LoRaWAN®

A DIGITAL REVOLUTION FOR OIL & GAS FROM SCADA TO INDUSTRIAL IOT

LoRa Alliance®

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ABSTRACT

LoRaWAN® is a cost-effective and quickly deployed specification for wireless Low-Power Wide-Area Networks (LPWAN) that enables the transition to Industry 4.0 by connecting remote sensors and devices allowing data to be captured and analyzed for industrial markets. Some segments taking advantage of the technology include agriculture, cities, buildings, utilities and manufacturing. In this white paper our focus will be on LoRaWAN applications and deployments within the Oil & Gas (O&G) sector. We'll address the LoRaWAN protocol, which provides multiple advantages to enable applications that empower O&G businesses to improve operations with reduced operational costs; improved worker safety, and environmental and social governance in order to remain relevant and profitable in a quickly digitizing world. It does so by allowing energy companies to capture and digitize the vast amount of data from assets that are part of its operations and allowing machine learning to generate numerous energy related use cases.

Players in the O&G sector around the world who are driving the long-term implications for O&G cost efficiency through digitization present examples of LoRaWAN deployments that have proven to be successful for day-to-day operations. They are Actility, Aloxy, Chevron, Lansitec, MultiTech, Orbiwise, Pepperl+Fuchs, TEKTELIC, Webee, and Yokogawa, and are all members of the LoRa Alliance®.
Finally, from a technical standpoint, the specific requirements that are imposed upon O&G firms due to the often hazardous areas they operate in, are explained through various levels of equipment certification following guidelines in different regions of the world.

INTRODUCTION

The 21st century has brought a digital transformation not only in the energy markets, but throughout society. Digital technology has the potential to offer cost savings and efficiencies that O&G firms can use to their advantages, especially during uncertain times. O&G operations are some of the most complex and mission-critical: partially because of the remote areas and hazardous environments involved, partially because of the engineering and technical expertise necessary for return on investment, and partially because of the critical nature of the product and its distribution.

The industrial sector is transitioning from the ISA-95 model of supervisory communications and data acquisition (SCADA) to the fourth industrial evolution, or Industry 4.0, which brings a new set of technologies to enable the Internet of Things (IoT) and, more specifically, the Industrial Internet of Things (IIoT). Industry 4.0 began in manufacturing, but has become essential for all industrial markets.

Industry 4.0 involves digitally connecting computers and networks to automate systems. Sectors such as energy are capitalizing on Industry 4.0 technologies to ensure they can cost effectively receive more data to boost efficiency, productivity and safety.

However, much of the estimated $2.5 trillion of value projected by the World Economic Forum in 2017 originating from digitization within the O&G sector remains on the table. This eye watering projection was predicated on existing O&G organizational and operational constraints being reassessed to enable the rapid adoption of emerging technologies. As these constraints are slowly being removed, O&G is demonstrating it can now more readily enjoy the benefits of proven technologies previously overlooked from adjacent industries. A key wireless technology enabling quick, cost-effective connectivity for assets at scale is LoRaWAN, an unlicensed, wireless protocol for the IoT that falls under the umbrella of Low Power Wide Area Networks (LPWANs), which provide long-range communication on small, inexpensive batteries that last for years. This family of technologies is purpose-built to support large-scale IoT networks sprawling over vast industrial and commercial campuses. LPWANs can connect all types of IoT sensors and are best suited for use cases that don't require high bandwidth and are not time sensitive.

Lessons learned by analyzing how adjacent market segments like smart cities, agriculture, and hospitals capturing big data from garbage bins, moisture and fertilizer sensors and more have been actively applied to transform legacy O&G workflows. This has unlocked stranded data found in remote geographies via secure, economical, and highly scalable LoRaWAN networks and devices, allowing operators to retire their clipboards and spend more time managing by exception.

O&G firms have unique applications from pipeline monitoring to predictive maintenance to asset tracking that can benefit from digital technology. Although each operation is unique and has specific requirements, technology providers are stepping in to help address the industry's needs, bringing long-term benefits. The global pandemic has sped up the sector's transformation to digital and heightened the need for technology to improve operational efficiency and effectiveness.

THE BENEFITS OF LoRaWAN IN OIL AND GAS

The LoRaWAN protocol is bringing a transformation to the energy market by allowing it to automate and digitize the vast amount of data and assets that are part of its operations. As a result, LoRaWAN leads the way for long-term implications for O&G cost efficiency, worker safety and evolving operations, and lays the foundation for numerous energy use cases.

Equipment built to LoRaWAN specifications offers an optimal trade-off of device density, long battery life and range with secure AES-128 encryption. The sturdy RF link budget of over 160 dB as well as support for antenna macro diversity means LoRaWAN has plenty of capability to coexist and communicate in noisy environments such as an oil field.

Furthermore, the protocol is effective for propagating RF signals hundreds of meters within dense and harsh industrial environments such as refineries, and greater than many kilometers in open upstream oil fields. Unlike previous technologies such as mesh networks, LoRaWAN also supports moving devices, opening applications for vehicle tracking and worker safety.

LoRaWAN enabled devices have optimized battery power, which means battery life can be 10 or more years. The price of the sensors and mobile data plan are much less than legacy protocols, not to mention the installation and maintenance fee. Not all IIoT applications require the broadband, low latency performance of 5G technology, making LoRaWAN a more cost-effective and efficient choice.

LoRaWAN is the perfect fit for automating tasks that don't require high data rates but do require a wide geographical reach and secure data transmission. LoRaWAN's low data rate and long-range IoT communications uses license-free RF spectrum in the sub-GHz industrial, scientific and medical (ISM) band. In the United States the ISM band is at 915 MHz, while European Union ISM is at 868 MHz and 433 MHz in some regions, and 920 MHz is generally the ISM spectrum used in the Asia Pacific region. The LoRaWAN protocol provides bidirectional communications in a simple star network topology, ideal for connecting sensors and actuators capable of localization for tracking.

LoRaWAN AN OPEN AND AGILE STANDARD FOR DEPLOYMENT AND OPERATION

The LoRa Alliance® is a non-profit organization representing over 400 member companies developing and operating LoRaWAN equipment from silicon to solutions. Members offer LoRaWAN chipsets, modules, sensors, actuators, gateways, servers, managed networks, data management platforms all used for consumer, commercial and particularly industrial deployments within energy-specific solutions.

Network deployments consist of LoRaWAN end-point devices ornodes, often battery powered for many years, connected wirelessly to gateways that in turn connect to a network server, securely routing data to a digital twin, analytics application or business system.

Many thousands of LoRaWAN end-point devices can connect to a gateway that may be located either outdoors on towers or masts, or indoors in buildings providing wide area coverage within a facility in difficult to reach places and even within a vehicle connecting systems, assets and cargo while on the move.

The network server can be centrally located in the cloud or on-prem, either as a public or private network and as a single or multi-tenant deployment. The network server authenticates and provides unique keys for end-point devices enabling AES128 encryption at both the network and application layers; manages network communication for best performance and device density;enables seamless mobility, and removes device message duplication received by multiple gateways, which can improve network performance and device battery life.

The agility of the open LoRaWAN standard enables the network server to be distributed to the network edge, controlling several gateways in a macro-diversity configuration, or residing in the gateway for local decision making, reducing cloud compute and storage costs while improving network resilience and privacy. Edge-compute and core-network virtualization filters out unnecessary and costly communication between gateways and a central network server, and is well suited to deployments where data is being consumed by often isolated on-prem SCADA & Process Control Networks (PCN) without Internet connectivity for security reasons.

The vast LoRaWAN ecosystem offers bridge products for many legacy technologies such as RS485 serial, Modbus TCP or 0-10v/ 4-20mA analog interfaces, making it easier to connect existing equipment to the overall IoT infrastructure.

UNIQUE CERTIFICATION REQUIREMENTS COMMON WITHIN OIL & GAS SEGMENTS

O&G companies share many requirements found in other industrial segments, including ingress protection (IP), a wide operating temperature range, and often operate in hazardous areas requiring U.S. National Electrical Code (NEC) Class & Division certified equipment. Cost pressures and security concerns heightened as a result of economics and risk aversion , all of which can be accommodated deploying standardized and certified equipment.

Three types of certifications are frequently involved in LoRaWAN deployments. The first is country-specific RF regulatory approvals. All U.S. wireless equipment must be FCC (Federal Communications Commission) certified, for example, to ensure compliance with RF emissions and electromagnetic interference guidelines. Other countries have similar certifications. The European Union (EU) provides the CE Radio Equipment Directive (RED) certification, which ensures health, safety, and environmental protection standards for products sold through the EU.

The second type of certification involves LoRaWAN specification compliance and is critical to the open standards environment and interoperability. The LoRa Alliance's LoRaWAN CertificationCM Program assures end users that their application-specific end devices will operate on any LoRaWAN network. The program includes a suite of regional tests for operations in various geographic regions. Achieving this certification is important, because many rollouts include several LoRaWAN suppliers, and all must work together for customer success. Look for the LoRaWAN CertifiedCM mark on equipment for assurance it has gone through the proper processes.

Beyond those two certifications, the O&G sector often operates within hazardous areas. Receiving certifications for products to safely operate in these areas is important to be a supplier to the energy sector. Most of the world operates according to ATEX/IECEx using their Zone ratings. North America operates on the Class & Division rating prescribed by UL per the NEC articles 500-503.

UL ratings are either Class I, II or III, Division 1 or 2, and Groups ranging A through G. Class I is gases, II is dusts, and III is fibers. Division 1 is for ignitable concentrations of the specified Class of product that exist under normal operating conditions. Division 2 involves ignitable concentrations

of specified Class of products that are likely to exist only under abnormal operating conditions. There is an effort underway to transition North America to a Zone system that is slightly different than the rest of world's counterparts and is per the NEC articles 505-506.

Though regulatory and hazardous-area certifications are essential for many companies, O&G operators generally understand that if a product will not be operating near a hazardous environment, such certification might not be required. For instance, if a sensor is deployed 100 meters away from an environment that is either non-hazardous or is well vented, certification is not required. This can be useful, since the certification process is quite rigorous and can lead to a more costly deployment than one with a similar device that has not been hazardous certified. For example, the LoRaWAN gateway can be deployed where the certificate is not required. LoRaWAN technology provides the distance capability for the gateway to communicate with the end nodes which are in the hazardous area. A reference for determining the area classification around a process area related to Petroleum Facilities can be found in API's Recommended Practice RP500.

Certification is important to expanding the overall addressable market, and the number of suppliers available in a vertical market, which translates to accelerated end user adoption. This is even more important in vertical markets such as O&G, and its multitude of sub-segments, where many untapped opportunities exist, and end users are still exploring new applications for LoRaWAN. Suppliers of LoRaWAN operated devices understand that participation in the certification process is simply a cost of doing business in the sector.

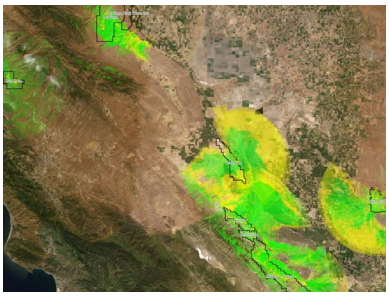
REAL-LIFE APPLICATIONS

OVERVIEW OF A LORAWAN APPLICATION DEPLOYED BY AN OIL & GAS SUPERMAJOR

Chevron, a leading multinational energy firm based in North America, operates a large oil field in San Joaquin Valley, California, where heavy oil makes up about 86% of its production. The field has many disparate assets, which operators often drive to and check, monitor and manually document operations. LoRaWAN technology has recently been deployed in this upstream operation, offering Chevron a paradigm shift.

San Joaquin Valley, California

About three years ago, Chevron's IT team began to receive requests from operators to automate part of the processes in the San Joaquin Valley. Chevron's responses to these requests were inspired by IIoT advancements in smart cities and adjacent markets. The team wanted to own the core LoRaWAN network for re-use to support varied use-cases, drive adoption of open standards in the partner ecosystem, target stranded, high volume, low consequence measurements, and shift the mindset from devices being assets to consumables. Criteria were to have flexible backhaul options and a stable technology, have both on-prem and cloud deployment options, tap a robust partner ecosystem, work with infallible devices, and iterate quickly. Chevron was also seeking more than a five-mile range and more than five years of battery life, all with low-power devices that cost less than $500 each.


San Joaquin Valley Business Unit - LPWAN Guardrails unlocking stranded value in the field

With such a long list of requirements, Chevron began its search for a solution that would solve the challenges in San Joaquin Valley but with potential for other areas of the company's vast operations. Cellular backhaul at the San Joaquin site combined with a LoRaWAN deployment fulfilled the requirements. In about six months, Chevron had 30 LoRaWAN IP67 rated outdoor gateways and 3,000 devices online, and the system has been in operation for about a year.

Chevron's San Joaquin Valley Business Unit deployed digital dipsticks for chemical management. The firm now has the devices performing transmission line measurement (TLM). The sensors track the flow of the fluid to the collection point

or tank. When the temperature drops, the lines can plug, and with 8,000 wells in one field, there are many locations for problems to occur.

Chevron collaborated with a chemical vendor to refine the sensor design and deploy ultrasonic tank lids. The sensors involved in the deployment cost about one-tenth of sensors using another technology. The company used the chemical vendor's cloud for the initial application and data flow.

Digital dipsticks – Ultrasonic tank lids

The LoRaWAN deployment integrates with the cellular network for backhaul, making governance and cybersecurity easier. Chevron deployed 30 Multi-Tech gateways that virtualize the network server for onboard edge-compute data processing, located at radio towers across six oil fields in the valley.
The topology allowed low-consequence data to avoid integration with many of the SCADA (Purdue Model) layers, yet still be securely ingested into the SCADA application layer. Chevron used existing radio service providers to deploy the gateways, along with remote device management to accelerate scalability. The LoRaWAN sensors were deployed quickly and began transmitting data to the cloud for distribution, delivery and consumption. The system has helped Chevron digitally transform its legacy model manual tank readings to one of supervisory enterprise control.

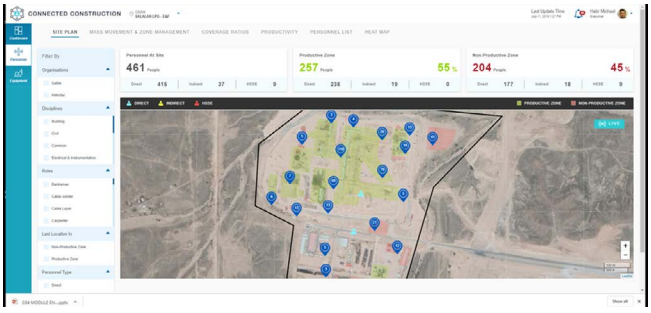
O&G operations include numerous small industrial sub-domains under one umbrella. Each sub-domain must transmit data from an oil field to the pipeline to the shipping company. For Chevron's established brownfield environments such as San Joaquin many new technologies must coexist with the brownfield operations' legacy control systems. Before the LoRaWAN deployment, Chevron sent workers in trucks to check the tanks every few weeks. The new LoRaWAN system offers hourly updates and an intelligent work order system. Because of the new technology, the company had fewer plugging events during winter of 2020 and expects even fewer this year. The energy firm recovered its investment and had a 100% return within the first year.

Long term, the system will transition to the Chevron cloud for multipurpose, standards-based data flows. Operating expenses (OPEX) are improving because the technology team can quickly swap broken equipment. Chevron also appreciates the 10-year battery life of the sensors; with thousands of devices, changing batteries is expensive. In addition, the ability to plug and play and move architecture where it's needed is beneficial.

A Chevron operations leader noted that digitizing the chemical management workflow had a higher return on investment than any well the San Joaquin Valley Business Unit could have drilled. The larger vision is to use the California deployment to paint a picture for the rest of the organization and develop a repeatable template that can be reapplied and improved upon in other areas of the business.

WORKER SAFETY AND PRODUCTIVITY AT PETROFAC

Petrofac is a leading provider of oilfield services, with operations in 29 countries. As outlined above, large oil production facilities require special equipment compatible with potentially explosive atmospheres. The LoRaWAN ecosystem already provides native ATEX/IECEx LoRaWAN devices certified for Zone 2 or Zone 1, such as Abeeway trackers which have been deployed by Accenture for Petrofac for one of the largest worker safety and productivity applications in operation in the O&G segment.



Dashboard - worker safety and productivity at Petrofac

Seamless indoor and outdoor connectivity was achieved throughout the extremely large campus leveraging Cisco gateways coordinated by Actility ThingPark Enterprise industrial network server, deployed in a high-availability configuration and seamlessly integrated to Microsoft Azure IoT. Asset and worker geolocation is achieved both indoors and outdoors leveraging a multi-technology fusion algorithm leveraging GPS, Wi-Fi and Bluetooth.

The Actility ThingPark Enterprise LPWAN platform deployed by Petrofac includes local processing capabilities with a full range of ready to deploy bidirectional drivers for all major device suppliers which normalize proprietary binary

protocols to uniform Json messages, which are then easily managed by local flow processing integrated to IBM Node-RED as well as built-in connectors to dedicated edge processing servers such as AWS Greengrass, and to all leading IoT cloud platforms including Microsoft Azure IoT & IoT Central, AWS IoT or PTC ThingWorx.

MORE ENERGY SECTOR USE CASES

As deployment of LoRaWAN technology has increased within the energy market, the LoRa Alliance has stepped in to facilitate collaboration among the various players. The LoRa Alliance helps connect O&G firms with equipment manufacturers to address sector-specific use cases and solve the real-world problems described below.

ENVIRONMENTAL GOVERNANCE

The Energy Industry is being tasked to accelerate decarbonization and reduce emissions not just from government policies, but also through large investment funds influencing how corporations set goals. Investment is being made across the industry from electric processing plants to setting up solar farms near large installations to move towards net neutral.

The Oil and Gas Climate Initiative (OGCI) has identified methane as a key gas for Intensity Target Transparency, targeting a 45% reduction in methane emissions by 2025 and 60-75% by 2030. OGCI has surpassed the original collective average upstream methane intensity target of 0.25% and will now aim to lower methane intensity to 0.20% by 2025. The progress to date represents a 22% reduction in absolute upstream methane emissions since 2017.

Most producers today do not have the means to measure the Green House Gases emissions they produce, but rather estimate the amount based on equipment efficiency and other metrics.

LoRaWAN technology is exceptionally well positioned to address Environmental Governance targets in most O&G producing countries, connecting advanced sensors for fugitive methane emissions capable to detect, measure and mitigate methane emissions and other Green House Gases remotely. Facilitating real-time audits upon request to measure improvements and performance against decarbonization targets in remote O&G fields, rigs and along millions of km of pipelines in use today (340,000 km in Canada alone).

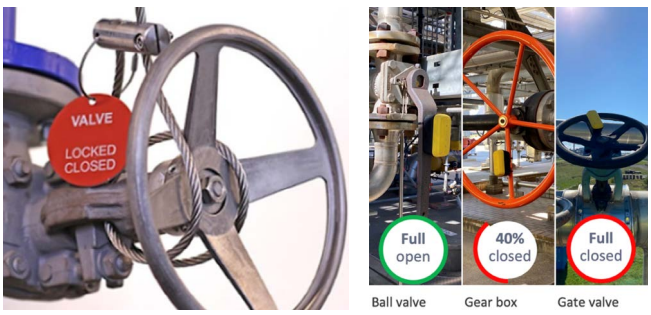
CONNECTING STRANDED ASSETS IN GREEN AND BROWNFIELD DEPLOYMENTS

Several O&G firms are deploying private LoRaWAN networks that virtualize the network server on-prem, closer to the various sensors to reduce data backhaul costs and to enhance security as their onshore and offshore platforms often run isolated control systems that are not interconnected to the cloud. Such edge processing can be co-located in the same facility as the network server and data management platform or even within a gateway publishing data to local application platforms or control systems. This works well for energy deployments that involve isolated systems where a private LoRaWAN network offers greater privacy, control and resiliency, particularly in hard-to-reach geographies providing visibility into stranded and remote assets; items such as chemical tanks, production tanks and flow tanks, all of which need to be remotely monitored cost effectively.

Chevron has also deployed an Orbiwise LoRaWAN network server within its data and IT system that can communicate with thousands of gateways and the LoRaWAN devices connected to them in green field oil fields and use cases. The technology serves as a traffic cop in many ways, ensuring the data goes to the appropriate applications. The technology makes sure Chevron's LoRaWAN network stays operationally balanced. OrbiWAN Edge could be added to an oil platform in a remote area or anywhere without an internet connection.

EQUIPMENT MONITORING

The chemical industry has many batch processes that require real-time feedback about the status of the process control system, ensuring valve position, do periodic checks and be critical to the system continually running effectively. LoRaWAN technology helps check whether valves on a pressure release system are in the correct position. Aloxy's LoRaWAN sensors at each end point in these applications enhance worker safety as well. With fewer workers in the field to check equipment, there is less exposure to dangerous environments.



Many O&G firms have small tanks that can be moved around a customer site. LoRaWAN is an excellent technology to track the tanks and ensure the levels are accurate. Pepperl+Fuchs manufactures sensors that allow an oil company to check the liquid level in a tank, and alert staff about any problems.

Energy firms all have cooling systems, and LoRaWAN helps the firms ensure the water pool is always filled with enough cooling water. Many O&G firms also need to track pipelines and control valve positions, and sensors can help meet these requirements.
Sensors are also used to monitor rotating equipment vibrations. Sensors from Yokogawa reduce downtime and unplanned maintenance costs and help energy firms migrate from periodic maintenance, run to failure, and manned patrols to 24-by-7 condition-based maintenance.

ASSET AND PEOPLE TRACKING

Because deployments are spread out, asset tracking is a common use case for O&G firms in the U.S. In a large oil field, a company will have a central office, which is generally an environmentally controlled trailer. TEKTELIC has deployed LoRaWAN technology in these areas to keep track of the trailers, monitor whether a trailer is warm and if there are people in the area.

Because an oil field has expensive equipment, often located in a remote area, a firm might set up a perimeter around the site with sensors that help track if anything comes into or goes out of the site. And tracking the assets within the site is just as important.

O&G firms often have emergency showers at facilities. If a worker is exposed to hazardous materials, the showers allow the worker to quickly wash. An oil firm needs to know when someone is in the shower so paramedics can be dispatched. A LoRaWAN sensor can automatically communicate that the shower is on. The showers also need to turn on every few weeks, so bacteria don't build up in the pipes. The technology allows the showers to automatically be started and stopped.

Emergency showers on hazardous sites

The first 10 to 15 seconds after exposure to a hazardous substance, especially a corrosive substance, are critical. Delaying treatment, even for a few seconds, may cause serious injury. Therefore you find many emergency showers spread over the chemical plant and providing additional insights in the usage of your existing safety showers and eyewash stations will increase safety and efficiency. The signal indicating that the safety shower is in use will improve Emergency first responder times, incident reporting, time stamp of inspections and detect failures caused by malfunctions of the actuator.

For some hazardous areas, people are not supposed to enter or stay for a long period of time. Lansitec has deployed people and asset tracking products and solutions with LoRaWAN to help O&G companies to reduce the risk and improve management efficiency. This technology can also be used to locate all workers in the field in case of emergency to provide support or evacuation.

DATA ANALYTICS

For some hazardous areas, people are not supposed to enter or stay for a long period of time. Lansitec has deployed people and asset tracking products and solutions with LoRaWAN to help O&G companies to reduce the risk and improve management efficiency. This technology can also be used to locate all workers in the field in case of emergency to provide support or evacuation.

As we said earlier, LoRaWAN technology is bringing a transformation to the energy market by allowing it to automate and digitize the vast amount of data and assets that are part of its operations. When sensors connect, they unlock massive amounts of data to be analyzed and leveraged as business insights. Connectivity is crucial to capitalize on the opportunities brought forth by data; it contributes to generation revenue.

Collecting various data sources can cause data to reside in silos, preventing end users from taking full advantage of the collaborative intelligence of understanding patterns, anomalies and accessing real-time data insights. In addition, it is often complex to identify multiple data tags, PLCs, gateways and eventual blind spots in case equipment is not properly connected. Normalizing data therefore is critical.

The data gathered during an O&G deployment of LoRaWAN technology can be collected and normalized through real-time software from providers like Webee. Their solution, which can run in the cloud or on-prem, ensures data is

collected, managed, then effectively visualized and distributed to complementary products such as ERPs and third-party APIs. Webee's flexible, no-code Visual Designer toolset allows users to receive real-time alerts and actionable insights while extracting behaviors within consolidated historical data at any given time.

Realtime data & analytics – example of Webee dashboard for Yokogawa's Sushi Sensor

LoRaWAN helps streamline an IIoT deployment process by penetrating data silos to normalize, process and analyze in real time. Because O&G firms often have data at the edge, the protocol is essential for collecting and normalizing data for processing. Some LoRaWAN suppliers have also developed multiprotocol gateways to connect LoRaWAN with other communication technologies.

RECOMMENDATIONS

Recent economic and global health factors have made the use cases around LoRaWAN technology critical for O&G firms – not just a «nice to have» option. With the LoRaWAN market expected to experience a 43% compound annual growth rate through 2025 to reach nearly 1.1 billion connections, the technology is ideal for massive scale rollouts[1]. In addition to power efficiency, the long range and star topology are distinguishing features of LoRaWAN from other connectivity options. LoRaWAN can be deployed for less than one fifth or as little as a tenth of an instrumental budget, making it a low-risk, high-gain proposition. Additionally, automating processes mitigates the risk of human error.

O&G companies must continue to challenge past assumptions in order to be able to unlock the full potential that digital transformation of assets, processes and decarbonization targets can bring to their business. This means moving outside of established SCADA and Process Control Network architectures, to using open, standards-based technologies with a broad ecosystem of vendors that can be interconnected and are increasingly interoperable.

The versatility and agility of LoRaWAN is revolutionizing established approaches to data capture that cost effectively connects stranded and underserved assets, unlocks silos and decouples devices from applications. With a simple to deploy and manage Industrial IoT architecture in green-field deployments, sensors are connected to LoRaWAN networks that are integrated to on-prem or cloud data management platforms. Ideal for new oil fields and use cases like monitoring door-opening sensors, valve positioning, and even if emergency showers are being used after exposure of personnel to a hazardous substance. LoRaWAN can integrate into existing, often isolated, SCADA and control systems by brokering data directly into the application layer, thereby bypassing many of the complex Purdue models layers, ideal for quickly accessing data from low consequence data coming from things like tank lids or flow sensors. LoRaWAN offers the opportunity to meet and exceed environmental and governance targets using the technology to automate monitoring such as continuous methane emissions with a full audit trail to achieve decarbonization targets.

The LoRaWAN device and infrastructure ecosystem is now reaching a tipping point where vendors are responding to demands by operators to connect their assets in hazardous environments by utilizing the long-range propagation and high noise-immunity characteristics of LoRaWAN into hazardous locations and certifying LoRaWAN equipment for such deployments, opening up further applications within refineries and other hazardous locations.

To learn more about certifying your device, please visit our Certification page.

For information and content on **LoRaWAN for Smart Industry,** please visit our Smart Industry page.

This white paper is the result of a fruitful collaboration between members of the Smart Industry Work Group of the LoRa Alliance. With special thanks to:

[1] *IoT Analytics; LPWAN Market Report 2020-2025 – Excerpt*