Reducing the impact of chemicals and solvents for efficient future CCS systems

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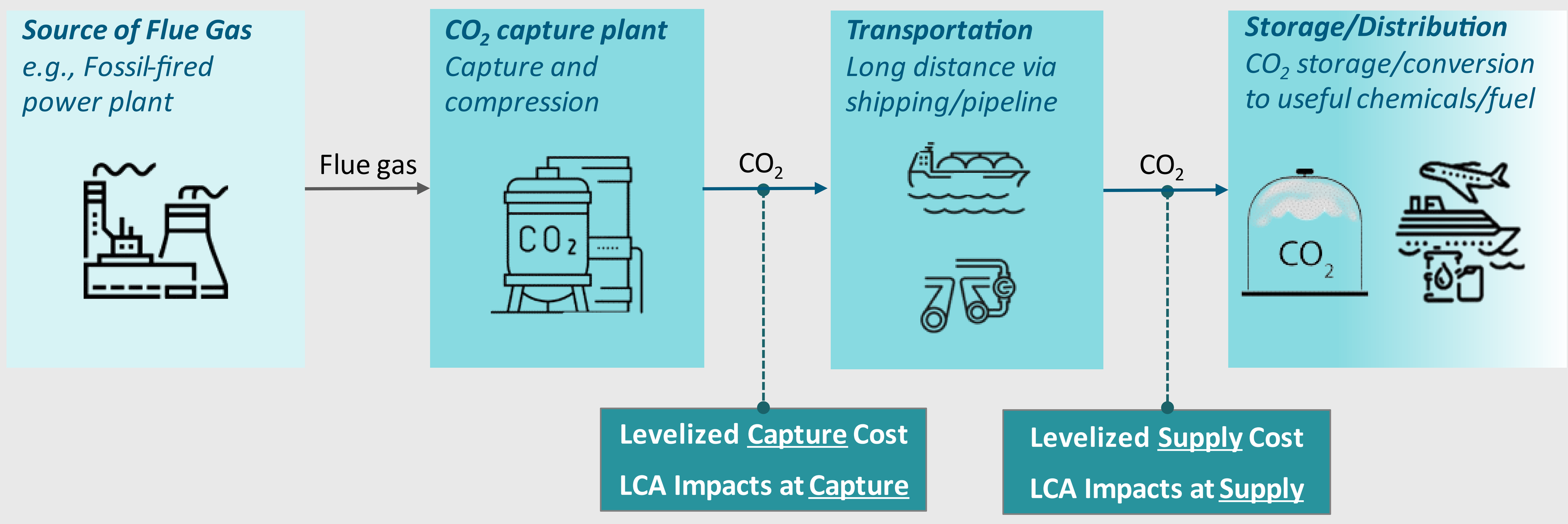
1. Project Introduction and Scope

- Carbon Capture and Storage (CCS) is vital for reducing CO_2 emissions in hard to abate industries, e.g., power sector
- Solvents and chemicals used in the CCS systems possess significant environmental burdens, i.e., needs holistic optimization
- A novel framework combining Life Cycle Assessment (LCA) and Techno-Economic Analysis (TEA) with multi-objective optimization enables the reduction of CCS environmental impacts without significantly affecting cost or performance



2. Aims and Objectives

Project Aim: Minimizing the environmental impacts of chemicals in amine-based post-combustion CCS (PC-CCS) systems while ensuring cost-effectiveness, efficiency, and sustainability across the process chain.

Project Objectives:

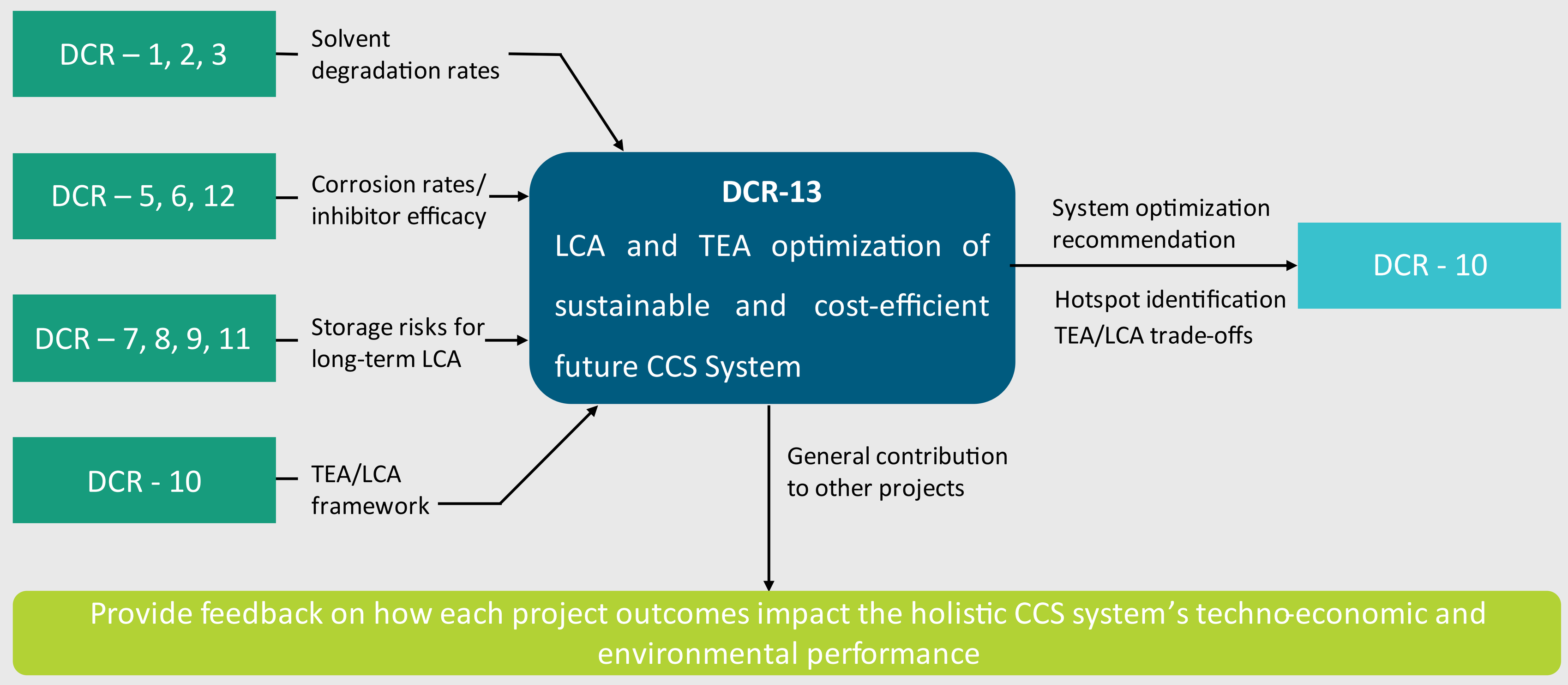
Literature Review
- Familiarize with state-of-the-art in MEA-based PC-CCS system modeling
- Identify the research gaps in TEA and LCA of PC-CCS

TEA Optimization Model
- Develop a TEA optimization model of MEA-based PC-CCS in Python
- Use modeling parameters from literature, technical reports and project partners

LCA Model
- Develop an LCA model of PC-CCS plant in Simapro
- Identify the main chemicals contributing to life cycle impacts

Testing Alternative Options
- Using alternative chemicals and observe the sensitivity of TEA and LCA KPIs
- Implement machine learning for prediction of inventory data/results

3. Placement of the Project in the MISSION-CCS Network

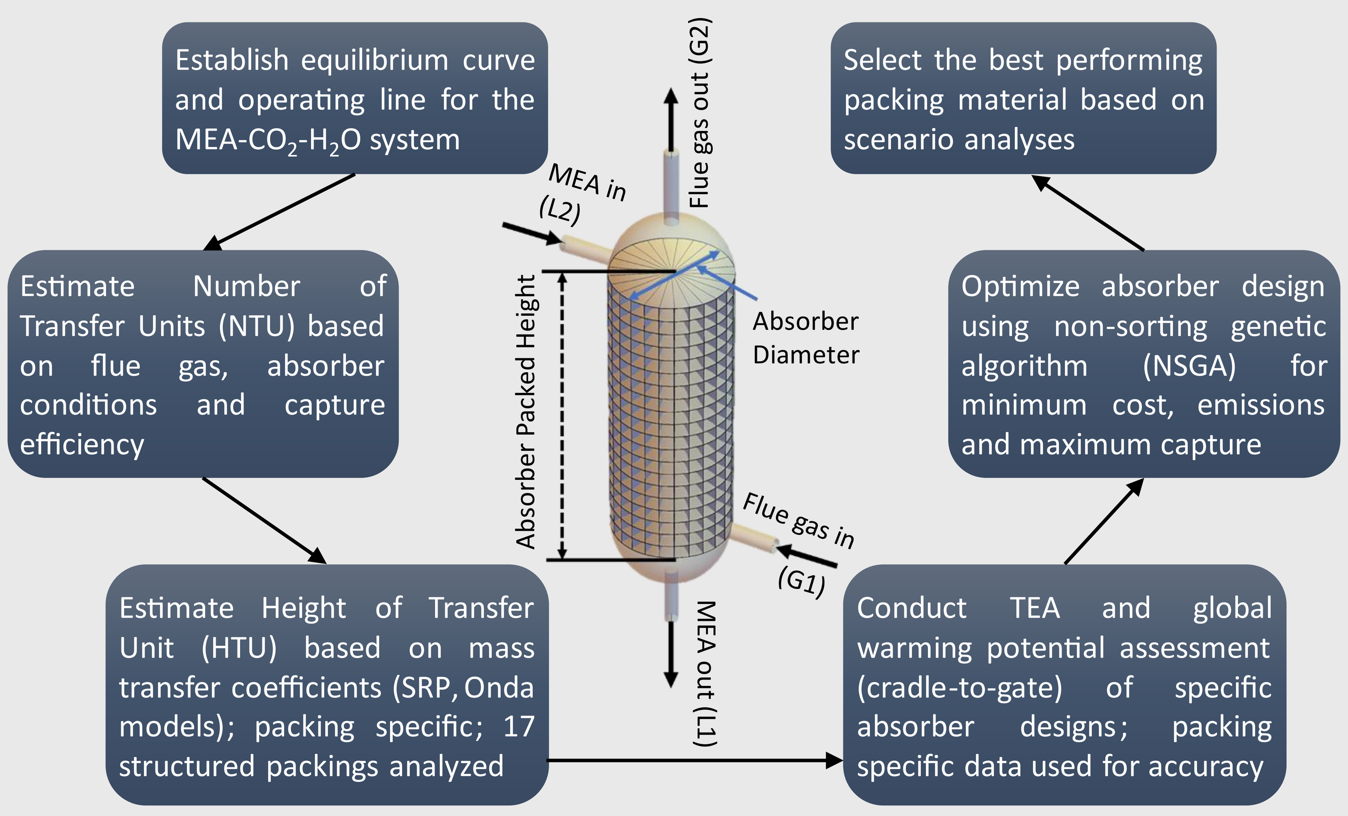


4. Progress to Date: A TEA and CO_2 Emissions-Driven Optimization Model of Monoethanolamine (MEA)-Based CCS Absorber

4.1. Novelty

- Integrates design with sustainability by combining absorber sizing, cost, and global warming potential (GWP) analysis into a single early-stage decision tool
- Enhances realism using packing-specific mass transfer and material-related CO_2 emissions
- Enables trade-off analysis through multi-objective optimization across cost, emissions, energy, and capture performance

4.2. Methodology



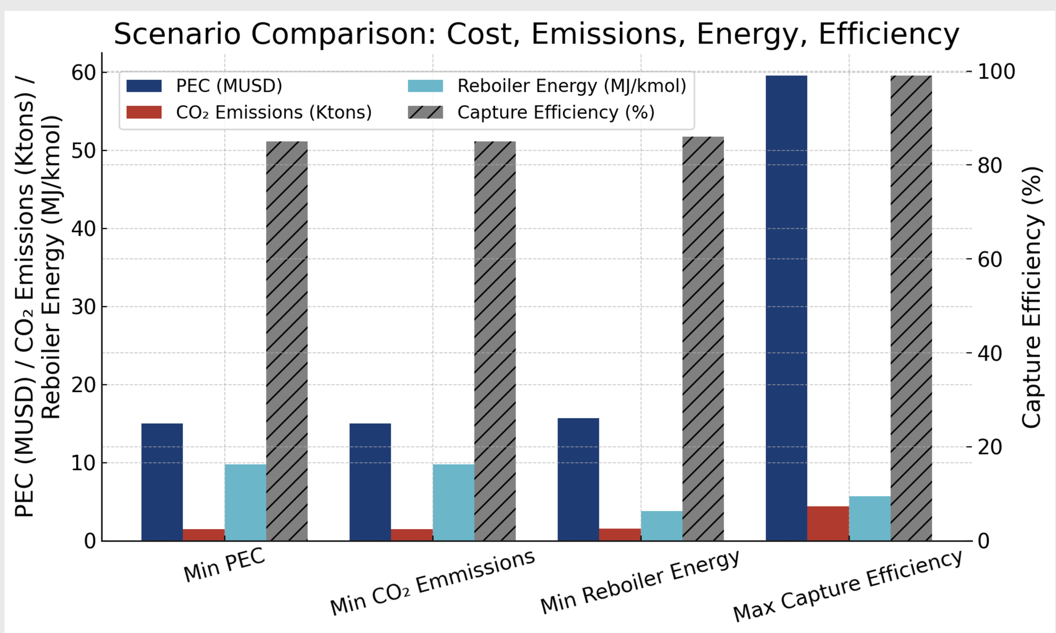
4.3. NSGA - II Optimizer Set-up

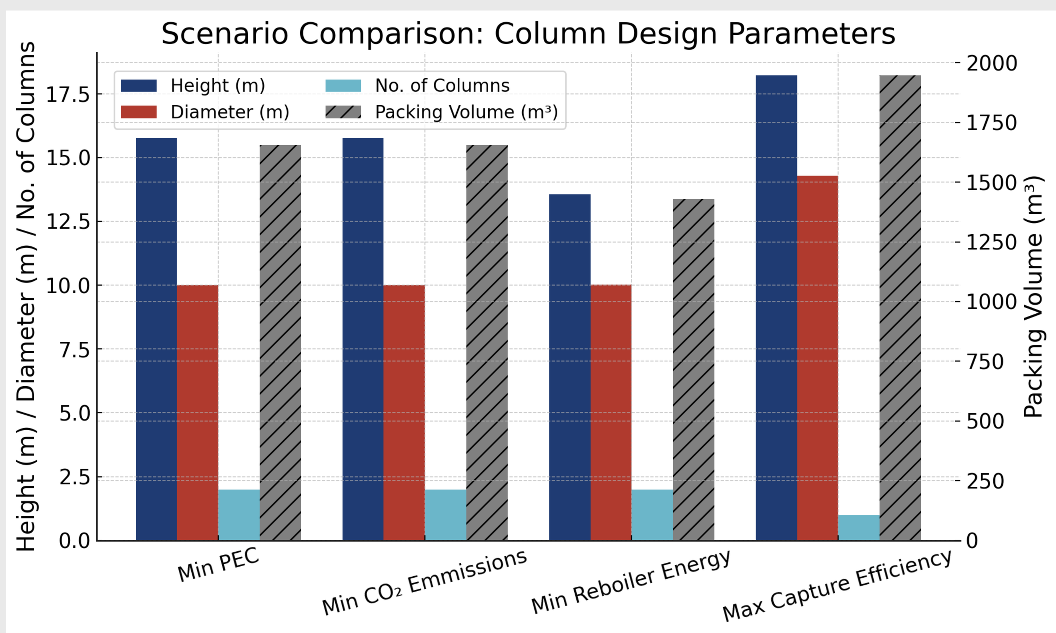
- Set-up using the Pymoo library in Python

Optimizer Section	Parameter	Range/ Comments	Unit
Input Variable	Lean CO_2 loading	0.15 – 0.25	mol/mol
	MEA concentration	20 - 40	%
	Capture efficiency	85 - 99	%
	Absorber temp.	40 - 60	°C
Optimization Objectives	Absorber cost (PEC)	USD (2023)	MUSD
	CO_2 emissions	-	ktons_{CO2}
	Reboiler energy	-	MJ/kmol
	Capture efficiency	-	%
Constraint	Rich CO_2 loading	<=0.45	mol/mol

5. Sample Results with Mellapak 250.Y Packing

- Results for 1,000 tons/h flue gas flow with 4.22% CO_2 (mol) from a natural gas power plant
- Higher capture efficiency (>95%) increases absorber size, costs and emissions significantly
- Min reboiler energy scenario has significant potential of cost savings via reduced utilities demand





6. Conclusion and Outlook

- Absorber model captures trade-offs in cost, energy, efficiency, and emissions using packing-specific parameters
- Holistic CCS model under development including capture, compression and drying, transportation and storage
- Hourly and part-load simulations planned to reflect real-world operation dynamics
- Solvent degradation and emissions from additional chemicals to be included in extended LCA modelling
- Future work targets dynamic prospective TEA and LCA for system-level trade-off analysis under several scenarios

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MSCA

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In loving memory of Millie