TECHNOLOGY CENTRE MONGSTAD

– catching our future

Predictive Emissions monitoring:

Exploring predictive emissions monitoring of ammonia at TCM carbon-capture plant using open-source machine learning libraries

PCCC-8
17.09.2025

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Technology Centre Mongstad is a Flexible Neutral CO_2 Capture Test Centre

Agenda

- ➢TCM's test experience
- ➢ Emissions: Permitting and measurement
- ➢Findings and lessons learned
- ➢Takeaways

We have Tested 17 different Technologies

> 40.000 hrs
Proprietary Campaigns

Solvent Technologies

Start 2012

Capturi · ALSTOM · Cansolv 1st campaign · Carbon Clean Solutions · Cansolv 2nd campaign · ION Clean Energy · FLUOR · Mitsubishi Heavy Industries · RTI International · Cansolv 3rd campaign · ION Clean Energy 2nd campaign · Honeywell

2025 >

Start 2020

Emerging Technologies

MTR · TDA · SAIPEM ACCSESS · PROSPIN ACCSESS · MOF4AIR · InnoSepra · Svante

Sponsored by TCM Owners, DOE, EC and CLIMIT

> 23.000 hrs
Non-proprietary Campaigns

> 70
Scientific publications

2013

2025 >

MEA-1	MEA-2	MEA-3	MEA-4	MEA-5	Align-CCUS	CESAR-1	AURORA	Owners Campaign

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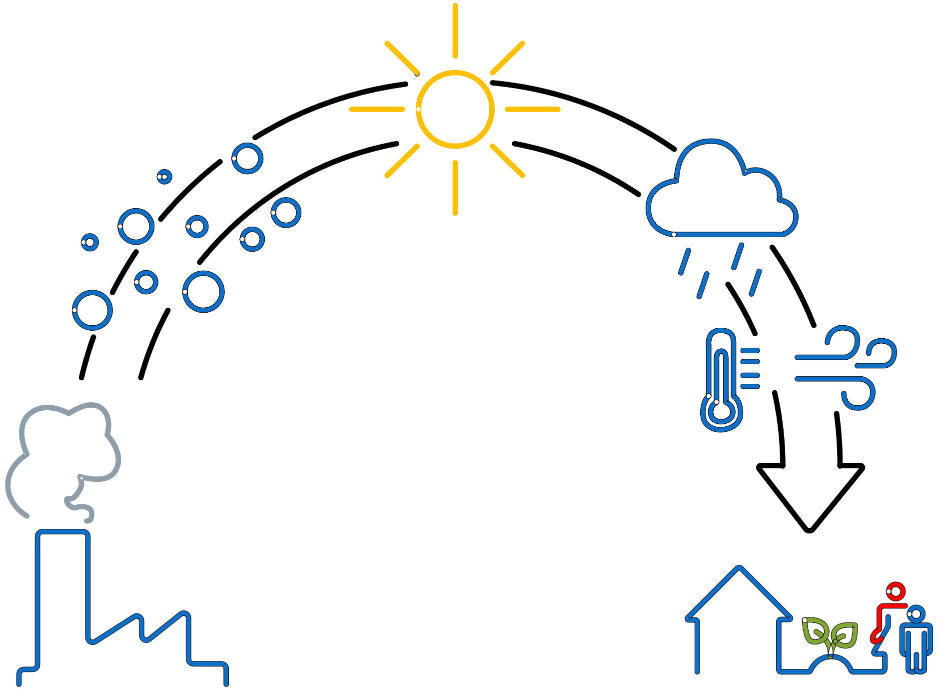
All Operations Have been under the TCM's EMISSION PERMIT

Atmospheric chemistry

Dispersion modelling:

- Dispersion of amines
- Photochemical reactions
- Predicting air and water concentrations



- Norway defined limits for these pollutants with respect to public health.
- Release from TCM should not lead to a concentration of the sum **nitramines** and **nitrosamines** that exceeds defined level.

Emission Components	Emission Limits	
	Daily limit	Yearly limit
Ammonia	100 ppmV	6,000 kg
Total Amines	6* ppmV	2,800 kg
Total Aldehydes	1 g/s	

* **Maximum hourly** average **emission is 15 ppmV**

Exposure path	Recommended max level
Drinking water	4.0 ng/l
Air	0.3 ng/m^3

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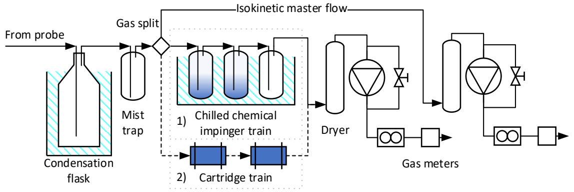
Measurements at the Top of TCM ABSORBER COLUMN

Instrument	Measured Components & Detection Limits
FTIR	Amines, Ammonia, Aldehydes (ppmV)
IMR-MS (Ion Molecule Reaction Mass Spectrometer)	Amines, Degradation products (10 ppbV)
PTR-tof-MS	Amines, Degradation products (pptV)
Extractive Impinger	Amines, Degradation products (ppbv)
Predictive emissions monitoring	Amines? **Ammonia?** Aldehydes **EPA PS 16**; CEN 17198



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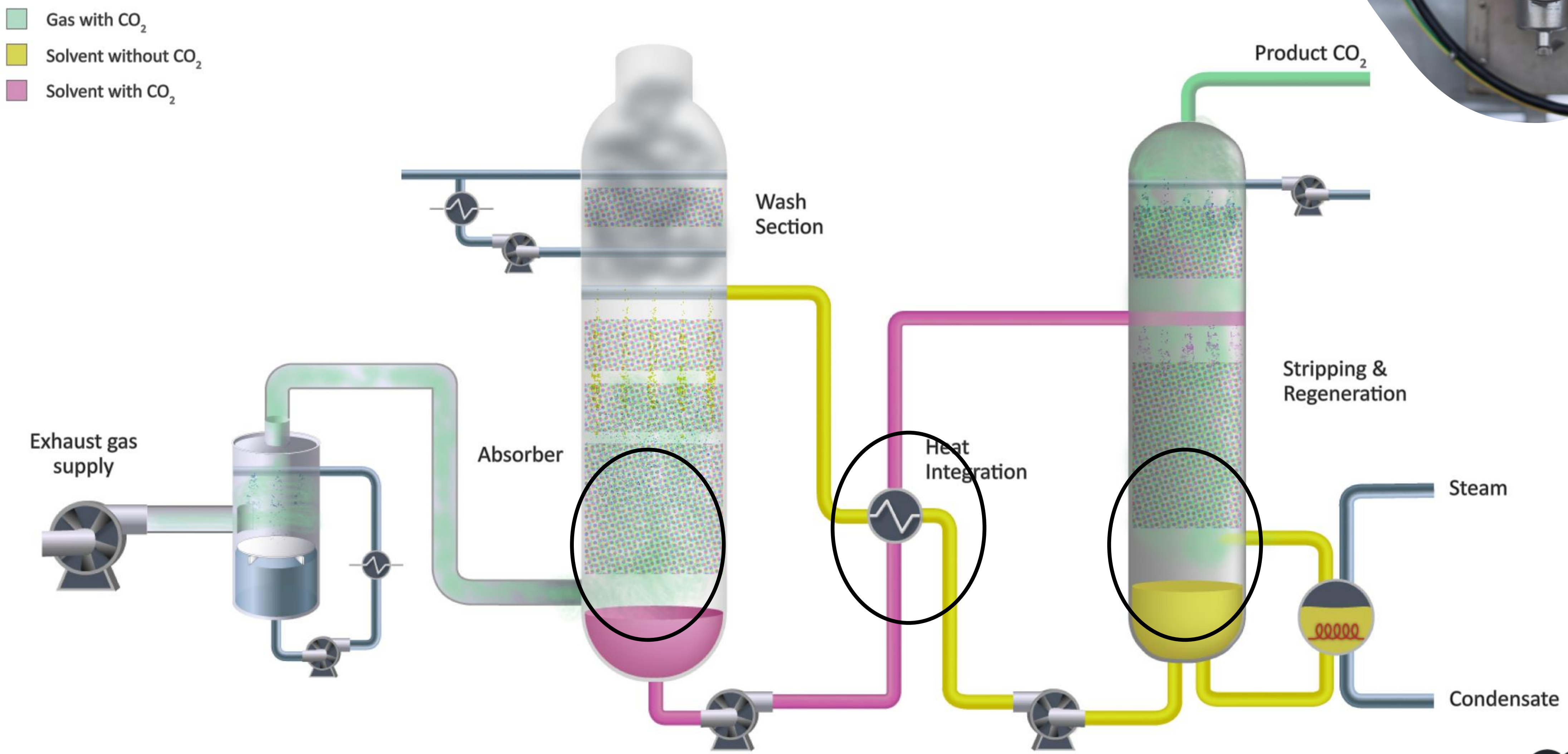
Tracing the Origin of Ammonia Emissions



Oxygen and metal ions, intermediates, temperature

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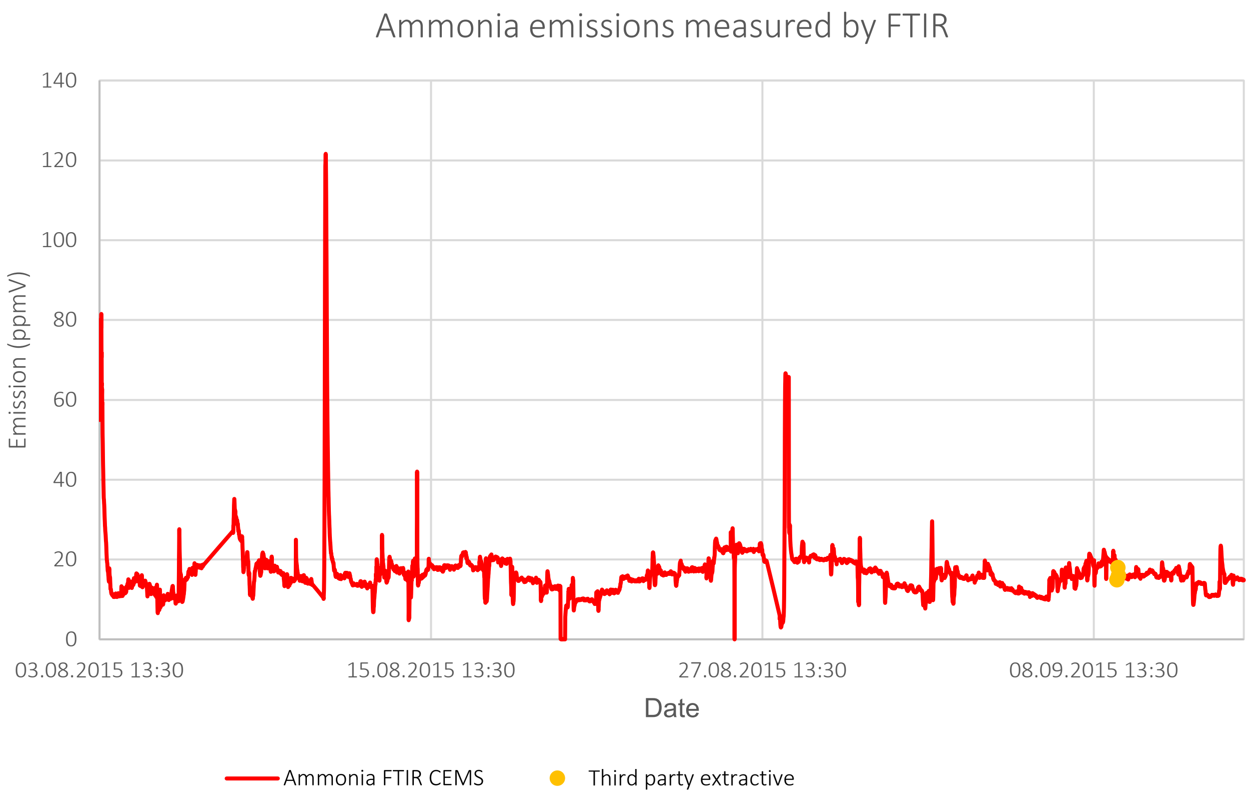
Measurements by **CEMS** and **Third-party** Verification



- Continuous operation period with two non-planned shutdowns (38 days).
- Ammonia emissions are mainly within the measurement range of the FTIR of 0–500 ppmV.
- Third-party measurements validated online measurements.
- Operational data was used to build the model

[1]For more information on the campaign:
Faramarzi et al. "Results from MEA testing at the CO_2 Technology Centre Mongstad: Verification of baseline results in 2015", **(2017) GHGT-13.**

Morken et al. "CO_2 capture with monoethanolamine: Solvent management and environmental impacts during long-term operation at the Technology Centre Mongstad (TCM)", **(2019) IJGGC 82 (175-183).**

Preparing Sensor Data for **Machine Learning**

83 sensors initially used as input

Gas composition component

- All inlet flue composition data
- Outlet composition removed and ammonia treated as labels.

Absorber and stripper profiles

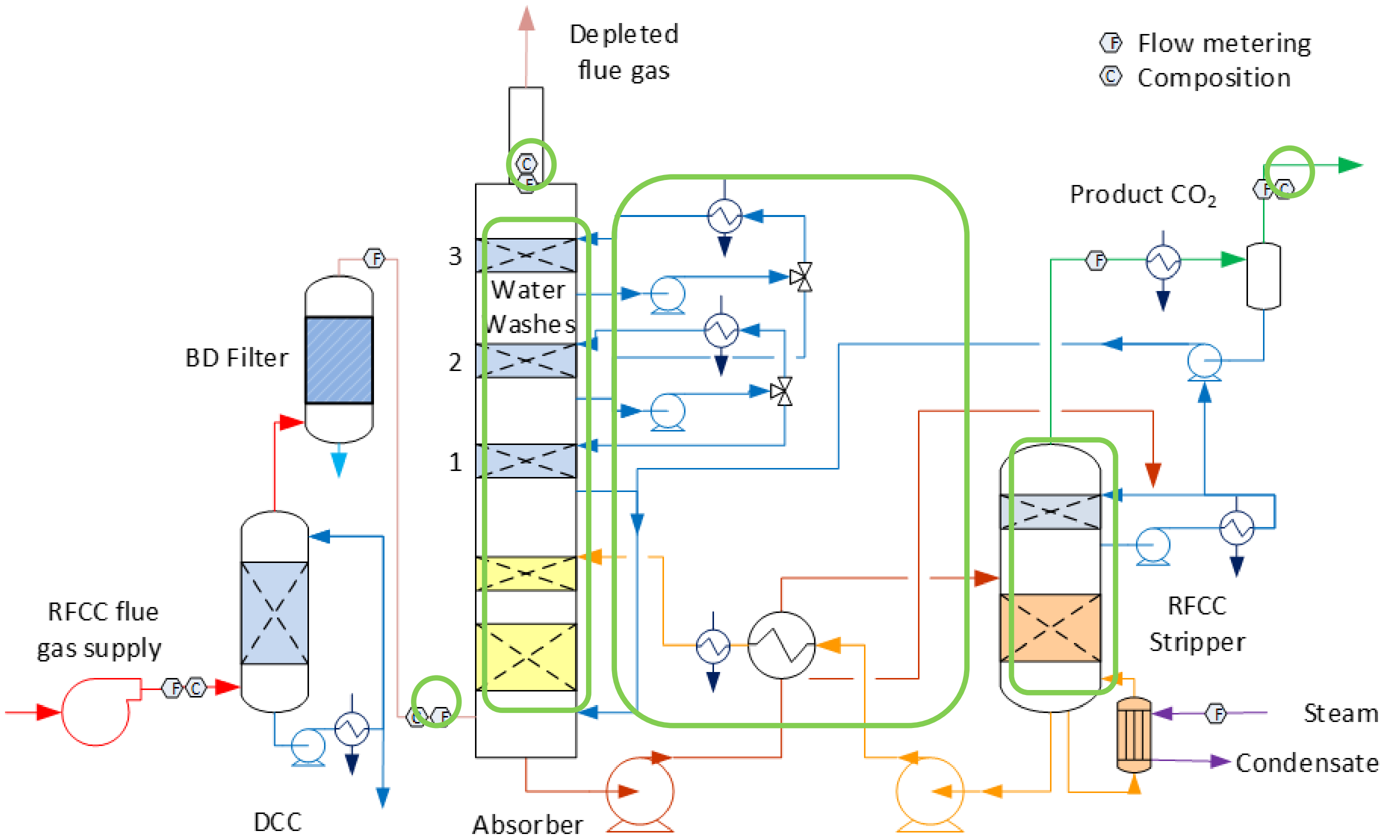
- Temperature and Pressure

Liquid sensors

- Flows and physical parameters

31 sensors dropped because of redundancy

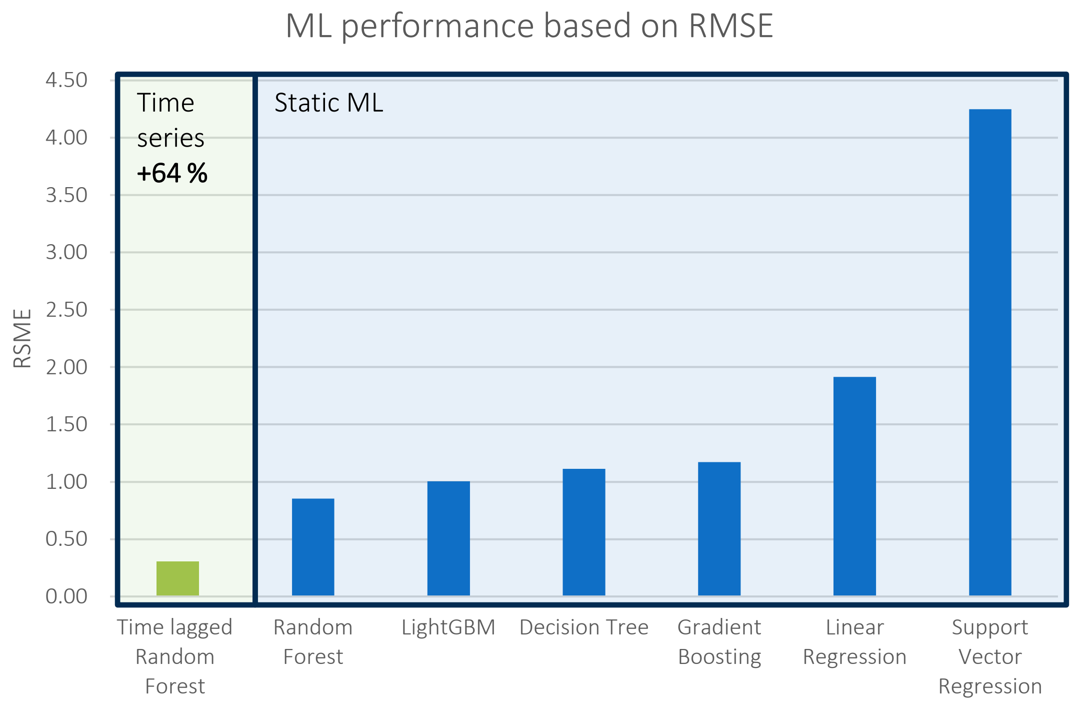
- 52 sensors were used for fitting

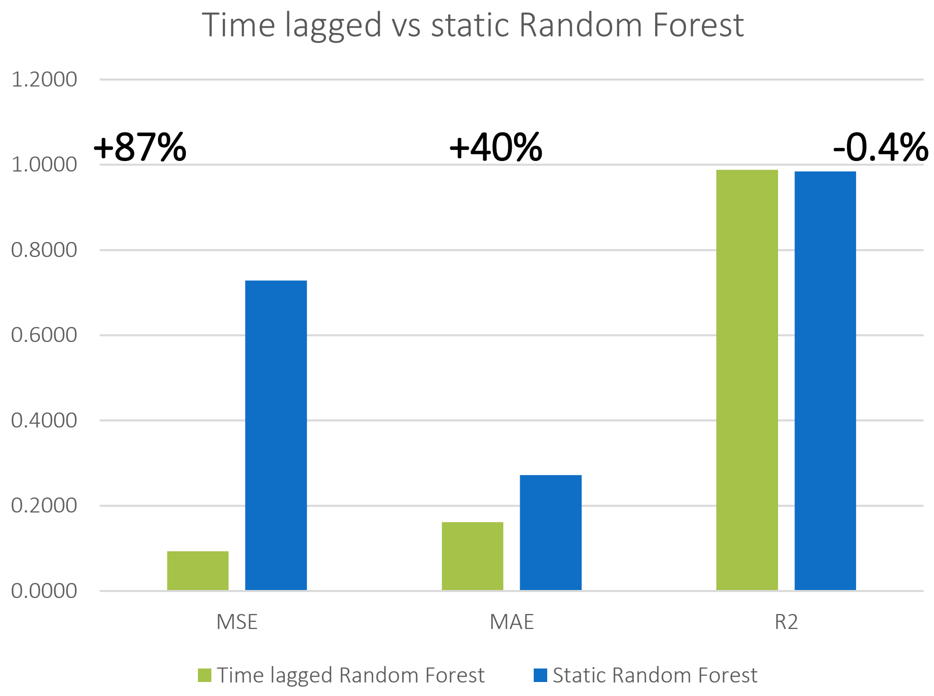


[1]For full list of TCM analysers please see publication: Hume et al. "Results from CESAR1 testing at the CO2 Technology Centre Mongstad. Verification of Residual Fluid Catalytic Cracker (RFCC) baseline results", (2022) GHGT-16.

Static and Time Series Models were Evaluated Using **RMSE**.

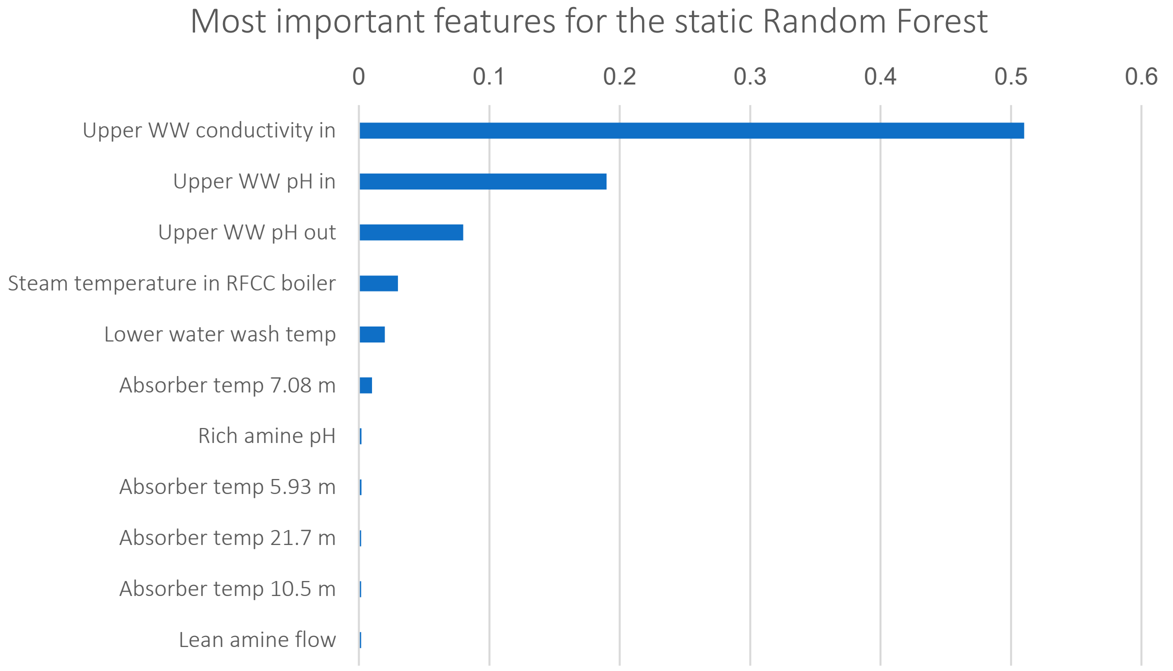
Introducing Memory and Feature Engineering Improved Model Performance.

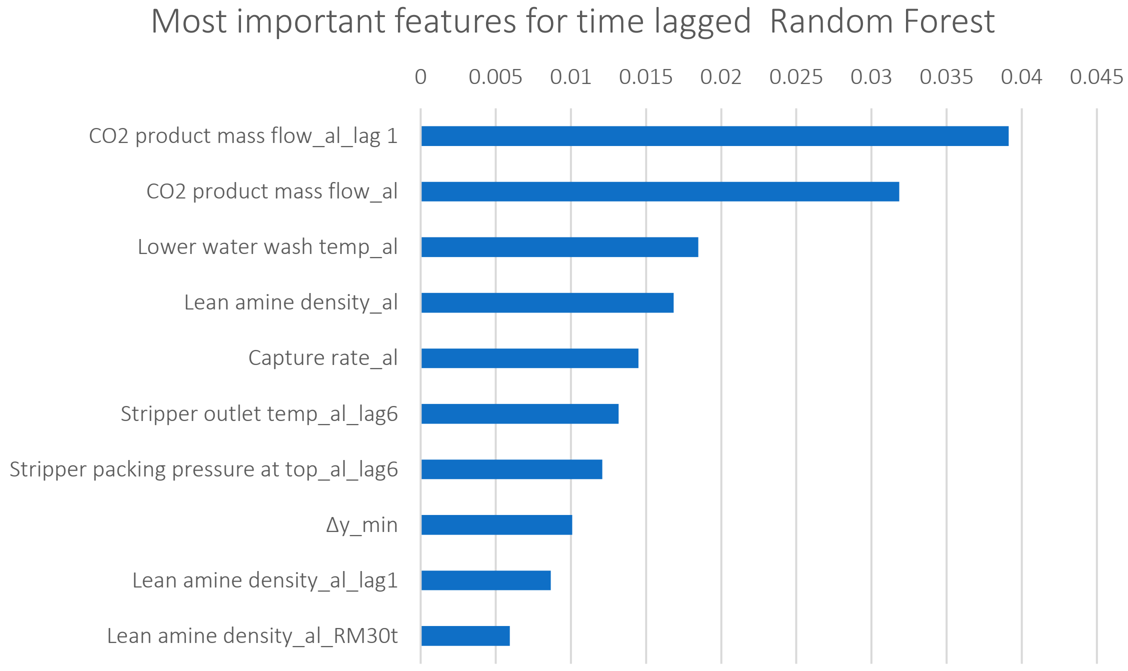




Initial static ML had no temporal dependencies modelled.
Feature engineering to predict change in y reconstructed in lagged time over a rolling mean of 30 minutes.

Feature Importance- What are the T**op 10 factors** that Drive Ammonia Emissions?



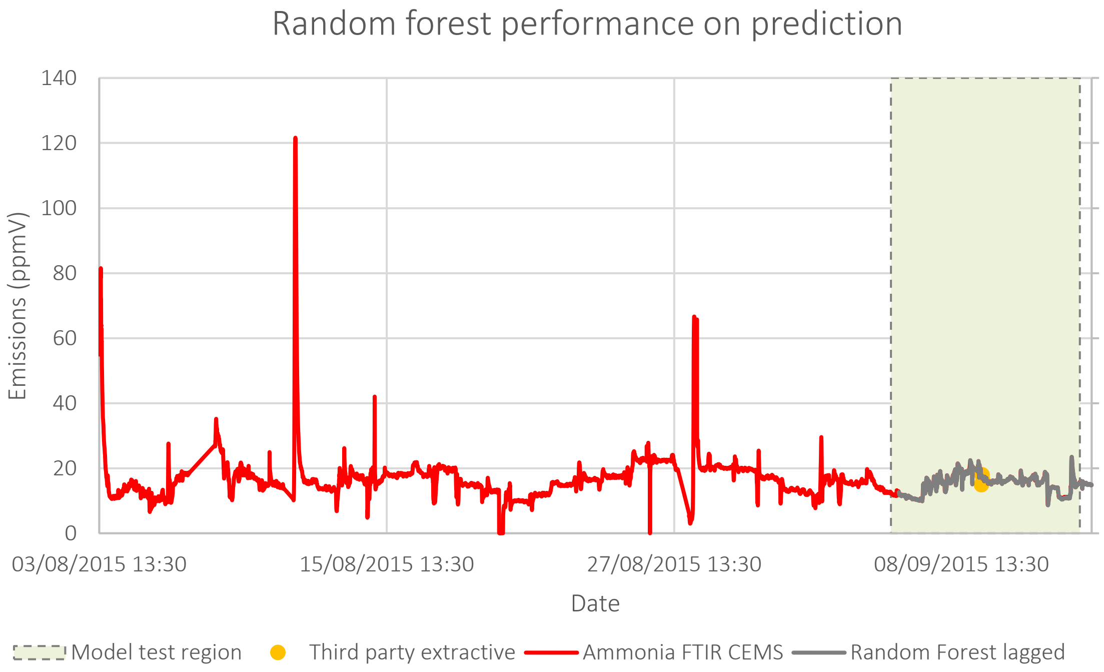


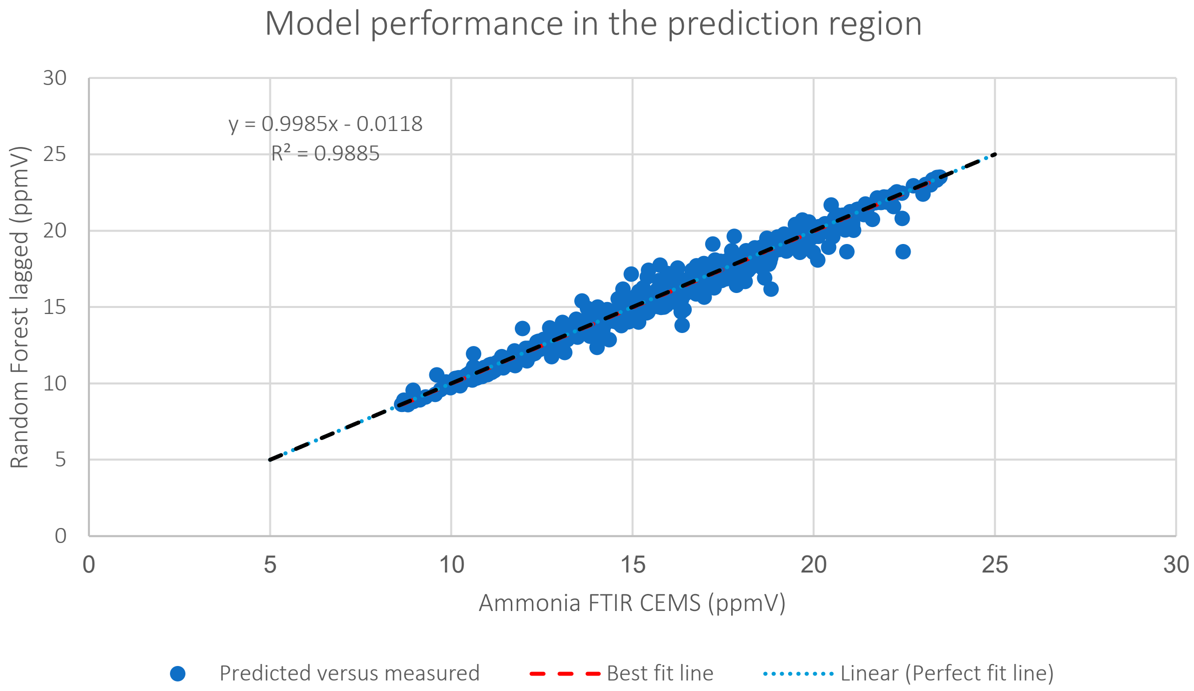
Static showed greater importance on emission control levers

Time lagged RF showed greater importance on plant control levers.

Predictive Emissions Using process parameters

There was a High Correlation Between the ML Model and the FTIR CEMS.





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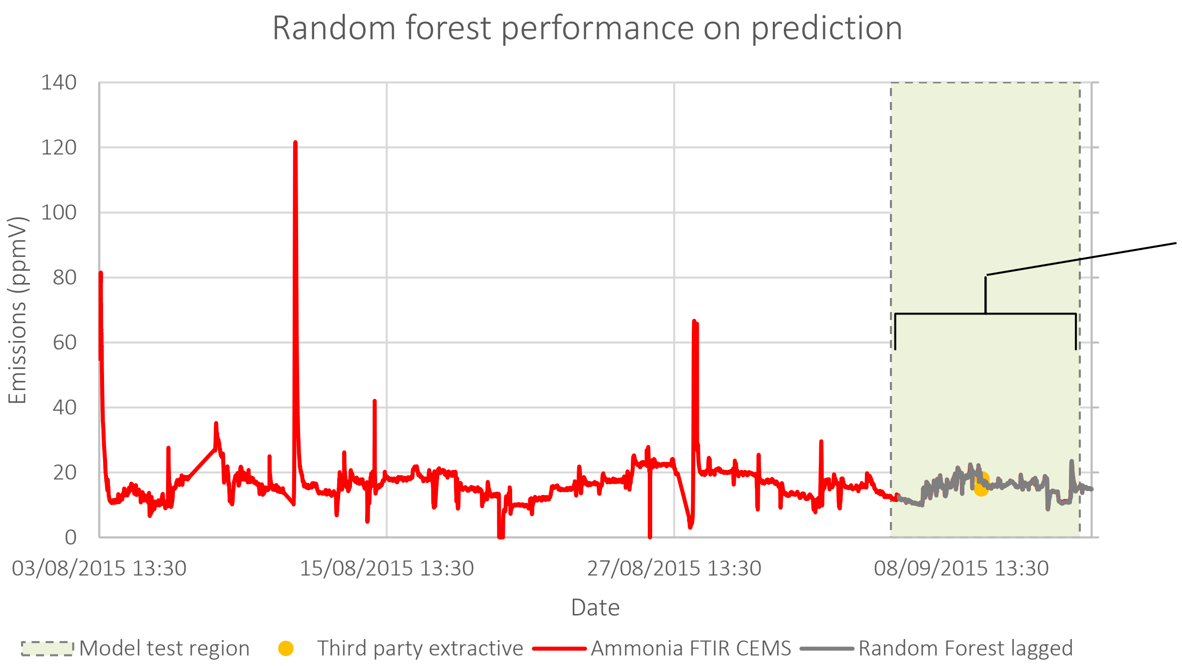
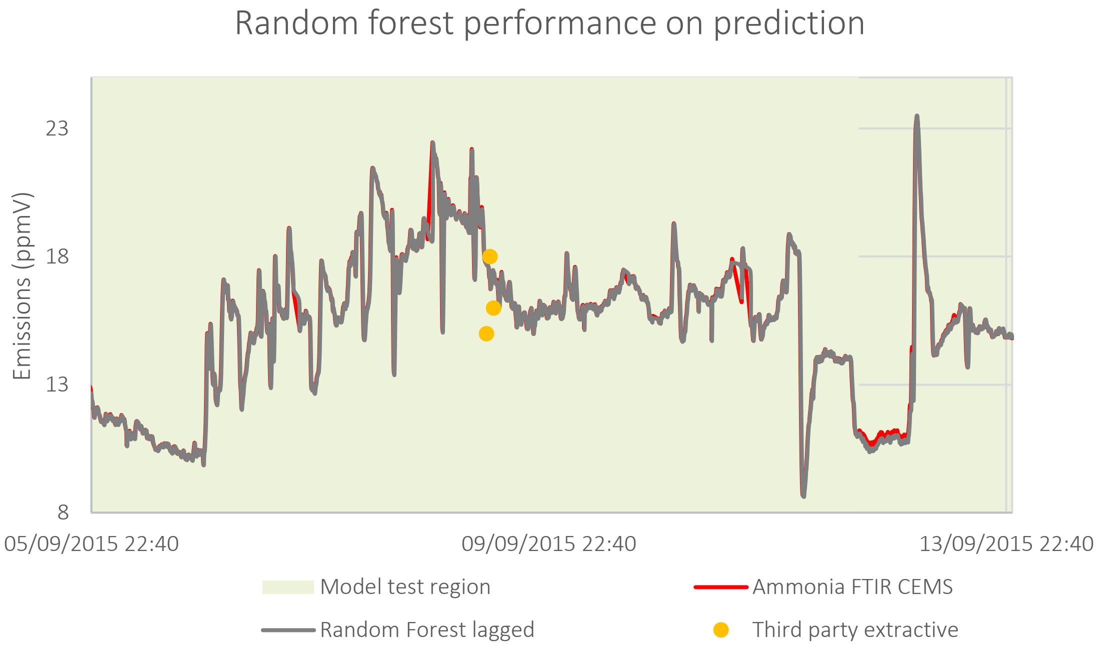
A Time Series Closeup of the Predicted Region





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PEMS- Performance Criteria of Ammonia Model

Predictive emissions monitoring	Amines? **Ammonia?** Aldehydes **EPA PS 16**; CEN 17198

Parameter	EPA PS -16	Random Forest (time lagged) vs FTIR CEMS
Relative accuracy	≤ 20%	0.31 %
Bias	If $d_{avg}<\|cc\|$ Pass, CF	Correction factor of 1.002
Variance	$F_{calc}<F_{crit}$ 0.95	N/A *1 data set at 1 test level
Correlation	≥ 0.8	0.994 vs CEMS

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TAKEAWAY!

- Predictive emissions modelling can be an acceptable way to report emissions.
- Further development in the CO_2 capture industry is needed to confirm the reliability of these models.

- Similar models can be developed for other components
- TCM's multi-analyser set-up can act as an opportunity to develop PEMS in the CC industry.

#CATCHINGOURFUTURE

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Connect with TCM

Partnering for CCS Deployment

Why TCM?

- +60,000 operational hours → proven, bankable performance
- 17 post-combustion capture technologies tested and derisked for commercial deployment → unmatched track record
- Neutral, independent test center → trusted by industry, investors & policy makers

What We Offer:

- **Advisory services**: technology screening, selection & scale-up
- **Project support**: from feasibility through FID
- **CO_2 quality expertise**: Characterization, specifications & impurity impacts on compression, Liquefaction, transport & storage
- Open for **new test campaigns,** Tailored **advisory services,** Strategic **partnerships & joint projects**

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