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.

Objectives

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

Methodology

- This research provides a multi-objective mixed-integer non-linear optimization model to find the optimal CCUS design.
- Objective function = Minimize $C = \text{Minimize } E_{\text{tot}} + \text{Minimize } \Psi$.
- Where, $C = \text{total annual cost, } E_{\text{tot}} = \text{Emissions, } \Psi = \text{safety index}$.
- **Economic Performance**
  
\[
C = C_{\text{Treatment}} + C_{\text{Compression}} + C_{\text{Transportation}} + C_{\text{Sinks}}
\]

- **Environmental Performance**
  
\[
F_{k,\text{tot}} = \sum_{k} F_{s,k} \Psi_{\text{comp,s,k}}, \text{ where } \theta_{k} = \text{sink emission parameter}
\]

- **Safety Evaluation**
  
\[
\Psi = \sum_{k} f_{k} \left( \Psi_{\text{comp,s,k}} + \Psi_{\text{c,s,k}} + \Psi_{B,k} + \Psi_{\text{stor,k}} \right), \text{ where } \Psi_{\text{comp,s,k}} \text{ is the compression safety index,}
\]

\[
\Psi_{c,s,k} \text{ is the chemical sinks safety index, } \Psi_{B,k} \text{ is the biological sinks safety index and } \Psi_{\text{stor,k}} \text{ is the geological storage safety index.}
\]

Discussion

- 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.

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.

Conclusions

- 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 CO₂ storage.
- Trade-off was observed between TAC and Safety Index as utilizing CO₂ into profitable sinks increases hazards.

References

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