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SMART MONITORING OF METHANE EMISSIONS

How sensors, drones, robots, and satellite measurements help with detailed reporting under harsh conditions.

CONTENTS

EU METHANE STRATEGY

Methane is the second most important gas contributing to climate change. In comparison to carbon dioxide, methane is 84-fold stronger over a 20-year period and 28-fold stronger over a 100-year period. Thus, methane is the second biggest contributor to climate change after carbon dioxide.[1] In this respect, reducing methane emissions is crucial to achieve the EU climate targets 2030 as well as climate neutrality by 2050.

In October 2020, the European Commission adopted an EU strategy to reduce methane emissions. The strategy sets out measures to cut methane emissions in the EU and internationally. Furthermore, it outlines concrete cross-sectoral and sector-specific actions. One of the priorities in the short term is to improve the measurement and reporting of methane emissions. An obligation to improve detection and repair of leaks in gas infrastructure will be proposed, and legislation to prohibit routine flaring and venting practices will be considered. Furthermore, the European Commission will engage in a dialogue with its international partners and explore possible standards, targets, or incentives for energy imports to the EU as well as the tools for enforcing them.[2]

In the short term, this means that energy companies will need to close existing data gaps and improve their monitoring and reporting of methane emissions on a voluntary basis. In the medium term, the European Commission will propose binding legislation with regards to methane emissions: 'The Commission will table in 2021 a legislative proposal on compulsory measurement, reporting and verification for all energy-related methane emissions, building on the Oil and Gas Methane Partnership (OGMP) methodology'.[3] A higher-tier reporting (see Section 2) will become mandatory. Furthermore, the new legislation 'should include an obligation to improve leak detection and repair (LDAR) of leaks on all fossil gas infrastructure, as well as any other infrastructure that produces, transports, or uses fossil gas, including as a feedstock'.[4]

In addition, the European Commission plans to develop methane standards for fossil fuels consumed and imported into the EU. A Methane Supply Index (MSI) at EU and international level will be compiled and published.[5] Therefore, energy companies will have to meet methane standards.[6] The legislation will affect all energy companies in the gas, oil and coal sectors and will apply to fugitive and vented emissions as well as incomplete combustion.

- Measurement, reporting and verification for all energy-related methane emissions will become compulsory in the EU.
- Methane-supply index (MSI) will be published.

METHANE REPORTING GUIDELINES: UNFCCC AND OGMP

According to the EU Climate Monitoring Mechanism, all EU Member States must monitor and report their emissions. The EU Climate Monitoring Mechanism describes EU internal reporting rules, which are based on international guidelines and obligations.[7] In this respect, the EU Methane Strategy refers to the guidelines and recommendations provided by the United Nations Framework Convention on Climate Change (UNFCCC) and the Oil and Gas Methane Partnership (OGMP).

The UNFCCC has a **three-tier reporting framework** for methane emissions, which applies to all sectors.

- **Tier 1** is the most basic approach and based on a combination of activity data and emission factors.
- **Tier 2** is less complex and demanding than Tier 3 and combines elements from Tier 1 and Tier 3.
- **Tier 3** refers to the most detailed reporting and is based on a rigorous bottom-up assessment at the facility level, involving identification of equipment-specific emission sources, equipment inventory, and measurement of emission rates per equipment type.[8]

In addition to the UNFCCC framework, the OGMP reporting guidelines seek to improve methane reporting by focusing on technology advancement and policy development. The new OGMP 2.0 framework for methane reporting covers all segments of the oil and gas sector and helps to report methane emissions from all assets - operated and non-operated.

The OGMP 2.0 framework allows companies to categorize asset-level reporting into five categories:

- **Level 1** is the lowest reporting level and is applicable only if a company has very limited information sharing.
- At **Level 4**, emissions are allocated to individual source types and estimates are based on specific emission factors (EF) and direct measurement.
- **Level 5** or Site-Level is the highest. At this level, emissions are allocated to individual source types, and reporting is based on site-level measurements to reconcile source and site level emission estimates.[9]

Level 4 and 5 are recommended by the European Commission and preferable for reporting methane emissions because they provide on-site quantification.

Currently, reporting approaches vary considerably across EU Member States. According to the EU methane strategy, ‘in the energy sector, [UNFCCC] Tier 3 reporting is achievable for industry and will therefore be the EU target standard’.[10] This means that the highest reporting standards, which are based on on-site source-level quantification, will become mandatory for the monitoring of methane emissions by energy companies. Thus, companies will have to set new goals in response to new requirements for methane monitoring: increase site coverage, frequency, and tracking, response-time efficiencies, overall cost-effectiveness and reporting transparency.

DETECTION OF METHANE EMISSIONS: TOP-DOWN AND BOTTOM-UP APPROACHES

Approaches to the detection of methane emissions can be divided into two major groups: top-down and bottom-up assessments.

The top-down approach includes various arial-based techniques using satellites, helicopters, airplanes, and drones. These techniques allow creating a global picture at scale with global/regional or site-specific focus.

Bottom-up assessments include methods such as measurements carried out by on-site teams equipped with Optical Gas Imaging (OGI) cameras and Hi Flow® Samplers, robots, and/or sensors. The bottom-up approach provides detailed information about individual sources, but it does not create pictures at scale.

Until recently, methane measurements have mostly been conducted by airplanes/helicopters and on-site teams. These detection and quantification methods could successfully meet the demands of previous regulations requiring infrequent reporting only. However, new regulations and higher reporting standards are much more demanding for companies, which, in this new reality, will have to ensure frequent on-site monitoring with minimal discrepancies between top-down and bottom-up measurements.

The following use case of monitoring a transmission pipeline and compressor station on a weekly basis illustrates these changing requirements. Previously, companies could fly over the pipeline with a helicopter or airplane once or twice a year and send out on-site teams to check the individual sources on a regular basis. However, if companies now must increase the frequency of inspections and implement weekly monitoring,

costs and time needed for inspection would increase exponentially. Furthermore, since the airplanes and helicopters cannot fly close enough to the source, the discrepancies between top-down and bottom-up measurements would remain quite substantial.

For this reason, the European Commission as well as gas associations[11] have underlined the increasing importance of new technologies in measuring methane emissions. Significant technological advances made in recent years have considerably improved accuracy and cost-effectiveness of methane monitoring through satellites, drones, robots, and sensors. Three 200-km satellite photos, for instance, could cover a transmission pipeline between two cities. The use of drones makes it possible to survey large amounts of infrastructure quite quickly and to identify individual sources. Importantly, drones can facilitate continuous monitoring – a key to addressing intermittent leaks.

As new methods get more widespread, it will become possible to regularly compare bottom-up emission inventories to independent top-down quantifications and to combine previously used tools with the newest ones. These comparisons will also guide the continual improvement of methane emissions inventories.

WHY CONTINUOUS MONITORING MATTERS

Continuous monitoring is crucial to the reduction of methane emissions, particularly as in many cases methane sources are intermittent and recurrent.

It is not possible to anticipate where the leakage is most likely to occur, since each potential leakage point is affected by different factors such as the technical condition of the equipment (e.g., the degree of deterioration, type of material) and the climatic conditions (e.g., temperature drops, humidity).[12]

Furthermore, it is difficult to identify a direct interrelation between the number of methane leaks and the total volume of methane emitted, given that the total volume of leaked methane largely depends on the intensity of the leaks rather than on the number of leakage points.

A small fraction of certain categories of equipment can therefore account for a large proportion of total emissions. These large emission sources are often called super-emitters and refer to a specific site or a facility with disproportionately high levels of emissions. During inspections, it is therefore not feasible to focus merely on certain areas of the pipeline or compressor station. Rather, it is more efficient to increase the number and frequency of inspections per year. Detecting the exact location of leaks as quickly as possible will significantly facilitate the reduction of methane emissions.

The following figures underline the importance of regular and frequent inspection: annual inspection allows decreasing methane emissions by 40%, quarterly inspection results in a 60% reduction and monthly inspection leads to an 80% reduction.[13]

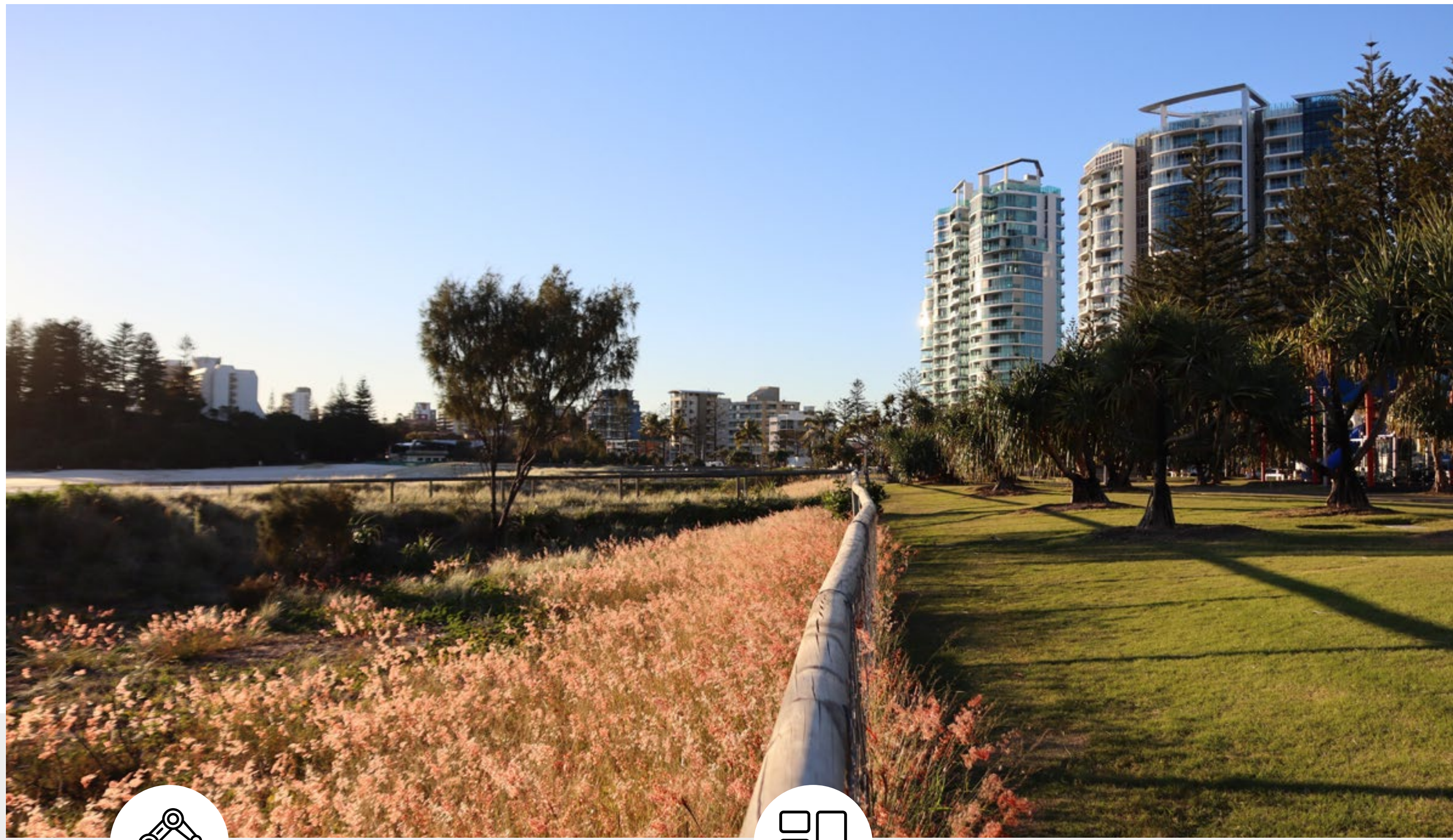
Increasing the frequency of inspections per year or, even more so, continuous inspection, could also improve transparency by closing data gaps and making it possible for companies to report on and explain the level of emissions at any point in time.

The future EU policy on the reduction of methane emissions will reflect these considerations. Accordingly, the main policy components will be based on:

- source-level quantification with increased accuracy;
- frequent inspections (continuous monitoring) that should remain efficient in terms of costs and time;
- the minimization of discrepancies between top-down and bottom-up approaches;
- transparent and trustworthy reporting that could be accepted by NGOs and policy-makers.

A SMART HOLISTIC APPROACH

New reporting standards bring new challenges for companies. A central question for companies in the energy sector is how to implement continuous monitoring in a cost-effective way.



A possible answer to this question is the integration of already established methods with new digital tools and the creation of a smart holistic monitoring system. Current knowledge regarding the detection and quantification of methane emissions could be supplemented and improved using new tools such as satellites, drones, robots, and sensors (see Sections 5.1-5.4 below). These tools could reduce the time required for monitoring and improve cost-efficiency. Furthermore, they could expand knowledge and skills, which could, in turn, be monetized. Importantly, smart digital tools can also aid the minimization of discrepancies between top-down and bottom-up measurements.

Holistic smart methane monitoring system[14]

SATELLITES
- Provide global picture at scale with high resolution
- Satellite measurements can be integrated with other data streams

DRONES
- Low-cost, long-range ant time-efficient, automated surveillance
- Can monitor methan, as well as infrastructure
- Minimal maintenace costs

SPOT ROBOTS
- Allow detailed identification of emission sources, completely autonomous
- Can measure emissions both at pipelines and compressor stations

DASHBOARDS
Show real-time emission levels at a particular point (e.g. compressor station); alerts and notifications

ENGINEERING REPORTS
Provide knowledge and observations regarding methane leakage points

SENSORS
- Cost-efficient, real-time monitoring, calibration, high accurancy
- Monitoring of CH_4,CO_2, CO, hydrogen, propane, LPG, smoke

SCADA-ARCHITECTURE
Can be integrated with cloud/on-premise infrastructure to assure scalability and flexibility

SATELLITES

A growing number of satellite projects have been set in motion over the past years, among them GHGSat, Sentinel-5, GOSAT, and SCIAMACHY. Satellites can detect and quantify methane emissions on a global/regional scale and particularly focus on plume detection.[15] They differ in terms of pixel resolution and data frequency and can thus complement each other. For these reasons, data from various satellites are often integrated.

TROPOMI, for instance, a single instrument on Sentinel-5, provides daily global coverage. GHGSat has a different strategy and targets limited viewing domains with very fine pixel resolution, detecting a wide range of methane point sources.[16] Therefore, drawing on both kinds of imaging, a 200-km view by Sentinel-5 can be zoomed in with a 12-km view of GHGSat.

The newest generation of satellites (GHGSat) has demonstrated the ability to map methane plumes at a resolution as granular as 30-50 m. For instance, GHGSat-D has an effective pixel resolution of 50 × 50 m^2 over targeted 12 × 12 km^2 scenes[17]. New upcoming satellites, for example MethaneSAT by the Environmental Defense Fund (EDF), are expected to detect methane at even finer resolutions. The data provided by satellites represent concentrations of methane, which are then converted into actual leakage rates. One of the difficulties is that satellites measure all methane available between the earth's surface and clouds. Furthermore, satellite measurements are seriously impacted by a variety of factors, among them cloud cover and surface brightness. If, for instance, the satellite imaging and detection is conducted every two weeks and the weather happens to be cloudy that day, no satellite images could be generated for at least 28 days. Considering the increasing number of satellite projects, continuous data collection with high resolution might become possible within a few years' time.

DRONES

Drones offer a more granular detection and quantification of methane emissions. In comparison to airplanes and helicopters, they can fly at a different altitude and speed, stop, and get very close to the source to record the divergence. They have a low detection and quantification limit, which ranges between 0-50000 ppm. Furthermore, the process of inspection can be speeded up through prior programming of a predetermined flight path. Similar requirements as those applied during measurements conducted by airplane should be complied with when using drones (e.g., measurements of wind speed, temperature, outside humidity).

As for the technical characteristics, it is important to mention that a new generation of drones has been tested in harsh environments around the globe: in low temperatures of -30 °C, at wind speed of 24 m/s, and in highly explosive environments. Currently, several drone manufacturers are going through the process of ATEX certification with classification 'Zone 1'.[18]

A drone equipped with a laser methane sensor can stay in the air for up to 45 minutes and cover a distance of 15 km. Methane can be measured at different altitudes of between 5 and 100 meters. A site of around 150 ha can be inspected within 11-12 hours by drone. In contrast, inspecting a similar site on foot using an OGI camera and a Hi Flow® Sampler would take an entire week. The accuracy of drone quantification accounts for 85-95% compared to that of usual ground measurements. A huge advantage of using drones in comparison to OGI cameras is that the sources of leaks can be seen directly and are obvious.

Finally, apart from monitoring emissions, drones can be deployed to assess structural changes in pipelines and predict potential leakage points well in advance. Light detection and ranging (LiDAR) create three-dimensional digital models to detect structural changes in pipelines over time. Using RGB imagery and thermal overlay allows predicting structural weaknesses and possible leakage points (e.g., predictive maintenance).

Using drones, the overall maintenance costs could be reduced, and potential leakage points prevented.

SPOT-ROBOTS

A new generation of leg robots, known as Spot robots, has been developed for carrying out autonomous inspections in potentially hazardous environments. Spot robots can climb as well as open, close and grasp certain objects. They move at a speed of 1.5 m/s and can cover a distance of up to 8-16 km. Spot robots can be used for methane monitoring in facilities such as LNG plants[19], offshore platforms, compressor stations, and pressure-reducing stations. Apart from methane monitoring, the following tasks can also be automated using Spot robots:

- fire safety: detection and inspection of fire extinguishers (including the identification of the last date of inspection)
- damage inspection under hazardous conditions in the context of physical (e.g., frost), chemical (e.g., chlorides, sulphates), biological (e.g., bacteria-biogenic sulphuric acid), and mechanical (e.g., abrasion, erosion) hazards
- reading of displays and creation of BIM models[20]

Finally, by using LiDAR sensor payloads, it is possible to create 3D models, known as digital twins. These are digital representations of physical objects that fully depict the main characteristics of the originals and make real-time interaction possible.[21] The main advantage of Spot robots is full

SENSORS

Fixed-location sensors are extremely cost-efficient and help monitor leakages in remote areas, in locations that are hard to access and in places of recurring leaks. Sensors offer real-time continuous monitoring of either methane alone or a wider spectrum of gases (CO2, LPG, hydrogen, propane).

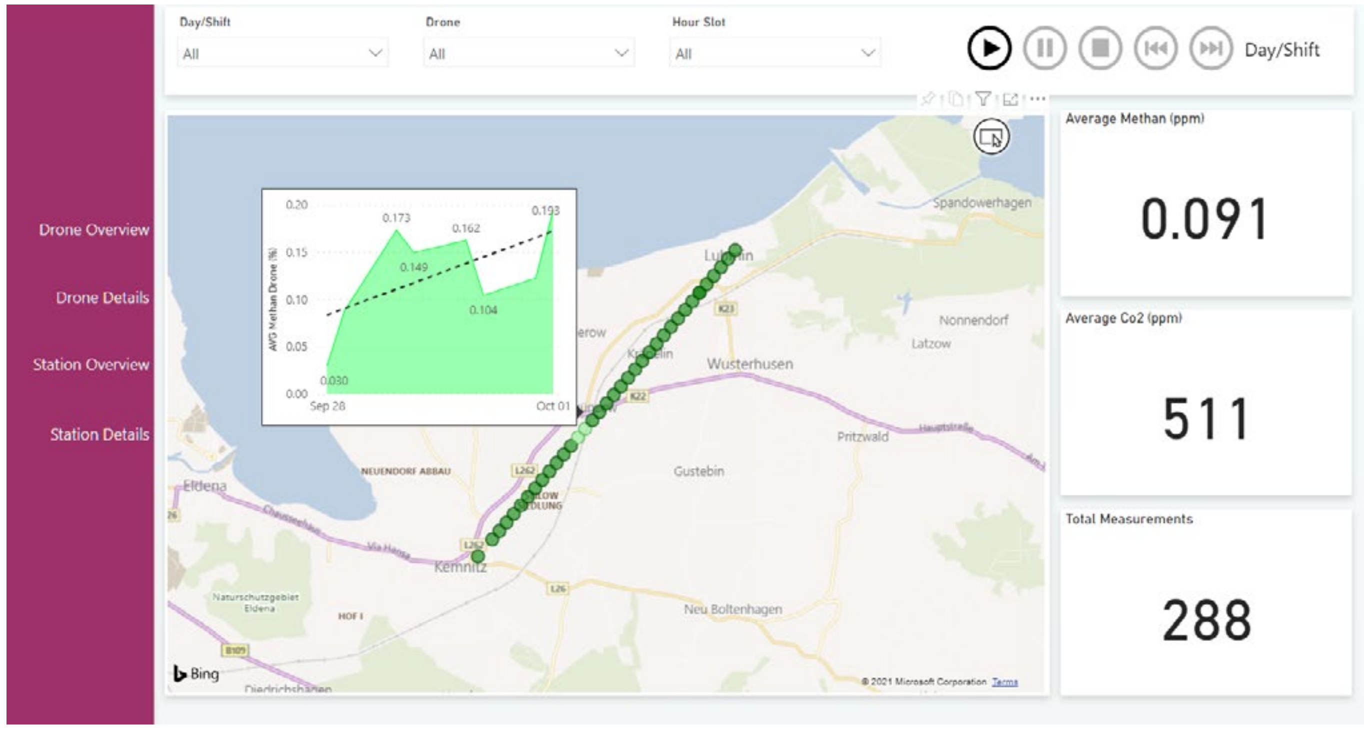
For an isolated 100 m^2 site, positioning the detector in downwind direction from the equipment will detect leaks as small as 100 ppb. For larger areas, multiple sensors need to be deployed across the site. When identifying where fugitive leaks may occur, the weather conditions specific to each site need to be evaluated to determine the optimum positions for the sensors. A sensor detects the plume downwind of a leak and uses the wind speed to calculate the total emissions at a site.
The main advantages of fixed-location sensors are continuous monitoring and instant notification in case of fugitive emissions, which facilitates the minimization of leakages. Furthermore, fixed-location sensors help identify emissions undetected during mobile inspections.[22]

TRANSPARENT REPORTING

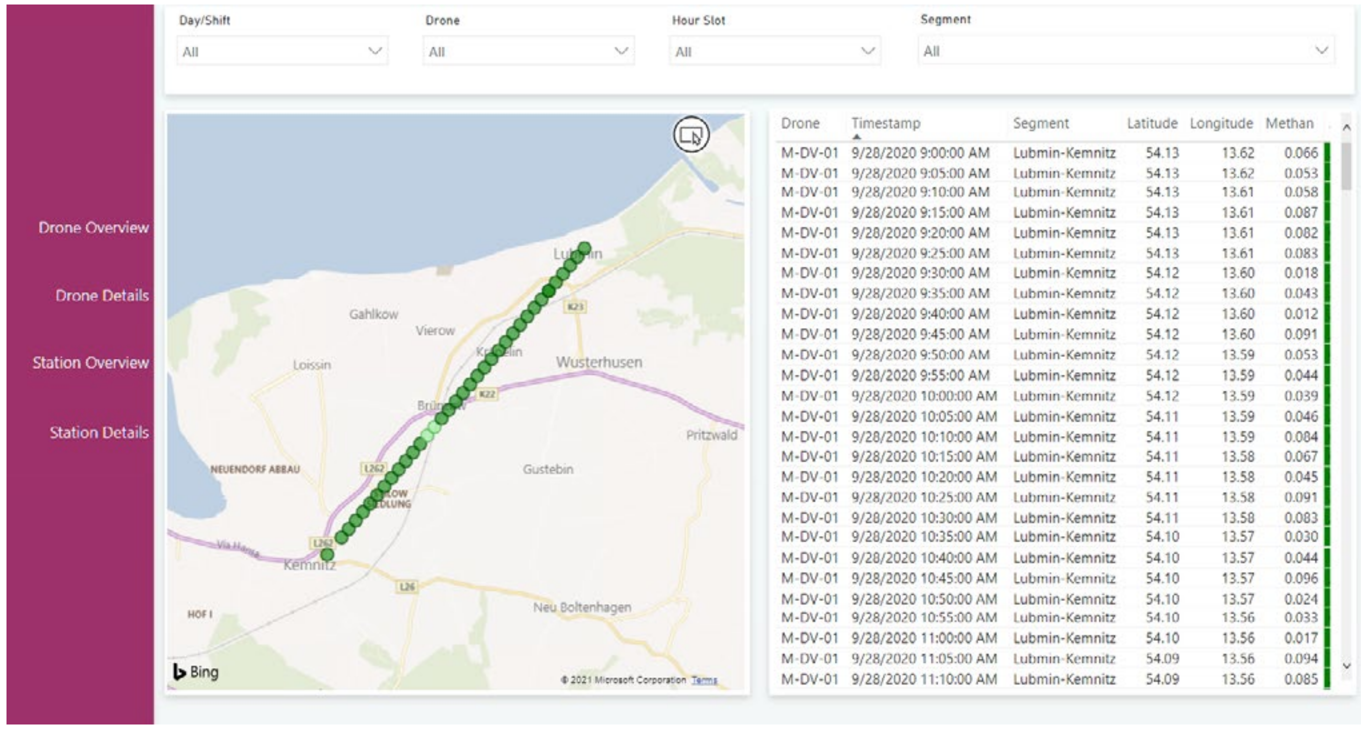
One of the main debates facing gas companies today regards data reliability and public acceptance. NGOs claim that data on methane emissions provided by companies is not transparent and therefore unreliable. Using smart digital tools could help increase transparency and deliver convincing data due to more frequent inspections, near real-time monitoring, and corresponding reporting.

The interactive dashboards used in smart digital approaches facilitate accessing the data and make it easy to track methane emissions. They display historical as well as real-time values and offer a variety of search functions, including filters for specific locations, facilities, and time points. Companies can therefore, at any moment, provide complete data sets for specific sites regarding leakages and leakage rates. Furthermore, in case of leakage, corresponding notifications are issued automatically (e.g., via email, signaling, and color changes). Therefore, transparent evidence of current emission levels is provided at any time.

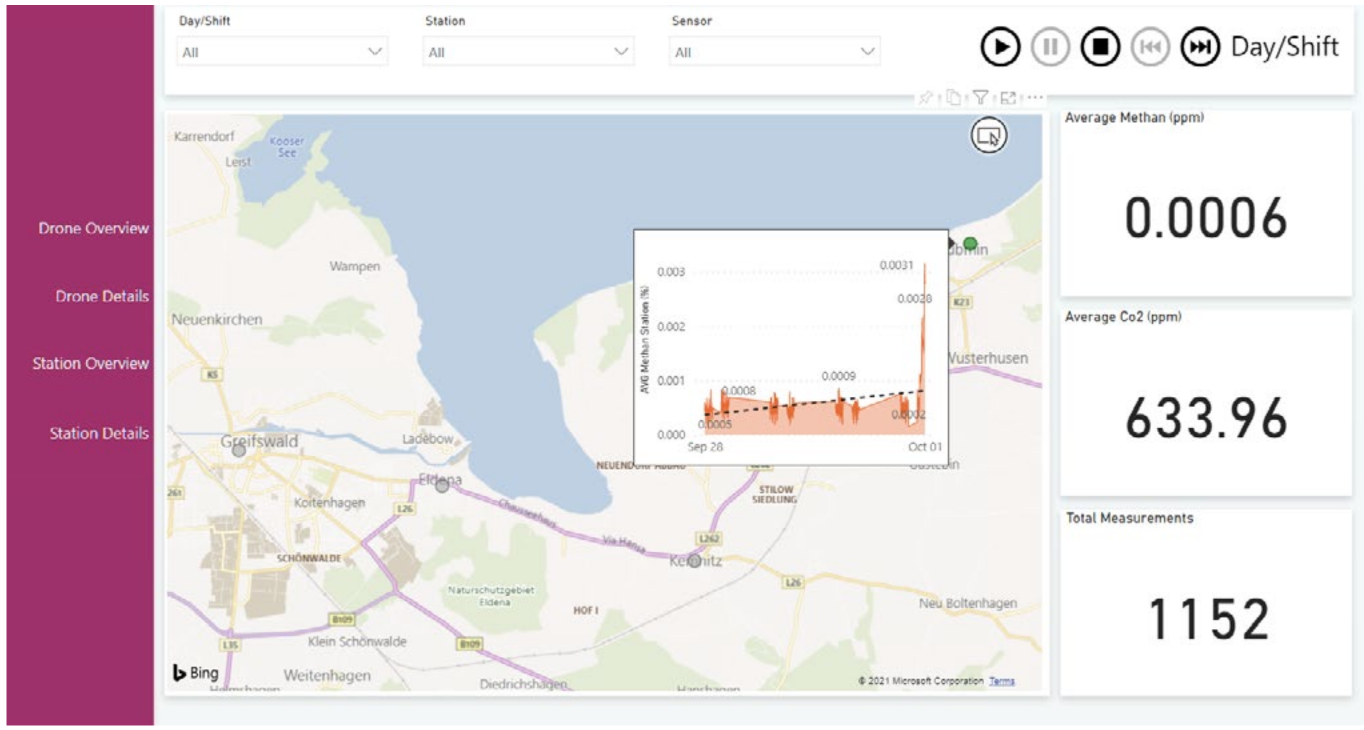
TRANSPARENT REPORTING



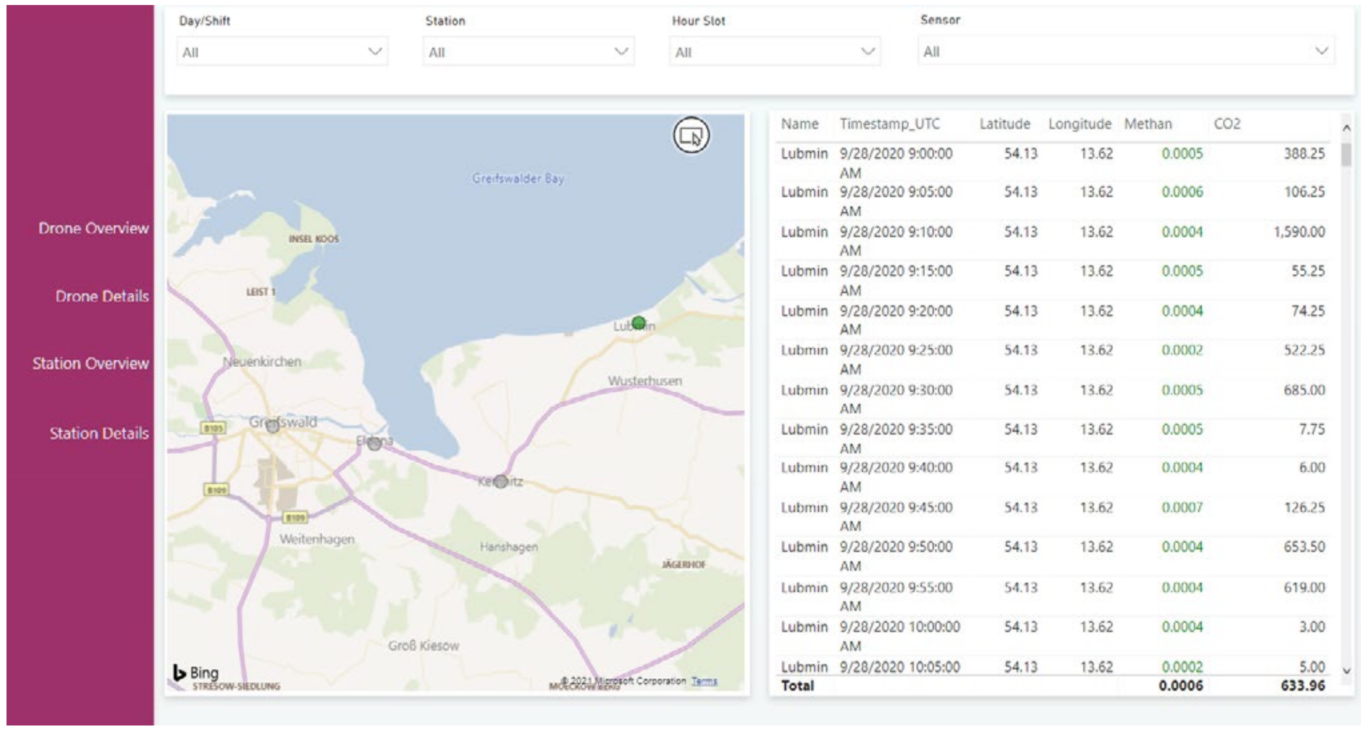
Drone data overview



Detailed drone data



Station data overview

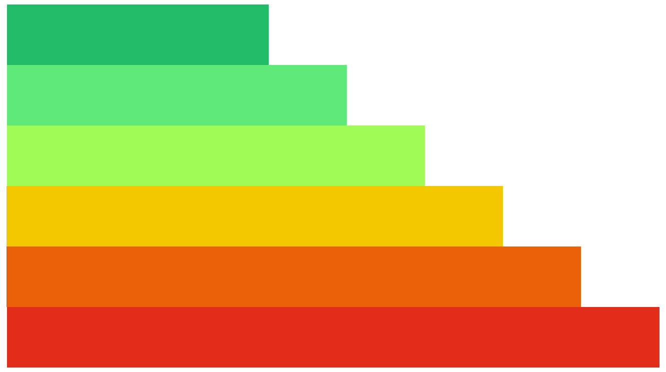


Detailed station data

In the long term, real-time monitoring with digital tools could aid the development of Gas Emission Certificates stating the level of methane emissions. Individual segments or facilities (e.g., compressor stations, pipelines) could be certified to fall within one of six methane emissions classes, reflecting a particular range level of methane emissions.

SUGGESTION FOR A CLASSIFICATION ACCORDING TO THE VOLUME OF METHANE EMISSION PER FACILITY

A	0 - 0.1	%
B	0.1 - 0.25	%
C	0.25 - 0.5	%
D	0.2 - 1.0	%
E	1.0 - 3.0	%
F	3.0 +	%



For instance, natural gas delivered to a certain region could be classified according to the extent of its methane emissions, ranging from the lowest methane emission (Class A) to the most problematic (Class F, equating a footprint like that of coal). Introducing Gas Emission Certificates would also resonate with the intentions of the European Commission to create a Methane Supply Index.

CONCLUSION

The development of holistic approaches to methane monitoring and combining smart digital tools with other tools deployed so far, could provide benefits to the oil and gas companies and to society at large. Adopting a holistic approach, companies can:

- increase frequency of inspections and, therefore, make the first step towards continuous monitoring;
- reduce overall maintenance costs and time needed for regular inspections;
- minimize discrepancies between top-down and bottom-up measurements due to near-continuous monitoring of emissions;
- build transparency and trust in monitoring and reporting;
- scale methane monitoring solutions quickly and adequately, considering the length of pipeline and number of compressor stations; and
- acquire new knowledge and skills that can be used in projects later on.

Use Case

INSPECTION OF TRANSMISSION PIPELINE AND COMPRESSOR STATION

For this case of inspection, a combination of various technologies was used to compare and verify results obtained with new digital tools and conventional methane quantification tools. Furthermore, the time and costs needed for inspection were compared.

Emissions were assessed by using a drone equipped with a laser sensor, a fixed-location downwind sensor, a Spot robot, OGI cameras and a Hi Flow® instrument. The results and accuracy of emission detection and quantification conducted by digital tools were compared with emission levels detected using OGI and quantified using a Hi Flow® instrument to verify the results.

Similar distributions of emissions were recorded across drone, downwind and conventional methods used for detection and quantification. Drones and sensors currently offer faster detection and quantification and outperform optical gas imaging (OGI) in terms of identifying sources of emissions (also visually). It is possible to see exactly where emissions occurred. For quantification, optical gas imaging (OGI) also developed a drone-mounted camera and a qOGI (quantitative OGI).

Downwind sensors immediately identified emissions, and the drone could pinpoint emissions from specific equipment and quantify those emissions. The Spot robot could replace an on-site team. Once the route was programmed, it was able to check emissions from the ground.

For the quantification of emissions deploying drones, a mass-balance model was used (multiplying the plume concentration and wind speed throughout the plume shape). In terms of cost comparison, inspections conducted with drones were up to seven times cheaper.

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[18] ATEX standards describe safety requirements of the workplace and equipment used in explosive atmosphere. Zone 1 classification means that equipment (e.g., drone) can be safely used in an explosive atmosphere consisting of a mixture with air of dangerous substances in the form of gas, vapor, or mist, that occur occasionally.

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