Use of Life Cycle Assessment in Analysis of Emissions Reductions and Sequestration Strategies for Power Generation

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Topics

- Life Cycle Assessment for Carbon Management
- Considerations for Carbon Sequestration
- LCA Methodologies for Multiple Product Systems
- Co-Product Function Expansion Application to IGCC with Sequestration
- Case Studies

LCA for Carbon Management

- Full lifecycle accounting is required to address CM
  - Lifecycle stages
  - Adequate timeframe
- Broad LCA literature for GHGs in Power and Transportation
  - NREL (Biomass, Natural Gas, Hydrogen)
  - NETL (IGCC, Coal)
  - Argonne National Laboratory (Transportation)
  - Nexant (GTL fuels, Power)
- Outstanding Issues
  - Allocation methodologies for multi-product systems
  - Incorporating sequestration over time
  - Appropriate functional unit definition

LCA Considerations for Sequestration

- Should captured CO_2 be classified as a product or waste stream?
- Sequestration leakage
  - For EOR, up to 30-40% of CO_2 returns to atmosphere (The Weyburn Monitoring Project, PTRC)
  - For sequestration, rates of 0.1% or lower have been shown to be equivalent to no leakage, and actual rates may be in this range (Ref: Lawrence Berkeley National Lab, CMU, MIT)
  - However, few LCA studies explicitly account for leakage
- Accounting for CO_2 emissions over time
  - Define an appropriate functional unit
  - Discount CO_2 based on a half-life of 5-200 years
- Accounting for losses in system efficiency
  - Identify the breakeven point of sequestration with "do nothing", relative to efficiency losses and leakage, examine sensitivities

Accounting for CO_2 Emissions Over Time

- LCA studies typically account for only single-period emissions
- With leakage, should account for emissions over time
- Definition of LCA Functional Unit
  - MWh produced over 100 years
- Account for emissions, sequestered CO_2, leakage, and CO_2 discounted over the functional time frame
- At the end of the period, assess total CO_2 remaining in atmosphere relative to total power produced

LCA for Multi-product Systems

- ISO 14040 Standards: Allocation and System Boundary Expansion
  - Allocation
    - All emissions are separately assigned to primary products and co-products based on allocation rules (heat content, mass, economic value)
  - System Boundary Expansion
    - System boundary is expanded to include all products, co-products and downstream functions for all systems under comparison
    - Quickly becomes prohibitively data intensive

Co-Product Function Expansion

- A novel methodology developed by Nexant and ConocoPhillips for the Ultra-Clean Fuels LCA for GTL Fisher Tropsch Diesel
- All emissions are allocated to a primary product, e.g. power
- Net impacts of co-products relative to competing products or processes in downstream applications are credited/debited to the primary product
- Scope is relative to a selected set of downstream alternatives, and not a complete system boundary expansion

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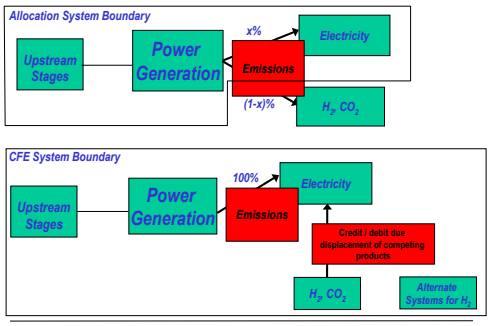
Modeling Co-products : Allocation vs. CFE



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Case Studies

- The Effect of CO_2 leakage, with discount, over 100 years, on IGCC with Sequestration
- IGCC for Power and Hydrogen, with Sequestration
  - Comparison with IGCC Power with no sequestration
- Application of Co-Product Function Expansion to IGCC multi-products

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IGCC: Effects of Leakage over 100 years

- FutureGen type facility
  - 275 MW, Equivalent Power and Hydrogen
  - 1,000,000 Metric Tons of CO_2 sequestered per year
  - Assume 25-year facility life, 100 year functional unit
  - Sequestered CO_2 leakage rate between 0.1% - 0.5% per year
  - CO_2 half-life of 50 years: 1.5% discount
- References
  - "FutureGen: Integrated Sequestration and Hydrogen Research Initiative," DOE, Office of Fossil Energy, March 2004
  - "Carbon storage: the economic efficiency of storing CO_2 in leaky reservoirs," Duong and Keith, Carnegie Mellon University.
  - "The Economics of CO_2 Storage," MIT Lab for Energy and the Environment

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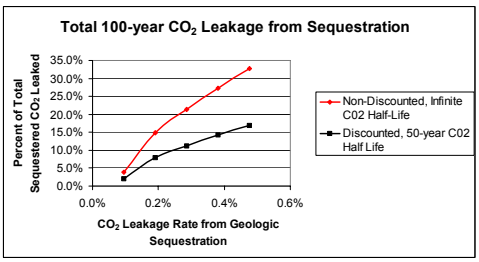
Effect of Leakage



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IGCC for Power and H_2 with Sequestration

Item	Base Case	Co-Product Case
Coal consumption, tons/day	3,171	3,171
Gas Turbine Power	272	143
Steam Cycle Power	189	44
Internal Power Consumption	-48	-77
Net Electricity, MWh	9,907	2,647
H2 Production, Equivalent MWh	0	10,157
CO2 product, kg/day	0	6,218,719
CO2 emissions, kg/day	6,724,018	497,135

Reference: "Energy-Cycle Analysis of a Gasification-Based Multi-Product System with CO_2 Recovery", Argonne National Lab, SAIC, NETL.

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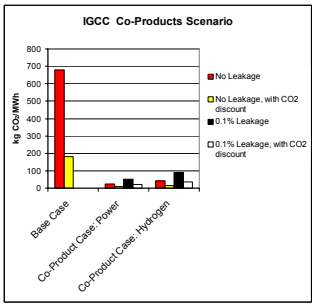
100-year Lifecycle Results



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Application of Co-product Function Expansion

- Allocate all CO_2 emissions to electricity
- Assess alternative H_2 production: steam reforming of methane
  - Reference: "Life cycle assessment of hydrogen production via natural gas steam reforming," Spath and Mann, NREL, 2001.
  - 425 kg CO_2/MWh of H_2 produced
- Emissions subtracted from electricity, and compared to power-only IGCC

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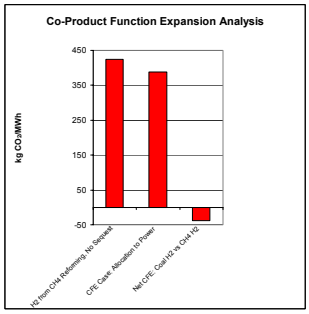
CFE Lifecycle Results



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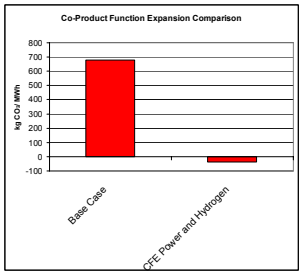
CFE Comparison with Base Case



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Summary

- CO_2 leakage from sequestration should be accounted for in LCA
  - Appropriate time frames/functional units must be defined
  - Effect can be significant at leakage rates greater than 0.5% per year
  - Rates below 0.1% may safely be ignored
- Accounting for co-products in IGCC, particularly H_2 production and alternative production methods, via System Boundary Expansion or Co-Product Function Expansion, demonstrates additional benefits of H_2 production from coal with sequestration

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