Deliverable report 10

AI and IAGEN Application Use Case

Methane Leak Detection in Vaca Muerta, Neuquén, Argentina

I. Introduction

Growing concern about climate change has highlighted the importance criticism of mitigating greenhouse gas emissions, including Methane occupies a prominent place due to its high global warming potential global, especially over short time horizons.

The oil and gas industry is an anthropogenic source of methane emissions, released during various stages of exploration, production, processing, transportation and distribution of hydrocarbons. In this context, early detection and accurate detection of methane leaks has become an imperative need for both the environmental protection as well as operational efficiency and compliance normative.

The Vaca Muerta formation, located in the province of Neuquén, Argentina, represents one of the most significant reserves of unconventional hydrocarbons in the world worldwide. Its vast expanse and growing oil and gas extraction activity, through techniques such as hydraulic fracturing, make the region a hotspot focal for monitoring and mitigating methane emissions. The application of Advanced sensing technologies, such as computer vision, offer a way promising to address this challenge in an automated and efficient manner.

This report aims to provide a comprehensive analysis and professional on the application of computer vision in leak detection of methane in Vaca Muerta, complementing and enriching existing information to offer a more complete and authoritative perspective.

II. The Challenge of Methane Emissions in Vaca Muerta

Methane (CHÿ) is a greenhouse gas that is significantly more potent than carbon dioxide (COÿ) in the short term. During the first 20 years after its release,
Released into the atmosphere, methane has a global warming potential of more than
80 times higher than that of COÿ. This characteristic underlines the urgency of reducing emissions
methane emissions to slow the pace of global warming in the coming
decades.

The Vaca Muerta Formation, an extensive shale formation that extends across
approximately 30,000 square kilometers in the Neuquén Basin of Argentina,
It contains significant reserves of unconventional oil and gas. Its geology is
It is characterized by being a parent rock rich in organic matter, which makes it a
prolific source of hydrocarbons.

Hydrocarbon production in Vaca Muerta has experienced growth
exponential in recent years, becoming a key driver of production
Argentina's total oil and gas production. This increase in production has been accompanied
an increase in the number of hydraulic fracturing wells. The magnitude of the
operations and the vast expanse of the formation entail an inherent risk of leaks
of methane, whether due to equipment failures, operational errors or deficiencies in the
infrastructure.

Hydrocarbon extraction presents several environmental challenges, including intensive water use, toxic
waste management, and concerns about the potential
induction of seismicity.

Independent research has detected significant levels of emissions of
methane and volatile organic compounds (VOCs) using optical gas imaging (OGI) cameras at various
fracking, processing and storage facilities in the region.

These findings suggest that methane emissions in Vaca Muerta are a real problem that requires continuous attention and monitoring to ensure a responsible and sustainable production.

III. Fundamentals of Computer Vision for Leak Detection Methane

Computer vision is a field of artificial intelligence that seeks to train machines to "see" and interpret the visual world. It involves the acquisition, processing and analysis of digital images and videos to extract meaningful information.

In the context of methane leak detection, computer vision is applied to analyze images and videos captured by various sensors, with the aim of identify visual patterns that indicate the presence of a leak.

A key technology in this field is optical gas imaging (OGI). OGI cameras use specialized spectral filters to visualize gases such as methane, which are invisible to the naked eye. Methane absorbs energy at wavelengths specific mid-infrared wavelengths. OGI cameras detect this absorption and visually represent the gas as a cloud or plume, allowing operators to identify the location and extent of the leak. The ability to visualize directly the methane leaks provides an intuitive and valuable method for their detection in oil and gas facilities.

IV. Artificial Intelligence Algorithms in Computer Vision for the Methane Detection

Artificial intelligence (AI) plays a key role in automating the Image and video analysis for methane leak detection. The algorithms machine learning, and in particular convolutional neural networks (CNNs), They are widely used to process images captured by cameras OGI and detect patterns that are indicative of methane leaks.

CNNs are deep neural network architectures specifically designed to process grid data, such as images. They are trained using large Labeled image datasets, indicating whether a methane leak is present or not. During the training process, the CNN learns to identify relevant visual characteristics, such as the shape, movement and intensity of the gas plumes, which distinguish a methane leak from other elements in the image.

Specific CNN architectures, such as GasNet, have been developed that are optimized for OGI image-based leak detection. The application of AI algorithms, especially CNNs, enables automated methane leak detection and potentially more accurate compared to manual image analysis OGI, which reduces dependence on operator judgment. This automation facilitates the continuous monitoring and faster detection, which is crucial for mitigation timely.

In addition, machine learning algorithms can analyze movement in OGI images to improve leak detection. Methane plumes at They can often appear translucent in OGI images and can be difficult to identify. distinguish from the background. By observing the movement of methane relative to the static elements of the image, algorithms can identify leaks with greater reliability.

The Smart LEak Detection (SLED) system, developed by SwRI, is an example of how Machine learning is applied to fuse OGI images with data from other sensors and analyze motion to detect and quantify methane leaks. The use Machine learning improves the reliability of methane detection by differentiating the actual leakage of other visual artifacts or movements, leading to a reduction of false alarms.

V. Methane Leak Detection Technologies: A Comparison

Methane leak detection in the oil and gas industry is addressed through a variety of technologies, each with its own advantages and limitations.

- Traditional Methods:
  - Point Sensors: These stationary sensors are installed in locations specific to continuously monitor the concentration of methane in the air. They can be highly sensitive at monitoring points, but their Spatial coverage is limited and may miss leaks that occur between the sensors.
  - Portable Analyzers (Sniffers): These are mobile devices used by personnel to manually detect leaks by bringing the sensor close to the infrastructure components. They are useful for identifying the exact source of a short-distance escape, but they are laborious, slow and can expose operators to safety risks in hazardous areas.
- Advanced Technologies:
  - Optical Gas Imaging (OGI) Cameras: These infrared cameras visualize methane leaks in real time, allowing scanning of large areas from a safe distance. Although they are safer for operators and allow for efficient inspection, are expensive and their effectiveness may be affected by weather conditions and differences in temperature. In addition, manual analysis of images requires operators trained.
  - Drones (UAVs): Unmanned aerial vehicles equipped with methane sensors (OGI cameras or laser sniffers) carry out aerial inspections in a remote manner. efficient. They can cover large, inaccessible areas and provide data precise location using GPS. However, the flight duration is limited by the battery, there are regulatory restrictions and its operation depends on weather conditions. Image stabilization also can be a challenge.
  - Satellites: Satellite sensors offer global coverage for the large-scale methane detection and quantification. They are capable of detecting large emission events, but their spatial resolution is lower than that of the

drones or ground methods, and may miss smaller leaks.
Coverage can also be affected by cloudiness.

Table 1: Comparison of Methane Leak Detection Technologies

Technology	Advantages	Limitations
Point Sensors	Continuous monitoring, high sensitivity in fixed locations	Coverage space limited
Portable Analyzers	Mobile phones locate sources escape	Hardworking, slow, security risks for the operator
OGI cameras	Time display real, large scan areas, operation more safe	Expensive, dependent of the climate and the temperature, require trained operators for manual use
Drones (UAVs)	Area coverage extensive and inaccessible, profitable, data from precise location	Time constraints flight restrictions regulatory, weather-dependent,

		challenges of image stabilization
Satellites	Coverage global, detection of large emissions, inventories regional/national	Minor resolution spatial, they can pass over leaks more small, affected by cloudiness

The choice of methane leak detection technology depends on the specific needs and the context of the application, considering factors such as scale, cost, accessibility, and desired accuracy. The combination of multiple technologies can provide a more comprehensive solution.

VI. Application of Computer Vision in Methane Leak Detection in Vaca Muerta

Computer vision has great potential to improve leak detection. of methane in oil and gas operations in Vaca Muerta. The algorithms of Computer vision can automatically analyze OGI images collected by fixed ground cameras, drones or even aircraft in the region.

The use of fixed OGI cameras, combined with AI-driven analytics, enables continuous facility monitoring. Systems like FLIR ADGILE provide automated real-time detection and alerts for methane leaks. This Continuous monitoring can provide early warnings of leaks, which enables faster response and mitigation, potentially reducing general emissions and associated risks.

Drones equipped with OGI cameras and AI algorithms offer a solution efficient to inspect the vast Vaca Muerta region, including wells, pipelines and other infrastructure. Integrating satellite data with AI can identify potential critical leak points throughout the region, which can then be investigated in greater detail using drones or ground-based methods. Initiatives as MethaneSAT and Carbon Mapper are providing valuable data for this purpose. A multi-level approach, combining satellite surveillance for a Broad coverage and anomaly detection with CV-enhanced OGI based on Drones and ground for detailed inspection, offers a robust solution for Vaca Dead.

In addition, computer vision can analyze video streams from surveillance cameras already implemented in oil and gas facilities to detect visual indicators of gas leaks or liquid spills. Companies such as Plainsight and Visionify offer AI-powered visual automation suites for the oil and gas industry. Leverage existing infrastructure by Adding AI-powered computer vision capabilities can provide a cost-effective way to improve leak detection without investment significant in new hardware.

VII. Application of IAGEN in Methane Leak Detection

1. Functionality and Scope of IAGEN

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.

IAGEN models, in the analyzed context, can be responsible for analyzing Images and videos captured by specialized cameras, both drones and Fixed devices installed in strategic areas of the infrastructure. Using computer vision algorithms, the technology identifies visual patterns.

associated with the presence of leaks, even under adverse lighting conditions or in complex environments.

2. Specific Technologies and Models

- Convolutional Neural Networks (CNN): Fundamental for the image processing and analysis, these networks detect anomalies and patterns that suggest the presence of leaks.
- Semantic Segmentation Models: They allow to isolate and highlight areas specific images that could correspond to methane emissions, improving detection accuracy.
- Real-Time Detection Algorithms: Integrated into the system to analyze continuously monitors the video stream, generating alerts immediately upon detection of possible leaks.
- Integration with Operational Management Systems: Direct connection with centralized monitoring platforms, allowing corrective actions immediate and a coordinated response to incidents.

3. Operational and Strategic Benefits

- Early and Accurate Detection: The ability to identify leaks in a matter of seconds allows for rapid intervention, minimizing the impact of the incident.
- Cost Reduction: By reducing dependence on manual inspections and Reduce the frequency and severity of repairs, optimizing costs operatives.
- Improved Safety: A quick response to leaks reduces significantly the risks to personnel and the environment, raising the level of security in operations.
- Scalability and Adaptability: The solution can be adapted to various operating conditions and configurations in Vaca Muerta, allowing its integration into multiple stages of the production chain.

VIII. Agentic Flow 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 Step-by-step objectives, 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 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 powered by generative AI models is the ability to automate processes
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 its potential impacts is fundamental to its effective and safe adoption in various professional contexts.

2. Phases of the Workflow with IAGEN designed and proposed

The IAGEN implementation process is structured in phases that ensure a Effective integration and agile incident response:

a. Data Collection:

- Image and Video Capture: Using drones and fixed cameras strategically located.
- Integration of Environmental Sensors: Complementing the information visual with gas sensor data for a more complete view.

b. Processing and Analysis:

- Image Preprocessing: Improving visual quality through normalization techniques, contrast adjustment and noise reduction.
- Application of Computer Vision Models: Use of CNNs and semantic segmentation models to identify anomalous patterns associated with leaks.

c. Alert Generation:

- Interpretation of Results: The algorithms assign a risk score to each image or video analyzed.
- Immediate Notification: Integration with centralized management systems that send alerts to response teams.

d. Response and Mitigation:

- Activation of Emergency Protocols: Once the anomaly is confirmed, the security protocol is activated to intervene and mitigate the leak.
- Registration and Documentation: Incident data is archived for analysis and continuous improvement.

e. Feedback and Continuous Improvement:

- Post-Event Analysis: Evaluation of the effectiveness of the system and adjustments in the detection parameters.
- Model Update: Incorporation of new data for to improve the accuracy of the system in future detections.

2. Description of the Agents Involved

The system is made up of different agents, each with a specific role within the operational flow:

- Capture Agent: Drone and fixed camera teams responsible for the collection of images and videos in real time.

- Preprocessing Agent: Module responsible for improving the quality of the images, eliminating interference and adjusting parameters to optimize the data entry.
- Analysis Agent: IAGEN core that applies machine vision algorithms. computer to detect anomalies associated with methane leaks.
- Alert Agent: Integrated system that evaluates the risk score and issues immediate notifications to the control center.
- Feedback Agent: Module that analyzes the recorded incidents and adjusts the model to improve detection in the future.

3. Concrete Example of Agentic Flow

Consider a facility in Vaca Muerta with multiple critical points:

Step 1: A drone equipped with an infrared camera flies over the facility every two seconds. hours, capturing images of strategic areas.

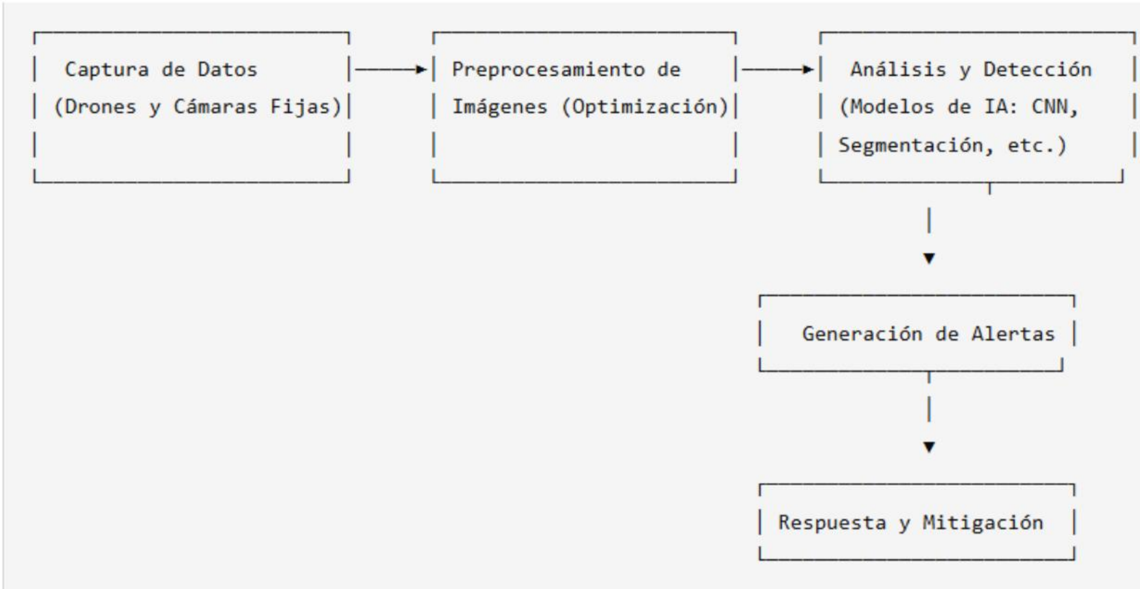
Step 2: Images are transmitted to a central server where the agent Preprocessing optimizes visual quality and removes interference.

Step 3: The analysis agent identifies a thermal anomaly in the pipeline area, generating a high risk score.

Step 4: If the score exceeds the defined threshold, the alert agent sends a immediate notification to the control center, activating emergency protocols.

Step 5: Intervention teams are deployed to assess and mitigate the leak, while the entire process is documented.

Step 6: After corrective action, the feedback agent collects and analyzes the data to update and adjust the model, ensuring continuous improvement.



IX. Regulatory Framework and Environmental Commitments in Argentina

Argentina has made important commitments in the fight against climate change. climate, including the presentation of its Nationally Determined Contribution (NDC) under the Paris Agreement, which commits to not exceeding the net emissions of 349 million tonnes of carbon dioxide equivalent for 2030. The country has also announced its intention to reduce methane emissions by at least 30% by the end of the decade, taking as a reference the levels of 2020. These national commitments drive the need to adopt technologies effective emissions detection in key sectors such as oil and gas.

Argentina's regulatory framework for oil and gas activities is established at both the federal and provincial levels. This evolving regulatory landscape, with an increasing focus on measuring and reducing emissions, will likely drive further adoption of advanced detection technologies of methane, such as computer vision-enhanced systems.

In addition to government regulations, there are initiatives and collaborations industrials that promote the reduction of methane emissions, such as the Charter of Oil and Gas Decarbonization (OGDC). These industry-led efforts, together with government regulations, can accelerate the adoption of better practices in methane detection and mitigation.

X. Effectiveness Metrics and Evaluation of Methane Leak Detection Systems

- The effectiveness of methane leak detection systems is assessed by several key metrics.
- The detection rate or probability of detection (PoD) indicates the percentage of leaks of a given size that the system can detect under operating conditions.
  Specific. Specifying the PoD along with the minimum detection threshold (MDT) is crucial to understanding the reliability of the system.
- Accuracy refers to the system's ability to correctly identify a leak (low false positives) and to accurately locate and quantify the source of the leak. Response time is the time it takes for the system to

  detect and report a leak once it occurs. • Sensitivity (MDT) is
  the smallest leak rate that the system can detect
  detect reliably.
- The false alarm rate indicates how often the system signals incorrectly a leak.
- Quantification accuracy is the accuracy with which the system can measure the rate of methane emission.
- Finally, spatial resolution is the level of detail in identifying the location of the leak source, relevant for satellite and land-based systems in drones.

To compare the performance of different leak detection technologies, it is
It is essential to have standardized testing and evaluation protocols. Initiatives such as the Methane Emissions Technology Evaluation Center (METEC) play an important role in this regard. Clearly defined and consistently measured KPIs are essential for assessing the effectiveness of systems.
methane leak detection and to make informed decisions about the

technology adoption.

X. Recommendation to achieve solutions based on AI and IAGEN in the short term and scalable

Short-term investment in AI agent implementation teams in technology and Training: Investment in proof of concept and pilot testing is required. The focus Here there has to be the formation of talent to implement, since a Cost reduction trend in systems that enable “no code” automation and "low code". For the first stage, it is also recommended to use teams with experience in the design and implementation of AI agents. Finally, it is key to train an in-house team for the accompaniment and appropriation of an agentic culture that redefines human-machine interaction.

XI. Conclusion

Methane leak detection is of utmost importance in the oil and gas industry. gas, especially in high-production areas such as Vaca Muerta. Emissions Methane emissions have a significant impact on climate change, and their mitigation is crucial to achieving global and national climate goals.

Computer vision, powered by artificial intelligence algorithms, emerges as a powerful tool to improve accuracy, efficiency and Automation of methane leak detection. The combination of technologies as OGI cameras with intelligent image analysis offer significant potential for early and accurate leak detection throughout the infrastructure Oil and gas in Vaca Muerta. A comprehensive and professional approach to the detection of methane leaks, supported by a robust regulatory framework and the adoption of metrics of clear effectiveness, it is essential to guarantee hydrocarbon production responsible and sustainable in the region.

Additionally,

- IAGEN's application for methane leak detection allows agile and precise responses, reducing the risk of critical incidents and optimizing operations in Vaca Muerta.

- Integrating computer vision into complex environments offers improvements substantial in terms of safety, efficiency and cost reduction operatives.
- The implementation of this system is aligned with environmental regulations and security, strengthening the competitiveness of companies in a market demanding.

Sources cited

1. Argentina's Vaca Muerta Fuels Oil Production Surge - Brazil Energy Insight, access: February 17, 2025, https://brazilenergyinsight.com/2025/03/13/argentinas-vaca-muerta-fuels-oil-production-surge/
2. Cow Dead - Wikipedia, access: March 17, 2025, https://en.wikipedia.org/wiki/Vaca_Muerta
3. Can oil and gas companies reduce their emissions at Vaca Muerta? - Dialogue Earth, access: February 17, 2025, https://dialogue.earth/en/business/can-oil-and-gas-companies-reduce-their-emissions-at-dead-cow/
4. Inadequate methane emissions data undermines oil and gas reports | Dialogue Earth, access: February 17, 2025, https://dialogue.earth/en/climate/381775-inadequate-methane-emissions-data-undermines-oil-and-gas-reports/
5. Geomechanical properties of the Vaca Muerta Formation - E3S Web of Conferences, access: February 17, 2025, https://www.e3s-conferences.org/articles/e3sconf/pdf/2020/65/e3sconf_icegt2020_03013.pdf

6. The Vaca Muerta Formation (Late Jurassic - Early Cretaceous), Neuquén Basin, Argentina: Sequences, Facies and Source Rock Characteristics - GeoLab Sur, access: February 17, 2025, https://www.geolabsur.com/Biblioteca/Legarreta_Villar_2015_VM_Urtec.pdf

7. Vaca Muerta Formation, Argentina by Ricardo Sebastian Martinez from U3 Explore, access: February 17, 2025, https://www.u3explore.com/reports/vaca-muerta-formation-argentina

8. Argentina oil and gas sector: Vaca Muerta shale can drive near-term growth and fuel medium-term opportunities - Deloitte, access: February 17, 2025, https://www2.deloitte.com/us/en/insights/economy/americas/vaca-muerta-argentina-energy-sector-boom.html

9. Argentina's crude oil and natural gas production near record highs - US Energy Information Administration (EIA), access: February 17, 2025, https://www.eia.gov/todayinenergy/detail.php?id=63924

10. The Vaca Muerta Tribunal Delegation, accessed: February 17, 2025, https://www.rightsofnaturetribunal.org/vaca-muerta/

11. Balancing energy security and a healthy environment | SEI, accessed: February 17, 2025, https://www.sei.org/publications/energy-environment-vaca-muerta-fracking/

12. Vaca Muerta Case (Argentina) - International Rights of Nature Tribunal, access: February 17, 2025, https://www.rightsofnaturetribunal.org/cases/vaca-muerta-case/

13. REPORT: Unearthing the truth & the power of people in Argentina - Earthworks, access: February 17, 2025, https://earthworks.org/unearthing-the-truth-in-argentina-an-in-depth-exploration-of-vaca-muertas-environmental-impact-and-beyond/

14. Argentina's Vaca Muerta: 10 Years of Fracking and Local Resistance - NACLA |, Accessed: February 17, 2025, https://nacla.org/argentina-vaca-muerta-fracking-resistance

15. Using Machine Learning for Methane Leak Detection and Quantification, access: March 3, 2025, https://www.swri.org/markets/industrial-robotics-automation/blog/using-machine-learning-methane-leak-detection-quantification

16. Optical Gas Imaging (OGI) Cameras - Opgal, accessed: March 3, 2025, https://www.opgal.com/fixed-optical-gas-imaging-ogi-cameras/

17. Optical Gas Imaging - Infrared Cameras, Inc., accessed: March 3, 2025, https://infraredcameras.com/industries-served/optical-gas-imaging

18. Optical Gas Imaging | Infrared Gas Detection | Teledyne FLIR, accessed: March 3, 2025, https://www.flir.com/instruments/optical-gas-imaging/

19. Gas Detection with Optical Gas Imaging (OGI) Cameras - Quickset, accessed: March 3, 2025, https://www.quickset.com/gas-leak-detection-ogi-cameras/

20. Methane Leak Detection | Southwest Research Institute, accessed: March 3, 2025, https://www.swri.org/markets/energy-environment/oil-gas/fluids-engineering/methane-leak detection

21. Using AI to Reduce Methane Emissions - energynews, accessed: March 3, 2025, https://energynews.pro/en/using-ai-to-reduce-methane-emissions/

22. Machine vision for natural gas methane emissions detection using an infrared camera, access: March 3, 2025, https://ngi.stanford.edu/sites/ngi/files/media/file/1-s2.0-s030626191931685x-main.pd F

23. Machine vision for natural gas methane emissions detection using an infrared camera - NASA/ADS, access: March 3, 2025, https://ui.adsabs.harvard.edu/abs/2020ApEn..25713998W/abstract

24. Machine vision for natural gas methane emissions detection using an infrared camera | Request PDF - ResearchGate, accessed: March 3, 2025, https://www.researchgate.net/publication/336927362_Machine_vision_for_natural_gas_methane_emissions_detection_using_an_infrared_camera

25. Methane Point Instrument | SLB, accessed: March 3, 2025, https://www.slb.com/products-and-services/decarbonizing-industry/methane-emissions-management/sees-end-to-end-emissions-solutions-family/sees-methane-point-instrument

26. Comparing Approaches to Leak Detection and Repair for Upstream Oil & Gas, access: March 3, 2025,

https://www.systemswithintelligence.com/blog/comparing-approaches-to-leak-detection-and-repair-for-upstream-oil-gas

27. www.mdpi.com, access: March 3, 2025, https://www.mdpi.com/2227-9717/12/1/67#:~:text=The%20traditional%20method%20cannot%20specify,the%20surrounding%20leak%20is%20necessary.

28. A new era in methane leak inspection - Sorama, accessed: March 3, 2025, https://sorama.eu/a-new-era-in-methane-leak-detection/

29. Gas Detection Cameras | FLIR Industrial, accessed March 3, 2025, https://www.flir.com/browse/industrial/gas-detection-cameras/

30. FLIR GF77a CH4 OGI thermal camera for methane - Apliter, accessed: March 5, 2025, https://www.apliter.com/en/product/flir-gf77a-ch4-camara-termica-fija-ogi-metano/

31. Satellites: a game-changer for methane leak detection? - Gas Outlook, access: March 5, 2025, https://gasoutlook.com/analysis/satellites-a-game-changer-for-methane-leak-detection/

32. www.flogistix.com, access: March 5, 2025, https://www.flogistix.com/methane-leak-detection#:~:text=Flogistix%20offers%20cutting%2Dedge%20methane,for%20unparalleled%20safety%20and%20precision.

33. Drones Detecting and Sealing Greenhouse Gas Leaks - Inside Unmanned Systems, access: March 5, 2025, https://insideunmannedsystems.com/drones-detecting-and-sealing-greenhouse-gas-leaks/

34. SeekOps: Emissions Monitoring, Detection & Quantification, accessed: March 5, 2025, https://seekops.com/

35. Drone Technology Advances Methane Leak Detection | Cat | Caterpillar, access: March 5, 2025, https://www.cat.com/en_US/blog/drone-technology-advances-methane-leak-detection.html

36. INPEX Conducts Successful Drone-based Gas Detection Test, accessed: March 5, 2025, https://www.inpex.com/english/news/english/news/assets/pdf/20230427.pdf

37. Methane Leak Detection - Phlogistix, accessed: March 5, 2025, https://www.flogistix.com/methane-leak-detection

38. Perfect solution for gas leak detection | GIS 320 - Thermal and infrared cameras, access: March 5, 2025, https://www.drone-thermal-camera.com/gas-leak-detection-gis320/

39. Aerial Methane Leak Detection - Flogistix, accessed: March 5, 2025, https://www.flogistix.com/methane-leak-detection/aerial

40. Integrating Methane Detection into Airborne Drones - YouTube, accessed: March 5, 2025, https://www.youtube.com/watch?v=_24SN9_f5pk

41. A Review of Methane Gas Detection Sensors: Recent Developments and Future Perspectives - MDPI, accessed March 5, 2025, https://www.mdpi.com/2411-5134/5/3/28

42. Methane Leak Detection with a Drone: Proof of Concept - SPH Engineering, access: March 5, 2025, https://www.sphengineering.com/news/methane-leak-detection-with-a-drone-proof-of-concept

43. Detection of Methane Leaks via a Drone-Based System for Sustainable Landfills and Oil and Gas Facilities: Effect of Different Variables on the Background-Noise Measurement - MDPI, access: March 5, 2025, https://www.mdpi.com/2071-1050/16/17/7748

44. Detection of Methane Leaks via Drone in Release Trials: Set-Up of the Measurement System for Flux Quantification - MDPI, accessed: March 5, 2025, https://www.mdpi.com/2071-1050/17/6/2467

45. Dronedesk case study - innovation in methane detection, accessed: March 7, 2025, https://dronedesk.io/case-study-innovation-in-methane-detection

46. Case Study: Using Drones for Gas Monitoring and Detection - DJI Ferntech, access: March 7, 2025, https://www.ferntech.co.nz/blog/news-case-studies/using-drones-for-gas-monitoring-and-detection

47. Laser OGI for Methane Emission Detection and Quantification - Xplorobot, access: March 7, 2025, https://www.xplorobot.com/laser-ogi

48. Natural Gas Pipeline Leak Detection Methods Continue To Advance, accessed: March 7, 2025, https://www.aogr.com/web-exclusives/exclusive-story/natural-gas-pipeline-leak-detection-methods-continue-to-advance

49. Detection technology | Methane - ExxonMobil, accessed: March 7, 2025, https://corporate.exxonmobil.com/what-we-do/delivering-industrial-solutions/methane/detection technology

50. MethaneSAT | Solving a crucial climate challenge, accessed March 7, 2025. https://www.methanesat.org/

51. How satellites, algorithms and AI can help map and trace methane sources - Google's Keyword Blog, access: March 7, 2025, https://blog.google/outreach-initiatives/sustainability/how-satellites-algorithms-and-ai-can-help-map-and-trace-methane-sources/

52. Machine Learning for Methane Detection and Quantification from Space - A survey - arXiv, accessed March 7, 2025, https://arxiv.org/html/2408.15122v1

53. How MethaneSAT is different from other satellites - Environmental Defense Fund, Accessed: March 7, 2025, https://www.edf.org/methanesat/how-this-satellite-different

54. Latest images demonstrate MethaneSAT's unique, powerful capabilities, access: March 7, 2025, https://www.methanesat.org/project-updates/latest-images-demonstrate-methanesats-unique-powerful-capabilities

55. Chevron Methane Report, access: March 7, 2025, https://www.chevron.com/-/media/shared-media/documents/chevron-methane-report.pdf

56. Carbon Mapper: Methane, CO2 Detection Satellite | Greenhouse Gas, access: March 7, 2025, https://carbonmapper.org/

57. Deep learning for detecting and characterizing oil and gas well pads in satellite imagery, accessed March 7, 2025, https://pmc.ncbi.nlm.nih.gov/articles/PMC11327246/

58. New AI Model Detects Methane Emissions From Space More Accurately, access: March 7, 2025,

https://www.asianscientist.com/2024/09/environment/new-ai-model-detects-methane-emissions-from-space-more-accurately/
59. New satellite offers breakthrough in global methane emissions tracking - UC Berkeley Law, access: March 7, 2025, https://www.law.berkeley.edu/article/center-for-law-energy-and-the-environment-tanager-1-satellite-global-methane-emission-tracking/
60. Daily detection and quantification of methane leaks using Sentinel-3: a tiered satellite observation approach with Sentinel-2 and Sentinel-5p | NASA Airborne Science Program, access: March 10, 2025, https://airbornescience.nasa.gov/content/Daily_detection_and_quantification_of_methane_leaks_using_Sentinel-3_a_tiered_satellite
61. Case Study Library Details | Global Methane Initiative, accessed: March 10, 2025, https://globalmethane.org/case-studies/library/details.aspx?id=14
62. Coal Mining Methane Emissions | Case Study - GHGSat, accessed: March 10, 2025, https://www.ghgsat.com/en/case-studies/coal-mining-methane/
63. Automated detection of regions with persistently enhanced methane concentrations using Sentinel-5 Precursor satellite data - ACP - Recent, accessed: March 10, 2025, https://acp.copernicus.org/articles/24/10441/2024/
64. Oil & Gas AI Solutions & Use Cases at Plainsight, accessed: March 10, 2025, https://plainsight.ai/services/oil-and-gas/
65. FLIR ADGiLE Automated Methane Monitoring Solution with Optical Gas Imaging, access: March 10, 2025, https://www.flir.com/products/flir-adgile?vertical=optical+gas&segment=solutions
66. Leak detection | Vision AI monitoring for Workplace Safety - Visionify.ai, access: March 10, 2025, https://visionify.ai/spills-and-leaks-detection/
67. Liquid Leak Detection - Noema.tech, accessed: March 10, 2025, https://noema.tech/leak/
68. Open sourcing code to improve methane emission localization and quantification, access: March 10, 2025, https://www.shell.com/what-we-do/digitalisation/collaboration-and-open-innovation/op

en-sourcing-code-to-improve-methane-emission-localisation-and-quantification.html

69. Argentina | NDC Action Project - UNEP, accessed: March 10, 2025, https://www.unep.org/ndc/action-area/argentina

70. Argentina's Second Nationally Determined Contribution - UNFCCC, accessed: March 10, 2025, https://unfccc.int/sites/default/files/NDC/2023-12/Argentinas%20Second%20NDC.pdf

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

72. Oil & Gas Laws and Regulations Report 2025 Argentina - ICLG.com, accessed: March 10, 2025, https://iclg.com/practice-areas/oil-and-gas-laws-and-regulations/argentina

73. Argentina: Hydrocarbons – Regulation of the new O&G framework: Decree 1057/2024, access: March 10, 2025, https://insightplus.bakermckenzie.com/bm/energy-mining-infrastructure_1/argentina-hydrocarbons-regulation-of-the-new-og-framework-decree-10572024

74. Legal 500 Country Comparative Guides 2025, accessed: March 10, 2025, https://www.legal500.com/guides/chapter/argentina-energy-oil-gas/?export-pdf

75. Alternative Methane Detection Technologies Evaluation - Alberta Energy Regulator, access: March 17, 2025, https://www.aer.ca/documents/reports/Alternative_methane_detection_tech_evaluation.pdf

76. Methane Detection Sensitivity and Probability of Detection - Bridger Photonics, access: March 17, 2025, https://www.bridgerphotonics.com/blog/methane-detection-sensitivity-probability-of-de protection

77. 5 Evaluation Guidelines and Principles, accessed: March 17, 2025, https://methane-1.itrcweb.org/5-evaluation-guidelines-and-principles/

78. www.bridgerphotonics.com, access: March 17, 2025, https://www.bridgerphotonics.com/blog/methane-detection-sensitivity-probability-of-detection#:~:text=One%20of%20the%20proposed%20detection,rate%20of%2010%20kg%2Fhr.

79. OGI Efficacy | METEC - Colorado State University, accessed: March 17, 2025, https://metec.colostate.edu/ogi-efficacy/

80. Methane gas monitor response times | Resources Safety & Health Queensland, access: March 17, 2025, https://www.rshq.qld.gov.au/safety-notices/mines/methane-gas-monitor-response-times

81. Irwin SX Gas Leak Detector | Southern Cross - Subsurface Solutions, accessed: March 17, 2025, https://www.subsurfacesolutions.com/product-page/irwin-sx-gas-leak-detector

82. Laser Methane Smart for Gas Leak Detection | Pergam USA, accessed: March 17, 2025, https://pergamusa.com/handheld

83. The Benefits of using Monitoring for Natural Gas Leak Detectors - NYC Rules, access: March 17, 2025, https://rules.cityofnewyork.us/wp-content/uploads/2023/10/The-Benefits-of-Monitoring-Natural-Gas-Leaks-01-03-23.pdf

84. Gas Monitor t90 Response Time - Newcastle Safety Servicing, accessed: March 17, 2025, https://newcastlesafetyservicing.com/t90-response-time-testing/

85. Evaluation of next generation emission measurement technologies under repeatable test protocols, access: March 17, 2025, https://energy.colostate.edu/wp-content/uploads/sites/28/2022/12/426-7344-1-pb.pdf

86. Understanding Methane Detection Sensitivity - Bridger Photonics, accessed: March 17, 2025, https://www.bridgerphotonics.com/blog/understanding-methane-detection-sensitivity

87. An Overview of Pipeline Leak Detection Technologies - ASGMT, accessed: March 17, 2025, https://asgmt.com/wp-content/uploads/2018/05/102.pdf

88. Comparing Natural Gas Leakage Detection Technologies Using an Open-Source “Virtual Gas Field” Simulator - ACS Publications, accessed: March 17, 2025, https://pubs.acs.org/doi/10.1021/acs.est.5b06068

89. Standard Test Procedures for Evaluating Leak Detection Methods - US EPA, access: March 17, 2025,

https://19january2017snapshot.epa.gov/sites/production/files/2014-03/documents/pi pe.pdf

90. An Evaluation Study of Leak Testing Technologies for Watertight Plate Heat Exchangers - Diva portal, access: March 17, 2025, https://www.diva-portal.org/smash/get/diva2:1762252/FULLTEXT01.pdf

91. How to Evaluate and Verify External Leak Detection Systems | C-FER TECHNOLOGIES, access: March 19, 2025, https://www.cfertech.com/insights/how-to-evaluate-and-verify-external-leak-detection-s systems/

92. Evaluation of leak-detection technologies, accessed: March 19, 2025, https://www.cfertech.com/insights/evaluation-of-leak-detection-technologies/