Deliverable report 54

AI and IAGEN Application Use Case

AI for optimizing water use in hydraulic fracturing in Dead Cow

I. Introduction

The Vaca Muerta formation in Neuquén is one of the shale oil and shale reservoirs the largest gas reserves in the world, whose exploitation is through hydraulic fracturing drives Argentina's energy development. This process is highly intensive in water use: each well requires injecting millions of liters of mixed water with sand and additives to release the hydrocarbons trapped in the rock. In fact, estimates that a single unconventional well typically requires on the order of *3 to 8 millions of gallons of water* (approx. 11 to 30 million liters) throughout its cycle billing. In Vaca Muerta, various local sources point to similar ranges or even higher consumption; for example, between *9 and 29 million* have been reported *liters of water per fractured well.*

This enormous demand for water, in a province with semi-arid conditions, imposes great pressure on local resources. Therefore, optimizing the use of Water in hydraulic fracturing operations is essential both for guarantee the environmental sustainability of the region as well as to ensure the continuity and economic efficiency of the development of Vaca Muerta.

II. Problem, challenge or opportunity

The large scale of water use in hydraulic fracturing entails multiple impacts and challenges. In environmental terms, extracting tens of thousands of meters cubic meters of fresh water for each well can affect local watersheds and compete with other uses, especially in dry seasons.

Furthermore, after the fracturing operation, a large portion of this volume returns to the surface as flowback fluid , which contains salts and chemicals; this wastewater must be treated or disposed of properly to avoid contamination.
of soils and aquifers, in compliance with strict environmental standards.

From an economic perspective, water represents a significant operating cost.
in unconventional developments. Their acquisition, transportation, and subsequent disposal constitute a substantial part of the cost per well over its useful life. In Vaca Muerta, this factor also becomes more relevant as activity intensifies. Intensive and inefficient use not only increases the cost of operations (due to the fuel, personnel, and infrastructure required to move millions of liters),
but also generates waste of a valuable resource.

In this context, optimizing water consumption – reducing untreated volumes sacrificing well productivity – presents itself as both an urgent challenge as an opportunity for substantial improvement in terms of sustainability and cost reduction for the industry.

III. Application of AI in the specific activity

With the industry's transition from conventional to non-conventional deposits
New challenges have emerged in the face of conventional challenges. Selecting the most appropriate artificial intelligence (AI) techniques is crucial to effectively address these challenges. Furthermore, current studies tend to focus on specific aspects individuals, and both academia and industry have not yet achieved a complete view on the practical impacts, applicability and
possible development paths of these technologies in the exploitation of unconventional oil and gas fields.

- Artificial intelligence (AI) is emerging as a key tool for optimizing water use in hydraulic fracturing. In practice, This involves applying *machine learning* algorithms and other techniques advanced data analysis to model and improve the design of fractures.
- From large volumes of historical data (geological well logs, past fracture designs, pumping pressures and rates, production results, etc.), AI models learn patterns

  complexes that relate the characteristics of a well and its development plan completion with the obtained performance. In this way, it is possible to predict more accurately how much water will actually be needed to fracture efficiently a given well, optimizing operating parameters such as optimal volume of water per stage, pumping pressure or even the dosage of chemical additives in the fluid.

For example, machine learning algorithms can determine the volume suitable for each stage of fracturing and adjust the pumping rate in real time, avoiding both under-supply (running short of fluid) and excess water that does not add value. In documented cases, the implementation of controls AI-based smart injections have managed to reduce the injection by around 15%. water consumption in fractured wells, maintaining or even improving the effectiveness of stimulation compared to traditional designs.

- AI facilitates continuous monitoring, anomaly detection, and adjustments dynamics of fluid injection rates in the processes of well stimulation. In addition, it can optimize injection rates hydraulic fracturing fluids to minimize water ingress maintaining the efficiency of fracturing.

There are water management applications that integrate data monitoring into Real-time and advanced analytics for sourcing, transportation, recycling and water disposal in hydraulic fracturing operations.

- Platforms with AI implementation provide a comprehensive view of the water life cycle, allowing operators to make decisions informed to reduce consumption and increase recycling, and demonstrate how AI can play a key role in achieving hydraulic fracturing smarter, reducing water use without sacrificing productivity.

In addition, Generative AI models can currently increase the benefits and optimization. Generative Artificial Intelligence (GENA) is a branch of artificial intelligence that focuses on the creation of new content, 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 often is indistinguishable from that created by humans. As will be seen, the combination with agents, allow processes to be optimized.

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

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 in high-demand cognitive tasks.

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From this capacity, a new technological architecture emerges: agents powered by IAGen. These agents are not simple conversational interfaces, but autonomous systems that can interpret instructions, make decisions, perform tasks and learn from their interactions with the environment.

An IAGen agent combines large language models with components additional features such as external tools, memory, planning and execution autonomous. 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 changes real-time context changes. These qualities distinguish them from traditional chatbots, and open up a spectrum of more sophisticated and customizable.

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 logistical tasks, and even, linked to the technical areas of production processes, acting as assistants intelligent technologies that collaborate with human teams. This ability to integrate knowledge and execute tasks autonomously transforms the way in which Organizations can scale their 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 their 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, from responsible design to human oversight. Therefore, Understanding its architecture, operational logic, and potential impacts is critical to its effective and safe adoption in diverse contexts professionals.

2. Proposal for the design of agents driven by IAGEN

a. Proposed agent

General function:

Assist operators, engineers and decision makers in **smart management of water,** using generative AI, machine learning and real-time data.

b. Agent Features:

Water consumption prediction:

- Use machine learning models to estimate how much water is required each stage of fracturing in a specific well.

Real-time dynamic optimization:

- Adjust pumping rates and volumes based on data sensors and micro-seismicity during operation.

Water efficiency analysis:

- Evaluate the hydrocarbon/water ratio per well and identify opportunities for improvement.

Scenario simulation with IAGEN:

- Generate and compare different fracture designs to minimize the water use without sacrificing productivity.

Automated operational recommendations:

- Generate reports and suggestions for operators using NLP (natural language processing).

Monitoring environmental and cost KPIs:

- Water savings per well, reduction of truck trips, less flowback volume, etc.

Generation of regulatory reports:

- Automate environmental compliance reporting using data collected and processed.

c. Requirements for its implementation:

- **Structured database:** fracture designs, water consumption, production, geological conditions.

- **Real-time sensors:** pressure, flow rate, injected and recovered volume.

- **Integration platform:** dashboards, data APIs, simulation modules.

- **Conversational interface:** allows the agent to answer questions from the technical team (for example, “What was the water efficiency of Well A15?”).

V. Comparison with traditional methods

Unlike traditional fracture planning methods – based on conventional physical simulations and the direct experience of engineers – AI approaches offer greater speed and accuracy in optimization.

With traditional methods, estimating optimal parameters (water volumes, pumping rates, stage sequences, etc.) often involves multiple iterations of numerical simulations that can take a long time and do not They always capture all the geological variability of the deposit.

In addition, many decisions have historically been based on spreadsheets and heuristic rules, which entails a wide margin of uncertainty and often leads to the design of conservative treatments.

In contrast, AI algorithms can process large amounts of data in minutes or hours. past fracture data sets and calibrate predictive models that generalize the expected result better in a new well. This allows for evaluating virtually hundreds of scenarios and obtain an optimal fracture plan much more quickly, drastically reducing planning time (from days to potentially hours) and enabling on-the-fly adjustments as information becomes available.

new information. In terms of accuracy, *machine learning* models , once trained, have been shown to predict well production behavior fractured with errors minor or similar to those of physical simulations traditional, but with much higher computational efficiency.

Conventional methods also tend to operate with a certain factor of safety that results in excess water use as a *precaution.*

AI, on the other hand, can fine-tune those margins based on empirical evidence. extensive, providing a design more tailored to the specific reality of each well. Furthermore, while a static simulation provides a fixed result, intelligent systems can incorporate real-time data (e.g., readings pressure and micro-seismicity during the fracture) to recalibrate the model and guide instant decisions, something impractical with manual methodologies.

All this means that, compared to conventional engineering, AI offers faster analysis, the ability to handle greater complexity, and more precise recommendations. In practice, this translates into fractures better calibrated hydraulics, with less trial and error, and executed in less time time. Streamlining not only applies to planning but also to execution: Being able to dynamically optimize sequences and volumes shortens the cycle Complete design and pumping of fracture per well, increasing the productivity of the crews and fracturing equipment in the field.

VI. Direct benefits in operational and strategic terms

Adopting AI to optimize water in fracking brings benefits tangible, both operational and strategic.

- Firstly, direct water savings are achieved per well: by fine-tuning the quantities actually needed per stage and avoid over-design, each well You can consume significantly less water than with traditional methods. Field studies report reductions of the order of 10–15% in volume of water injected per well after applying AI-based predictive models. This decrease implies tens of thousands of liters less per well, which This translates into less waste and a reduced water impact. operation. By using less water initially, less water is generated residual that needs to be managed
- Secondly, the reduction in water consumption leads to a decrease operating costs: if a well requires less water, they are reduced

proportionally the costs of purchasing or capturing that resource, as well such as the logistics costs of transporting it (whether by tanker truck or through temporary pipelines to the location). For example, by cutting ~15% of water in a typical Vaca Muerte well, costly hundreds can be avoided truck trips, with the consequent savings in fuel, hours of road work and maintenance, in addition to lower costs of treatment of the effluents generated.

- Another key benefit is the increase in production efficiency per unit of water used. By adjusting the fracture design so that each liter of water provides the greatest possible stimulation to the rock, the productivity of water resources. In other words, it improves the relationship between hydrocarbons obtained and water consumed. If AI achieves the same (or greater) production with less water, the yield per square meter cubic capacity used increases considerably.
- Additionally, by optimizing water use, the amount of residual fluid that requires handling is reduced (less volume returned to be treated), simplifying post-fracturing logistics and reducing environmental risks. associated with large volumes of waste. Together, these benefits position AI not only as a savings tool, but as a factor that increases the overall efficiency of the operation (more production per resource invested), something critical for the competitiveness of shale projects.

VII. Challenges and strategies to overcome them

Despite its advantages, the incorporation of AI into fracturing operations Hydraulics faces a series of challenges that must be managed to achieve a effective implementation.

- One of the main obstacles is of a technical-economic nature: the AI and digitalization solutions require high initial investments in infrastructure (sensors, communication networks, cloud data platforms, specialized software, etc.), which may be out of reach for smaller operators. Additionally, integrating these new technologies tools with existing infrastructure is not trivial; many companies have difficulties in making their traditional systems compatible with the advanced digital platforms.

- Linked to this is the issue of data availability and quality: AI is only as good as the data it is trained on. In reservoirs, it is not heterogeneous conventional ones like Vaca Muerta, sometimes the data historical data are limited or scattered, and ensure reliable data in real time can be complex. Successful implementation requires investment in data capture and management (e.g., consistently collecting information from wells, water volumes used, recorded pressures, production obtained, etc.) to feed predictive models; however, in practice, obtaining quality data in a timely manner is often a challenge. This The technical aspect goes hand in hand with the need for personnel trained to handle these tools: the learning curve can be pronounced and require specialized training of the human team.
- Other challenges are organizational and cultural. The adoption of AI involves changes in work processes and requires new skills; Staff must be trained in the use of these tools and in the interpretation of their results. It is common to find some resistance to change by engineers and operators accustomed to methods traditional, either due to distrust of an "algorithm" or fear that automation will reduce the value of their experience.
- Overcoming this barrier will require training and awareness programs, in addition to gradual integration: for example, starting by applying AI as a decision support system (validating its suggestions with human experts) until it generates confidence in its recommendations. It is also crucial to address internal acceptance by showing successes. early: pilot the technology in one or two initial projects and Clearly communicate the water savings and operational improvements achieved can help convince the organization of its value.
- Short-term investment in implementation equipment is recommended. AI agents in technology and training. Investment in testing is required.

of concept and pilot testing. The focus here has to be on the formation of the talent to implement, since a trend of reduction is verified costs in systems that allow “no code” and “low code” automation. For the first stage, it is also recommended to use equipment with experience in designing and implementing AI agents. Finally, it is It is key to form an in-house team for support and ownership. of an agentic culture that redefines human-machine interaction.

VIII. Conclusion and recommendations

In conclusion, the application of artificial intelligence in water optimization for Hydraulic fracturing in Vaca Muerta represents not only an innovation technological, but a strategic decision for the energy sector. International experiences and the first local steps indicate that the techniques AI can significantly reduce the water required per well, cut costs, and improve productivity per unit of water, all without sacrificing performance. in production.

As activity in Vaca Muerta continues to expand – with scenarios in the future where thousands of wells could be drilled annually, eventually requiring dozens of millions of cubic meters of water per year – the role of AI will become increasingly important important to manage this resource intelligently and sustainably. It is It is expected that the integration of models will be consolidated in the coming years real-time predictive analytics during fracturing operations, combined with automated water recycling systems, which could bring the industry closer towards an almost closed cycle in water use.

Those companies that manage to internalize these digital capabilities will obtain a competitive advantage in efficiency and environmental compliance, an increasingly most valued by investors and regulators.

Strategic Recommendations: To make the most of this opportunity, suggest the following actions for effective adoption of AI in the water optimization in Vaca Muerta:

- Implement AI pilot projects focused on fracture planning hydraulics, starting on a limited scale (e.g., on one or two test pads). This will allow water savings and operational improvements to be quantified in a controlled manner before mass implementation.
  Successful pilots will serve as a demonstrative business case within the company.
- Invest in data and monitoring infrastructure: Ensure accurate and real-time measurement of key parameters (water volumes per stage, pumping pressures, flow rates, recovered flowback volume, etc.) and
  integrate that data into a central platform. A high-quality database
  Quality is essential to train and feed AI models with reliable information.
- Train technical teams: Develop training programs in data science, predictive analytics and AI tool management for the engineering and operations staff. The goal is for engineers to reservoir and completion become familiar with these new tools, learn to interpret their results and use them as support in decision making daily decisions.
- Collaborate with experts and technology providers: Partner with companies specialized in analytics for oil & gas or with R&D centers can accelerate the learning curve. These alliances facilitate access to advanced know-how, cutting-edge algorithms, and best practices
  implementations that have been tested in other projects.
- Monitor key performance indicators: Continuously monitor Metrics such as *water savings per well* achieved compared to the baseline, *reduction in costs* associated with water (transportation, treatment) and *water productivity* (volume of hydrocarbons obtained per m^3 of water).
  These KPIs will allow to objectively evaluate the impact of AI and adjust the strategy according to results.

In short, AI offers a powerful optimization lever for efficient use of water in the Vaca Muerta hydraulic fracturing industry. Its adoption leads to savings significant improvements in operational efficiency and a lower environmental impact –

critical factors for the long-term viability of unconventional development. recommends that companies in the sector proactively move forward in incorporating of these technologies, since investing today in AI and smart water management will result in more resilient, profitable and sustainable operations, ensuring the future success of Vaca Muerta as a world-class energy hub

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