31.10.2025

Testes com CO_2 em fase densa

Corrosão e reações químicas

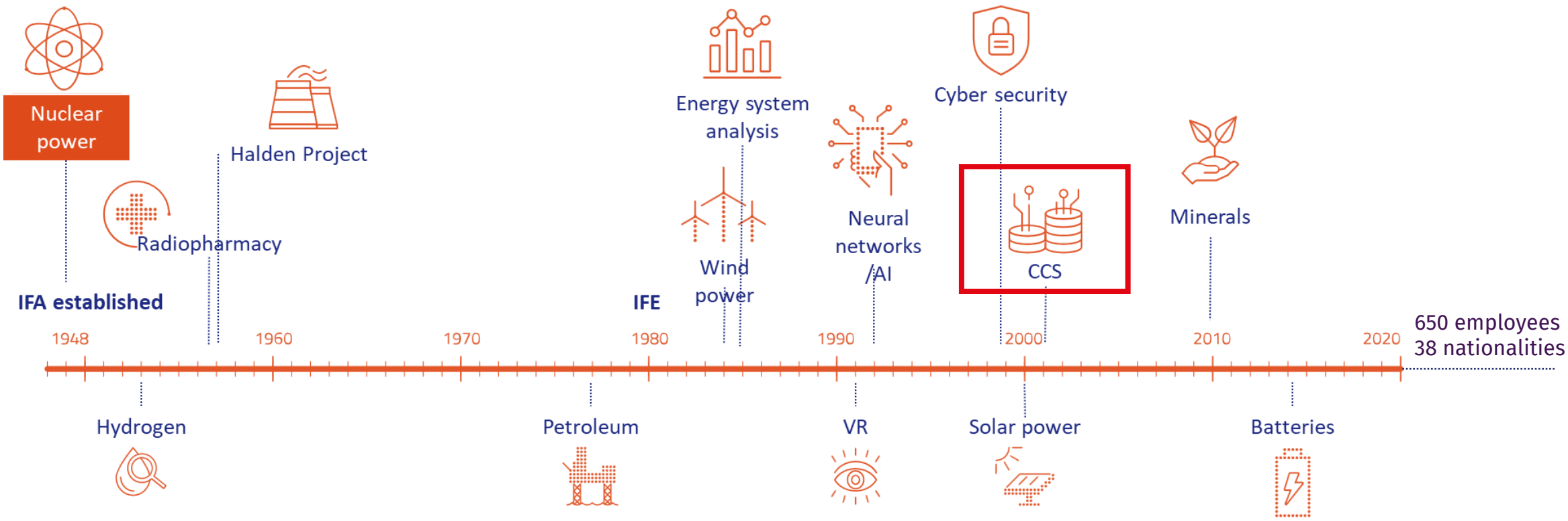
Pedro Netto da Silva
pedro.netto@ife.no

Agenda

Where are we?

Instituttveien 18, 2007 Kjeller, Norway
www.ife.no/en

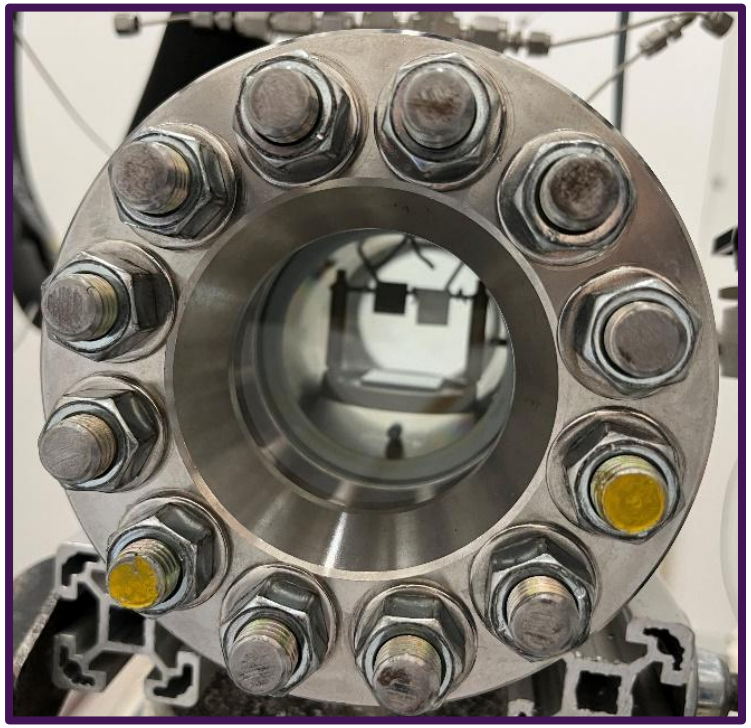
IFE in time and numbers



Kjeller Dense Phase CO_2 (KDC-IV)

Participants (23+)

Shell	EBN
TotalEnergies	ArcelorMittal
Equinor	Vallourec
BP	AirProducts
Chevron	Fluxys
ExxonMobil	Gasunie
Saudi Aramco	Enbridge
ENI	NaTran
Harbour Energy	Air Liquide
Petrobras	Woodside
ADNOC	Ørsted
Gassco	



Duration: 5 years, Sept 2023 – June 2028

CO_2WellMat-II

Participants (16)

Shell	Vallourec
ExxonMobil	Tenaris
ConocoPhillips	JFE
ENI	Halliburton
Harbour Energy	Tubacex
Repsol	Nippon Steel
Petrobras	AlTiSS
ADNOC	VDM Metals

Duration: 2 ½ years, Sept 2023 – June 2026

CCS labs – test setups

- **Pipeline transport setup**
  - 70 to 180 bar
  - -20 to 100°C
  - 7 individual injection lines
  - 12 impurities, down to 1ppmv
  - Corrosion testing

- **Ship transport setup**
  - 1 to 45 bar
  - -30 to 6°C
  - 7 individual injection lines
  - 12 impurities, down to 1ppmv
  - Corrosion testing

- **Well setup**
  - 70 to 180 bar
  - 20 to 110°C
  - 1 line of pre-mixed impurities
  - Corrosion and 4PB stress corrosion testing

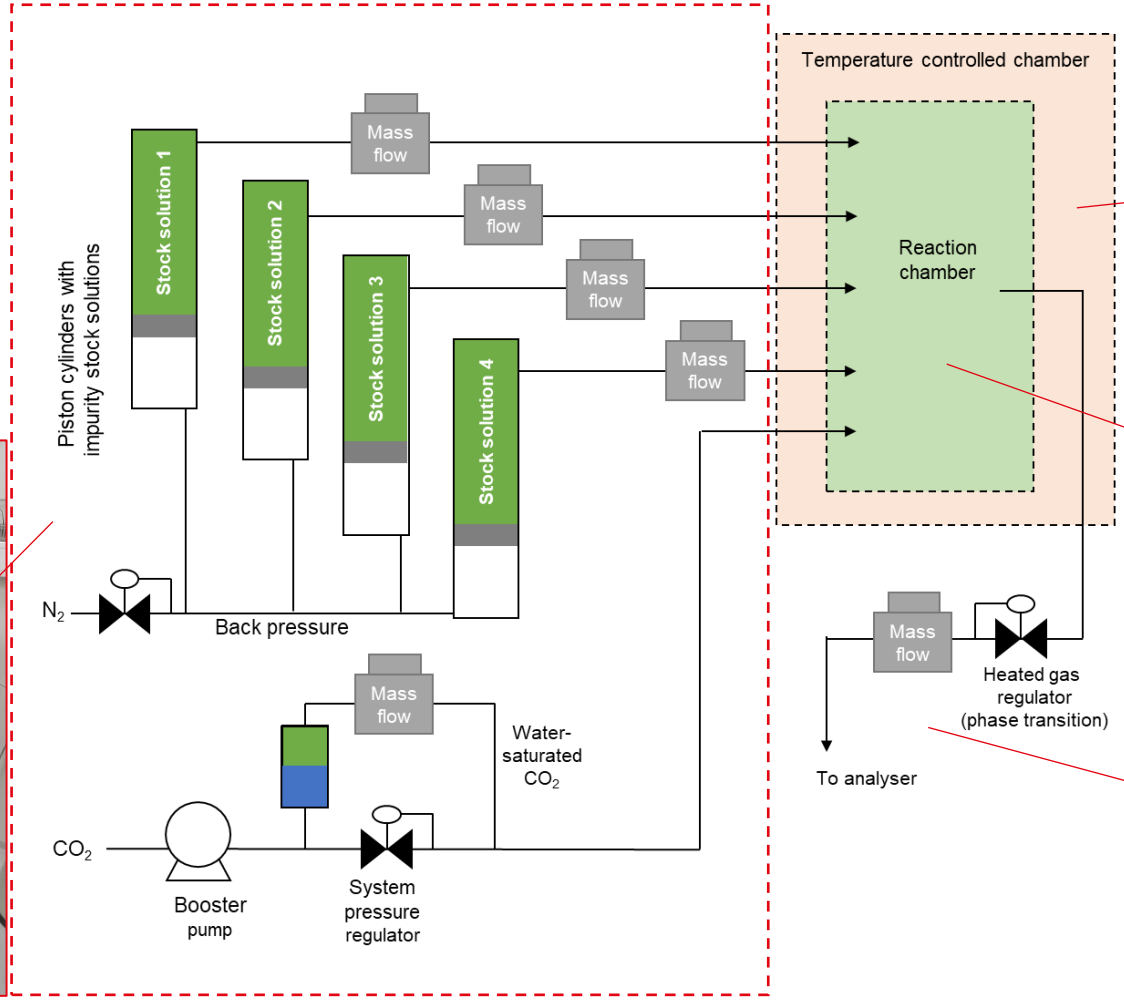
- **Combined transport and well setup**
  - Low pressure setup
    - 2 to 40bar
  - High pressure setup
    - 70 to 170 bar
  - 5 individual injection lines
  - Corrosion and 4PB stress corrosion testing

Pipeline transport setup

Continuous feed
70 to 180 bar
-20 to 100°C
7 individual injection lines

CO_2	NO_2
$CO_2 + H_2O$	NO
SO_2	O_2
H_2S	

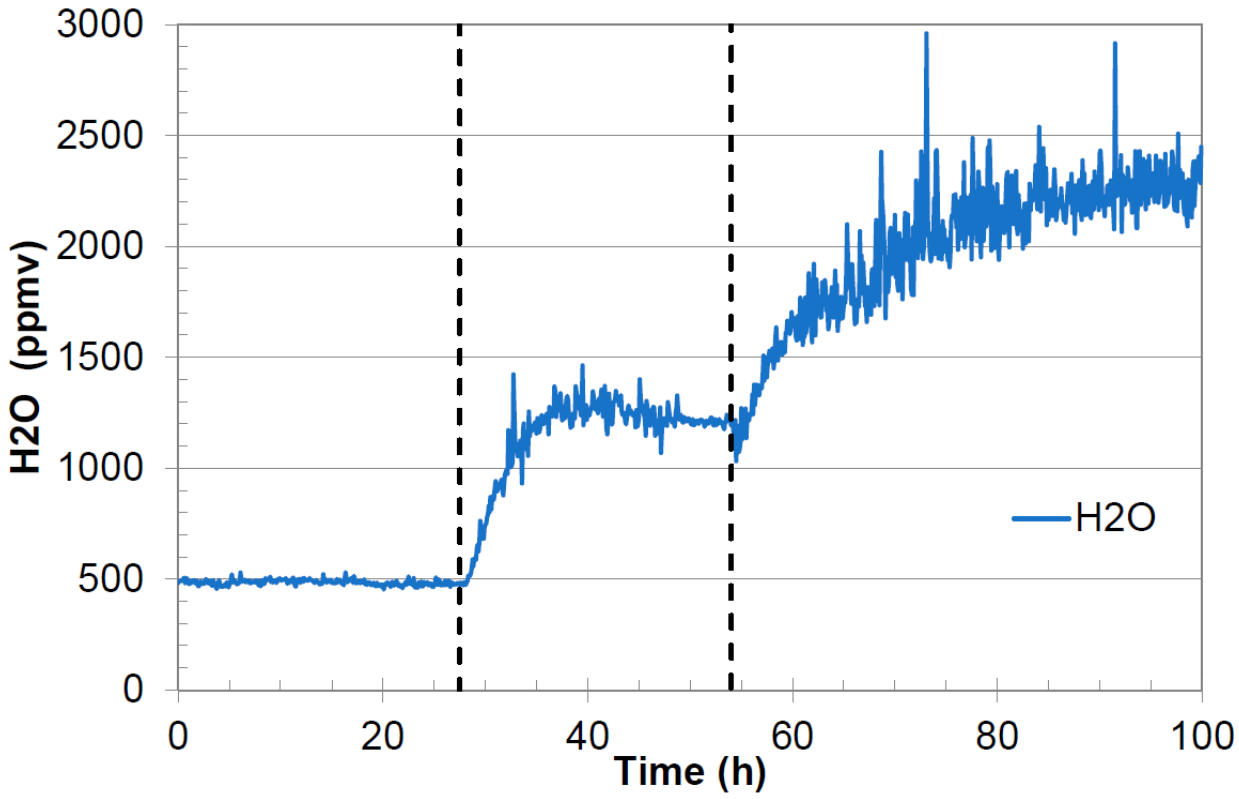
12 impurities, down to 1ppmv
Corrosion testing



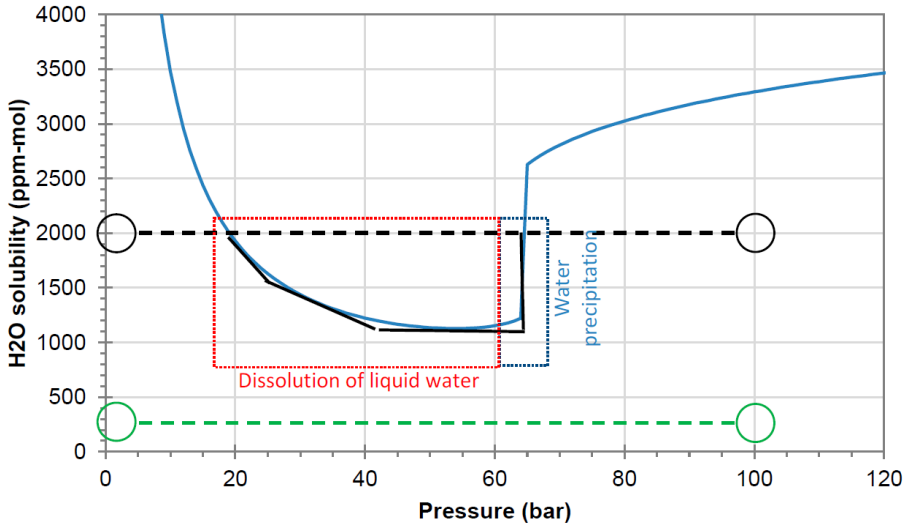
Laser absorption gas analyser

Experimental considerations

Pressure challenge



Pressure must be reduced for the analyser
Phase transformation at the gas regulator
Effect on solubility:
- Water Precipitation
- Hydrate formation
- Acid drop-out
- Precipitation of solids



Morland, B.H.; Svenningsen, G.; Dugstad, A. The Challenge of Monitoring Impurity Content of CO2 Streams. Processes **2021**, 9, 570.
https://doi.org/10.3390/pr9040570

Experimental considerations

Calibration
Some instruments (GC, UV- and IR-photometers) need regular calibration

Adsorption of species on internal surfaces
Impurities may adsorb on internal surfaces (gas regular, flowmeter, analysing lines etc.)
If the analyte composition changes, there will be a lag time in the readings by the analysers

Example:
20 metres of 1/16” stainless steel tubing
3 valves
2 filters
1 heated gas regulator
300 ml autoclave / reaction chamber

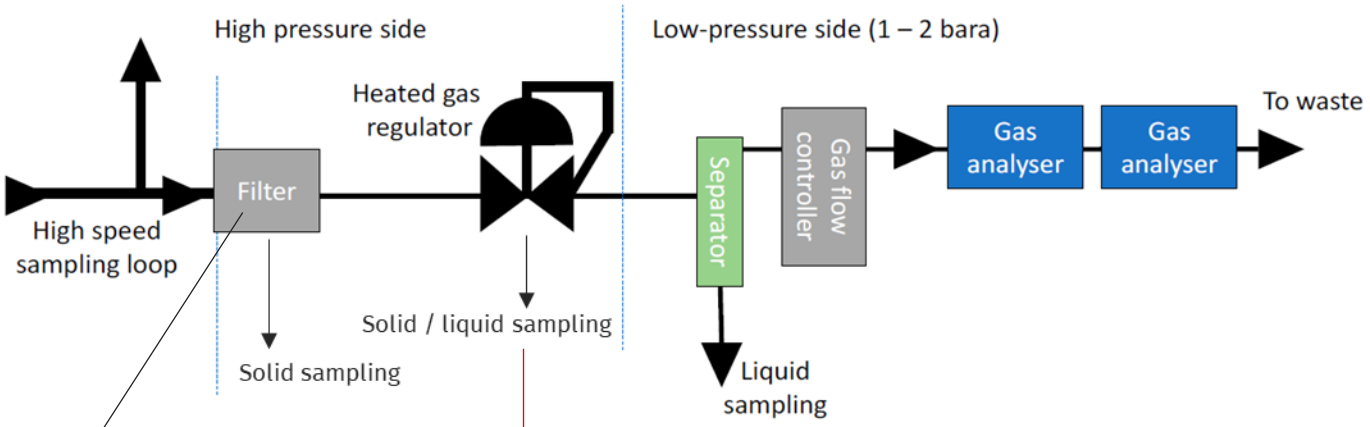
Water content: 5 → 1500 ppmv (500 ml/min)
16h to saturate the setup

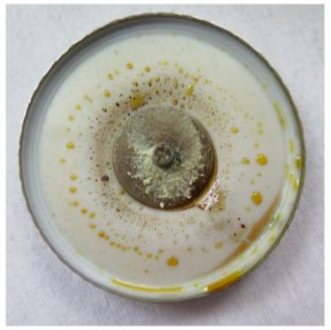
Water content: 1500 → 1000 ppmv
2h to achieve stable measurements

Dry-up: 1000 → 1 ppmv
2 weeks

Experimental considerations

Phase separation and analysis





Different phases require different types of analysing technique

Gaseous species:
- Laser absorption gas analysis
  - Longer calibration intervals
  - High analysis frequency
  - Limited number of species
- FTIR
- Gas chromatography

Solids:
- XRD
- SEM-EDS
- Chemical analysis after dissolution in suitable solvent

Liquids:
- Ion chromatography
- Liquid chromatography

Morland, B.H.; Svenningsen, G.; Dugstad, A. The Challenge of Monitoring Impurity Content of CO2 Streams. Processes **2021**, 9, 570. https://doi.org/10.3390/pr9040570

Experimental considerations

Reactions

$$H_2S + 3NO_2 \rightarrow SO_2 + \boxed{H_2O} + 3NO$$

$$2NO + O_2 \rightarrow 2NO_2$$

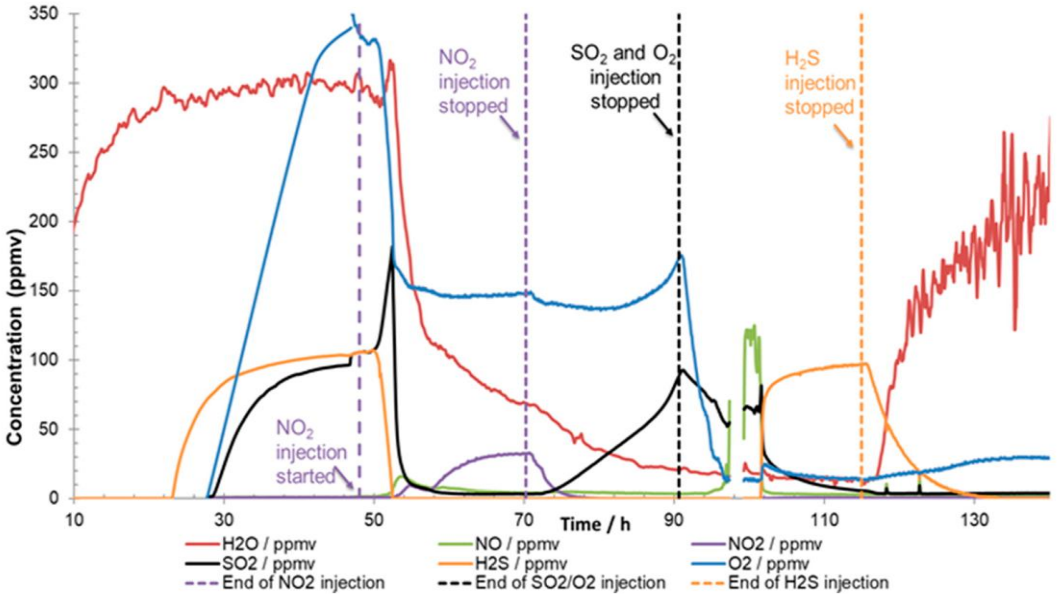
$$SO_2 + H_2O + NO_2 \rightarrow NO + \boxed{H_2SO_4}$$

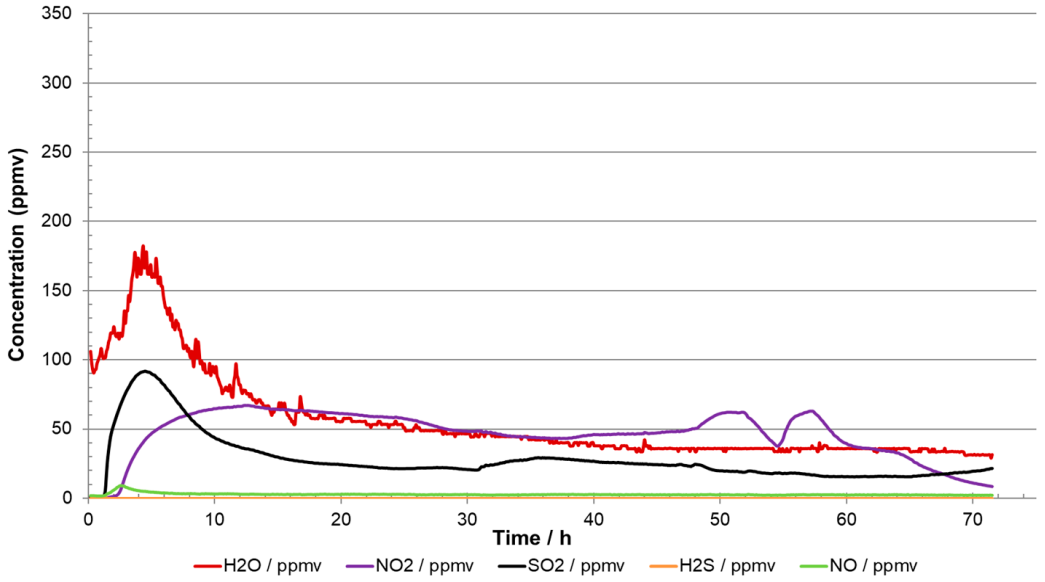
$$2NO_2 + H_2O \rightarrow \boxed{HNO_3} + HONO$$

Same impurity concentrations

Injection of impurities starting at <u>different times</u>

Injection of impurities starting at the <u>same time</u>

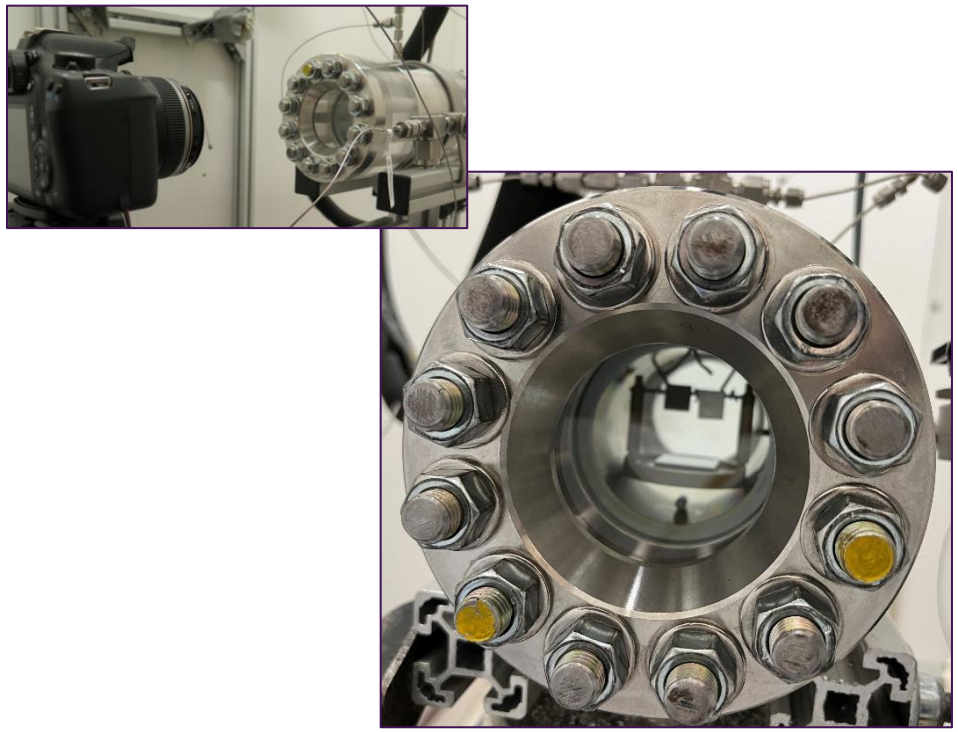


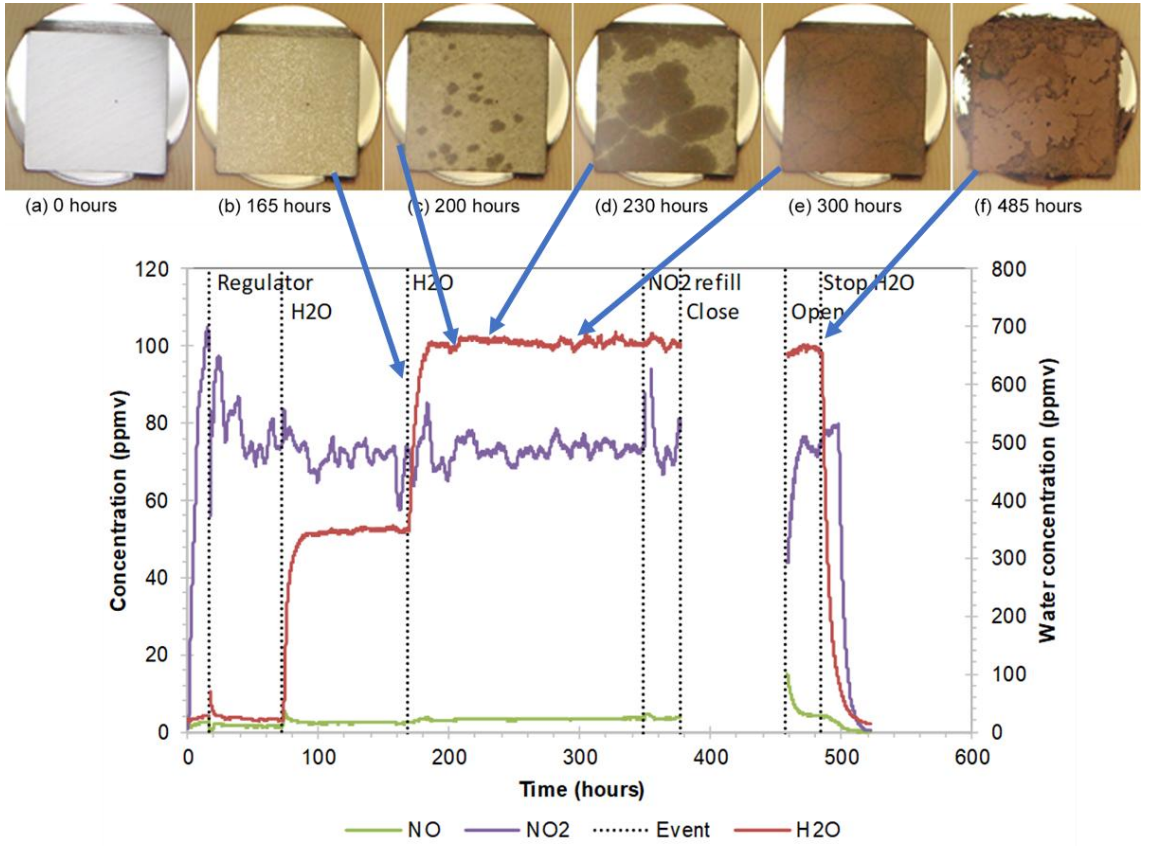


Morland, B.H.; Svenningsen, G.; Dugstad, A. The Challenge of Monitoring Impurity Content of CO2 Streams. Processes **2021**, 9, 570. https://doi.org/10.3390/pr9040570

Experimental considerations

Corrosion tests monitoring





Morland, Norby, Tjelta, Svenningsen, Effect of SO2, O2, NO2, and H2O concentrations on chemical reactions and corrosion of carbon steel in dense phase CO2, CORROSION, 75, 11 (2019) pp. 1327-1338

Recommended publications

Morland, Dugstad, Svenningsen, Experimental based CO2 transport specification ensuring material integrity, *International Journal of Greenhouse Gas Control*, (2022) p. 103697.

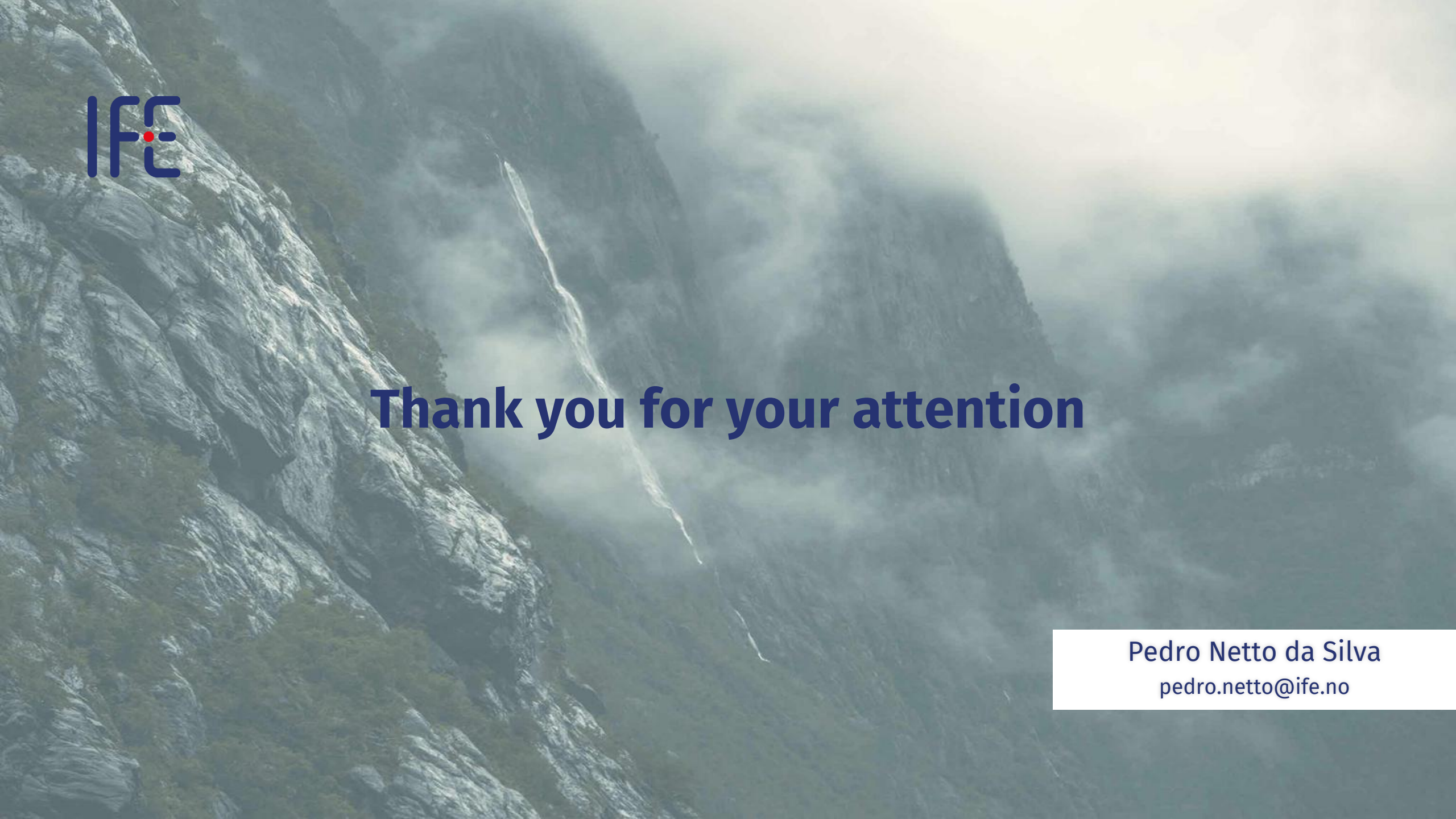
Morland, Svenningsen, "Corrosion of carbon steel in simulated CCS streams", 15th International Conference on Greenhouse Gas Control Technologies (2021).

Svenningsen, Morland, "Corrosion and chemical reactions in simulated ship transport CO2 containers", CORROSION/2021, paper no. 16669 (Houston, TX: NACE International, 2021).

Morland, Svenningsen, "Pitfalls and artefacts in corrosion experiments with dense phase CO2", CORROSION/2021 conference, paper no. 16667 (NACE International, 2021).

Morland, Svenningsen, Dugstad, The Challenge of Monitoring Impurity Content of CO2 Streams, Processes, 9, 4 (2021) p. 570.

Svenningsen, Morland, Dugstad, Thomas, Stress corrosion cracking testing of 13Cr stainless steel in dense phase CO2 with oxygen, Energy Procedia, 44, 7 (2017) pp. 6778-6799.



Thank you for your attention

Pedro Netto da Silva
pedro.netto@ife.no