Quantum Lidar for Widespread Methane Monitoring

Murray Reed, CEO

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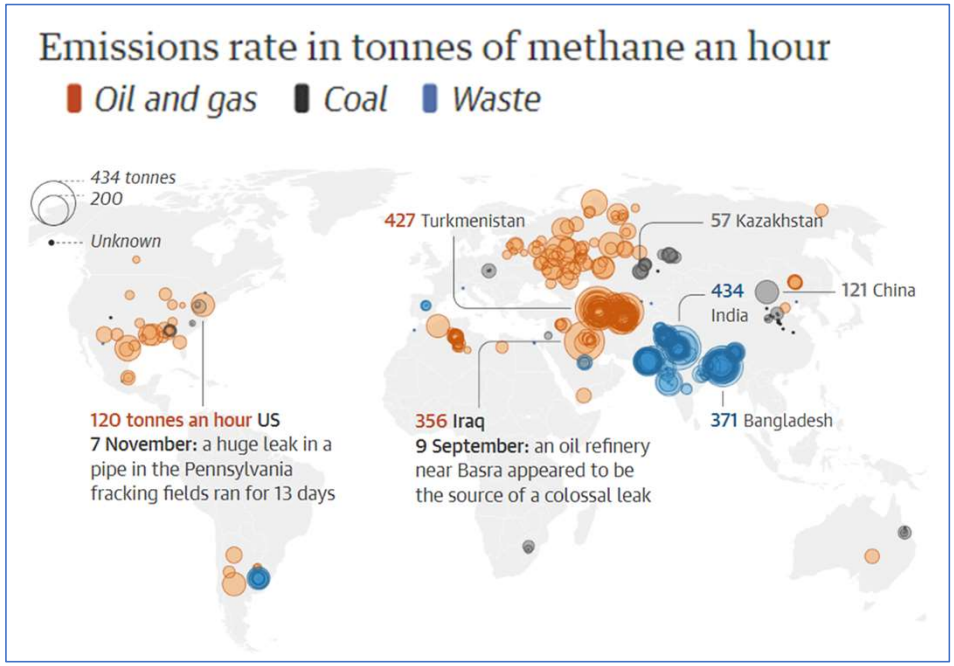
Renewable Energies

Outline

- QLM Gas Lidar methane measurement technology
- Methane Emissions Technology Evaluation Centre (METEC) trial results
- Severn Trent waste-water renewable energy monitoring
- QLM next steps

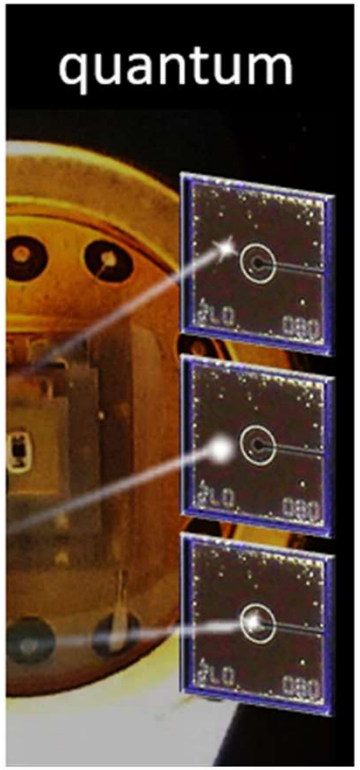
Methane is a Major Driver of Climate Change

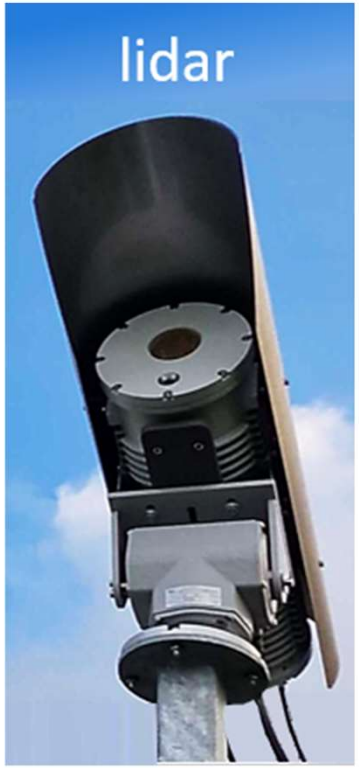
- Methane is the 2nd most important greenhouse gas contributor to climate change.
- 60% of global methane emissions result from human activity in energy and waste. Waste conversion to energy could completely displace fossil fuel but needs to happen with low emissions.
- Stopping methane emissions is the quickest route to slow climate change. Government regulations and industry commitments to stem releases are accelerating worldwide.
- The global market for methane detection technologies is forecast to exceed $900million by 2025 . The total addressable market is $15billion (BloombergNEF)

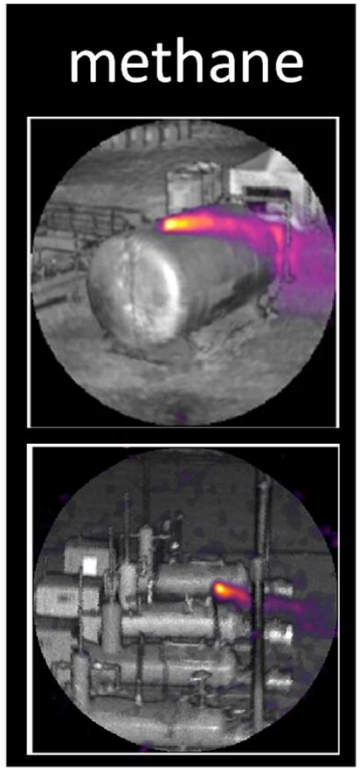


QLM Quantum Gas Lidar

- Unique Technology with UK and USA Patents
- Low Cost - scalable lidar integration path
- Huge Opportunity - millions of units required
- Specific - only sees methane, not other gases
- Accurate - precise location and size of leaks
- Long-range – >200m and at a safe distance
- Continuous - autonomous cloud software
- Rugged - extreme weather, any time of day
- Reliable - telecom qualified technology
- Low Power –battery and solar potential







Tunable Diode Single-Photon Gas Lidar

Low power semiconductor DFB laser
- tuned up/down in wavelength ~1μs
- methane $\lambda = 1651\text{nm}$, $\Delta\lambda = 0.3\text{nm}$
- amplitude code modulated ~5ns

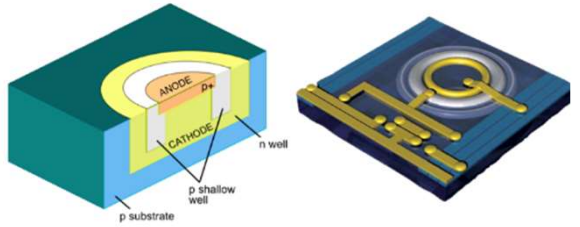
Projected to a remote solid surface

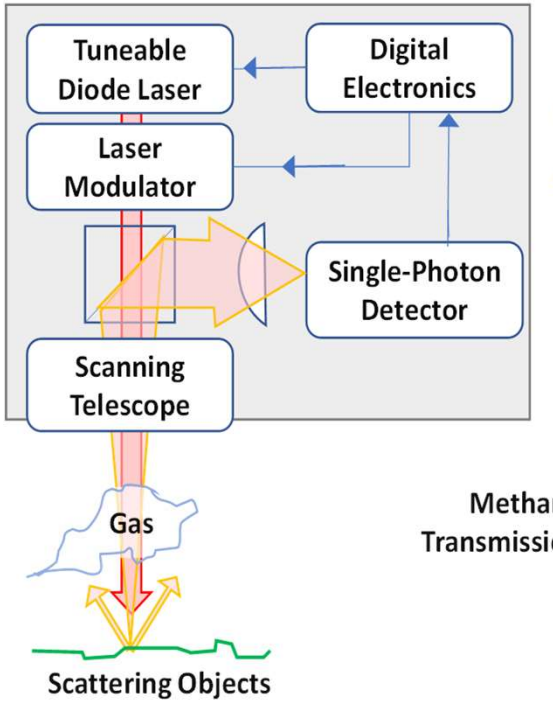
Scatter return detected by Single-Photon Avalanche Detector (SPAD)
- ns digital output
- practical, solid-state and low cost

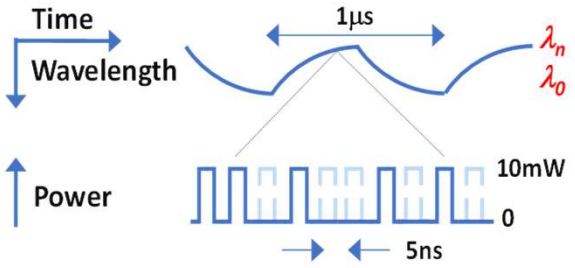
Time correlated signal gives
- distance to scattering surface (m)
- path integrated gas concentration (ppm.m)

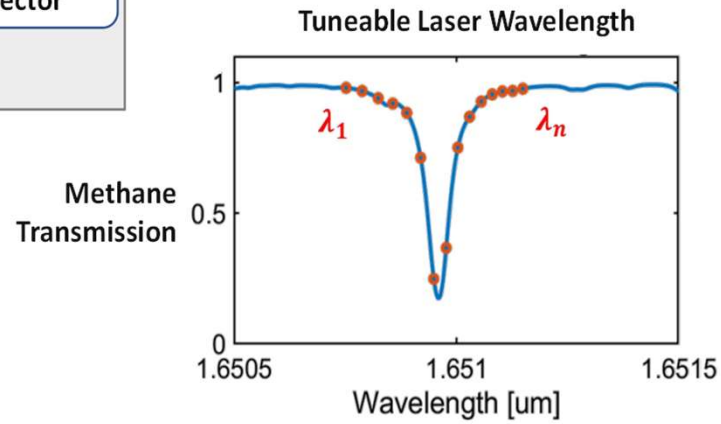
Raster scanning of laser beam builds 3D images

Single-Photon Avalanche Detector (SPAD)

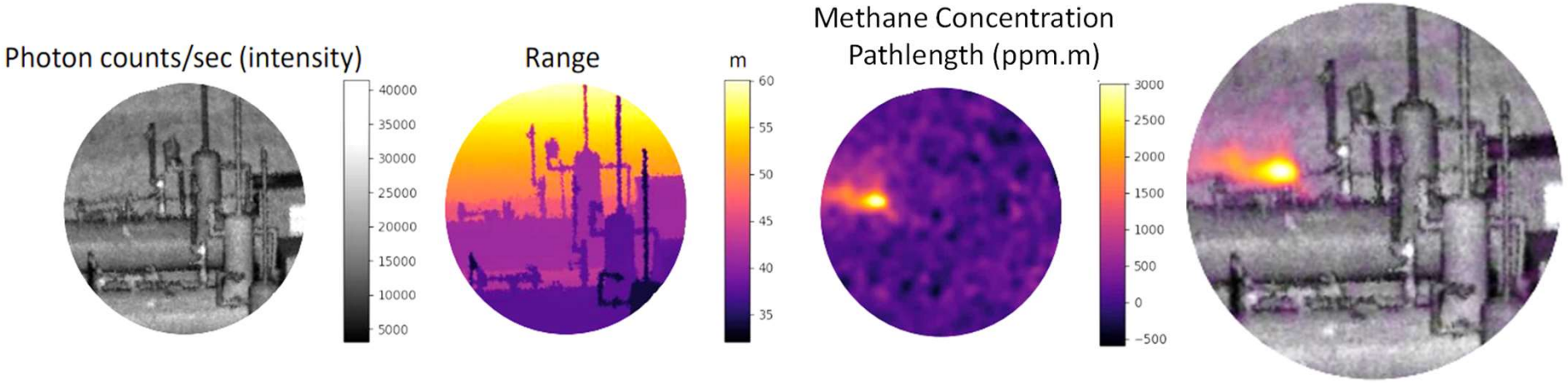




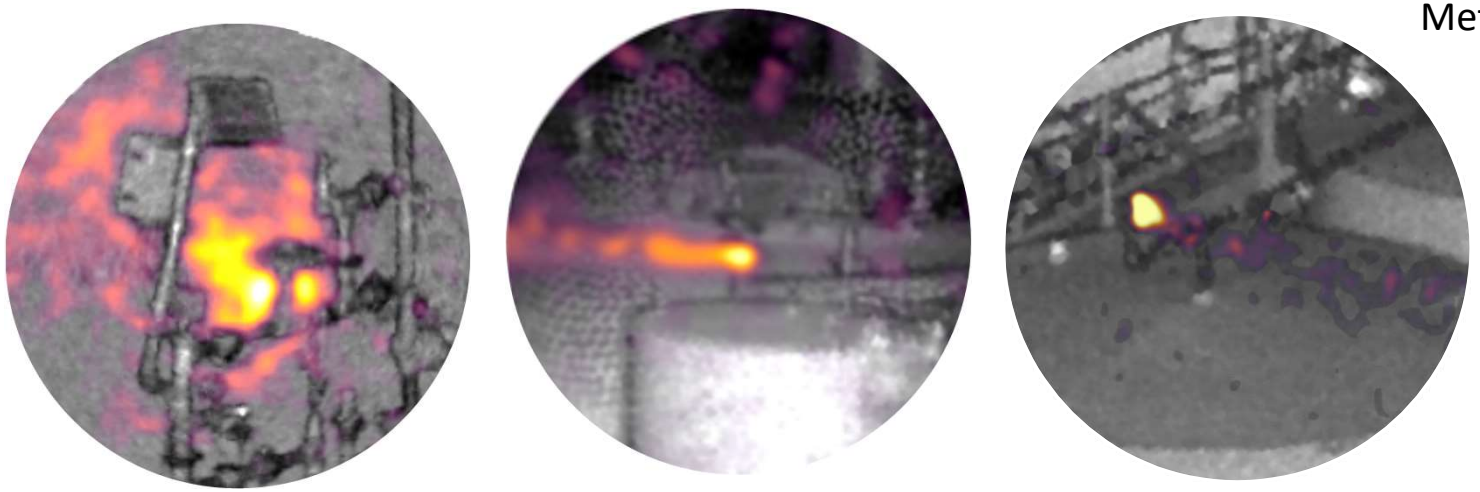




We Can See Precisely Where Methane is Being Emitted

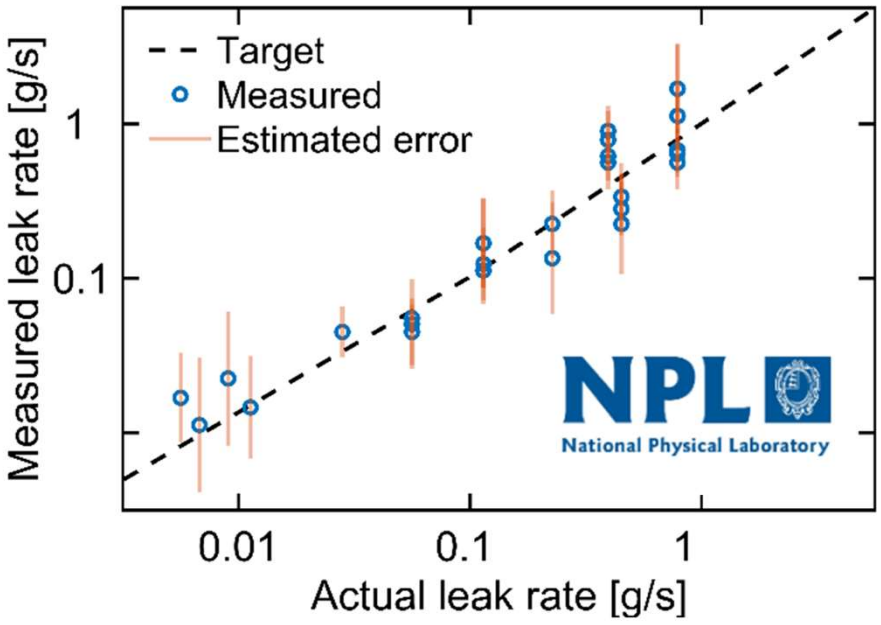


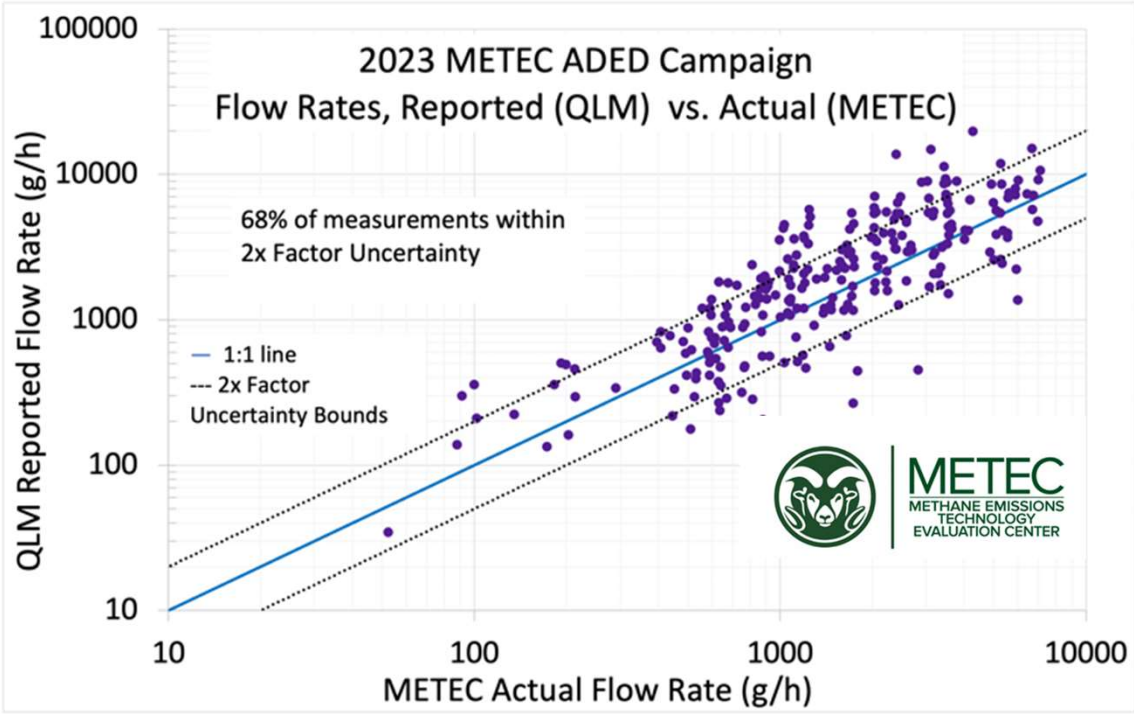
Methane overlay images



We Can Measure Exactly How Much Gas is Being Emitted

- QLM lidar measures solid objects and methane emissions in 3 dimensions enabling extremely accurate plume size measurement and therefore high emission rate quantification accuracy





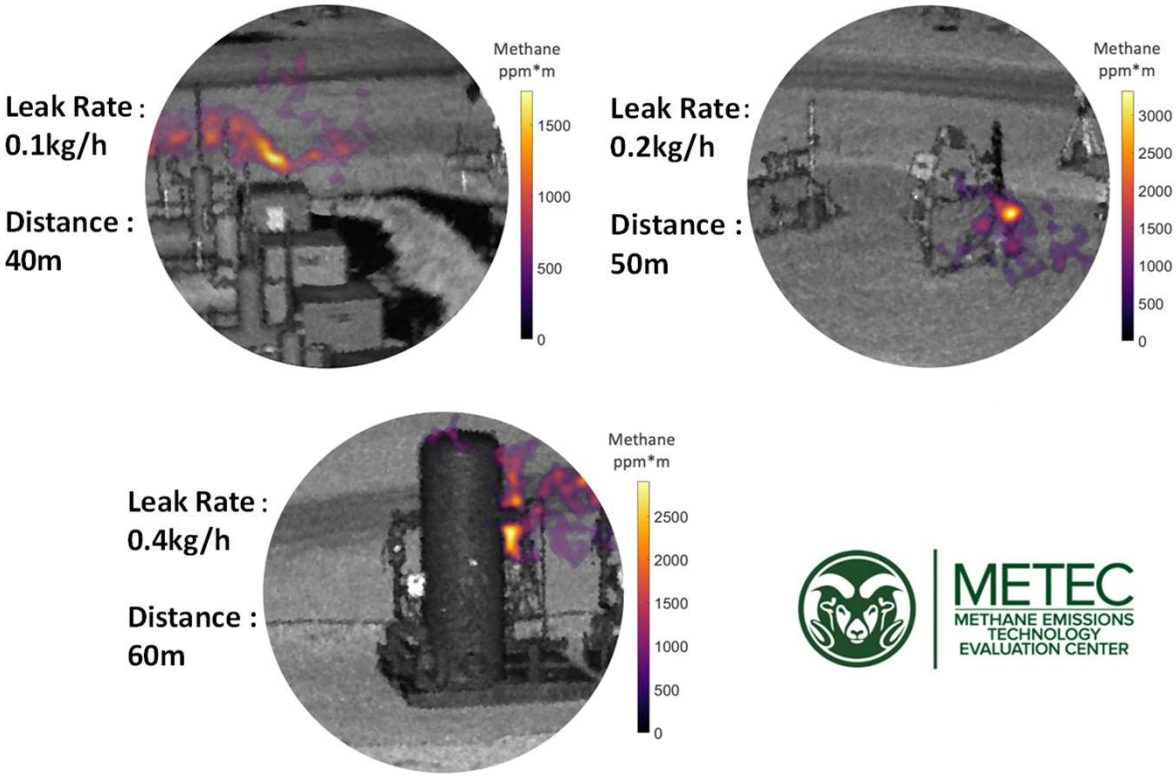
METEC Trial for Continuous Monitors

METEC ADED Campaign Feb-May 2023

- 10 competitors
- Continuous 24/7 blind trial over 11 weeks
- 574 separate leak events on 20 different pieces of equipment
- -20C to +30 C, snow, wind, rain

- **QLM 1st in Quantification Accuracy**
- QLM 1st in Source Location Accuracy
- QLM 1st in Time to Detection
- QLM Limit of detection <<0.4 kg/hr EPA requirement

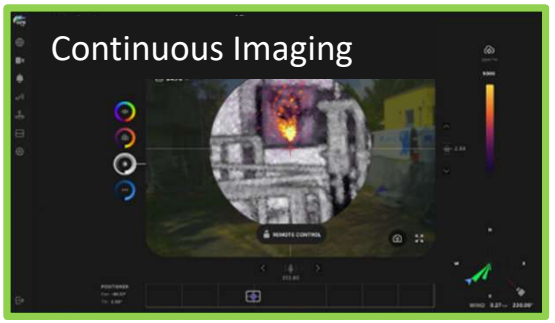
Advancing Development of Emissions Detection

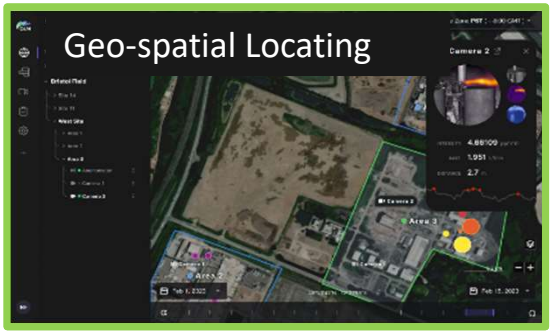


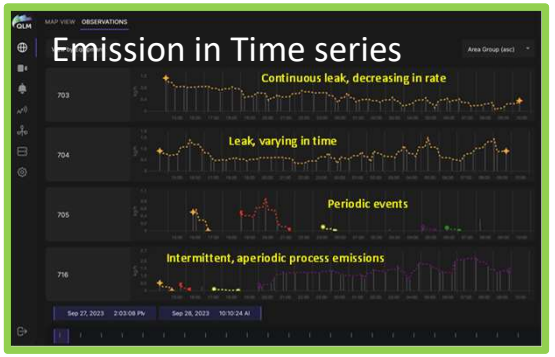
METEC
METHANE EMISSIONS TECHNOLOGY EVALUATION CENTER

First Cloud System Products Now Being Deployed

- QLM systems have live 4G connection to QLM Cloud for data collection, analysis & reporting
- Data output from QLM system:
  - Emission location, start/end/duration, flow quantification
  - Lidar imagery: intensity, methane density, range & visible
- We are selling Multiyear SaaS contracts as the preferred customer business model
- Our system makes it easy for customers to get the data they want in the form they want it







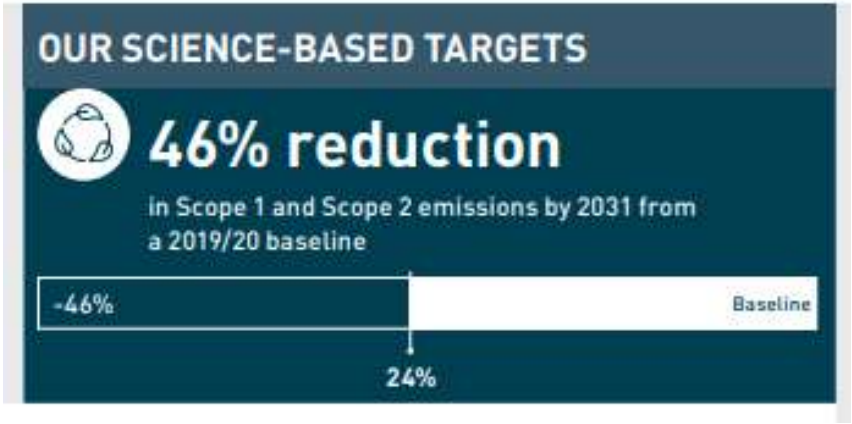
Severn Trent Water Waste-to-Energy

- STW is one of the UK's largest water companies providing water and sewerage services to millions of people across England and Wales
- They use sewage sludge in anaerobic digestion facilities to produce methane-rich biogas as a renewable energy source
- Some of the biogas is consumed on site and the rest is cleaned, upgraded and fed into the natural gas distribution network
- Their Minworth site has been operating for 60 years and was first in the UK to inject biogas into the natural gas network
- STW currently generates and self supplies 53% of its energy consumption.
- Increasing energy from renewables and improving energy efficiency is a high priority. Finding, quantifying and fixing emissions is part of this.


Minworth STW


Wanlip STW

Severn Trent Net-Zero Targets



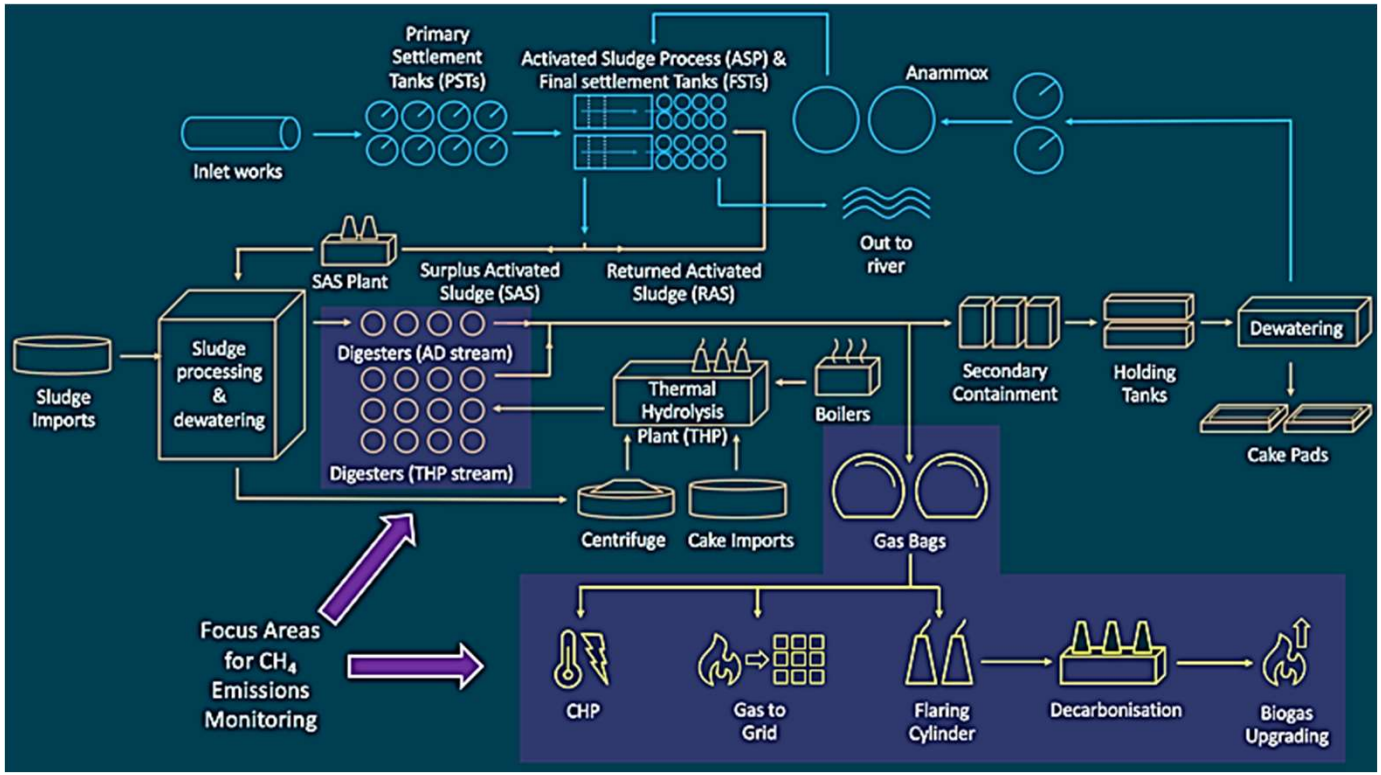
SEVERN TRENT

NET ZERO HUB AT STRONGFORD

STW Strongford will be a world-first net-zero waste water treatment plant, with green powered thermal hydrolysis to maximise CH4 production and NO2 capture.

QLM Lidar Deployment at STW

- Focus areas for methane monitoring are digesters, gas storage, combined heat and power engines and gas to grid plants
- Use detected emissions for reporting and to inform further emissions reduction activities
- Deployment of QLM's emissions quantification solution is part of Severn Trent's Triple Pledge to achieve net zero carbon emissions by 2030



Minworth STW Site & Process Schematic:

QLM Lidar Deployment at STW

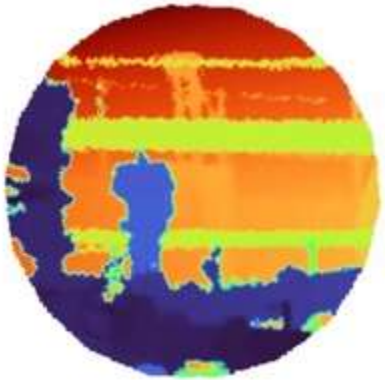
- Minworth STW site: 2 QLM lidar systems
- Wanlip STW site: 1 QLM lidar system
- 10-meter mast deployments,
- 360^{o} pan tilt pointing with ~200m range
- Optical zoom from 20^{o} to 1^{o} Field of View
- Monitoring 24/7, targeting each area/equipment unit sequentially. ~1 hour to cover all site targets

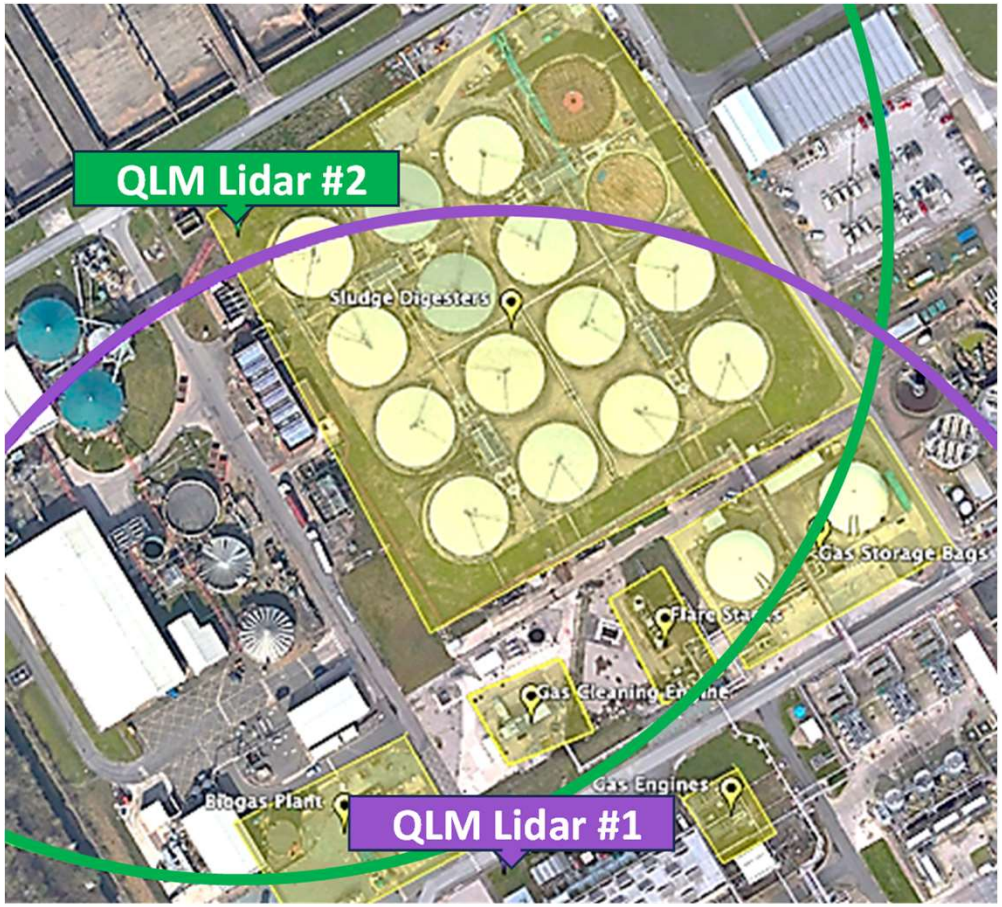
Minworth lidar fields of view

QLM Lidar Deployment at STW

- Locations of two QLM lidar at Minworth
- 200m coverage radius shown for each system (purple, green circles)

- Lidar range image of a frame with high optical zoom showing the lidar's ability to spatially resolve features of only 10cm at 50m range

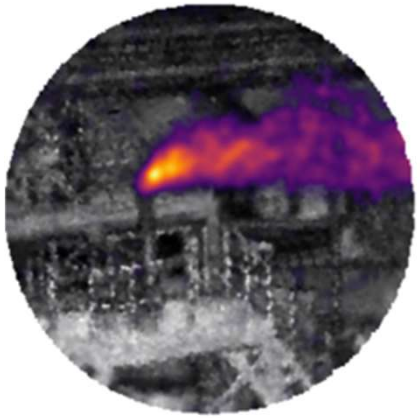




Case Study: Biogas Upgrading Plant

- Biogas needs to be cleaned before injection into the gas grid
- VOCs & H_2S are absorbed in passing through media
- Media must be recharged often (~every 10 mins) and recharge allows some of the biogas to be vented to atmosphere
- This venting is now fully quantified
- Trialing of a different media types with longer saturation to bring down emissions significantly is ongoing
- Emissions reductions in venting and recapture are being quantified during these trials

Plume from biogas plant venting: ~20 kg/h

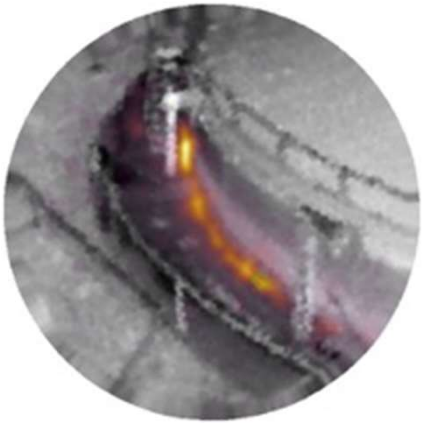


Biogas plant vessels

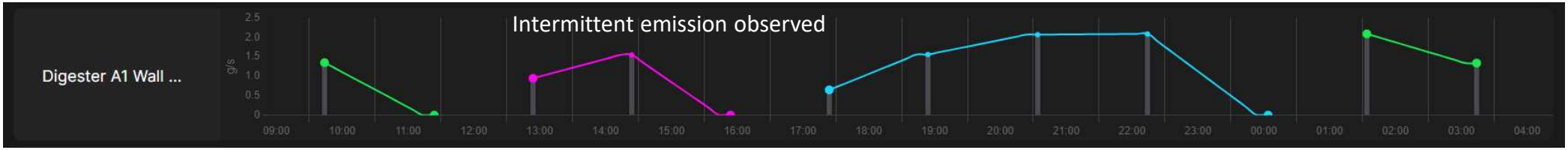
Case Study: Floating Roof Digesters

- Floating roof digesters are a legacy design not deployed for decades, but still operating
- The seal around the base of the anaerobic digester tank is supported by the sludge to be digested
- Continuous monitoring quantifies and tracks the continued emission
- A programme to replace the roofs is underway and we are able to monitor the newly fixed roofs and confirm the emission benefits
- This allows Severn Trent to support investment decisions across all these assets

Methane emission around sludge seal: ~19 kg/h

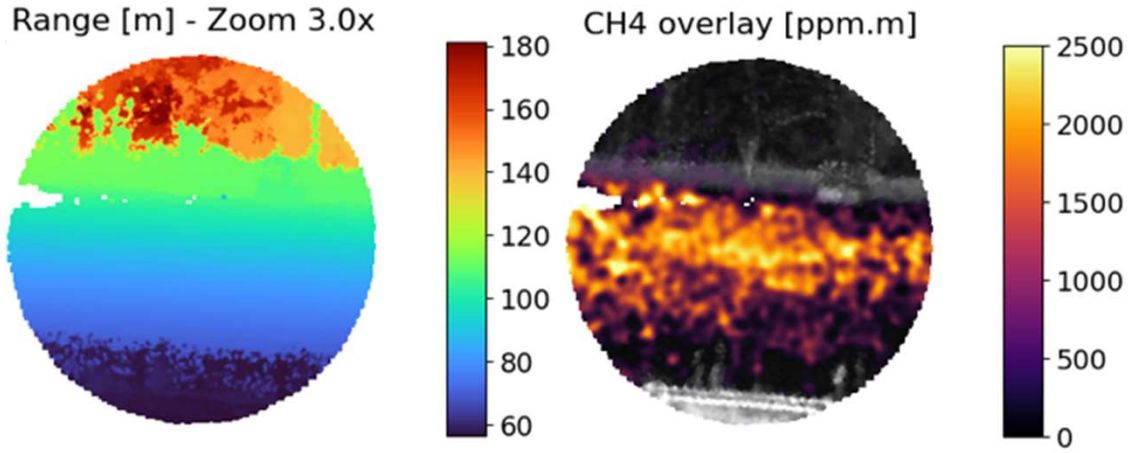


Floating Roof Digester

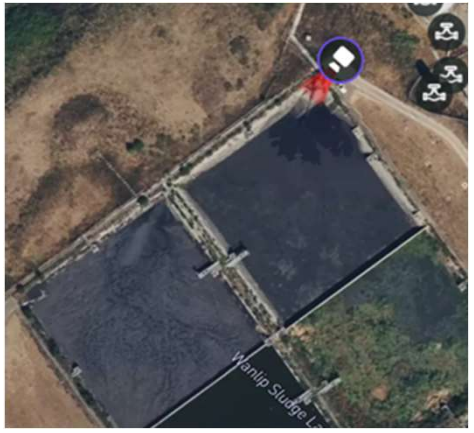


Case Study: Sludge Lagoon

- The methane flux from a wide area diffuse source is difficult to quantify
- We can ‘tile’ a wide area with multiple images and integrate the total emission
- Continuous quantification allows process, diurnal and seasonal variations to be tracked
- Allows immediate assessment of environmental impact of mitigation strategies and of potential economic benefit of capturing lost methane



Methane emission from section of sludge lagoon: ~7 kg/h

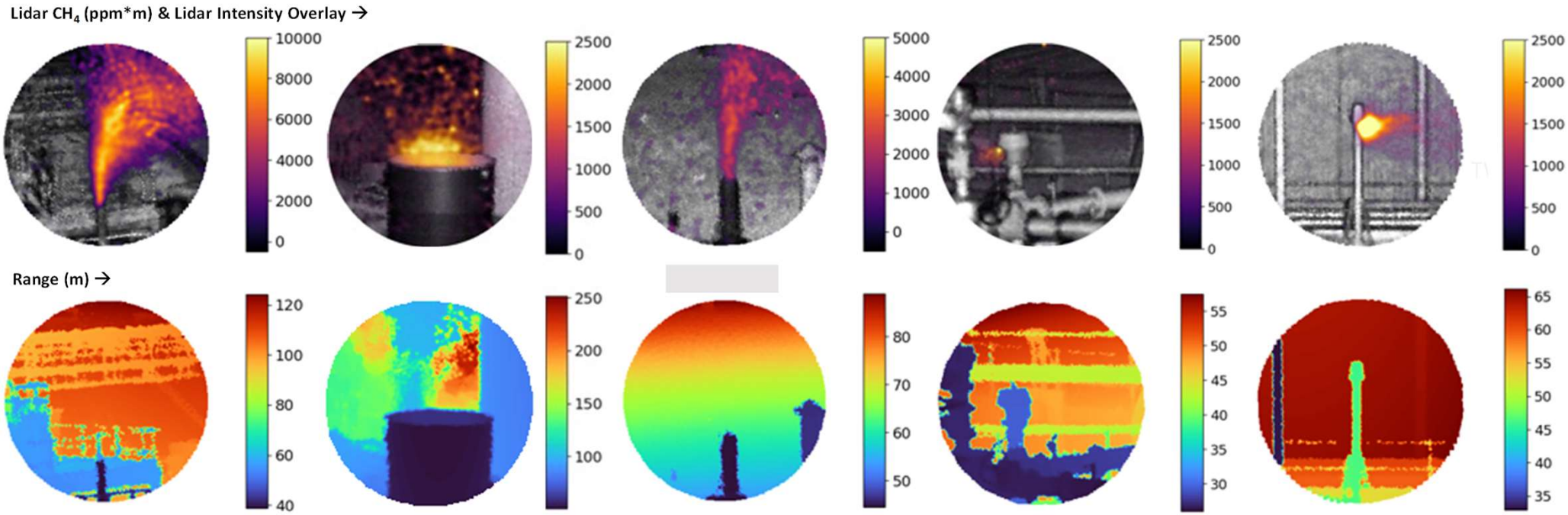


Position of lidar

Visual image from lidar

Many Other Examples Observed

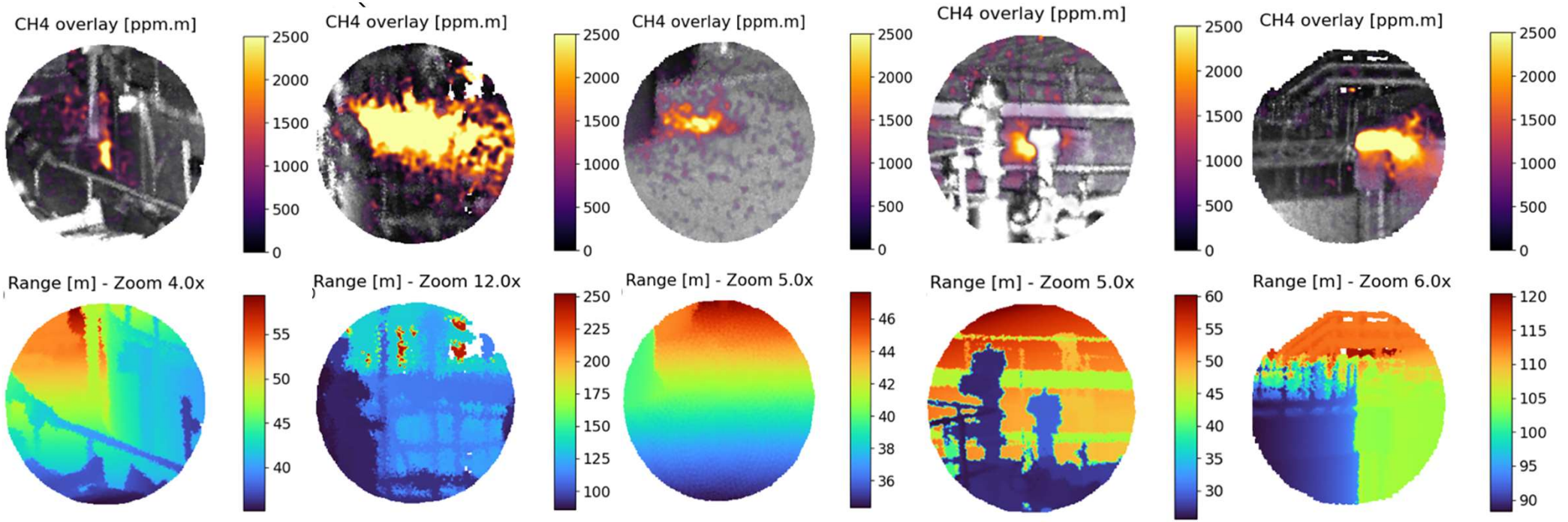
- Multiple intermittent emissions are observed regularly as part of normal operation and process upgrades



Biogas Upgrading 11 kg/h | Flare Stack 8 kg/h | Decarboniser Chimney 0.5 kg/h | Digester 0.6 kg/h | Pressure Relief Valve 0.9 kg/h

Complete Site Monitoring

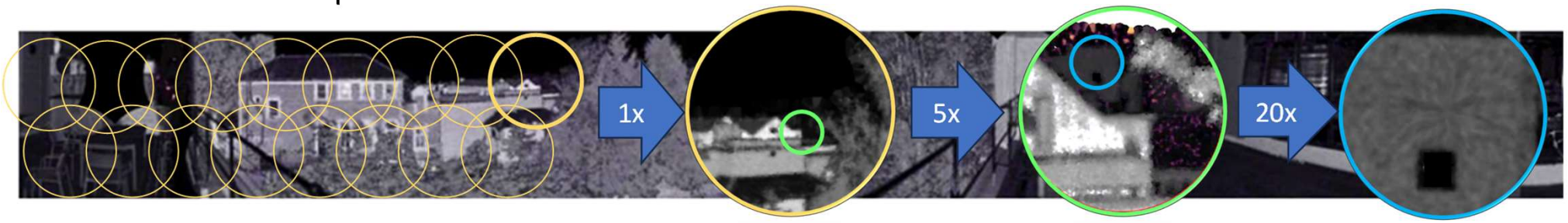
- Scanning a wide area allows all site emissions to be detected, reacted to and repaired quickly



Digester 12 kg/h | Digester 6 kg/h | Subsurface pipes 0.7kg/h | Digester 0.8 kg/h | Digester Roof 0.4 kg/h

QLM Next Steps

Site wide emission quantification

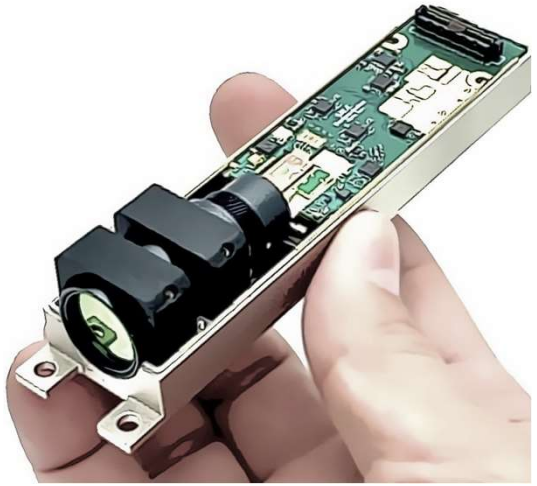


- panoramic 360° imaging with high resolution can be integrated over the entire field of view

CO_2, NH_3 and multiple other gases

Smaller, faster, cheaper, mobile sensors

- distance lidar for autonomous vehicles is available from multiple suppliers for <$1k and <1kg
- handheld and drone deployment is in development



QLM

QLM's gas imagers are

- **accurate, long range** and **practical**,
- **field proven** with **industry**,
- use **high reliability** components that scale to **low cost**

and so enable the
widespread, autonomous & continuous monitoring
needed to
enable greenhouse gas emission control