Vaca Muerta requires a significant initial investment, as well as ongoing investments in research and development. Substantial investments are also needed to upgrade existing technologies and improve data management practices. Attracting investment capital for Vaca Muerta's development remains a challenge. The economic viability of AI implementation will depend on balancing potential benefits with investment costs, which requires a clear understanding of the return on investment in the specific context of Vaca Muerta.

5. Occupational Safety and Automation Regulations:

Argentina has established regulations regarding workplace safety. The implementation of AI-powered automation in Vaca Muerta must take these regulations into account and address potential concerns about worker displacement. It is essential to strike a balance between automation and human oversight, while also considering the ethical implications of AI in the workplace.

6. Short-term investment in AI agent implementation teams, technology and training

Investment in proofs of concept and pilot testing is required. The focus here must be on developing the talent needed to implement the solution, 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 the design and implementation of AI agents. Finally, it is key to form an in-house team to support and foster an agentic culture that redefines human-machine interaction.

VII . Recommendations and Future Perspectives

1. **Strategic Recommendations for Energy Companies in Vaca Muerta:** To fully leverage the benefits of computer vision and generative artificial intelligence (CGI) in Vaca Muerta, energy companies must prioritize data quality and establish robust data management strategies. Investing in AI skills development through training programs and strategic collaborations is crucial. Starting with pilot projects in key areas is recommended to demonstrate the value of these technologies. Developing a clear AI strategy aligned with business objectives and regulatory considerations is critical, fostering collaboration between IT, operations, and subject matter expert teams for successful implementation. Considering cloud-based solutions can offer scalability and flexibility. Implementing robust cybersecurity measures is essential to protect sensitive operational data. Finally, engaging with regulatory bodies is crucial to stay informed about the AI landscape in Argentina.

2. Discussion of Future Trends and the Evolutionary Role of AI:

Continued growth in AI adoption is expected in the oil and gas industry . There will be an increasing focus on predictive and prescriptive maintenance , as well as greater integration of AI with the Internet of Things (IoT), edge computing, and digital twins . Autonomous operations and human-machine collaboration will be key trends . AI will play an increasingly important role in driving sustainability and reducing the environmental footprint . AIGEN is anticipated to evolve to create new solutions and optimize complex processes . The use of drones and robots for automated inspections will also become more widespread .

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