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The connected oil refinery:

How private 5G networks enhance efficiency, safety and sustainability

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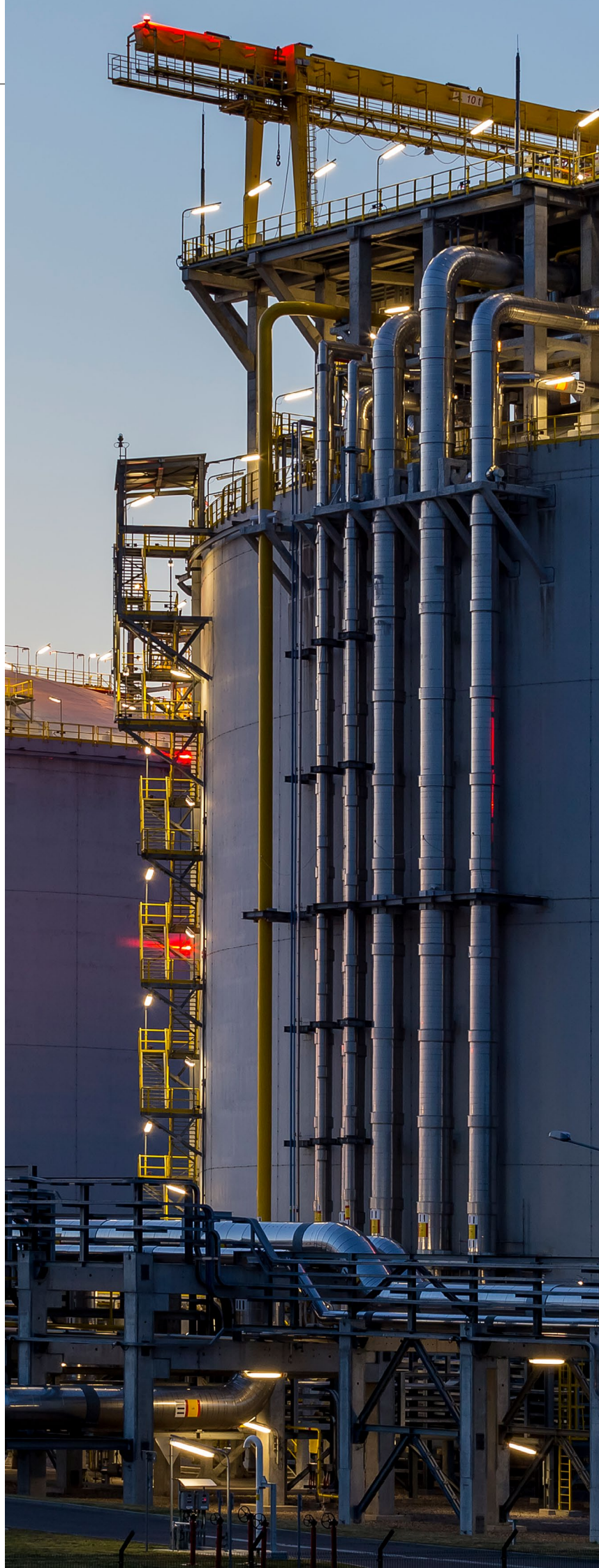

Executive summary

Oil refineries rank among the most complex and demanding industrial environments in the world. With thousands of pieces of equipment, miles of piping and hundreds of skilled workers spread across sprawling campuses, refineries depend on uninterrupted production, precise process control and a highly trained workforce. Coordinating all these moving parts to maintain safe, efficient and profitable operations increasingly requires a powerful communication network capable of delivering real-time data to and from connected devices and workers.

Traditional cabling lacks mobility, while Wi-Fi is insecure, prone to interference and unable to ensure consistent blanket coverage. Refineries are struggling to keep up with the increasing number of connected devices and the demands of automation.

Private 5G networks provide a secure, robust, reliable and cost-efficient alternative that simplifies network management while enabling seamless mobility across large, complex refinery sites.

This paper, presented in partnership with Ericsson, explores how private 5G networks overcome the limitations of legacy networks to strengthen operational resilience, boost productivity and unlock competitive advantage for the modern refinery.

Market challenges demand new operational strategies

Refinery operators face a complex challenge: Meet rising global fuel demand while navigating volatile market conditions, regulatory issues, sustainability imperatives and workforce transitions. According to Wood Mackenzie,[1] 101 of the world's 410 refineries—accounting for 21% of total global refining capacity—are at risk of closure. Common operational challenges include:

- Operational efficiency
- Workforce development
- Sustainability

[1] Wood Mackenzie. "Global refinery closure outlook to 2035." https://www.woodmac.com/news/opinion/global-refinery-closure-outlook-2035/

Operational efficiency: Cutting costs and addressing bottlenecks

Equipment repair and replacement typically consume more than half of a refinery's maintenance budget, while energy conservation and safety and environmental compliance consume more than a third, and reliability improvement programs represent nearly 10%.[2] Underlying these line items are inefficiencies that drain time, money and productivity.

On the workforce side, typical worker inefficiencies include inspectors and other experts needing to travel hours to remote locations to conduct routine maintenance or environmental checks. When on-site operations workers try to troubleshoot problems, they must resort to the cumbersome task of searching through manuals when they don't have connections to off-site experts. Many processes are also still manual, resulting in human errors that impact efficiency and safety.

Equipment inefficiencies compound the issue. Without real-time data and insights, failures often occur without warning, and planned maintenance schedules are often suboptimal. Unplanned maintenance takes longer than necessary, driving up costs.

Addressing these challenges isn't just about fixing equipment faster—it's about adopting smarter, technology-driven approaches. Even incremental advances that provide real-time visibility can translate into substantial cost savings, improved reliability, and stronger operational resilience over the long term.

[2] Oil & Gas Journal. "Survey Points to Practices that Reduce Refinery Maintenance Spending." https://www.ogj.com/home/article/17212026/survey-points-to-practices-that-reduce-refinery-maintenance-spending

Workforce development: Keeping workers safe and skilled

Worker safety is always the top priority for refineries. Private 5G enables the connection of multiple wireless sensors to mobile devices to monitor worker vitals, detect falls, prevent fatigue and provide heat detection. In addition, gas detection and geofencing can protect workers from entering dangerous zones through notifications in real-time.

Traditional land mobile radios (LMR) can't keep pace with modern needs. Cellular mobile devices, tablets, and wearables open secure access to hundreds of applications for mission-critical communication, video conferencing, remote expert support, Augmented Reality (AR), workforce management and maintenance record-keeping—all on a secure and reliable digital platform.

At the same time, knowledge retention is vital as experienced workers retire. By digitizing expertise and storing it securely on local servers and the cloud, refineries can train new hires and apply machine learning and AI powered tools, supporting them in the field. For this vision to succeed, refinery operators need to connect everything—enabling both the real-time capture of data on mobile devices from the field and seamless sharing of information back to workers in the moment.

Sustainability: Meeting environmental targets

Refineries around the world are under pressure to comply with upcoming corporate and government environmental targets, such as zero-flaring by 2030 commitments.[3] Yet, legacy environmental reporting processes are often manual and inadequate, creating compliance challenges at a time when regulations are only getting stricter. Refinery operators need digital solutions to streamline monitoring and reporting, ensuring accountability and progress toward sustainability commitments.

Refineries generate data from tens of thousands of sensors in real time and span sites covering hundreds of acres.[4] Digital devices and real-time connectivity are central to tackling the complexity to deliver operational efficiency, workforce development and sustainability challenges.

The cost to connect these sensors using wires is prohibitive because refineries are live operational environments. Wi-Fi is not secure and can't provide comprehensive, robust coverage across refinery campuses, particularly with so much metal equipment blocking signals. It is a risk to connect critical infrastructure to public networks, which are designed for commercial consumer uses, not for industrial and mission critical applications.

All these issues highlight the need for a more effective solution.

Private industrial 5G networks are on the rise

In 2023 and 2024, 60% of all newly announced private networks were 5G networks, according to Analysys Mason.[5] Major industrial sectors, such as oil and gas, are turning to private 5G due to the greater flexibility of cellular networks to support key capabilities like process automation and bottom-line benefits like improved worker safety.

[3] Zero Routine Flaring by 2030 Initiative. https://www.worldbank.org/en/programs/zero-routine-flaring-by-2030/about

[4] Multivariate Sensor Data Analysis for Oil Refineries and Multi-mode Identification of System Behavior in Real-time. https://www.researchgate.net/publication/328434213_Multivariate_Sensor_Data_Analysis_for_Oil_Refineries_and_Multi-mode_Identification_of_System_Behavior_in_Real-time

[5] Analysys Mason. "Private LTE/5G network deployments: trends and analysis 2H 2024." January 2025

Private 5G in action: Driving operational innovation

Private 5G delivers reliable, secure, high-speed and ultra-low-latency wireless connectivity. While Wi-Fi will continue to be a valuable platform for refineries, their operational goals may require private 5G to become a reality. The wide range of business-critical applications private 5G can enable at refineries includes:

- Real-time equipment monitoring
- Predictive maintenance
- Remote and automated operations
- AI-powered robotics for autonomous inspection
- Real-time alerts and connections to outside expertise for workers
- Augmented reality (AR) tools and digital twin modeling for remote maintenance and troubleshooting

These capabilities reduce unplanned downtime, extend asset life, boost process efficiency and enhance workforce safety in hazardous areas. Private 5G delivers the predictable low-latency and always-on connectivity essential for advanced, real-time monitoring in refinery operations. Through high availability network controllers and support for a dual redundant core, refinery networks can be designed to ensure no single point of failure exists. This robust architecture, combined with session continuity and geo-redundancy features, sets private 5G apart. When combined with machine learning, these connectivity capabilities empower predictive and proactive maintenance, drastically reducing costly unplanned downtime.

In practice, refinery workers with 5G access experience undisrupted connectivity. In one deployment of private 5G, an oil and gas company equipped field workers with AR wearables. The workers could instantly access checklists, capture photos and consult remote experts while tapping into real-time company data. The result: a 33% improvement in maintenance efficiency.

Inspections conducted by automated or remotely controlled robotics are a critical capability for safety and cost savings. Private 5G enables robotic inspections to operate seamlessly across expansive refinery sites, delivering continuous, high-quality video feeds that support real-time monitoring and analysis. For example, an automated, 5G-connected robot using AI can inspect 1,400 data points and report any issues every day, which is significantly more than what traditional inspection practices are capable of delivering.

What if you could improve equipment downtime by 25% and slash inspection times by 90%?

You can automate routine maintenance checks and enable proactive maintenance, thus freeing technicians from inefficient inspection and unplanned maintenance cycles. Private 5G network and autonomous inspections performed by robotics make it possible.

5G-powered innovations deliver bottom-line benefits

Private 5G is proving to be a catalyst for measurable business impact in refinery operations. For every dollar invested in private 5G-enabled capabilities, refinery operators are seeing returns through efficiency gains, safety improvements and sustainability progress.

Efficiency gains—Productivity improvements and reduced downtime translate directly into lower costs and greater profit. Refineries offer an abundance of use cases to leverage 5G connectivity for increased bottom-line benefits, including:

- Lower-cost remote operations and monitoring through robotics and edge analytics
- Worker safety and productivity gains through wearables, push-to-talk and real-time alerts
- Predictive maintenance and process optimization through sensors, real-time visibility, data analysis and digital twins

The business case is compelling: a refinery leveraging private 5G to better connect workers can reduce equipment downtime by 25%, just by providing workers access to real-time remote expert support. For an oil refinery with a capacity of 200,000 bbl/day, that could yield a $17 million improvement in income lost due to downtime. Private 5G can also enable operations to slash inspection times by 70% by using robotics, in turn boosting workforce productivity by 8.5%.

Safety improvements—The refinery of today is becoming increasingly data-driven. Sensors now monitor heat, vibration, sound, gas levels and other crucial variables across every piece of equipment. Automated drones and robotics provide continuous visual inspections through high-definition video feeds. Connected workers are equipped with tablets and other technology that deliver real-time alerts, keeping them out of harm's way. Together, these innovations drive a safer operating environment—enabled by the robust, low-latency communication of private 5G.

Sustainability progress—Around the world, oil and gas companies are racing to meet commitments to reduce flaring and decrease greenhouse gas emissions. The best tools are digital ones, such as sensors that measure methane levels and can communicate with systems that deliver real-time alerts, allowing leaks to be fixed quickly, before they become major contributors to emissions. More efficient and safer operations are also inherently more sustainable, supporting positive environmental, worker and financial outcomes.

Global deployments with real results

Ericsson has partnered with refineries worldwide to deploy private 5G as the backbone of their digital transformations.

In one pilot in the United States, the solution deployed by Ericsson and its partners allowed the refinery to reduce its routine maintenance by 20-30%.

Ericsson tapped learnings from that initial pilot to deploy private 5G networks for three refineries operated by three different customers in other countries. At one of the largest refineries in Europe, an industrial 5G field lab was created to enable preventative maintenance across a complex pipeline network. Ultra-high-definition cameras, combined with machine learning algorithms, drive improved maintenance predictions. The 5G network is also used to support engineers with tablets and AR so that work processes can be further digitized and optimized.

In each of these use cases, implementation follows a staged approach. First, the operations are connected to a private 5G network. Data is then collected to enable asset condition monitoring, followed by a stage of machine learning and predictive maintenance, and finally, the ability to create a digital twin of the refinery environment for a host of operational improvements.

Building the refinery of the future

The path forward is clear: Digital technologies will drive the next era of refinery performance—but only if powered by the right network foundation. Operational efficiencies, safety gains, and sustainability outcomes are no longer optional; they are essential to drive bottom-line improvements and remain competitive.

Private 5G delivers the secure, scalable, high-performance connectivity needed to integrate advanced sensors, automated robotics, worker wearables, AI-powered analytics and more. It is the platform to enable the more efficient, safe and sustainable refinery of the future.

Ericsson brings deep expertise and proven deployments to help refineries operationalize private 5G globally and help them accelerate toward their efficiency, safety and ESG goals.

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