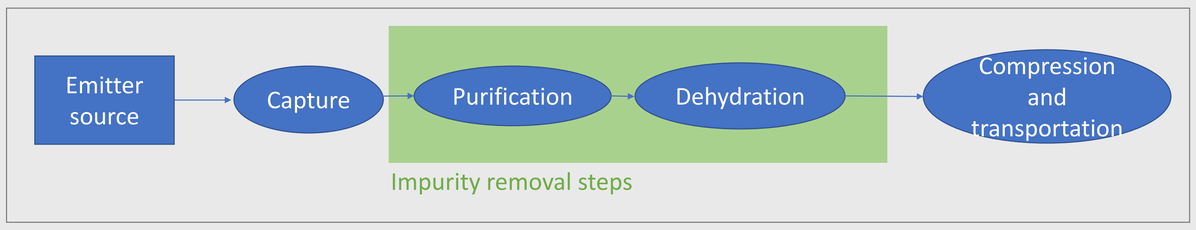
Minimising corrosion impacts in future CCS systems: Developing techno-economic and lifecycle based systems analysis approaches (DCR10)

Benedetta Martellotti, Timothy Cockerill, Bernard Normand
Benoit Ter-Ovanessian, Sabrina Marcelin, François Ropital

Objective

What level of **impurity removal** is needed to achieve the best environmental 🍃 and economic € trade-off?



Part of CCS (Carbon Capture and Storage) process

Need to assess impact of key engineering uncertainties on **TEA (Techno-Economic Analysis)** and **LCA (Life Cycle Assessment)**

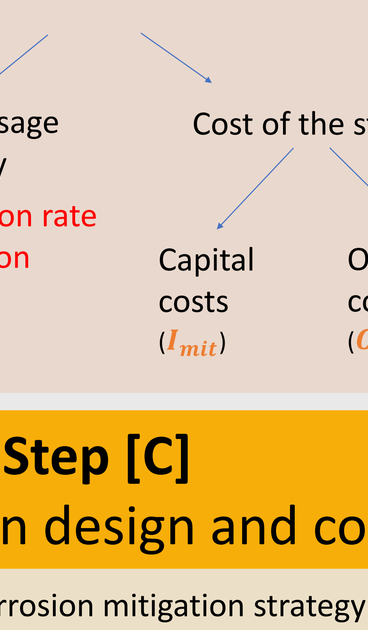
Highlight

Starting point:

Assess impact of **corrosion** on **cost** of **transport**

Model to obtain **Cost base case**

Extension of the model to assess **Cost due to impurities**



1st year of PhD

Methodology

Step [A] Corrosion prediction from Machine learning (ML)

Variable Test **Dataset*** (P, T, impurities type and quantity)

Variable Training **Dataset*** (P, T, impurities type and quantity)

Corrosion Rate Training **Dataset*** (mm/year)

Supervised ML model

CR_{ML} (Predicted Corrosion rate from machine learning model) (mm/year)

Setting the reference corrosion allowance

$CA_{ML} = CR_{ML} \cdot lifetime$

$CA_{safety} = 3\ mm$ From AMPP guideline [3]

The CA_{ref} will be selected as $max(CA_{ML}; CA_{safety})$

***Dataset**
- From literature (at present) [4]
- From **DCR4** (in the upcoming stages)

Fixed parameters
- S-CO_2 rich phase
- API 5L X-series pipelines

INPUTS:
- Pressure
- Temperature
- Impurities type and quantity

Step [A] Corrosion prediction

Corrosion severity

-Max. Fluid Flow Rate
-Fluid Inlet Temperature
-Pipeline Length
-CO_2 Inlet Pressure
-CO_2 Outlet pressure
-Material Roughness

PIPELINE PERFORMANCE MODEL — **From McCoy and Rubin [1] (2008)**

Pipe Diameter

-Material
-Corrosion allowance (CA)

PIPELINE COST MODEL — **From Knoope *et al.* [2] (2014)**
- Capital Costs (I_{pipe})
- Operation and Maintenance Costs (OM_{pipe})

-Discount rate
-Number of years in the lifetime
-Deflation rate
-Length of pipeline

Step [B] Mitigation strategy selection

List of **possible strategies** to control the corrosion severity

Step [C] Definition of impact on design and costs

LC_T

Step [B] Corrosion mitigation strategy selection

Mitigation strategies
- Coatings
- CRAs
- Corrosion inhibitors (**DCR6**)

For each of them we consider

CR after the usage of the strategy

CR_{mit} (Corrosion rate after prevention strategy) (mm/year)

Cost of the strategy

Capital costs (I_{mit})

Operative costs (OM_{mit})

Step [C] Impact on design and costs

Identify the corrosion mitigation strategy that minimizes the **levelized cost of CO_2 transport (LC_T)**, based on key input variables such as pressure, temperature, and the type and quantity of impurities

$$LC_T = \frac{CRF \cdot (I_{pipe} + I_{mit}) + OM_{pipe} + OM_{mit}}{m \cdot H \cdot 3.6}$$ Adapted from [2]

$$I_{pipe} \propto C_{material} \propto t \propto CA \propto CR$$

Where:
- $C_{material}$ = material costs for the pipeline (€)
- $t = thickness$ (m)
- $CRF = Capital\ recovery\ factor$
- $m = mass\ flow\ \left(\frac{ton}{h}\right)$
- $H = annual\ operation\ time\ \left(\frac{h}{year}\right)$

Cost comparison framework

The cost of corrosion is computed as:
- **Reference cost**: using only the predicted CA without mitigation (CA_{ref})
- **Mitigated cost**: based on the selected strategy, updated CA (CA_{mit}), and direct cost of the mitigation (I_{mit}, OM_{mit})

Next steps

Short Term
- Finalizing the **ML model** for corrosion prediction
- Expanding the **database** of mitigation strategies and their costs/efficiencies
- Applying the framework to selected **case studies**
- Performing **sensitivity analysis** and **uncertainty quantification**

Long Term
- Extend the analysis to include **Life Cycle Assessment (LCA)** of each mitigation strategy
- Compare the **cost of removing impurities** to specified input levels with the cost of pipeline protection

Secondments/Collaborations

UNIVERSITY OF LEEDS

wood.

Acknowledgements

The authors would like to acknowledge funding provided via the European Commission's Horizon Europe research and innovation programme under the Marie Skłodowska-Curie Grant Agreement ID: 101118369, Material Science Innovation for Accelerated, Sustainable and Safe Implementation of Carbon Capture and Storage (MISSION-CCS).

MSCA

References

[1] McCoy, Sean T. "The economics of CO_2 transport by pipeline and storage in saline aquifers and oil reservoirs." (2008)
[2] Knoope, M. M. J., *et al*. "Improved cost models for optimizing CO_2 pipeline configuration for point-to-point pipelines and simple networks." International Journal of Greenhouse Gas Control 22 (2014): 25-46.
[3] SC 20-Internal Corrosion Management. "Guideline for Materials Selection and Corrosion Control for CO_2 Transport and Injection." (2023).
[4] Sun, Haofei, *et al*. "Corrosion challenges in supercritical CO_2 transportation, storage, and utilization—a review." Renewable and Sustainable Energy Reviews 179 (2023): 113292.