# INDUSTRIAL EMISSION MONITORING: METHODS AND EMERGING TECHNIQUES

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# OUTLINE

- Standard methods
- Research from sampling towards online monitoring
- Emerging Technologies

# Standard Methods:
## Emissions to air; stack / point emissions

| Analyte | BAT | Monitoring | Standards | Methodology |
|---|---|---|---|---|
| Dust | 155-158 | Continuous/Annual | EN 13284-2/EN 13284-1 | Gravimentric |
| Cd, Pb, Tl | 156 | Annual | EN 14385 | HPLC |
| Cr(IV) | 156 | Annual | No EN std. | |
| Hg | 156 | Continuous/Annual | EN 14884/EN 13211 | UV fluorescence/absorption |
| $SO_2$ | | Continuous/Annual | EN 14791 | Ion Chromatography |
| $NO_x$ | 13 | Continuous/Annual | EN 14792 | Chemiluminescence |
| TVOC | 160 | Annual | EN 12619 | GC-FID |
| PCCD/F | 159 | Annual | EN 1948-[1-3] | GC-MS |
| B[a]P | 160 | Annual | ISO 11338-[1,2] | GC-MS |

# Example: Non Ferros Metals; BAT 159

1.7.2.3. *PCDD/F emissions*

BAT 159. In order to reduce PCDD/F emissions to air from a furnace producing ferro-alloys, BAT is to inject adsorbents and to use an ESP and/or a bag filter.

BAT-associated emission levels: See Table 47.

*Table 47*

**BAT-associated emission levels for PCDD/F emissions to air from a furnace producing ferro-alloys**

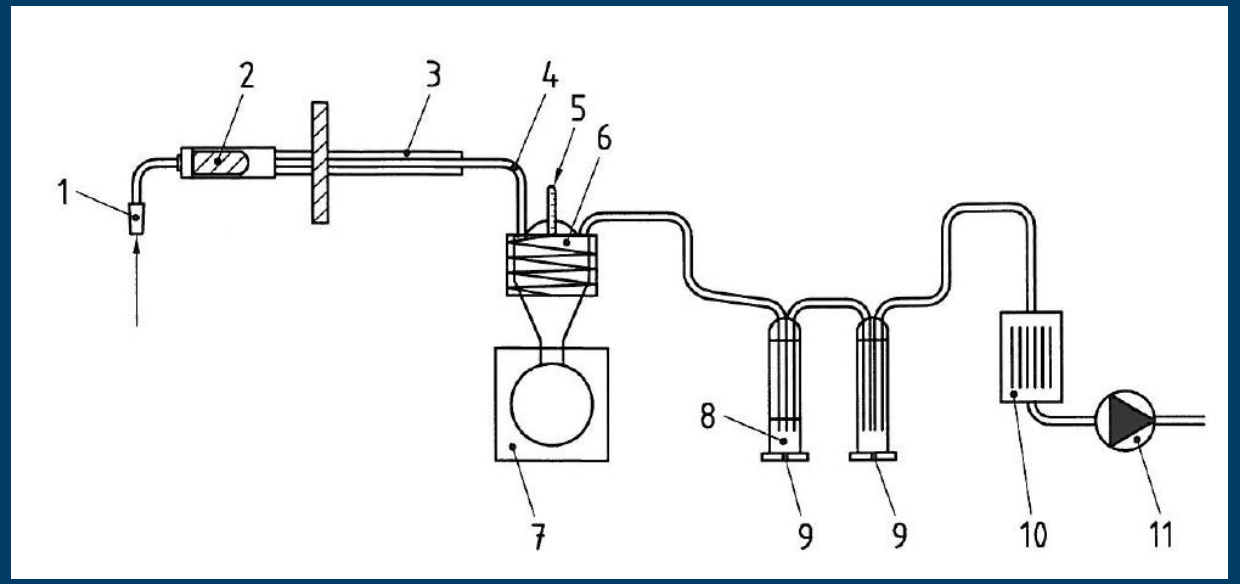
| Parameter | BAT-AEL (ng I-TEQ/Nm$^3$) |
|---|---|
| PCDD/F | ≤ 0,05 (1) |

(1) As an average over a sampling period of at least six hours.

The associated monitoring is in BAT 10.

# Sampling from ducts and point sources

- Extractive sampling
  - Filtering of particulate matter
  - Adsorbtion of volatiles
- Sampling conditions
  - Access for personell
  - Isokinetic withdrawl and stable flow
  - Stable temperature, pressure and dust load



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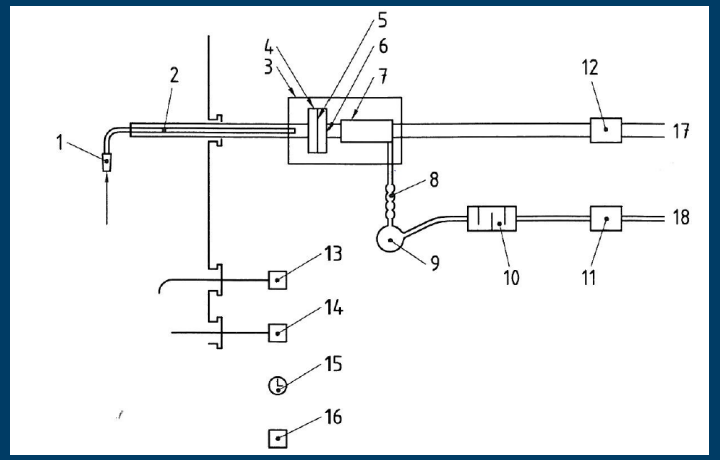
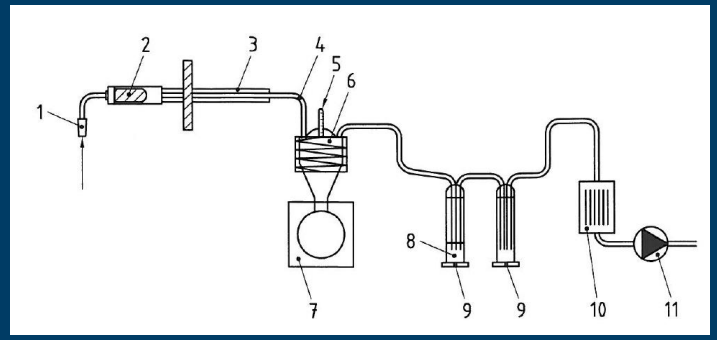
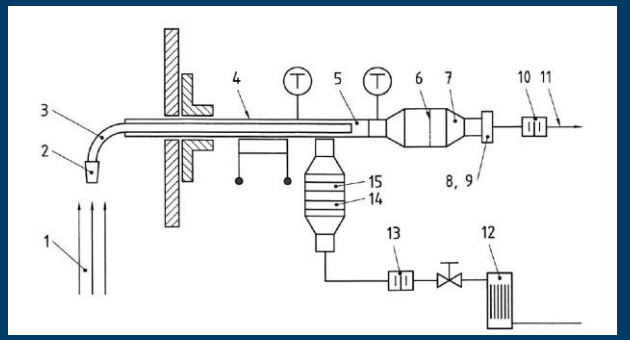
# ISO 11338-1: Sampling PAH

- Three equivalent strategies
- Rquirements
  - Isokinetic flow
  - Particulate filtering
  - Water separation
  - Adsorbent (XAD-2)
- Further work: IPN PAHSSION (2019)



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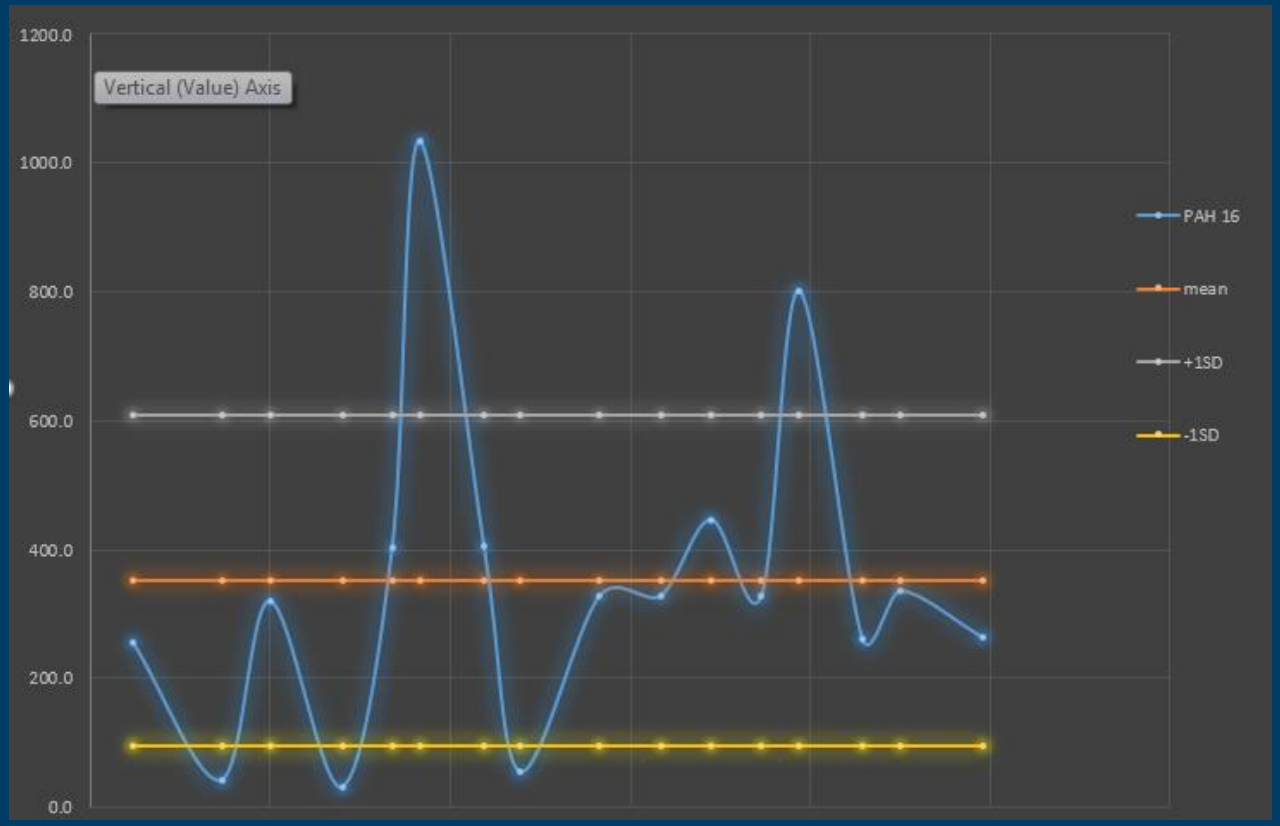
# From discrete to online monitoring

- Considerations
  - Sampling duration
  - Process variation
  - Sampling Intervals
- Offline method more accurate for short interval
- Online cover variations in processes over time



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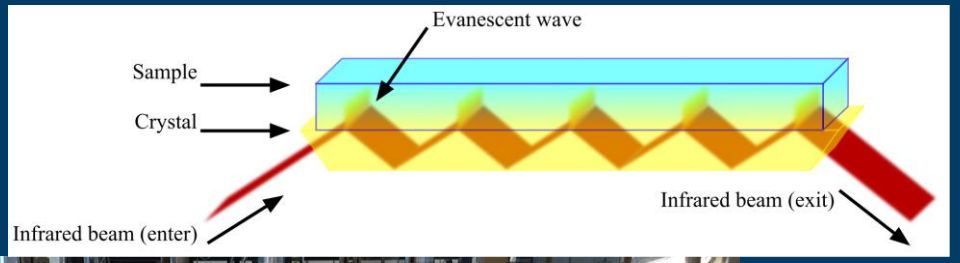
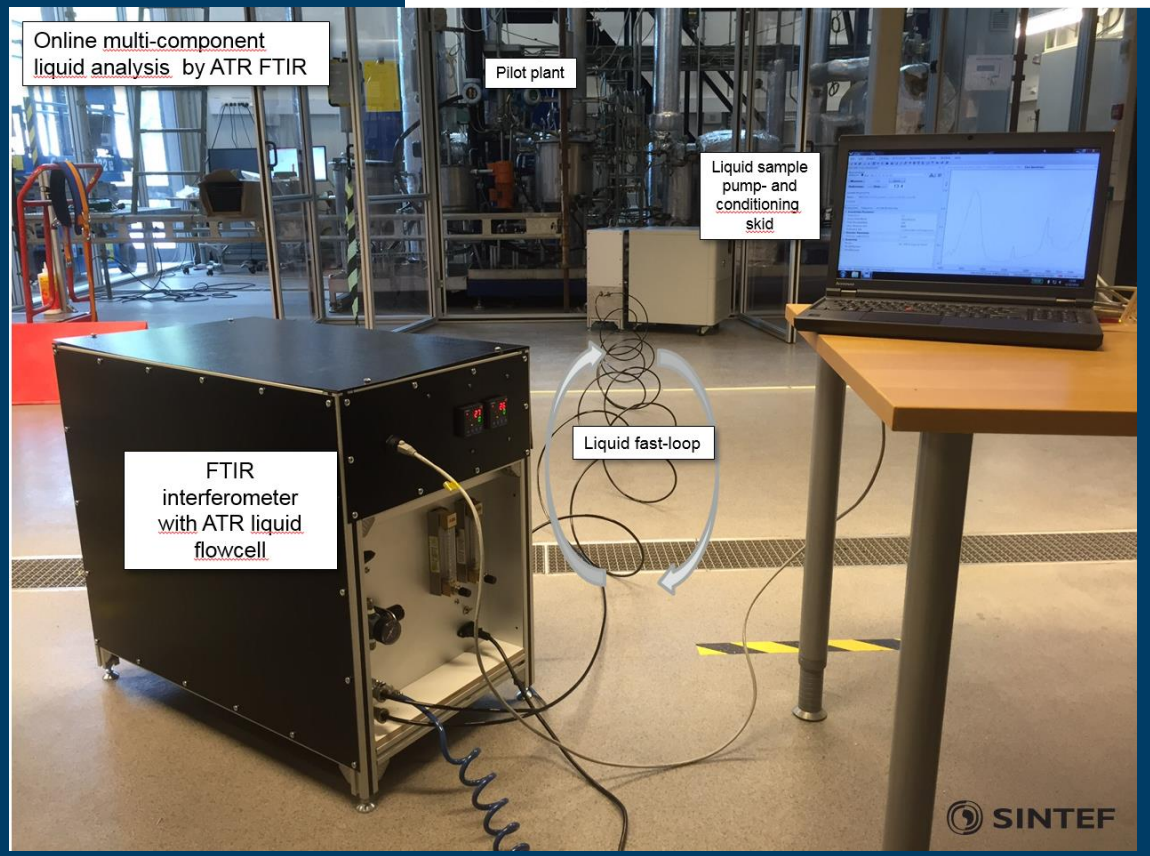
# Research towards online sampling

- Convert established offline analysis system to online monitoring

- Example:
  - Attenuated total reflectance (ATR)



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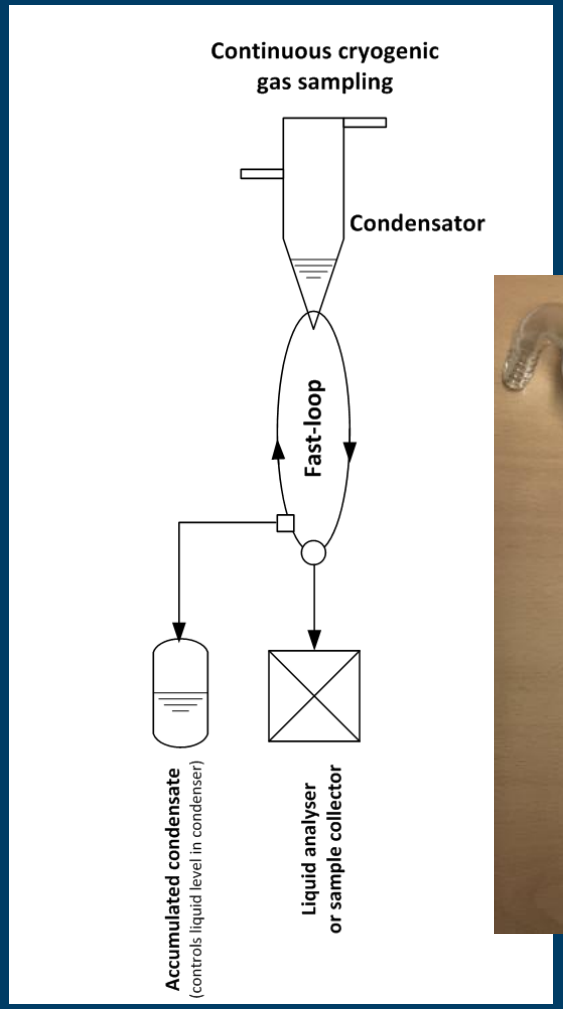
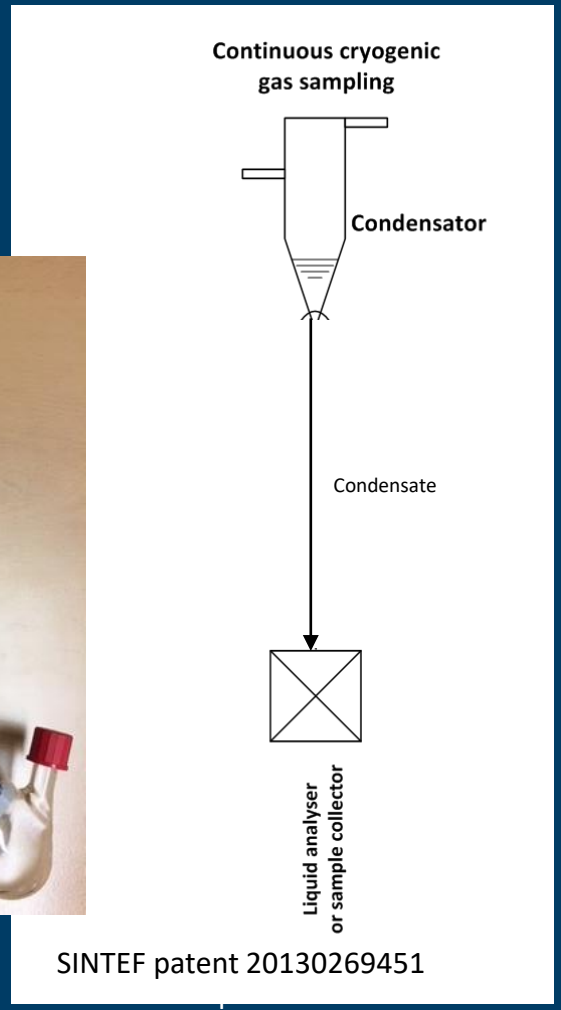
# Research towards online sampling (cntd)

- Concept: **A**bsorber **C**ontinuous **E**mission **M**onitoring **S**ystem




SINTEF patent 20130269451



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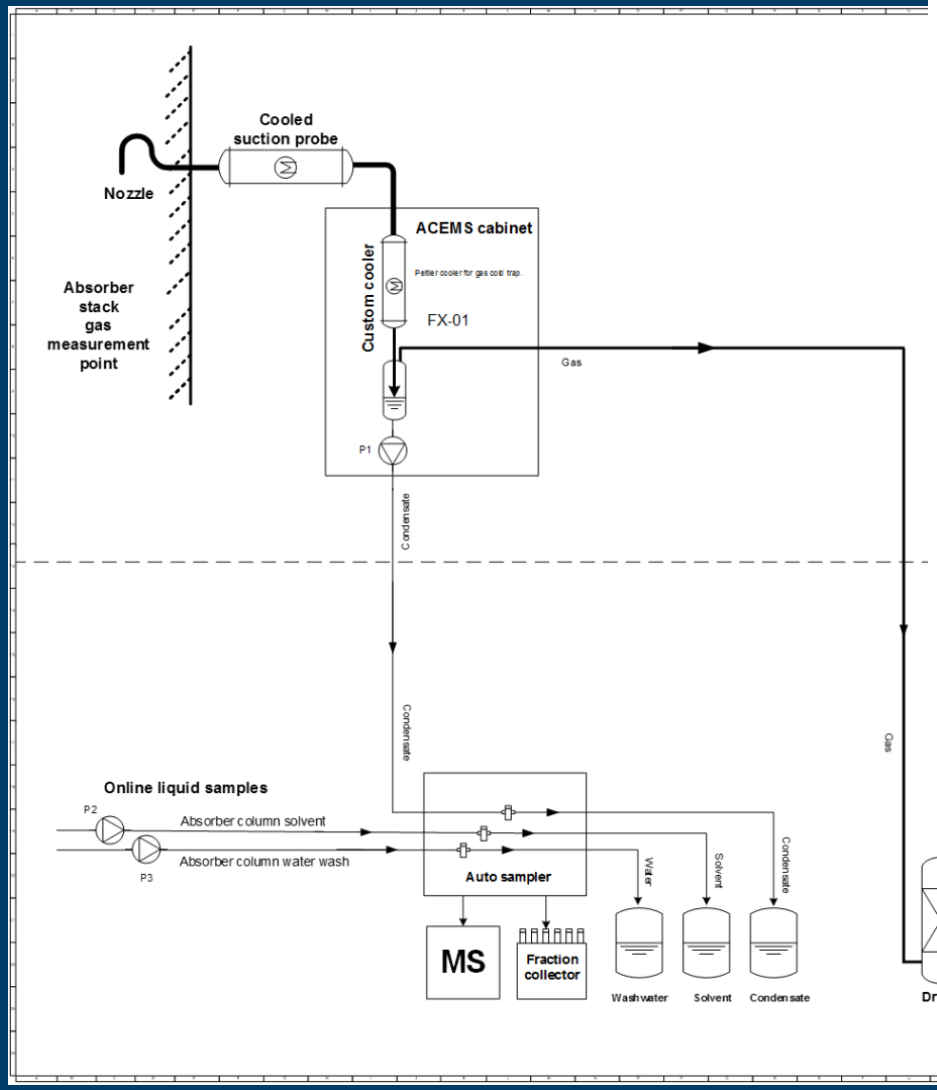
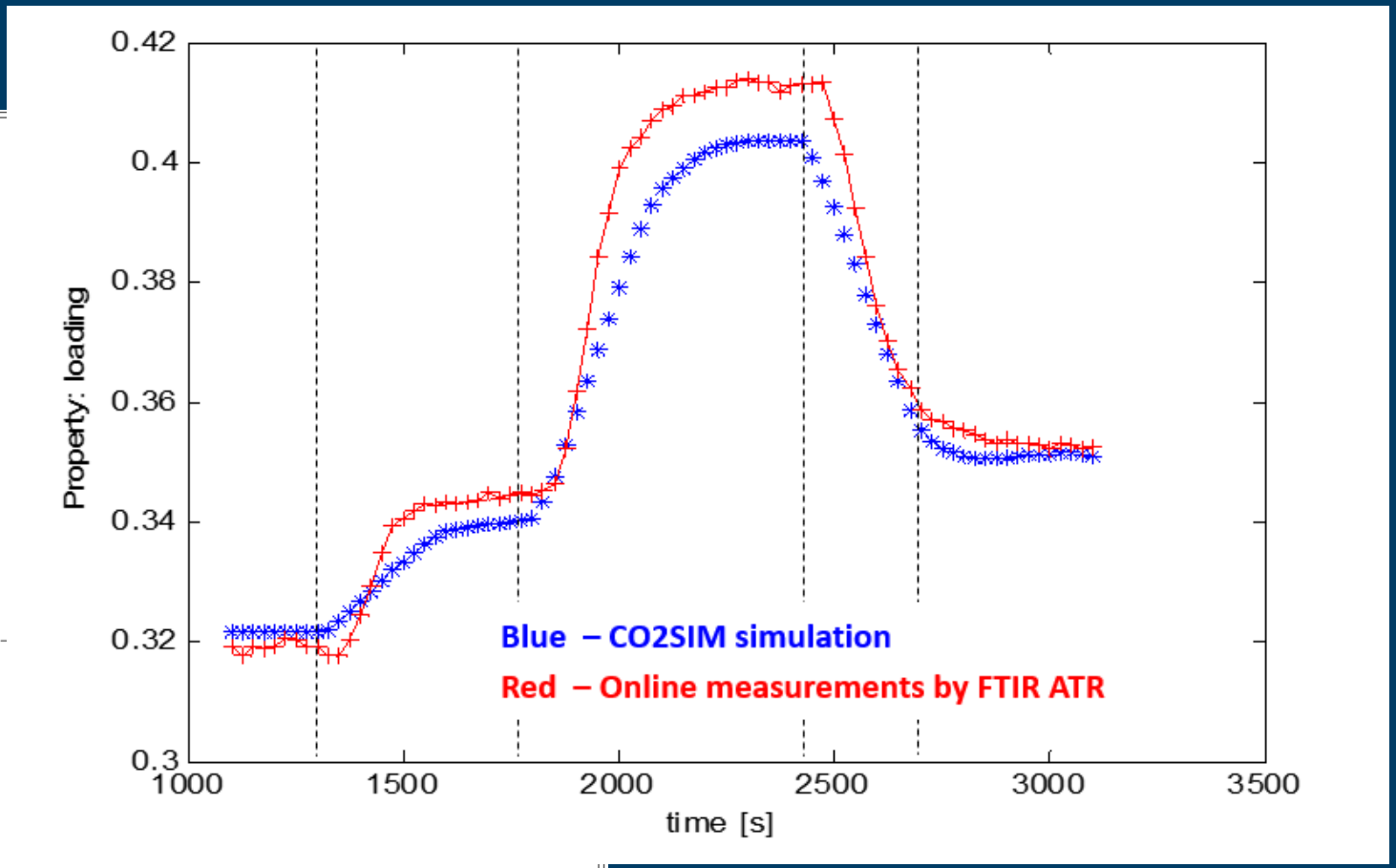
# ACEMS: online sampling in $CO_2$-absorption plant

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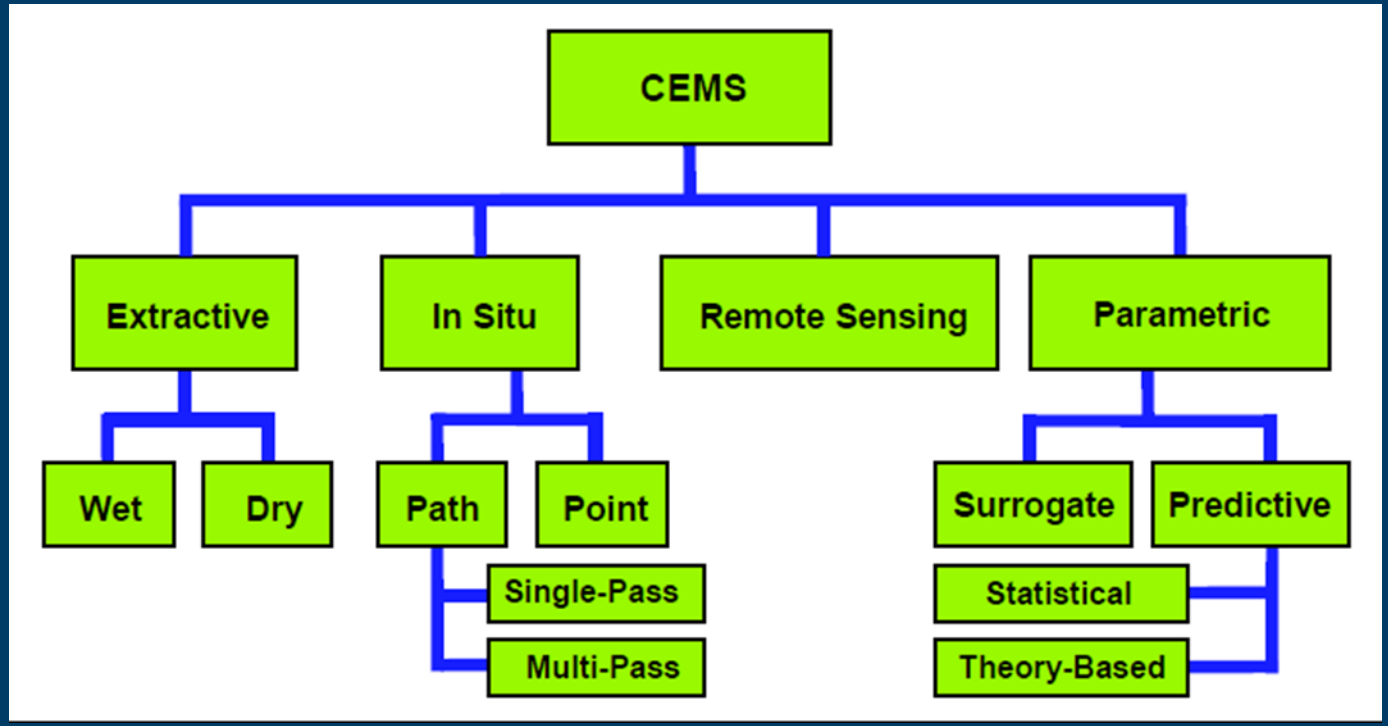
# Continous emissions monitoring system (CEMS)

- Measurement conditions
- Sample extraction and handling
- Data acquisition and analysis
- Calibration
- Reproduceabilty and Reliability
- Quality Assurance



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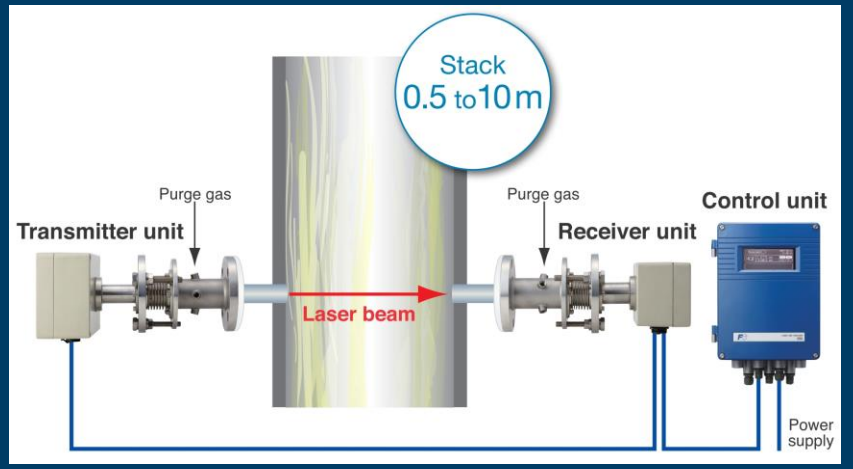
# Continous emissions monitoring system (CEMS)

- Cross Stack masurements or moderate distance
- Flange purging (dust)
- Tuneable Diode Laser
  - Monochromatic lasers customized spectre/wave length
  - HF, Dust, CO, $CO_2$, $NH_3$ …
- Quantum Cascade Laser
  - Midt – to far Infrared
  - $NO_x$, $CF_4$
- Can be tuned to cover 2-3 analytes



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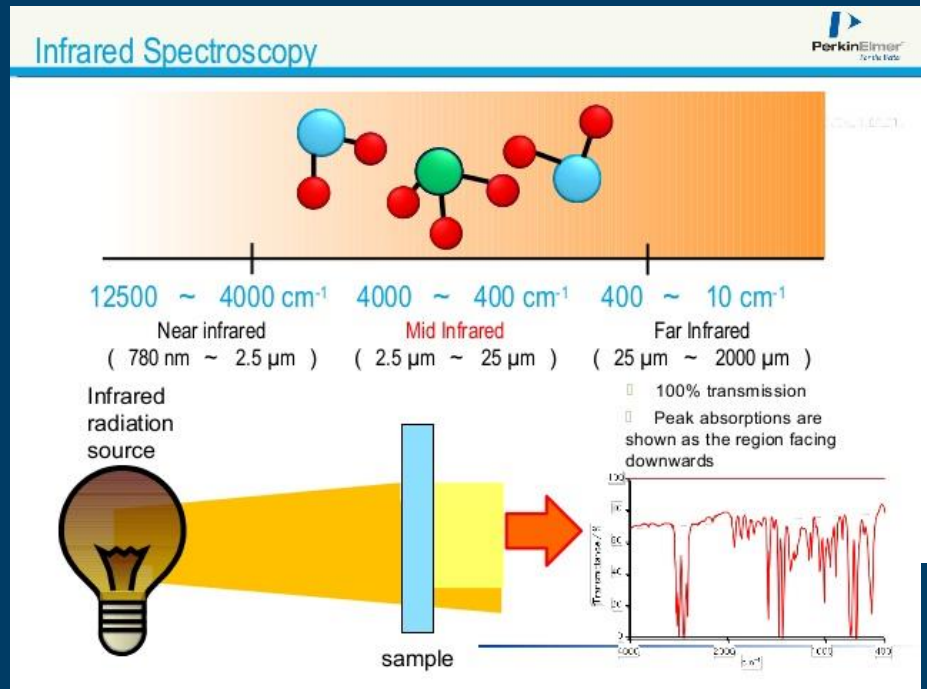
# Multicomponent optical analysers

- Single point extraction
- Across stack
  - FTIR (Fourier Transform Infra-red Spectrophotometer)
  - DOAS (Differential Optical Absoprtion Spectroscopy)
    - IR and UV-spectra
  - Tuneable Diode Laser



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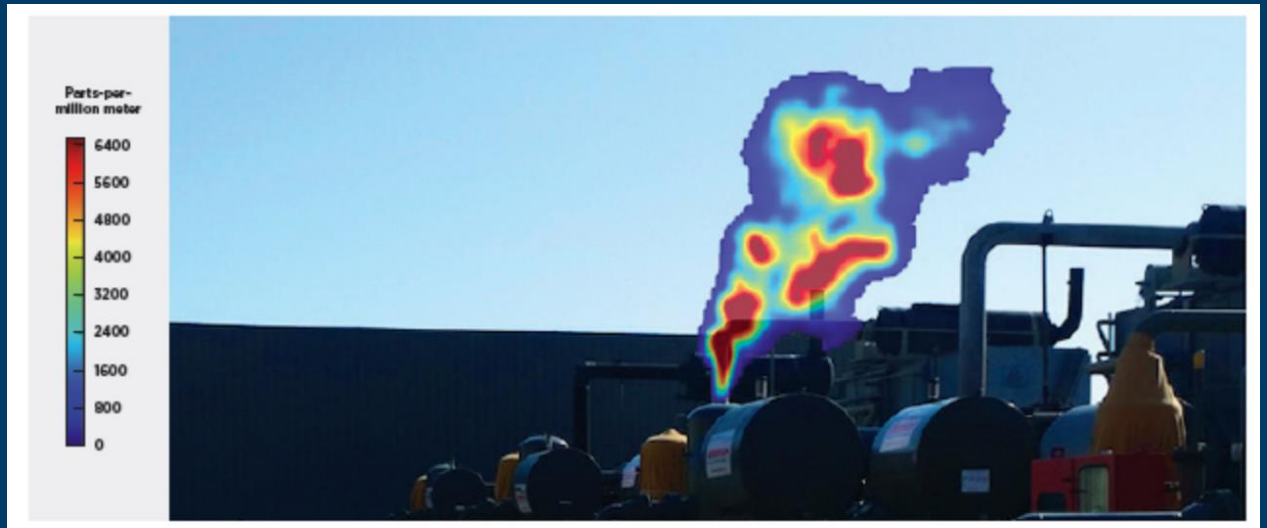
# Emerging Technologies

- Hyperspectral Imaging og gas emissions
- Predicitve Emission Monitoring Systems
- Fugitive Emissions

# Hyperspectral imaging of gas emissions / Detection of fugitive emissions


- Optical Gas Imaging
- LiDAR
  - Light (Imaging) Detection and Ranging
  - Dependent on light source also detection of compounds possible
- Thermal imaging
  - Energy and flow detection/monitoring
  - Leak detection of a single compound
- Quantification improved (needed)
- Challenge: calibration




Rebellion Photonics' Gas Cloud Imaging technology provides gas detection videos and images of methane and other gases. The color scale corresponds to gas concentration.



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# Predictive emissions monitoring system (PEMS)

- Software analyser which predict emissions based on process parameters
- Validate correlation with actual measurement
- Back-up to traditional analyzers
- ABB commercial solution available

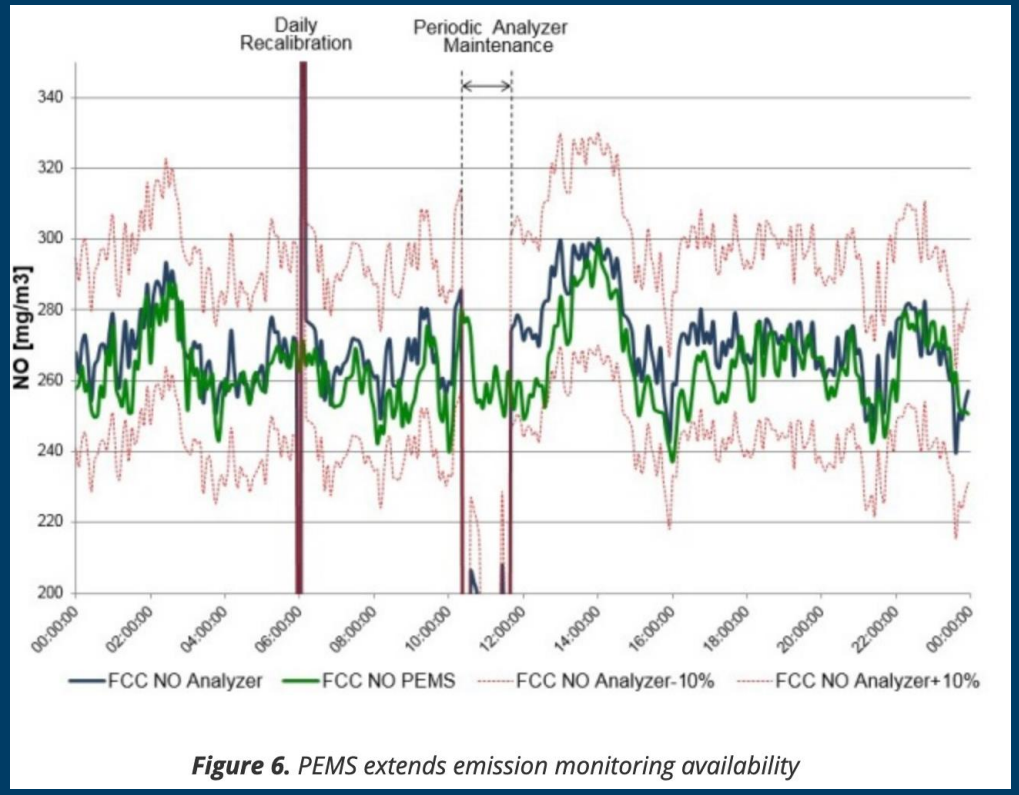


***Figure 6.*** *PEMS extends emission monitoring availability*



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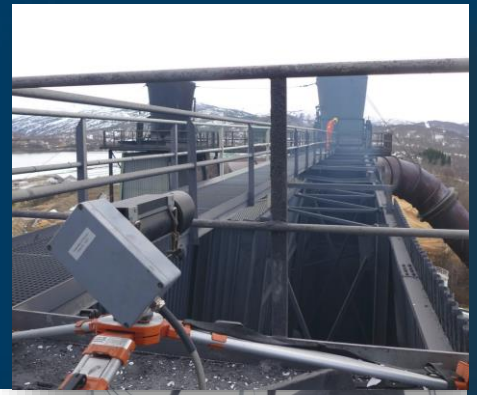
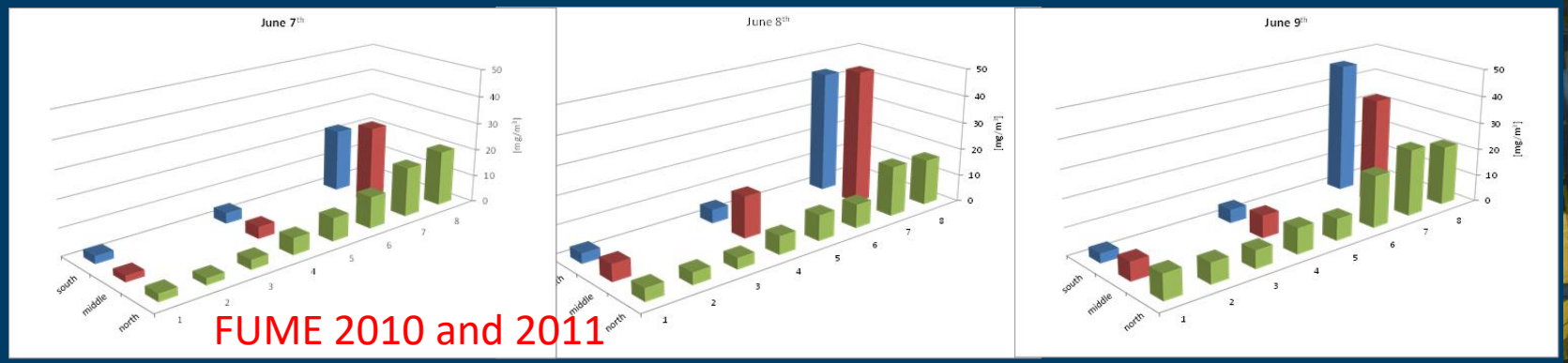
# Fugitive emissions: Dust

- Long pass dust sensor
- Anemometer (velocity, direction, pressure, temperature) to monitor velocity in cross section
- Verification with several gravimetric filters
- Challenge:
  - Find "right" supplier for long pathes
  - Calibration over a long distance





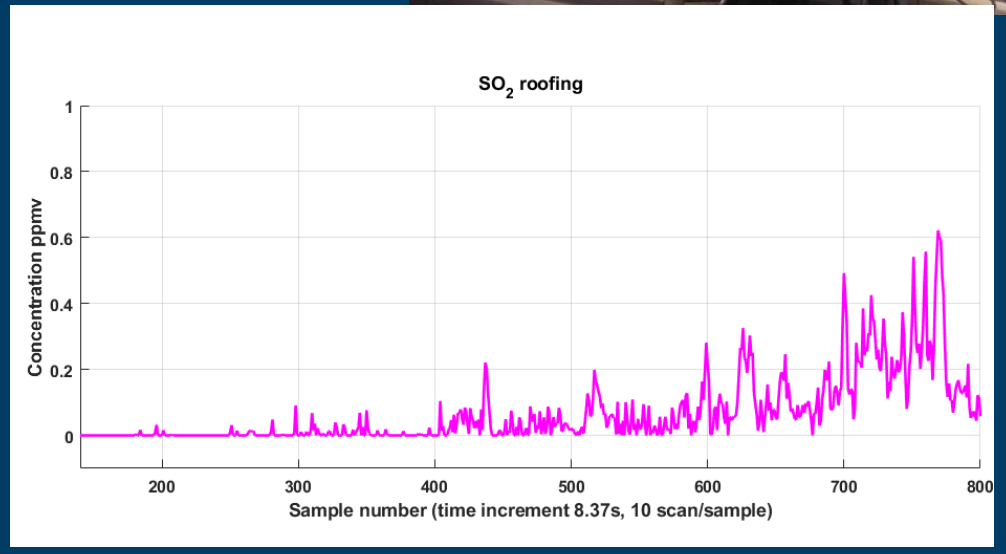



FUME 2010 and 2011

# Fugitive emissions: Gases

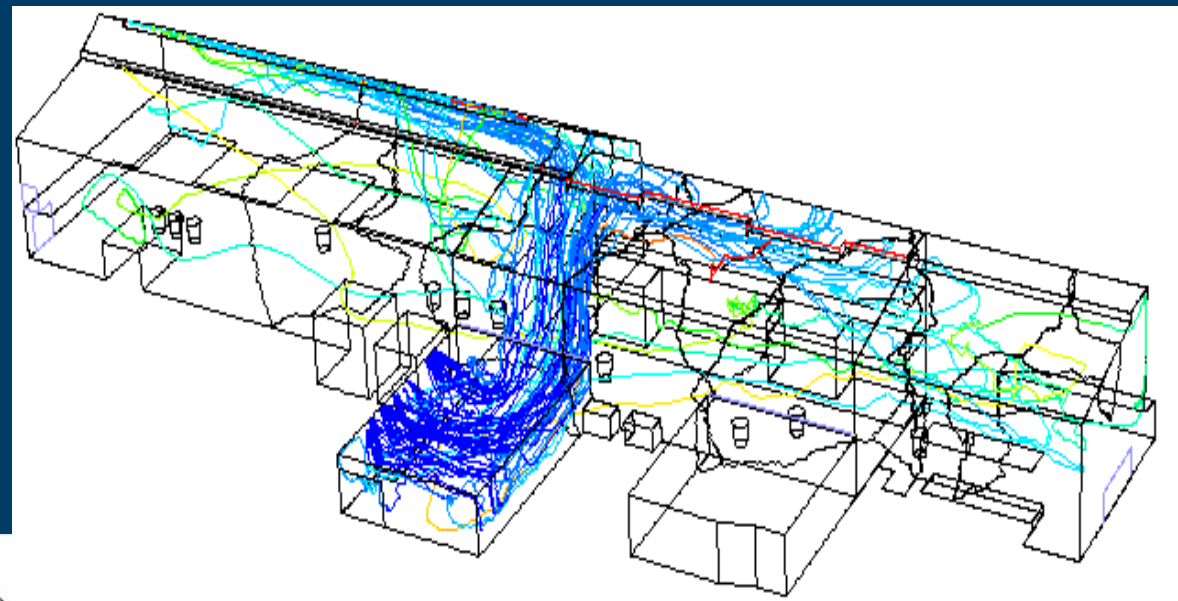
- Open PathFTIR 2x25 meter
- Anemometer to monitor velocity in cross section
- Verification with filter and absorption
- Good correlation between estimates for a three day average!

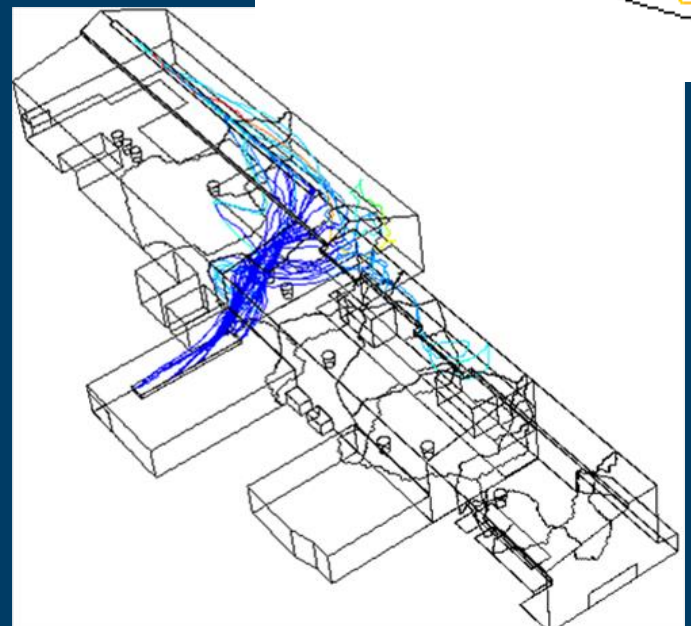


# Digitalisation: On-line Optimization of a plant wide monitoring system

- Challenges
  - Modelling: Highly complex and nonlinear system to be implemented in an CFD-environment
  - Measurements are erroneous
  - Comprehensive integration of secondary measurements and CFD-model
    - Temperature
    - Hall wind strength and direction
    - Position (open/closed) of doors and roof openings
    - Local weather (wind direction, temperature difference
    - Operation in a given a part of the plant
- Benefits
  - Control of plant operation
  - Optimize measurement position







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