Welcome to Vaisala Webinar

Turn On Your Bio-Engine – Increasing Biogas Process Profitability

Speaker: Product Manager Antti Heikkilä

VAISALA

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Vaisala's Beginning

Founded in 1936 by Dr. Vilho Väisälä (1889–1969):

- Innovator and scientist
- Pioneer in modern-day meteorology

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Technological Milestones

Upper air soundings

1930 –1960

Revolution of sensing technologies

Industrial measurements of relative humidity and dewpoint

1970 –1990

Application solutions

Information technologies

Remote sensing
Carbon Dioxide (NDIR) measurements

2000 –

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Employs
1850
professionals worldwide

Has over
30
offices
in
17
countries

37%
of Vaisala people work outside of Finland

Serves
customers
in over
150
countries annually

Committed to using
100%
renewable electricity by
2020

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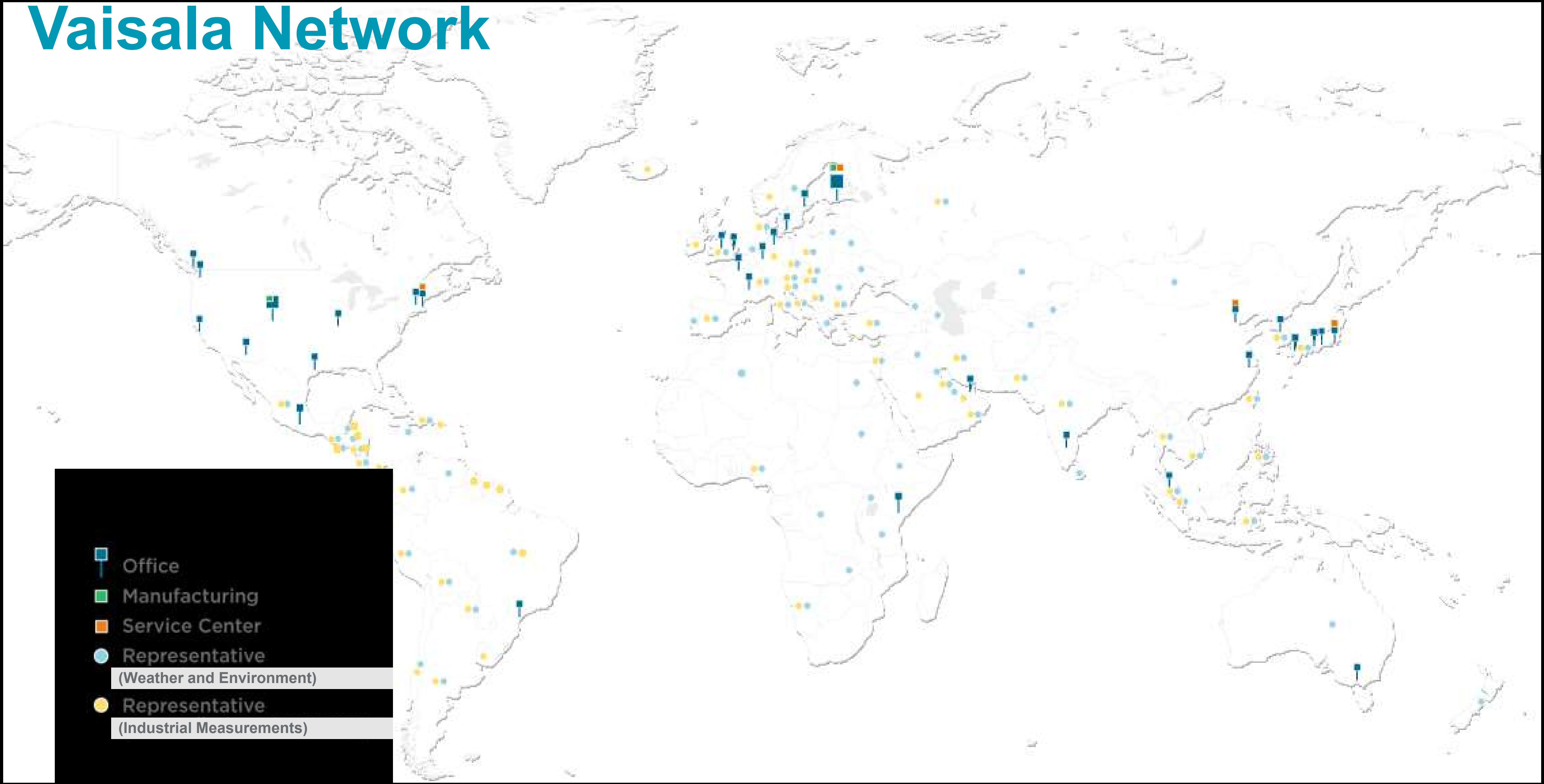

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Introductions

Antti Heikkilä, Biogas Measurement Expert & Product Manager at Vaisala

- Antti has over 15 years of experience in process and emission monitoring instruments and infrared gas analysis and holds a M.Sc. degree in Physical Chemistry. He is an active member of multiple international standardization workgroups (both ISO and CEN) on air quality and greenhouse gas measurements.

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Agenda

- ❑Waste to value – a global perspective
- ❑Typical measurement challenges and the importance of humidity measurement
- ❑The key measurement points for humidity, methane and carbon dioxide
- ❑Installation examples

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Waste to Value
– a Global Perspective

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Waste to Value

- Waste is a key challenge along with the growing population
- Anaerobic digestion is one of the best ways of tackling biowaste; it helps to improve the nutrient cycle and to keep the soils healthy
- Turning the digestate into methane for other processes mitigates the climate impact of waste and adds value as an energy source

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Typical Measurement Challenges and the Importance of Humidity Measurement

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For the Forerunners Sensing Sustainable Future

- Organic waste is converted into biogas using anaerobic digestion (AD) process
- Biogas is used as a fuel in a combined power and heat (CHP) engine to provide electricity and heat
- Biogas can be upgraded into high purity biomethane for vehicle fuel use and injection into natural gas grid
- Gas measurements are made in the anaerobic digestion process and before CHP engine or biomethane upgrading unit

- Direct measurements with Vaisala multigas instrument enable accurate and reliable process control

Helping You Improve Plant Profitability

Increase revenue with methane measurement

- Maximize electricity and heat generation
- Get more methane out of waste
- Ensure timely process control with a reliable in situ measurement

Reduce operating expenses with moisture measurement

- Prevent the engine from wear and shutdowns
- Prolong the refill interval of activated carbon filters

Helping You Improve Plant Profitability

Increase revenue with methane measurement

- Measuring Methane and Carbon Dioxide at anaerobic digestion reactor gives insight to the bacterial process taking place in the reactor
- Engine output can be increased by adjusting engine settings to measured Methane concentration

Helping You Improve Plant Profitability

Prolong the refill interval of activated carbon filters

- Activated carbon filtration is a commonly used technique for cleaning the biogas before CHP engine or biomethane upgrading unit
- Activated carbon pellets have an optimal humidity range in which they work best
- Carbon refills are expensive

Measuring humidity at carbon filters saves money.

Helping You Improve Plant Profitability

Prevent unwanted condensation in pressure regulators

- Gas pressure is typically reduced before the engine
- Reducing pressure causes the gas to cool down
- Condensation may occur in the regulator
- If biogas is transferred in pipeline to a nearby off-site powerplant, condensation in the transit is a risk.

Helping You Improve Plant Profitability

Prevent the engine from wear and shutdowns

- Excess humidity in biogas fed to CHP engine increases moisture in engine oil
- Oil exchange intervals are based on moisture, sulfur (from Hydrogen Sulfide) and silicon (from Siloxanes) accumulation in oil
- Knowing the humidity of biogas going into the engine helps to spot and correct problems before they occur

Why current biogas instruments are not enough

- Typical biogas instruments are *extractive* – they require pumps and gas tubing to move gas from process to an instrument panel
- Typical biogas instruments are based on fixed wavelength infra-red measurement and electrochemical cells – two technologies known to require frequent recalibration in the field
- Typical biogas instruments do not measure humidity – it is lost in the sample extraction and cannot be measured without in situ instruments
- **The ideal biogas instrument is an *in situ* device inserted directly in the process, without any moving parts or consumables, and with long calibration check intervals…**

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Vaisala MGP261 Multigas Probe

Introduction and overview

The Key Difference

World's First In Situ 3-in-1 Biogas Measurement Instrument MGP261

Superior stability and accuracy

- Methane, carbon dioxide and the world's first optical humidity measurement device for biogas
- CARBOCAP® autocalibration
- Heated sensor head for avoiding condensation

Low operating cost

- Real-time and in situ
- No sampling lines, pumps or moisture remo
- No calibration gases needed in routine use

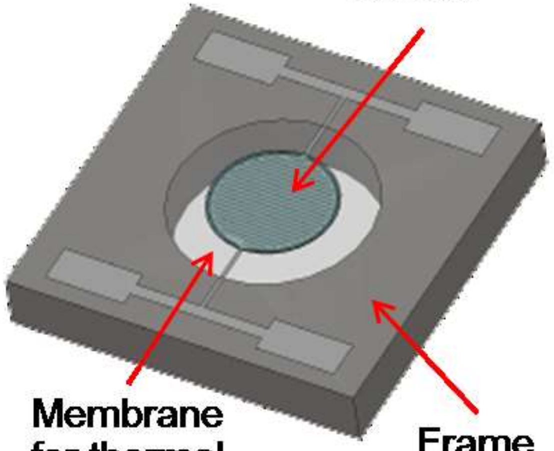
Compact and robust

- IECEx/ATEX certified
- Corrosion resistant material
- IP66-rated

2nd Generation CARBOCAP® Technology

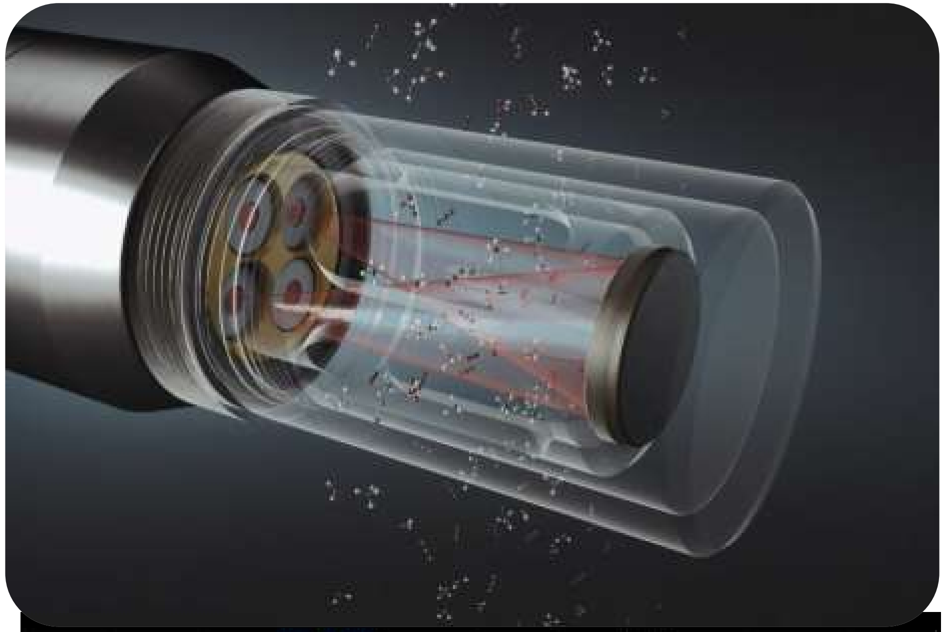
- Miniature filament light bulb replaced with a microglow – a micromechanical component manufactured by Vaisala
- Compared to a filament lamp used by most competitors, the microglow source gives:
  - Longer lifetime: >15 years
  - Low power consumption
  - Stable light output
  - Fast response at startup
  - Enables manufacturing hermetically sealed Ex certified products protected by potting compound

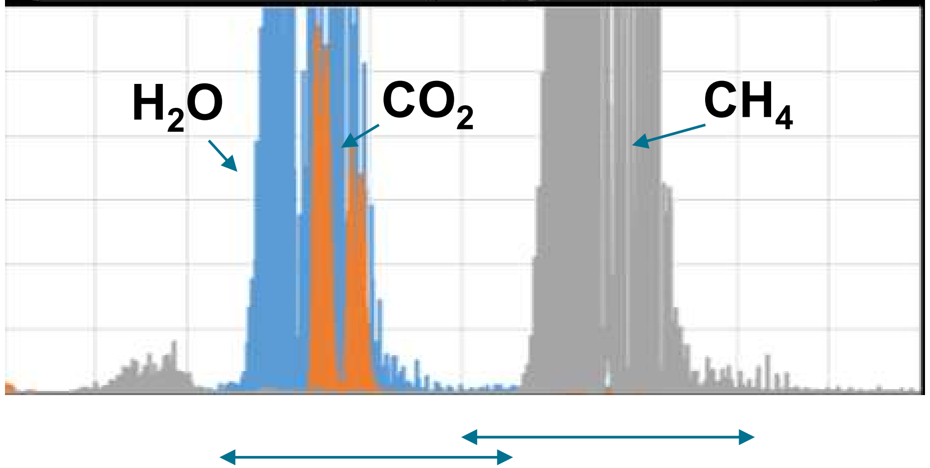
Vaisala-patented microglow, a silicon MEMS emitter infrared source.



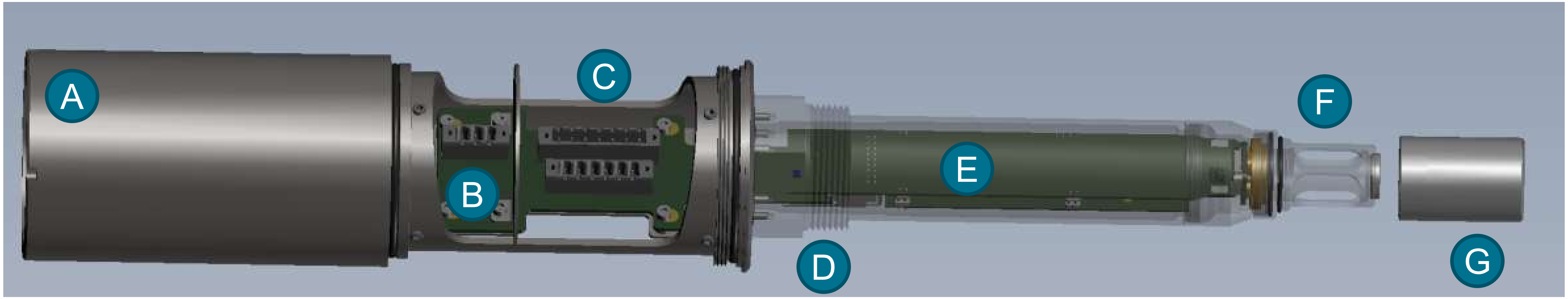
Multigas measurements with CARBOCAP®

- Vaisala proprietary silicon-based tunable infrared filter enables measurement of multiple gases with one tunable filter (Fabry-Perot Interferometer) element
- In MGP261 biogas probe, Humidity and Carbon Dioxide are measured with same optical filter
- During each measurement, the filter is tuned to several wavelengths including
  - H_2O absorbance wavelength
  - CO_2 absorbance wavelength
  - Common reference wavelength
- Second optical channel measures Methane



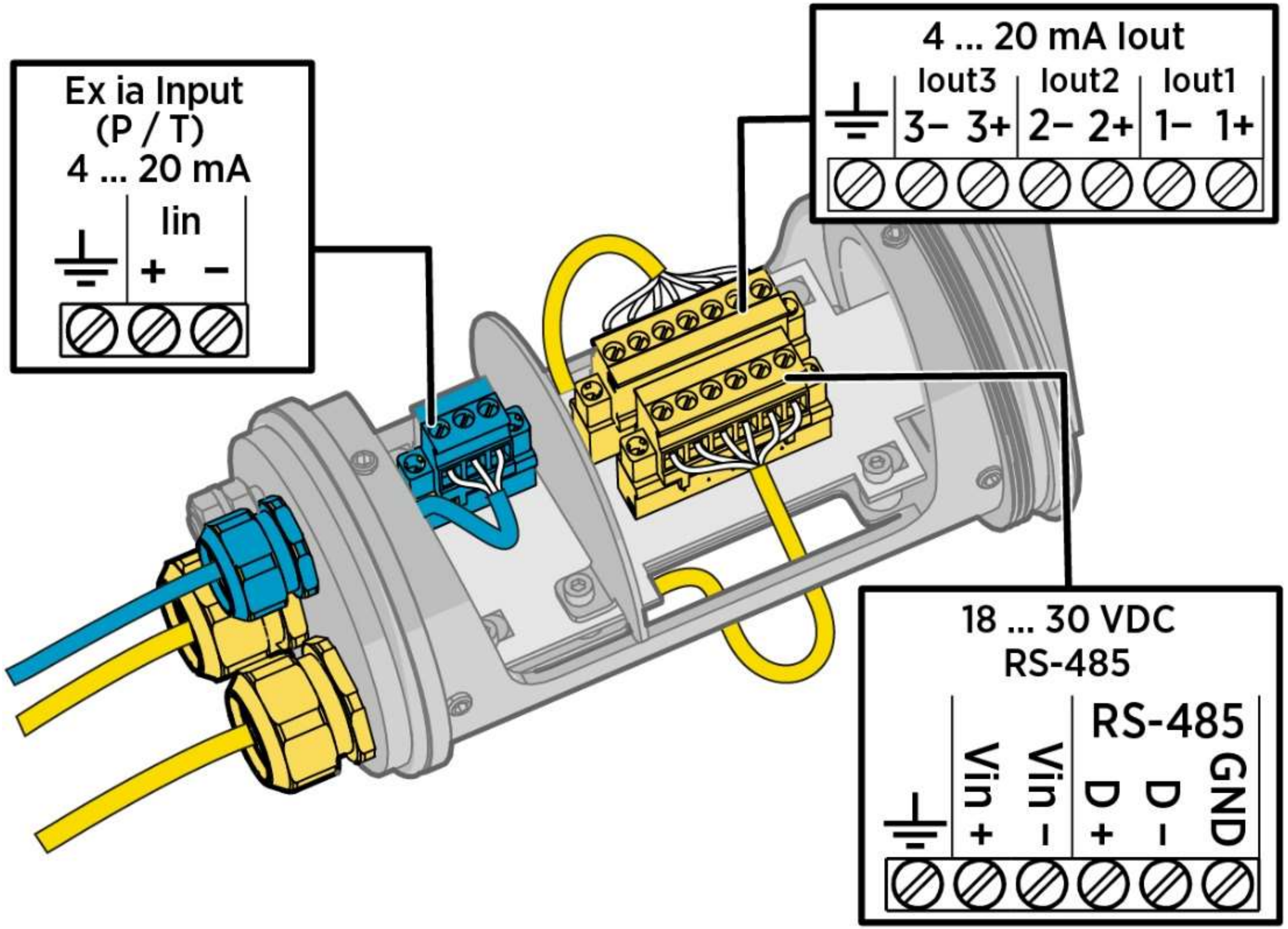


Probe Structure

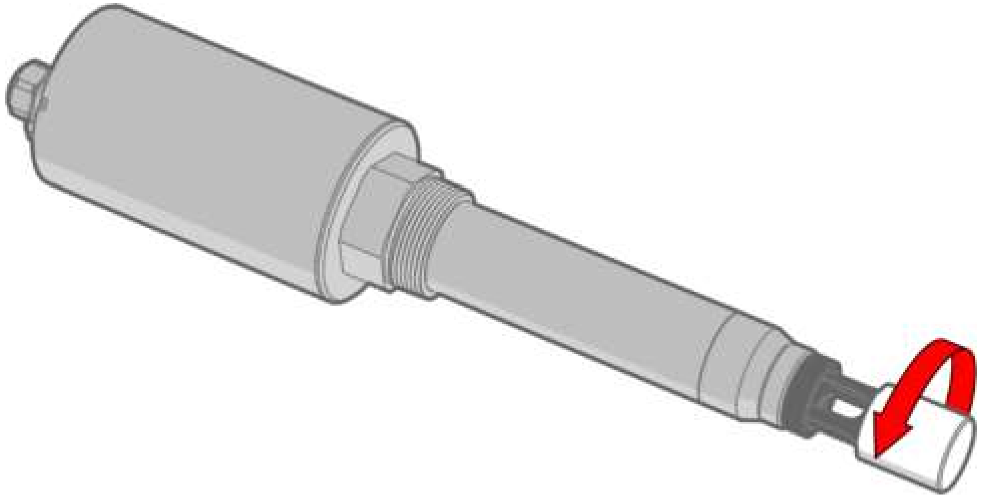


A. Connection box cover
B. Intrinsically safe 4…20 mA safe input (p or T)
C. Analog outputs, RS-485 connector, 18…30 DC power supply input
D. 1.5” male NPT thread
E. Electronics encapsulated inside probe
F. Sample cell
G. Probe filter

Connectivity



Ease of maintenance



Changing the Filter

- Change the filter to a new one if it shows visible signs of contamination or dirt

Calibration and adjustment

- using calibration gas as a reference with flow through cell accessory, Insight software and USB cable

Cleaning the Probe

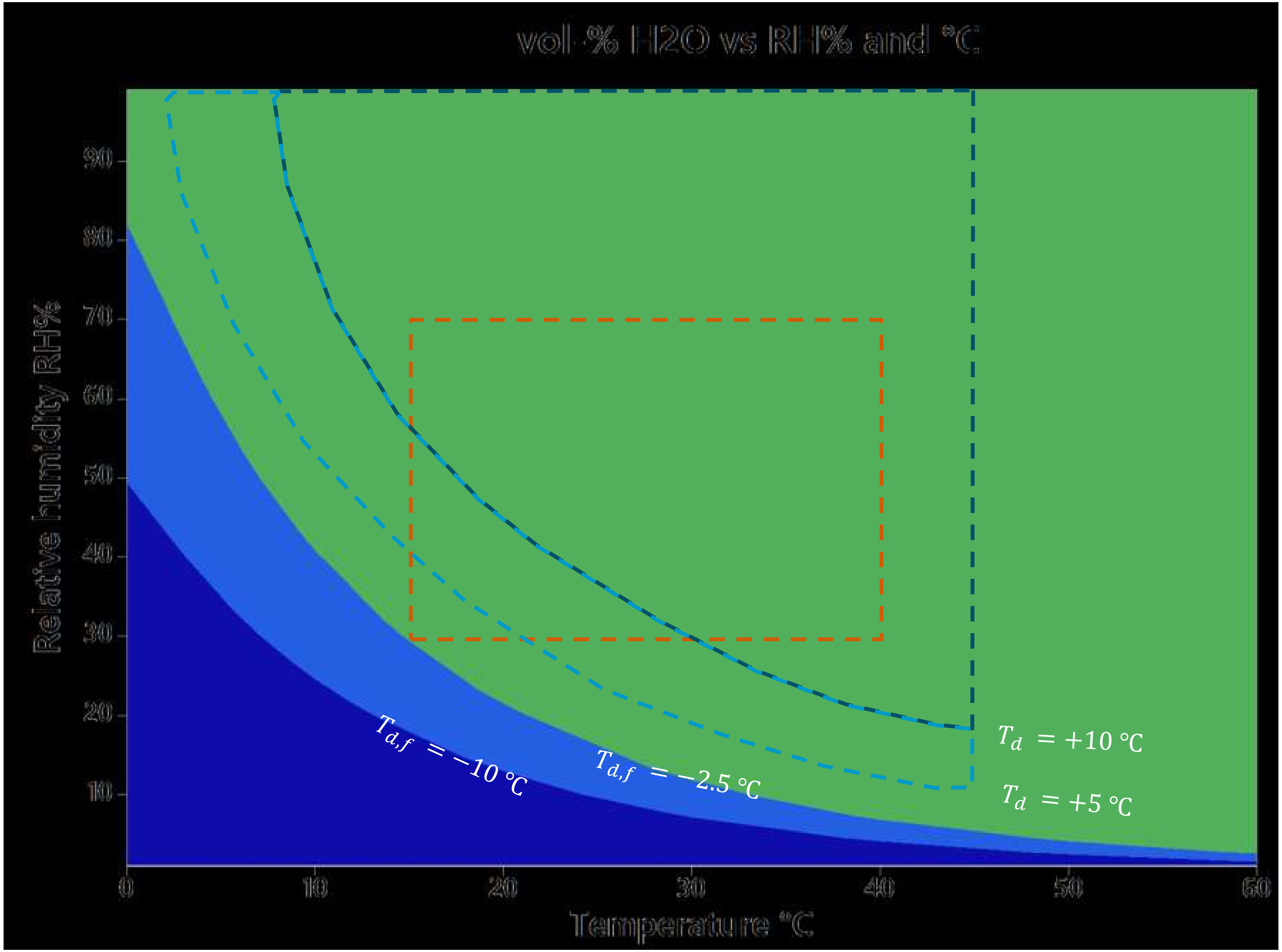
- You can clean the probe body by wiping it with a moist cloth.
- Chemical tolerance
  - H_2O_2 (2000 ppm), alcohol-based cleaning agents such as ethanol and IPA (70 % isopropyl alcohol, 30 % water), acetone, acetic acid, Virkon™ S disinfectant (active agent: Oxone)

Optical Humidity Measurement

Volume-% vs dew point, wet basis vs dry basis

Measurement units for optical humidity measurement

- Optical humidity measurement gives volume concentration (parts per million or vol-%) directly
- Other measurement units in common use are dew point temperature and relative humidity
- Volume concentration and dew point temperature are linked by a simple conversion factor and the MGP261 is configurable for both output parameters
- Conversion of volume concentration to relative humidity depends very strongly on gas temperature measured by external reference temperature sensor, so this needs to be calculated outside the MGP261 instrument



Normal performance
H_2O 0.5 … 25 vol-%
Accuracy ±0.5 vol-%

Above detection limit but less than accuracy spec
H_2O 0.3 … 0.5 vol-%

Below conservative detection limit estimate
H_2O < 0.3 vol-%

Typical measuring range for activated carbon filter monitoring RH = 30…70

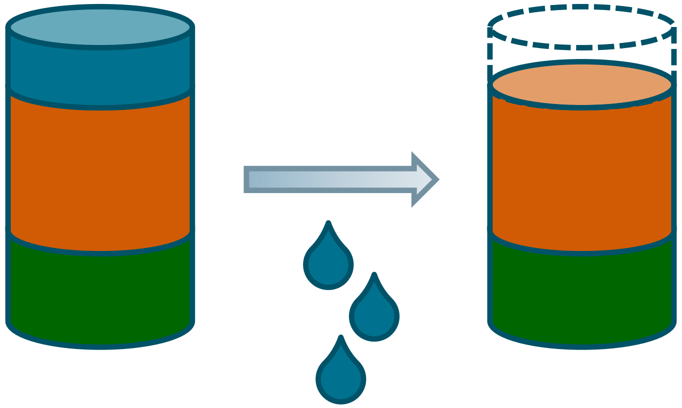
Typical measurement range for CHP engine inlet after heat exchanger

Typical measurement range for raw gas without heat exchanger

MGP261 is expected to perform well in wet gases, T_d > 0 °C and process temperature < 65 °C

What are wet basis and dry basis vol-%?

- For instruments measuring gases directly without removing moisture, the concentration can be expressed either as dry or wet gas
- The difference becomes significant when gas humidity is higher than in ambient air (>2 vol-%)
- Dry gas concentration is always higher than wet gas concentration
- Conventional extractive gas analyzers usually remove moisture before measurement, so they work in dry basis
- MGP261 measures in wet basis, but can be configured to output CH_4 and CO_2 in either format



	WET	DRY
H_2O	20%	- - -
CH_4	52%	65%
CO_2	28%	35%

$$c_{\mathrm{dry}} = \frac{c_{\mathrm{wet}}}{100\% - \mathrm{H_2O}}$$

When should I use wet or dry basis?

- If water vapor measurement is needed, it frequently makes sense to report all gases as wet basis
  - $H_2O + CH_4(wet) + CO_2(wet) \approx 100$ vol-%, as the concentration of other gases in biogas is close to zero
- If you are only interested in CH_4 and CO_2, or you wish to compare the readings of MGP261 to other dry basis instruments, dry basis works better
  - $CH_4(dry) + CO_2(dry) \approx 100$ vol-%
- Expressing water content as dew point temperature works equally well with wet basis and dry basis CH_4 and CO_2 measurements

Word of warning: using dry basis for H_2O not recommended…

- Expressing water vapor in dry basis gives unexpected results with high concentrations: a glass half full of water is 100% H_2O dry basis, and a glass ¾ full is 300% H_2O dry basis!?
- Expressing water vapor in wet basis (default in MGP261) is more logical: a glass half full is 50% H_2O, and a glass ¾ full is 75% H_2O.

Is it 50% full or 100% full?

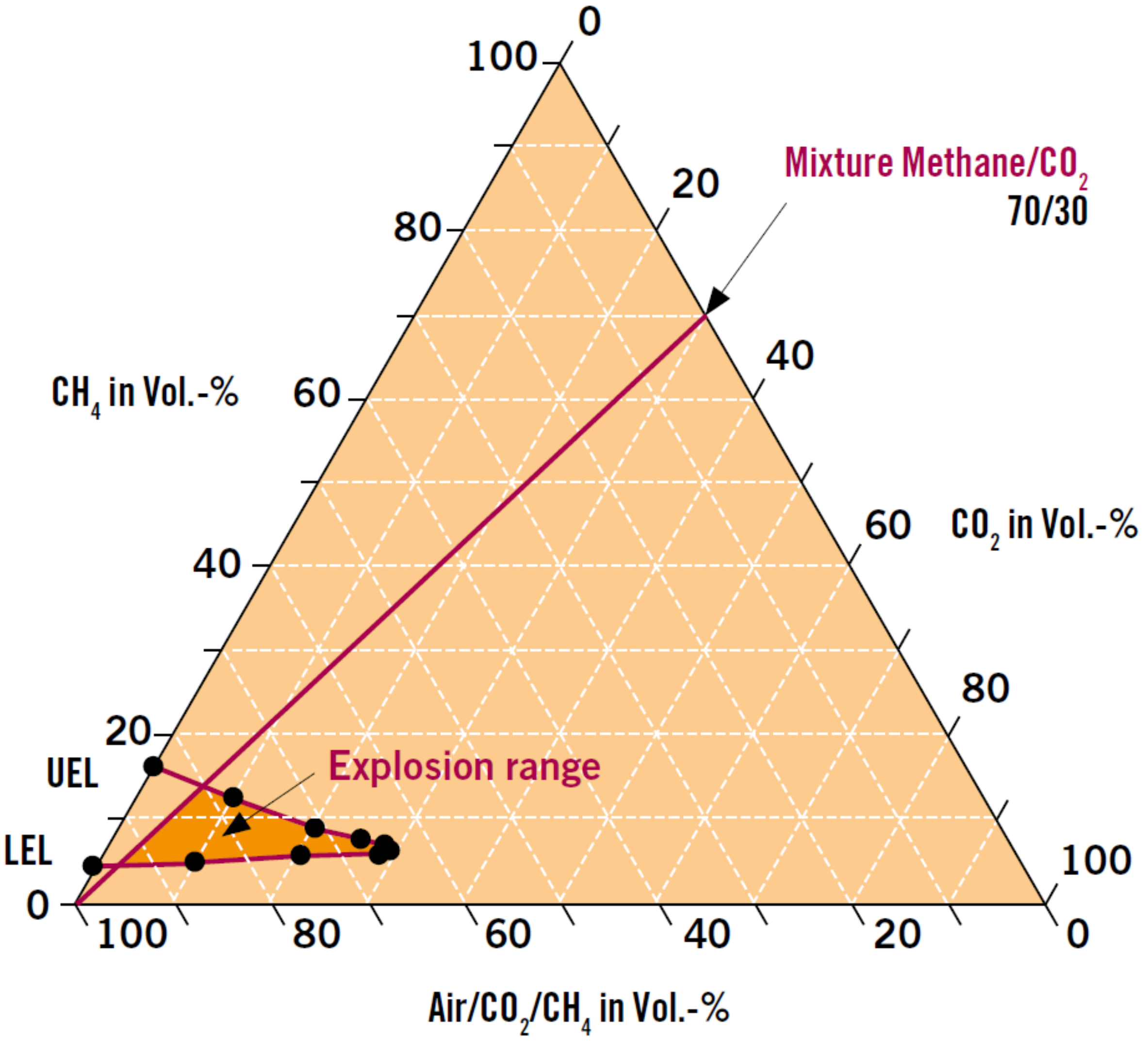
Explosion Hazardous Areas and Biogas

Brief review

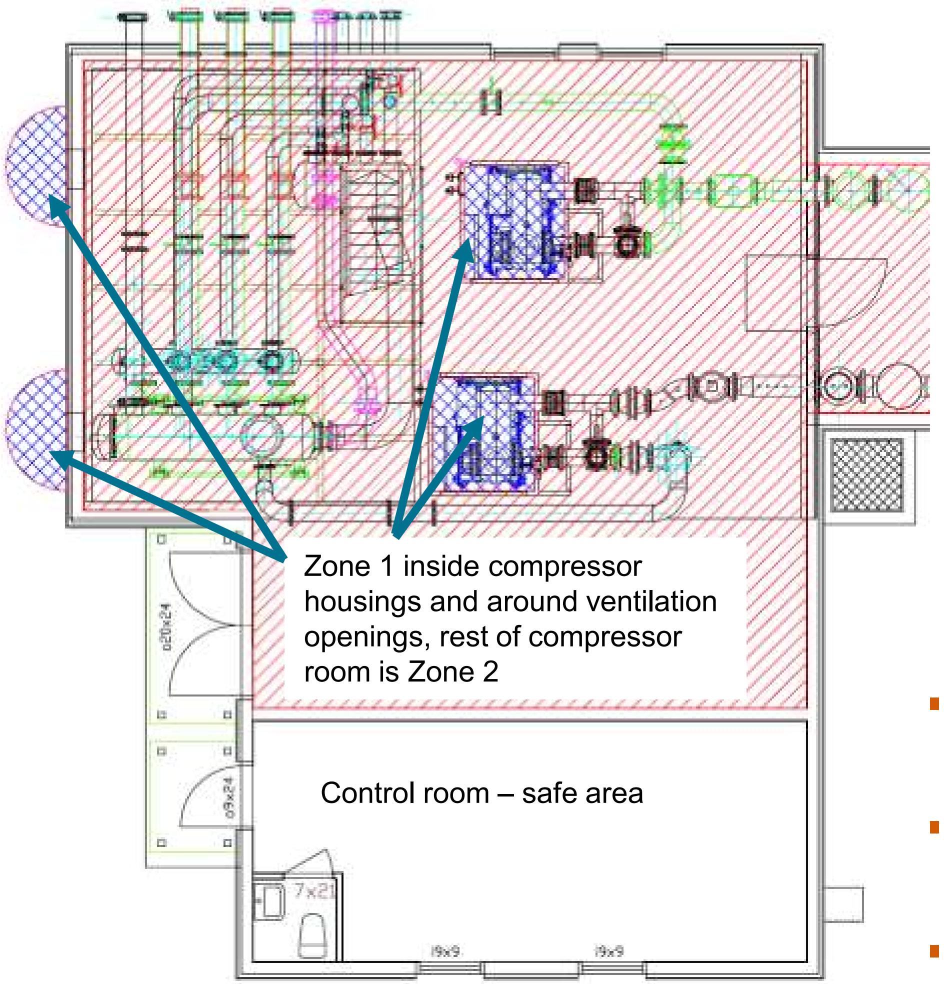
Explosion hazards in Biogas

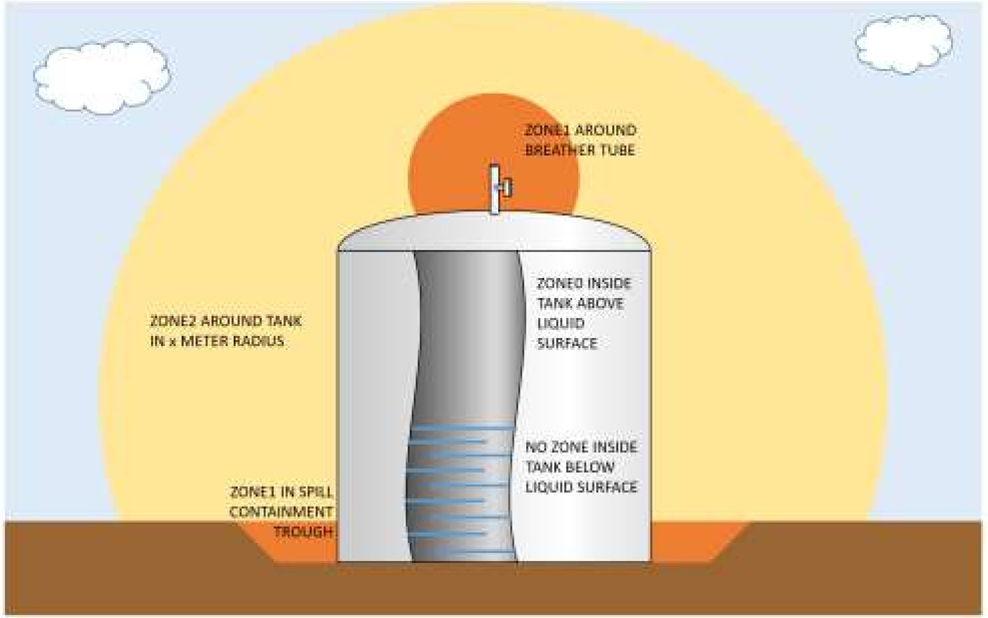
- Biogas is essentially a Methane / Carbon Dioxide mixture containing varying amounts of water vapor
- After drying, biogas is ~ 70% CH4 and 30% CO2
- The range of explosive concentrations is rather small in the triangle diagram
- Explosive mixtures mostly occur when biogas is released into air from vents, valves, process connections in plant equipment

	Biogas	Methane
Ignition temp	700 °C	595 °C
Lower explosive limit in air	6 vol-%	4.4 vol-%
Upper explosive limit in air	22 vol-%	16.5 vol-%
Heating value	6 kWh/m³	10 kWh/m³



Ex zone classification in a typical biogas plant





- These illustrations are examples only and show typical cases. Always consult actual classification diagrams for each site.
- Zone 0 – explosive conditions occur for long periods or frequently in normal operation
- Zone 1 – explosive atmosphere is present occasionally in normal operation
- Zone 2 – explosive atmosphere does not normally occur and if it does, it is limited to short periods

Explosion protection markings explained

- The Ex code can be quite complex. The Vaisala MGP261 is an example of a product certified for a boundary between two zones:

Ex II 1/2 (1) G Ex eb mb [ia] IIB T3 Ga/Gb -40 °C ≤ Tamb ≤ +60 °C

  - II – above ground (not mining)
  - 1/2 (1) - For use in zones 0 and 1, containing a subassembly for zone 0
  - G - protection against gases (not dust)
  - eb mb – protection concepts Enhanced Safety and Mass Encapsulation for Zone 1
  - [ia] - contains intrinsically safe assembly for Zone 0
  - IIB – gas group B i.e. most explosive gases, however not > LEL levels of H_2, acetylene)
  - T3 – temperature group 3, highest surface temperature in fault situations < 200 °C
  - Ambient temperature range -40 … +60 °C

The Key Measurement Points

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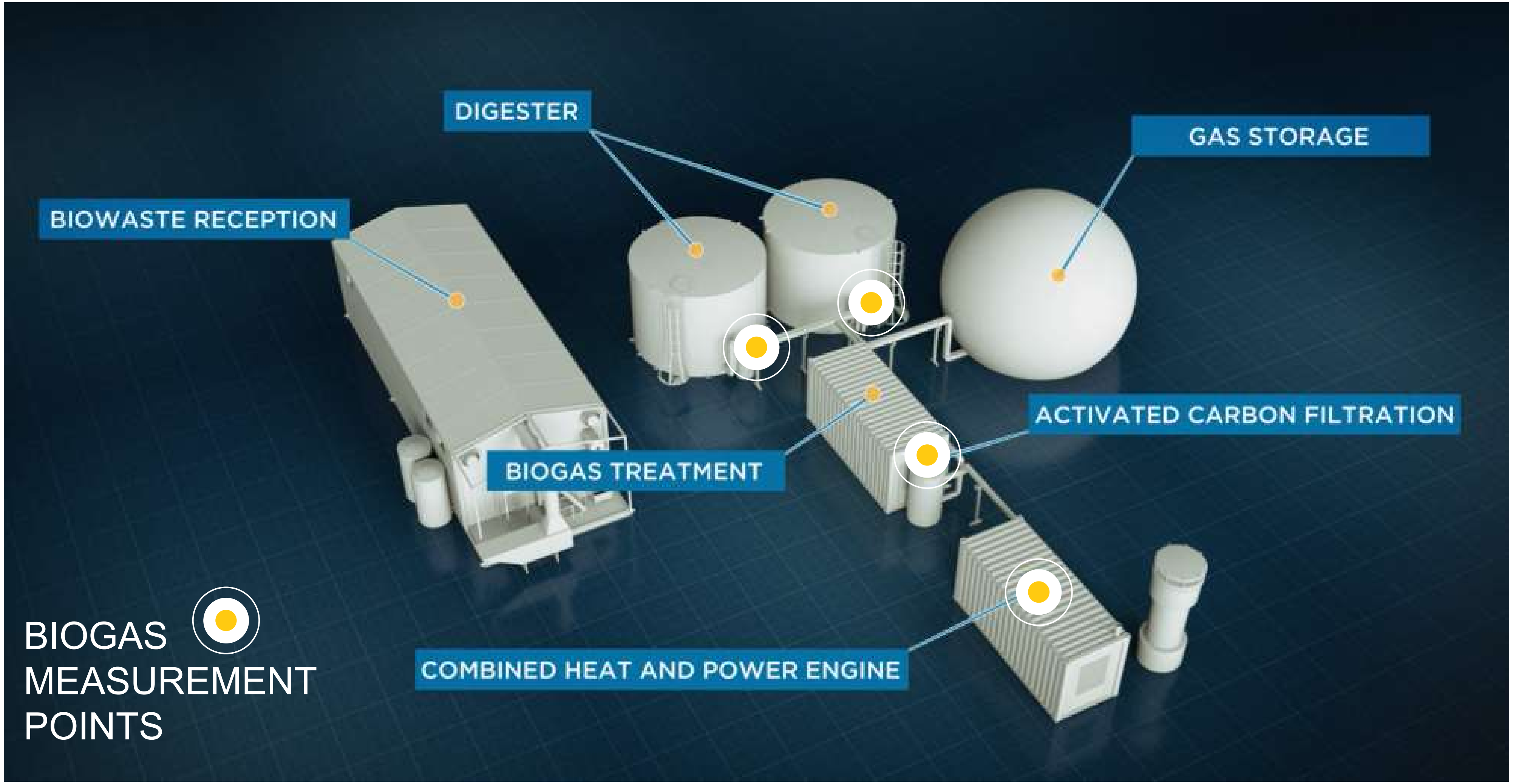
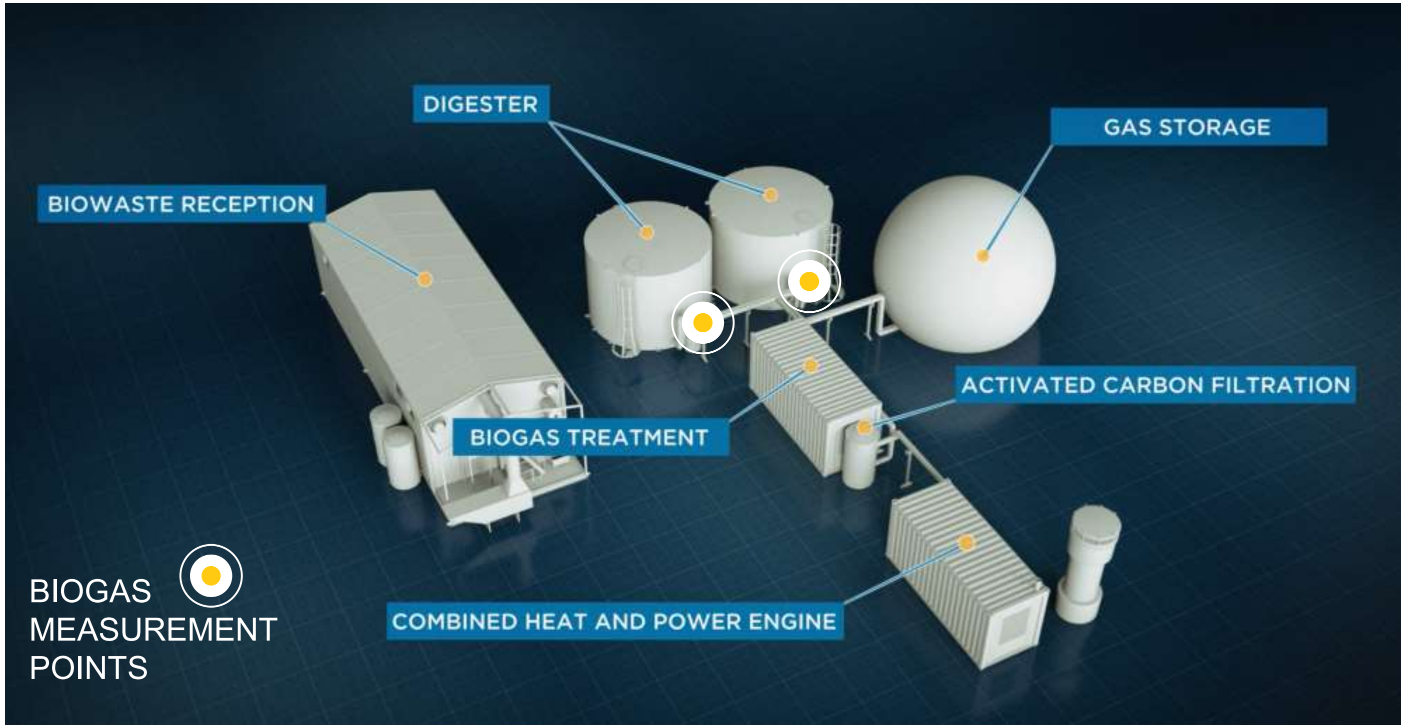
Typical measurement points on an Anaerobic Digestion plant

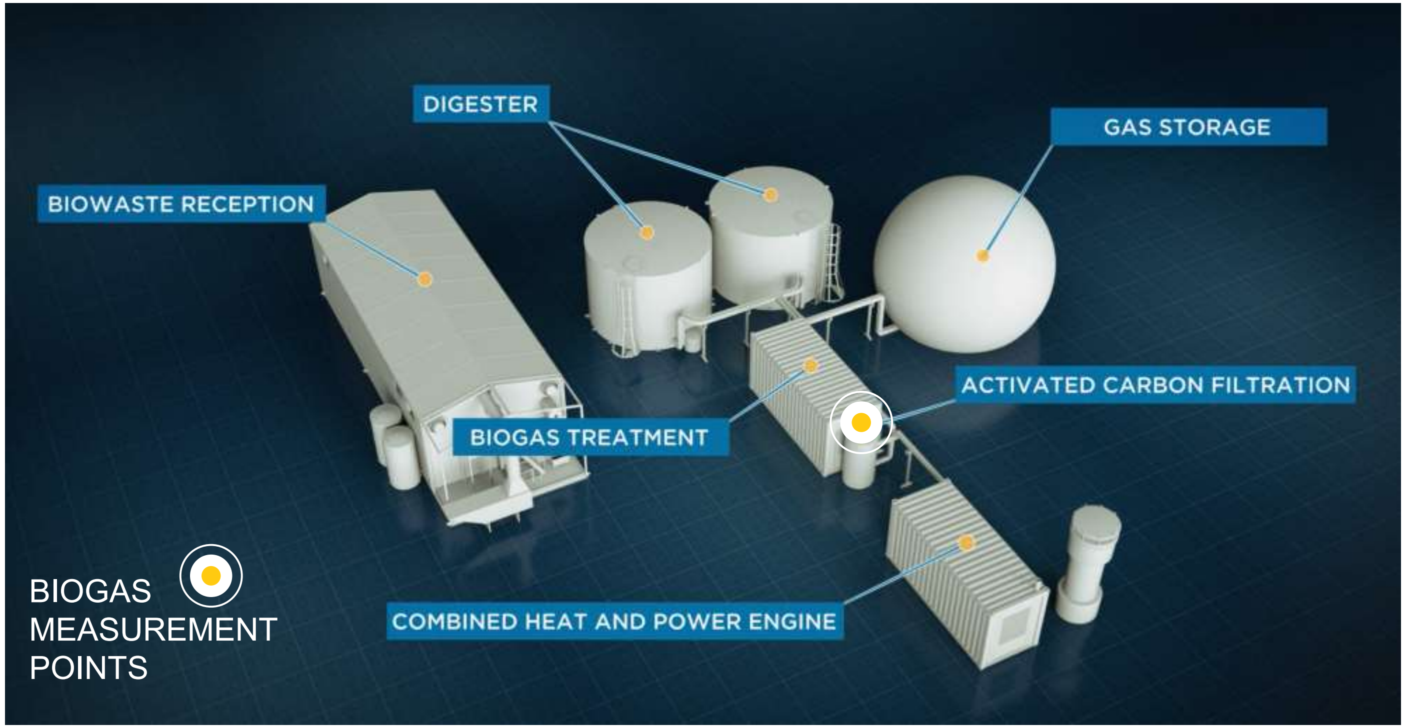


Measuring at Digesters



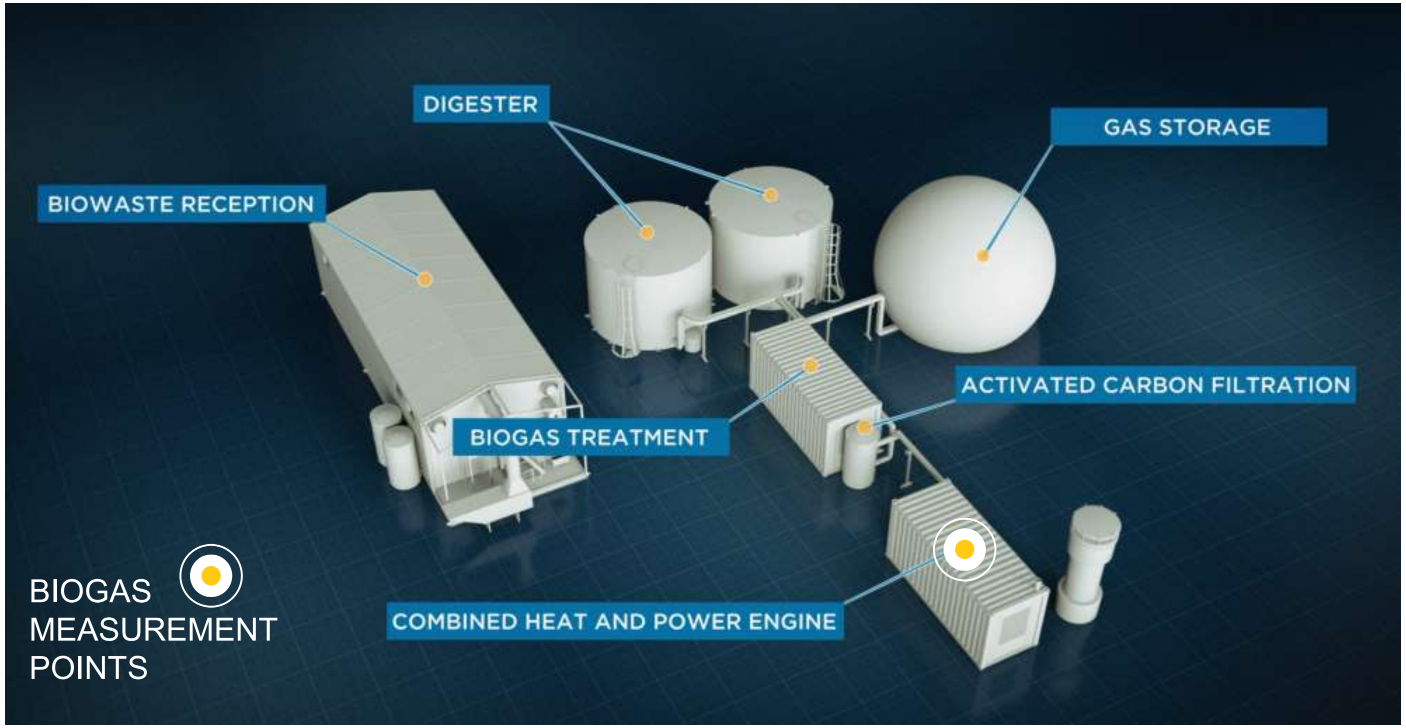
- Key parameter: Methane and Carbon Dioxide
- Measuring in the digester or immediately after the digester allows automated reactor control
- Loading rate of waste and retention time in the digester are important parameters for maximizing methane production
- Humidity is usually saturated at this point

Measuring at gas treatment unit



- Key parameter: humidity
- Measurements after heat exchanger and before filtration serve two purposes:
  1. Control the heat exchanger used to dry the gas
  2. Monitor the humidity of gas going into active carbon filters to avoid problems with condensation or too dry gas

Measuring at internal combustion engine



- Key parameter: Methane and Humidity
- Measurement of Methane enables more precise and efficient engine control
- Measurement of Humidity helps to detect problems with gas quality before they damage the engine or cause shutdowns

Installation Examples

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Anaerobic digestion plant, food industry waste

- The biogas plant currently processes food industry side streams as well as separately collected and packaged biowaste. Packaging materials are delivered for energy use and biodegradable fractions are used in the biogas process.
- Biogas from the plant is sold for use in the boiler and CHP engine of an energy company located nearby for electricity, heat and process steam production.
- An early prototype of the MGP261 was installed in a flow through adapter and used as an extractive analyzer inside a blastproof Ex d enclosure for 12 month test period
- Results were compared with an existing extractive analyzer

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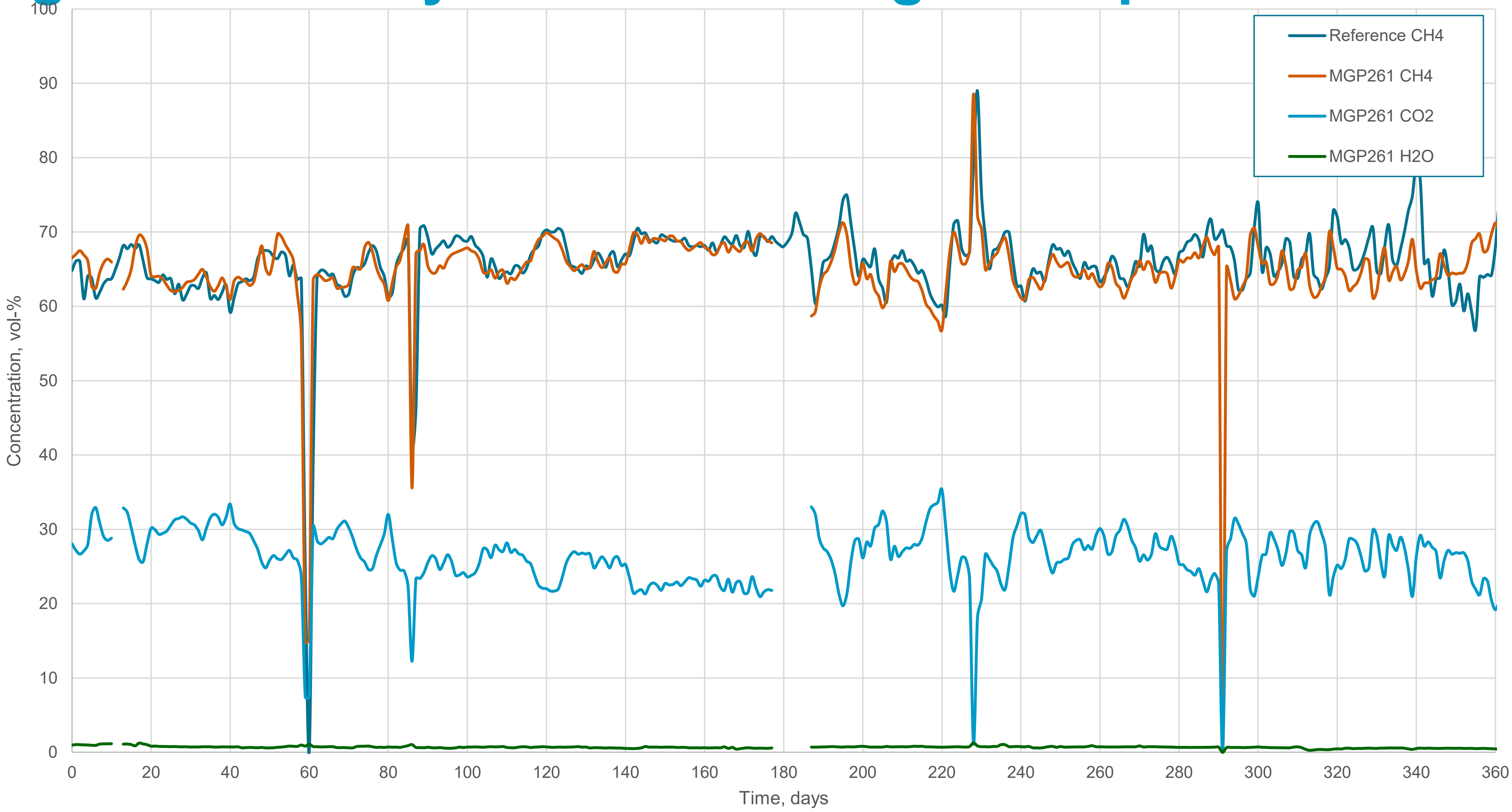
Long-term stability at anaerobic digestion plant



Landfill gas plant

- One of the largest landfill gas plants in Europe was selected as an in situ test site.
- There are two landfills on the site with multiple gas pumping stations, one of which now has an MGP261 monitoring gas quality
- Gas is filtered and passed to multiple CHP engines generating a total of 15 MW electric power
- In addition, the heat produced in the CHP engines makes the site self-sufficient in terms of energy.
- Carbon dioxide emissions of the waste treatment site are reduced by ca. 3000 tonnes per year by the utilization of landfill gas
- In the online data on next slide, rapid response time of the in situ measurement probe is highlighted by the repeating pulses on the graphs. These happen when active carbon filters automatically switch between two banks of filters.

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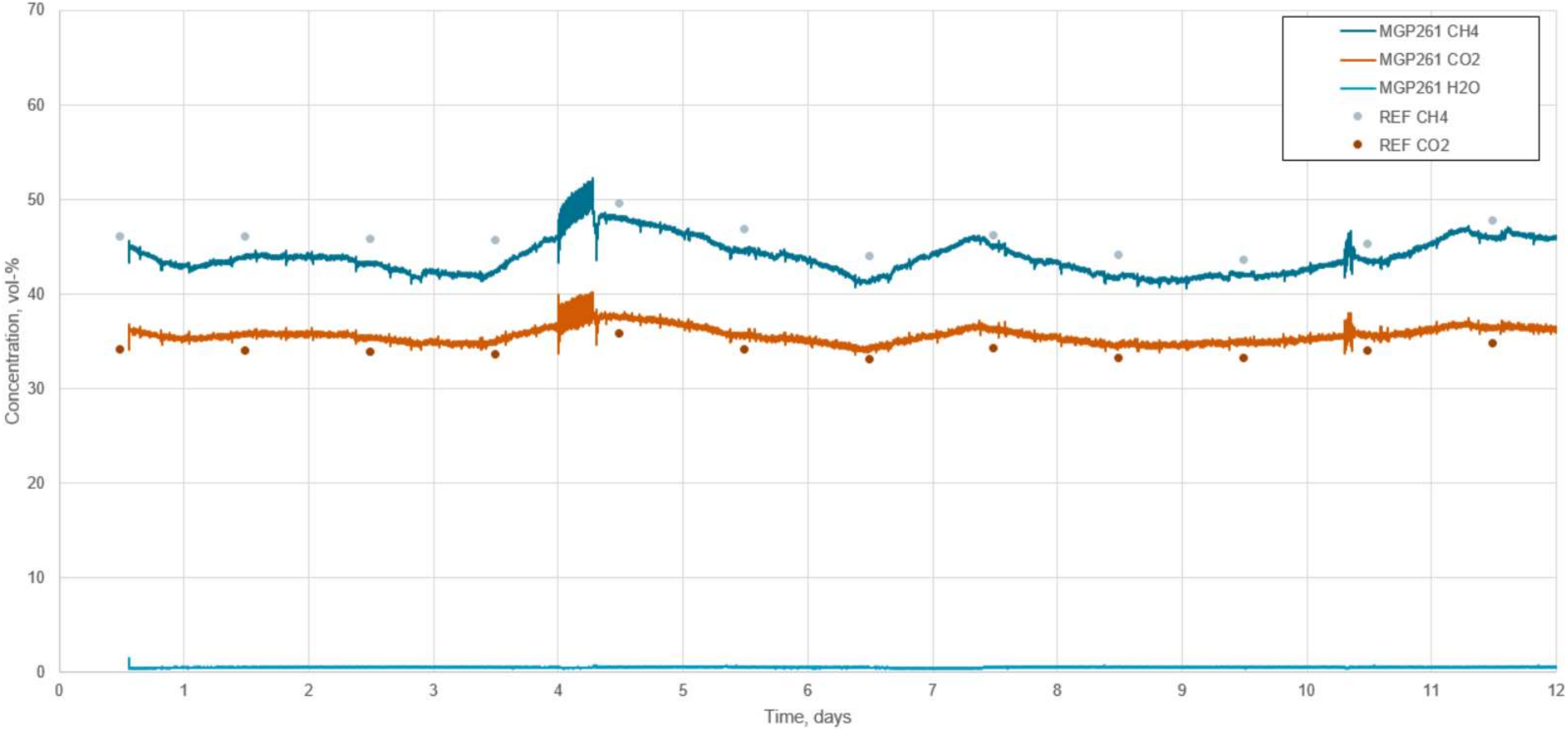
In situ measurement at landfill gas plant



Summary

- Accurate and reliable measurements in biogas are needed for process optimization
- Measuring in situ reduces operating costs and simplifies gas analysis compared to extractive gas analyzers
- New Vaisala MGP261 enables humidity to be measured and used in process control in addition to methane and carbon dioxide

Thank you for your participation! For more information, visit www.vaisala.com/biogas

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