A Holistic Approach to Safe and Sustainable Carbon Capture Utilization and Storage Supply Chains

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Introduction

- Climate change is driven by increasing greenhouse gases (GHGs) concentrations.
- In 2020, carbon dioxide was the primary GHG, responsible for 79% of US emissions.
- Carbon capture utilization and storage (CCUS) decreases GHG emissions and maintains global temperatures.
- Considering safety helps search for optimal safe designs, provides insights to decision-makers, and improves social acceptance.

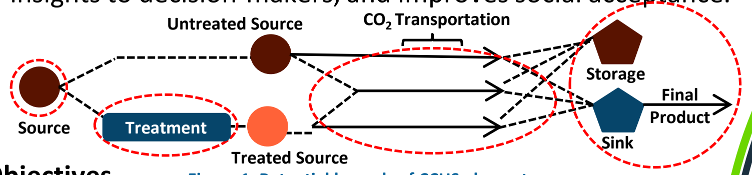

Figure 1: Potential hazards of CCUS elements

Objectives

- To develop safety indices for some CCUS elements.
- To provide a systematic approach for optimal CCUS design considering safety, economics, and environment.

Research Highlights and Impact

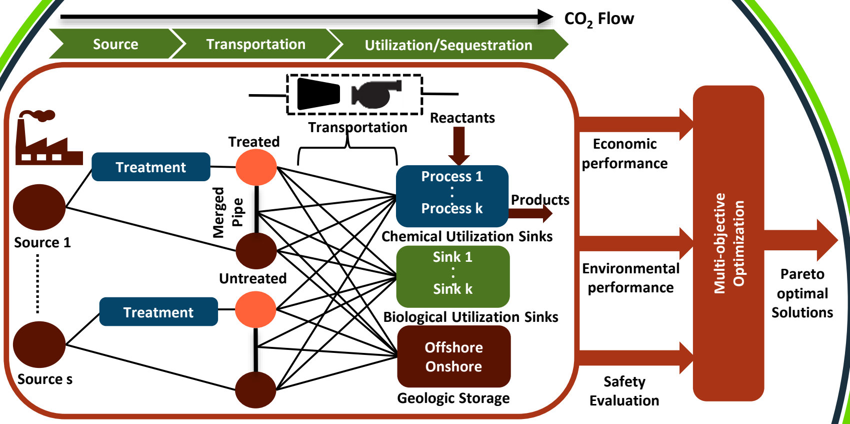

Figure 2: Multi-objective optimization of CCUS network

- The tool enables simultaneous optimization of economic, environmental, and safety performances for CCUS design.
- The developed safety indices for biological sinks and geologic storage can be used for safety evaluation.

Methodology

- This research provides a multi-objective mixed-integer non-linear optimization model to find the optimal CCUS design.

Objective function = Minimize C + Minimize $E_{k,tot}$ + Minimize Ψ.

Where, C = total annual cost, $E_{k,tot}$ = Emissions, Ψ = safety index.

- **Economic Performance**

$$C = C_{s,k}^{Treatment} + C_{s,k}^{Compression} + C_{s,k}^{Transportation} + C_{k}^{Sinks}$$

- **Environmental Performance**

$E_{k,tot} = \sum_{k\in K} \theta_k \quad F_{s,k}$, where θ_k is the sink emission parameter

$F_{s,k}$ is the sink carbon dioxide flowrate.

- **Safety Evaluation**

$\Psi = \sum_{k\in K}(\Psi_{comp,s,k} + \Psi_{c,s,k} + \Psi_{B,k} + \Psi_{stor,k})$, where $\Psi_{comp,s,k}$ is the compression safety index, $\Psi_{c,s,k}$ is the chemical sinks safety index, $\Psi_{B,k}$ is the biological sinks safety index

$\Psi_{stor,k}$ is the geological storage safety index.

Results

- Case study consists of 4 sources (Ammonia, Steel, Power Plant, Refinery) and 6 sinks (Algae, Greenhouse, Methanol, Urea, Acetic Acid, Storage).
- Data collection included compression, pressure drop, emissions, and safety indices parameters.
- The result is represented by a Pareto optimal surface.

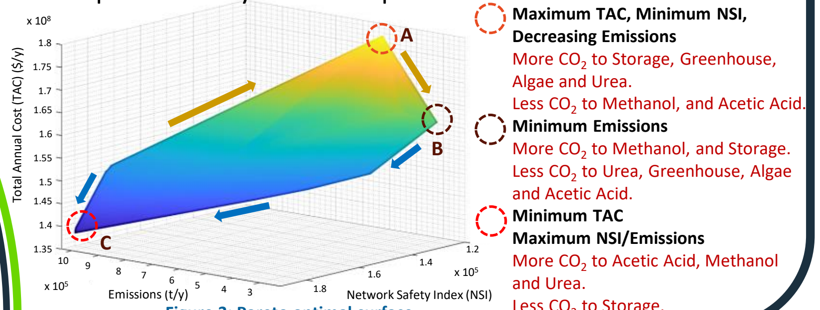

Figure 3: Pareto optimal surface

Discussion

- Geologic storage is the main contributor to TAC in all designs.
- Trade-off was observed between TAC and environmental emissions due to the increasing cost of CO_2 storage.
- Trade-off was observed between TAC and Safety Index as utilizing CO_2 into profitable sinks increases hazards.

Conclusions

- A multi-objective optimization model was developed for designing CCUS considering economic, environmental, and safety performances.
- Trade-offs were captured between the objectives using Pareto surfaces.
- The tool supports decision-making and assessing policies.
- **Future work:** To include renewable energy, resilience, and social aspects.

References

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