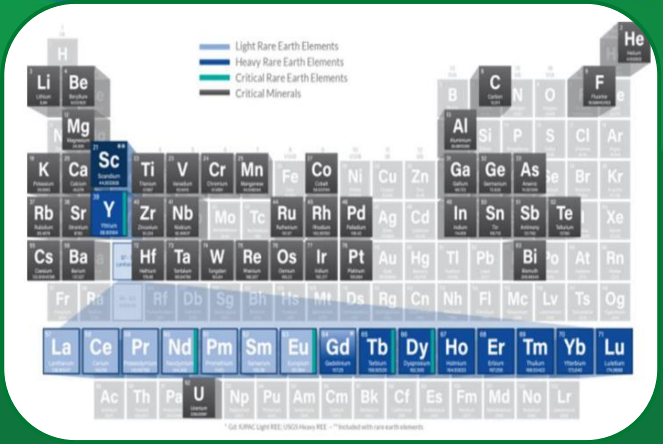
U.S. DEPARTMENT OF
ENERGY
Fossil Energy and
Carbon Management

Life Cycle Analysis for Direct Air Capture and Utilization

Innovation for Cool Earth Forum (ICEF)
October 4, 2022

Greg Cooney
Office of Fossil Energy and Carbon Management (FECM)





Why do we need LCA when evaluating CDR?

Adapted from CDR Primer (2021)

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- Chemicals
- Energy
- Water
- Land

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- Co-product
- Transport
- Storage
- Waste Mgmt
- Conversion

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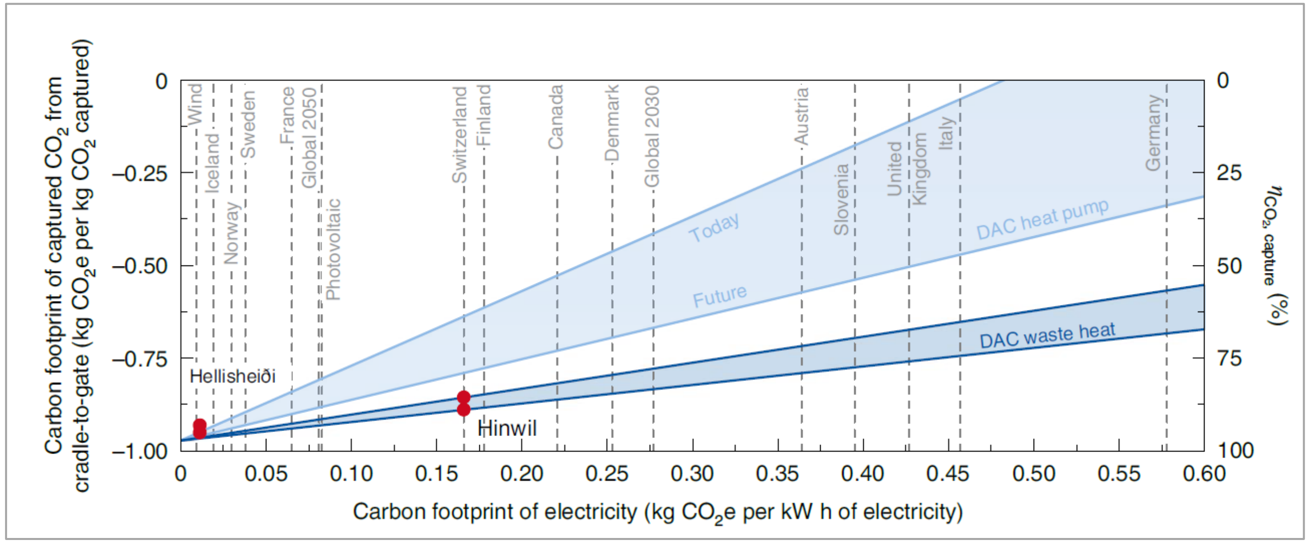
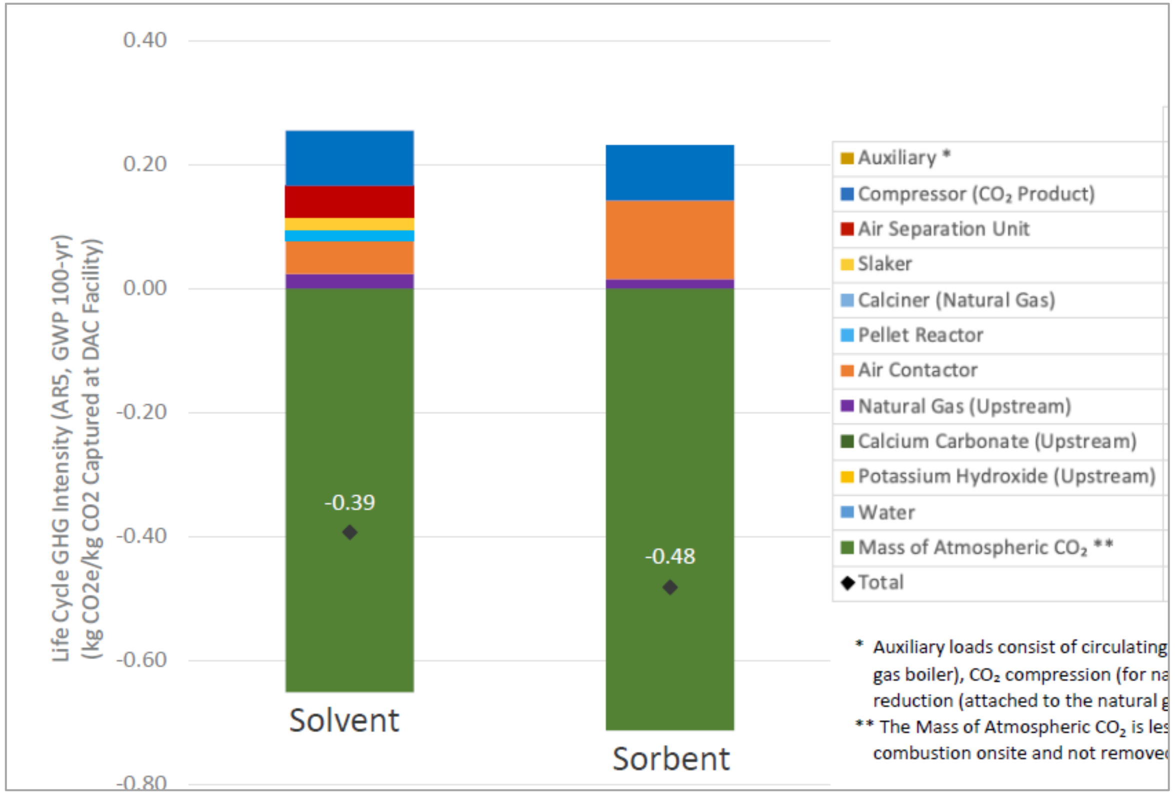
Why do we need LCA when evaluating CDR?



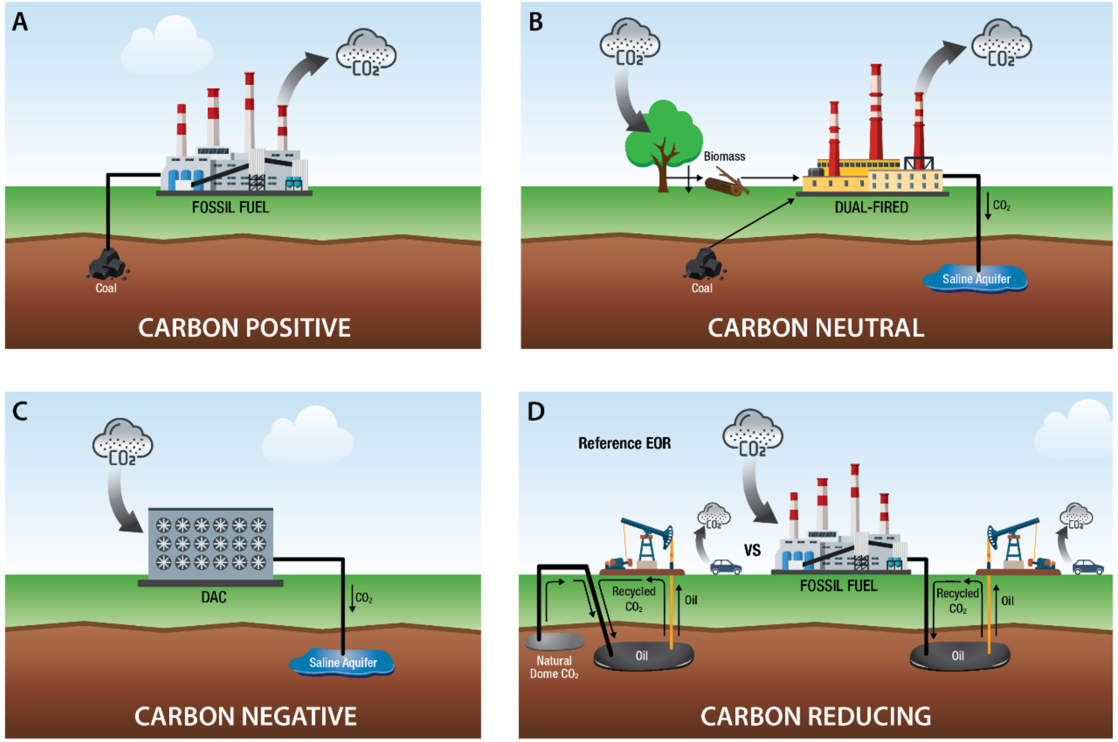
Deutz and Bardow (2021)



NETL (2021)

LCA can help us make sense of GHG mitigation approaches

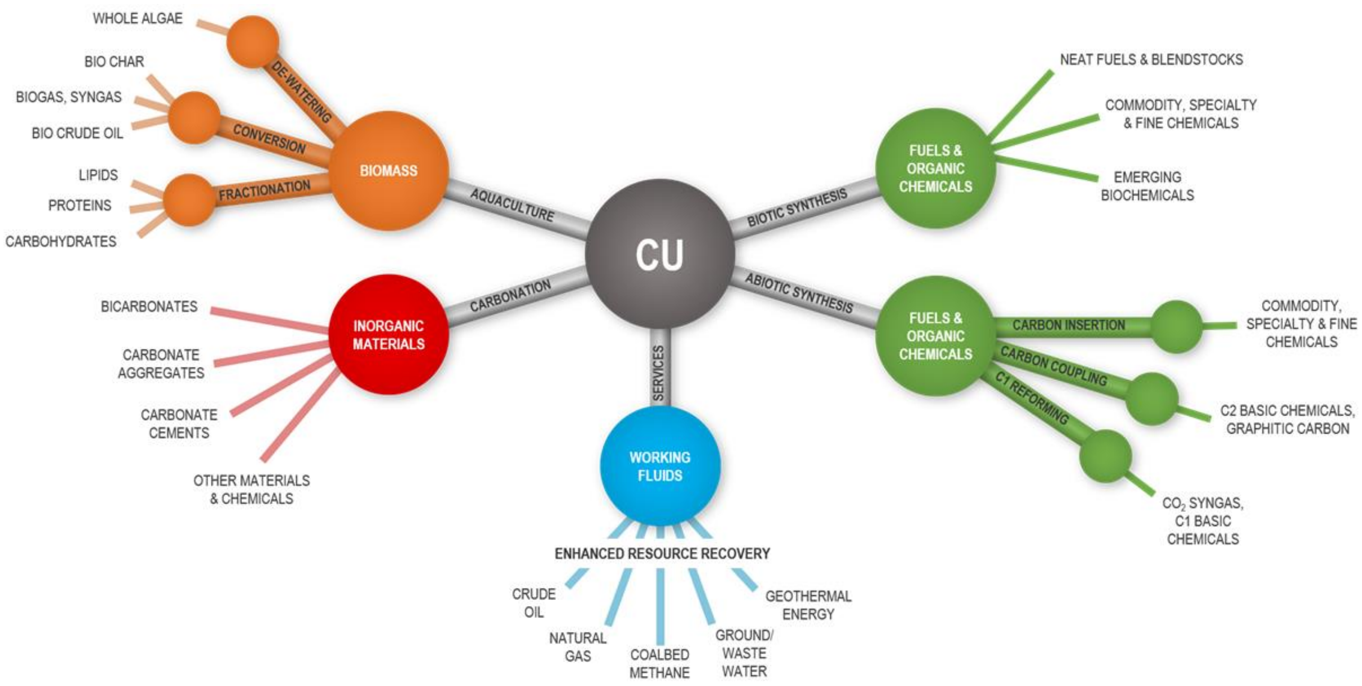
- LCA can be used as a framework to account for the **net emissions** of proposed pathways
- It can also be used to assess **potential tradeoffs** in other environmental impacts
- A carbon utilization system is likely to require **more energy** to produce something than incumbent system
- A **lifecycle comparison** of both systems is necessary to ensure we're not adding more carbon to the atmosphere



Source: NETL (2022)

Application of LCA to CCUS Systems

- CO2U systems are unique in that they **combine** two sectors (CO2 source and CO2U product)
- Variety of sources and uses make assessment **complex**
- Comparison of integrated system to combination of systems that yield the **same function**
- Consistent LCA approaches are necessary to ensure **comparability** for robust decision making

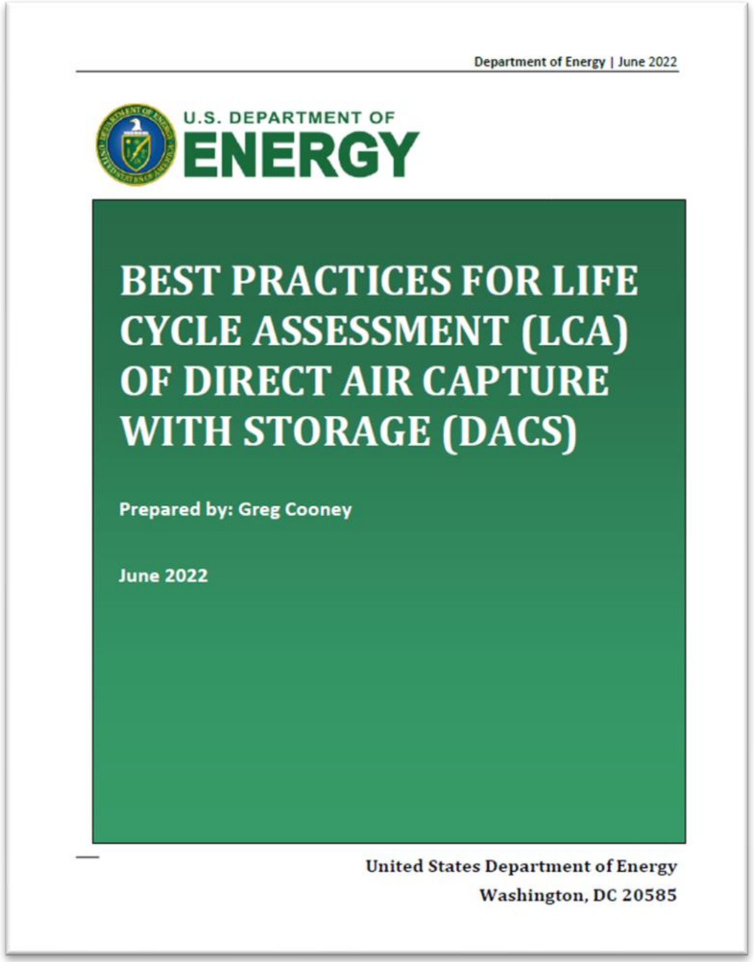


While standards exist, there are key subjective elements that require consideration when applying LCA to DAC + Utilization

- Clarity and consistency in functional unit
- System boundary definition
- Negative emissions accounting
- LCI data consistency/representativeness
- Temporal dynamics for removal and emissions
- Early TRL scaling uncertainty

DOE FECM Best Practice Document – Goals

1. Foster **consistency** of LCA of DACS systems to enable more complete understanding of potential impacts of CDR
2. Assess **sensitivity and uncertainty** in results to provide confidence in the study outcomes and potential risk envelopes for technology performance
3. Understand **potential tradeoffs and co-benefits** of DACS systems
4. Leverage **best practices** from the LCA research and practitioner community


Department of Energy | June 2022

U.S. DEPARTMENT OF ENERGY

BEST PRACTICES FOR LIFE CYCLE ASSESSMENT (LCA) OF DIRECT AIR CAPTURE WITH STORAGE (DACS)

Prepared by: Greg Cooney

June 2022

United States Department of Energy
Washington, DC 20585

https://www.energy.gov/fecm/best-practices-LCA-DACS

Specificity in function is essential to ensure comparability and consistency

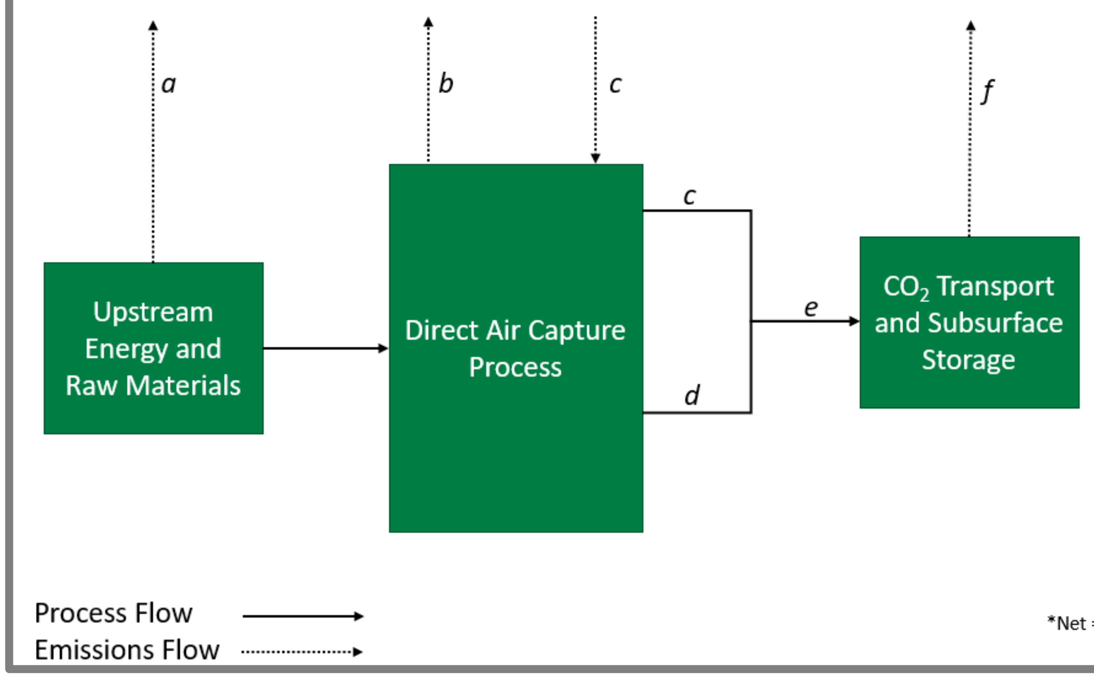
Potential Functional Units

Cradle-to-gate:

1. Mass of CO_2 captured
2. Mass of CO_2 captured from the atmosphere

Cradle-to-grave:

3. Mass of CO_2 captured from the atmosphere and permanently stored
4. Mass of net CO_2e captured from the atmosphere and permanently stored



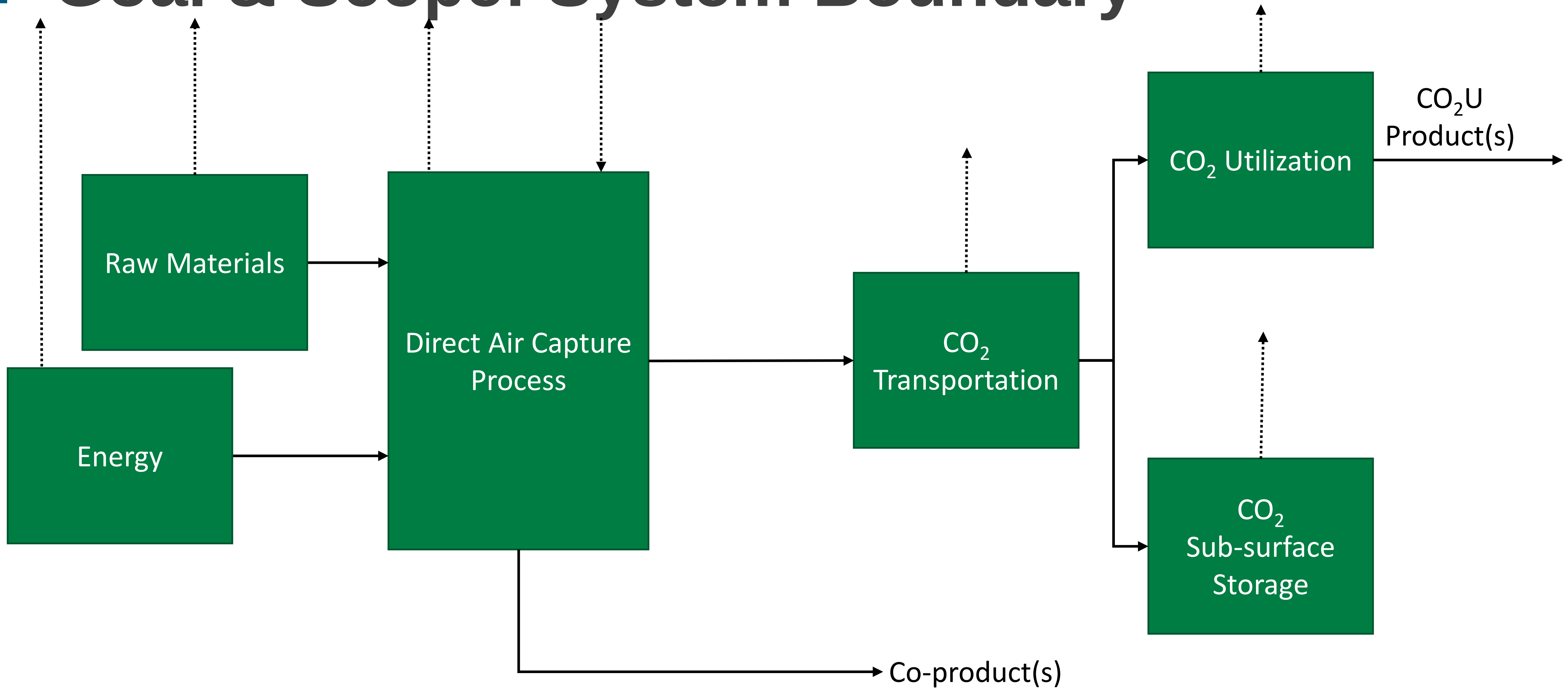
	Flow Description
a	Upstream supply chain
b	Uncaptured on-site fossil
c	Captured atmospheric (net)*
d	Captured on-site fossil
e	Total captured (atmospheric + fossil)
f	Downstream supply chain + operations + leakage

*Net = Mass of Atmospheric CO_2 In – Mass of Atmospheric CO_2 Out

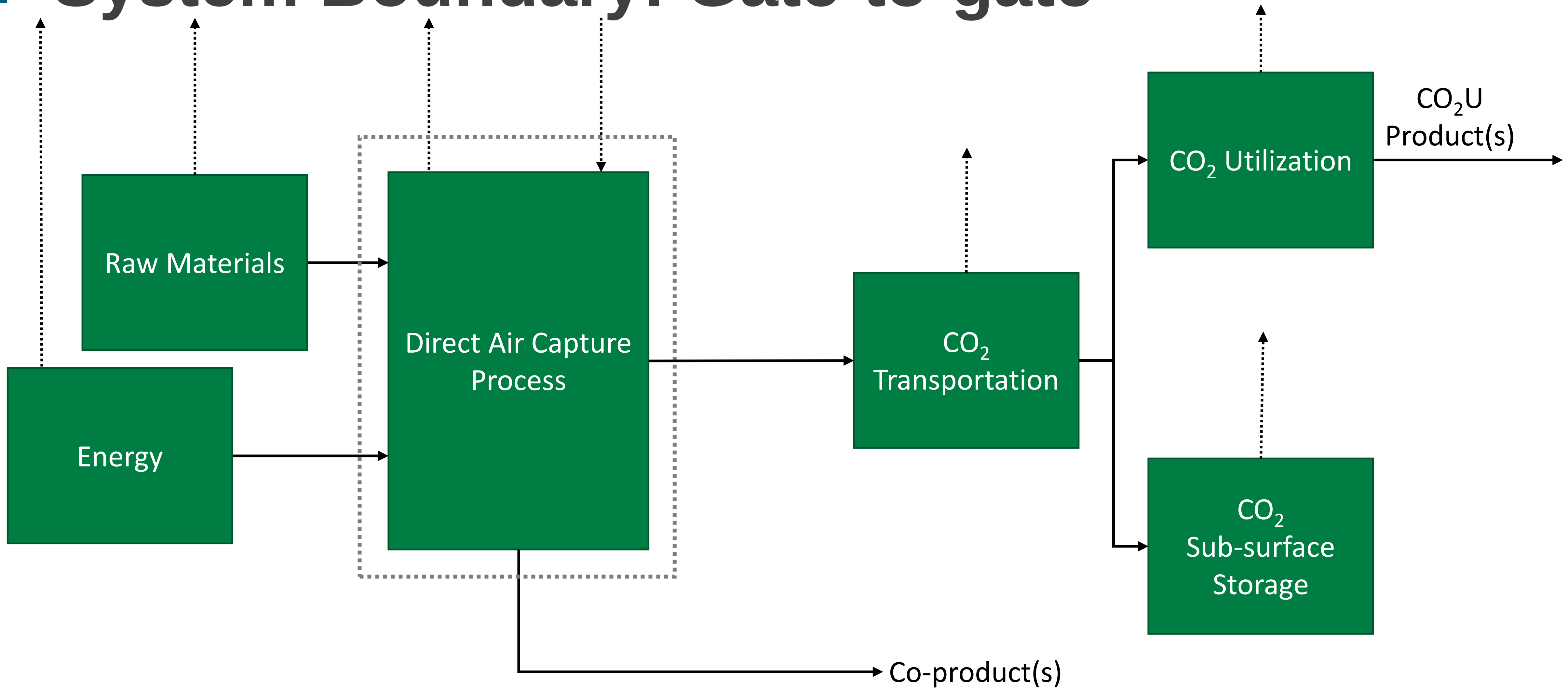
Specificity in function is essential to ensure comparability and consistency

Functional Unit		System Boundary	Calculation (kg CO_2e/FU)
1	kg CO_2 captured	Cradle-to-gate	c = 1 $\text{kg } CO_2e = \frac{a+b-c}{c+d} = \frac{0.40+0.05-1.00}{1.00+0.50} = -0.37$
2	kg CO_2 captured from the atmosphere	Cradle-to-gate	c = 1 $\text{kg } CO_2e = \frac{a+b-c}{c} = \frac{0.40+0.05-1.00}{1.00} = -0.55$
3	kg CO_2 captured from the atmosphere and permanently stored	Cradle-to-grave	c = 1 $\text{kg } CO_2e = \frac{a+b-c+f}{c} = \frac{0.40+0.05-1.00+0.01}{1.00} = -0.54$
4	net kg CO_2e captured from the atmosphere and permanently stored	Cradle-to-grave	Scale up factor c’ $= \frac{-1}{FU\ 3\ Result} = \frac{-1}{-0.54} = 1.85$ $\text{kg } CO_2e = \frac{c'(a+b+f)-c'}{1} = \frac{0.85-1.85}{1} = -1$

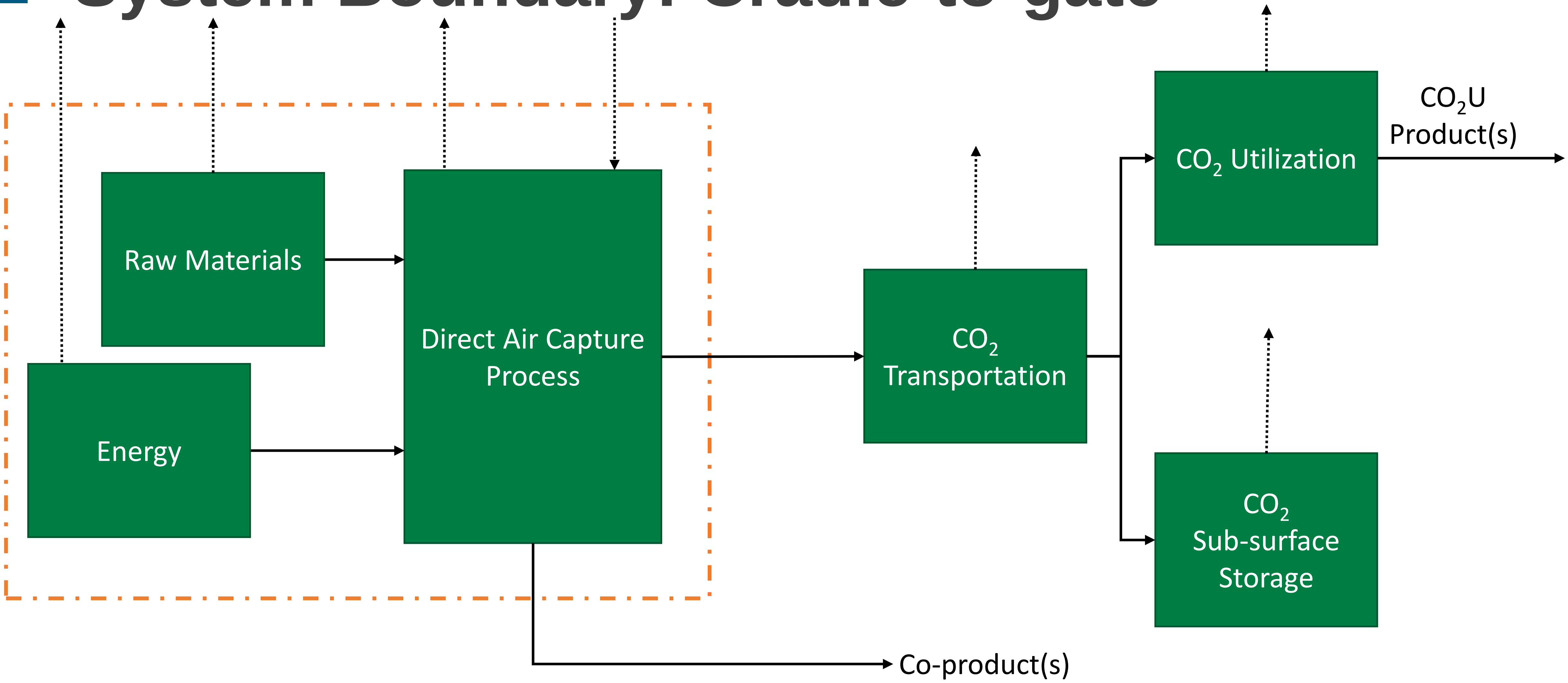
Goal & Scope: System Boundary



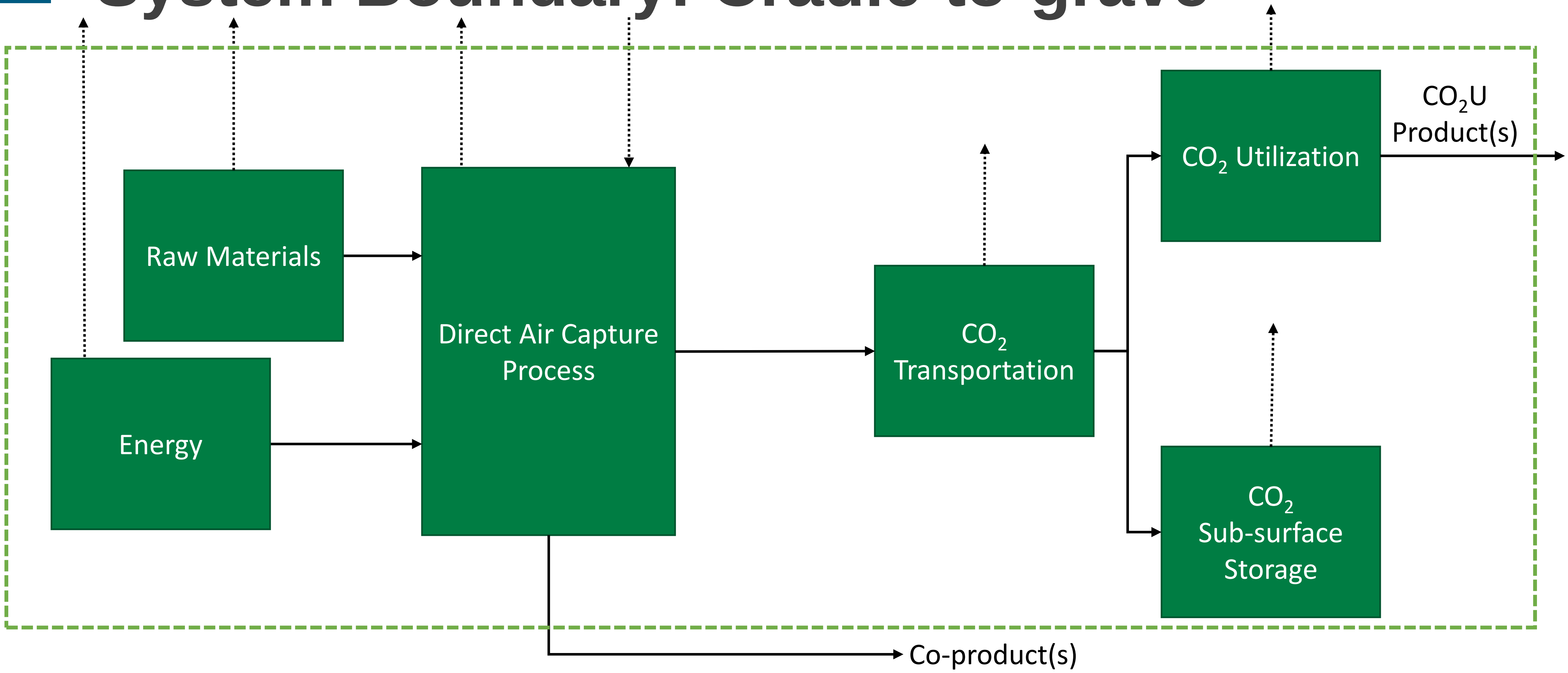
System Boundary: Gate-to-gate



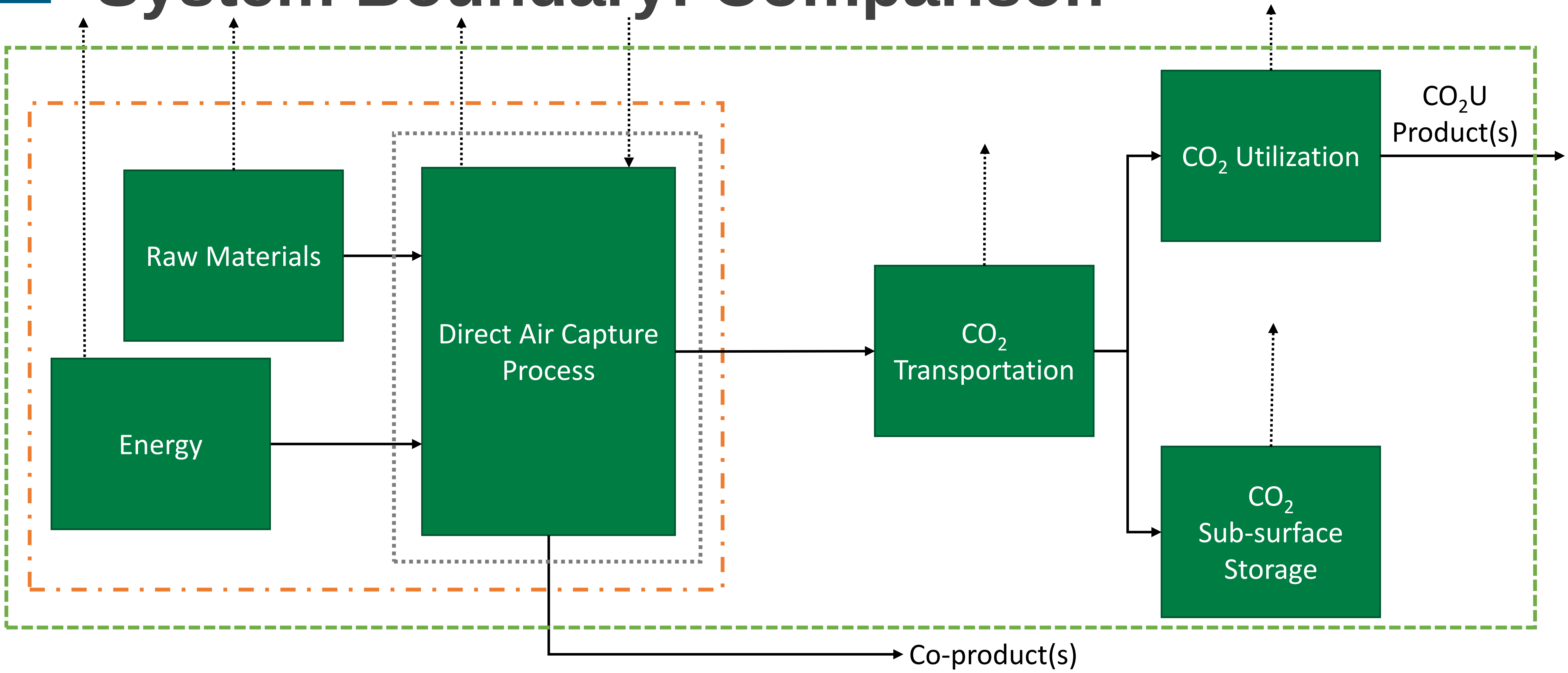
System Boundary: Cradle-to-gate



System Boundary: Cradle-to-grave



System Boundary: Comparison



Functional Unit and System Boundary

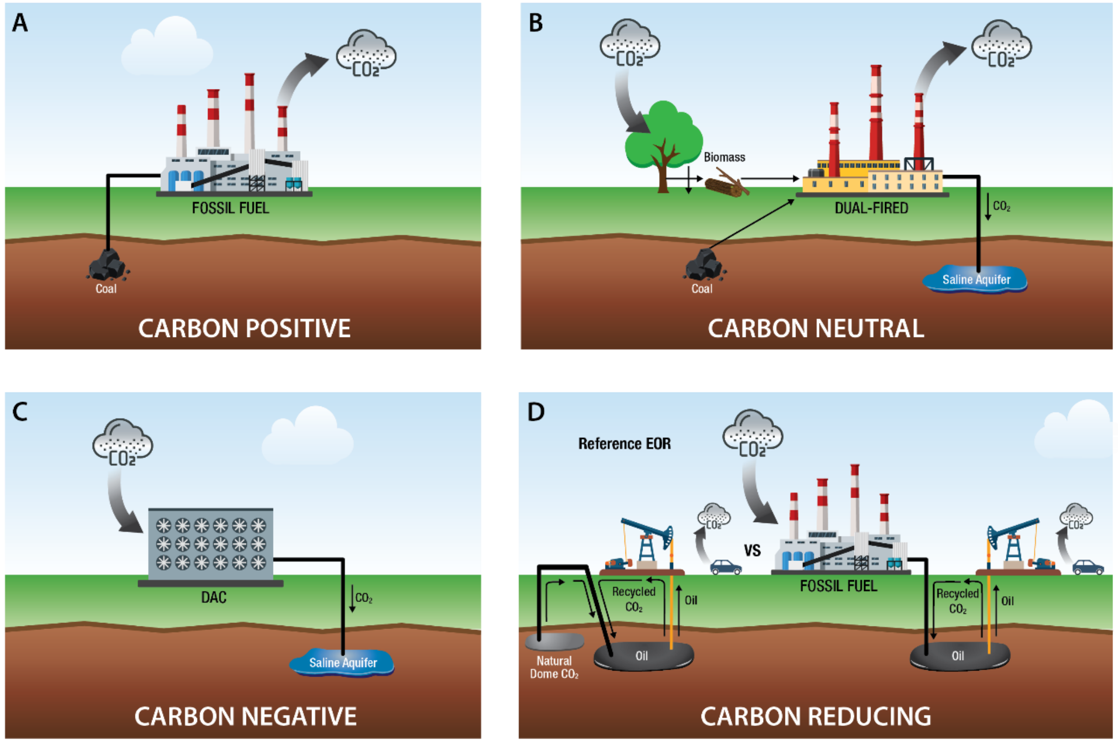
DOE FECM Best Practices

- ☑ Analyze DACS using this functional unit: **Mass of CO_2 captured from the atmosphere and permanently stored**
- ☑ Evaluate DACS with a **cradle-to-grave boundary** to fully account for the function of the system
- ☑ For all dispositions of the captured CO2, which include utilization/conversion or EOR, the system boundary should encompass the **downstream fate of the captured CO_2** as well as any associated activities
- ☑ Depict the system boundary graphically using a **process flow diagram** to depict processes included within the analysis scope

Correctly interpreting negative emissions

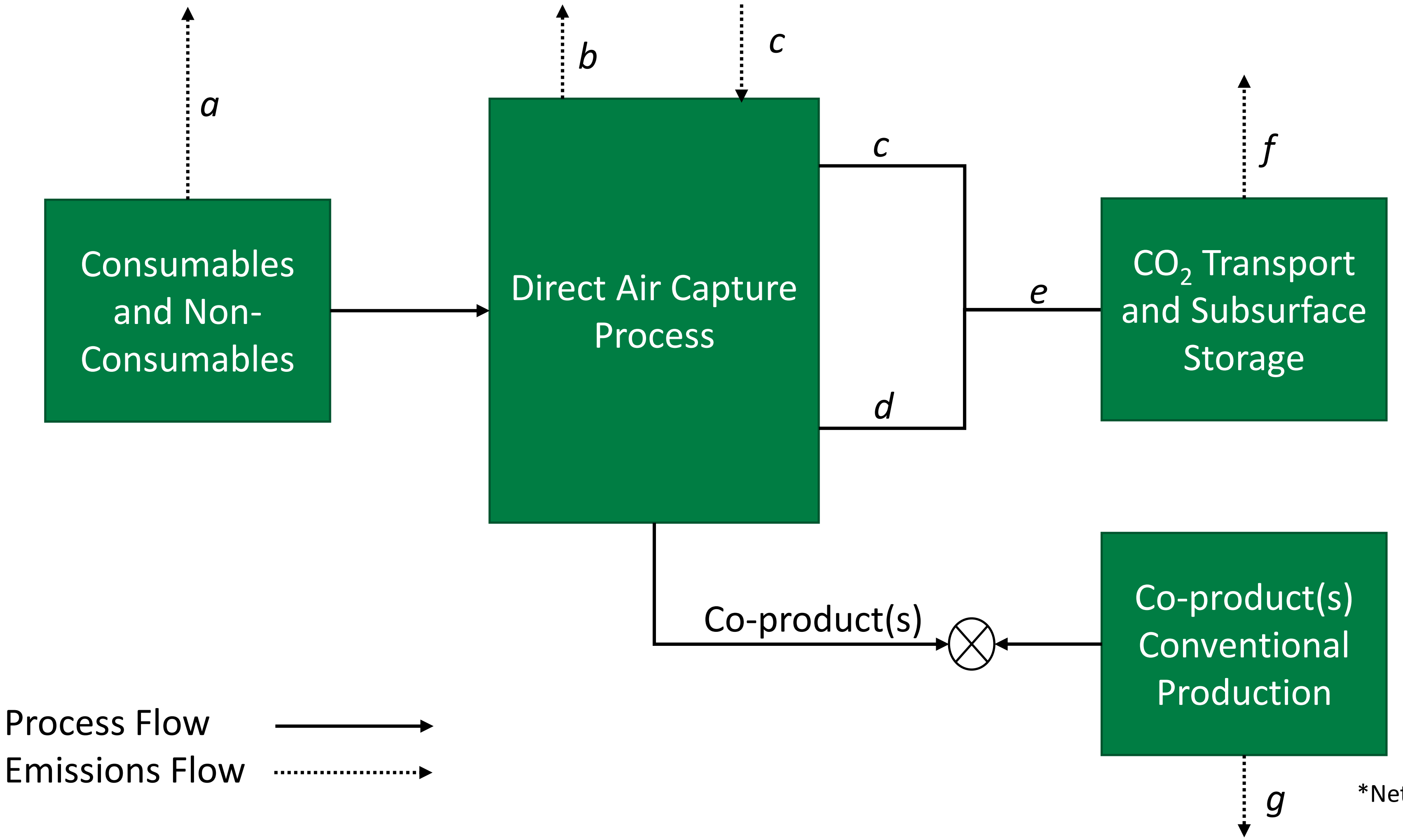
In LCA, negative emissions can arise from one of two situations:

1. **Removal** of the emission species from an environmental compartment
2. **Avoided** emissions associated with the production of a product by another means



Source: NETL (2022)

Interpretation: Negative emissions



	Flow Description
a	Supply chain
b	Uncaptured on-site fossil
c	Captured atmospheric (net)*
d	Captured on-site fossil
e	Total captured (atmospheric + fossil)
f	Downstream supply chain + operations + leakage
g	Co-product cradle-to-gate

*Net = Mass of Atmospheric CO_2 In – Mass of Atmospheric CO_2 Out

Interpretation: Negative emissions

Scenario		Functional Unit	Calculation (kg CO_2e/FU)
1	No Co-Products	kg atmospheric CO_2 captured and stored	c = 1; g = 0 $\text{kg CO}_2\text{e} = \frac{a+b-c+f}{c} = \frac{0.40+0.05-1.00+0.01}{1.00} = -0.54$
2	Co-Product Accounting: Combined avoided and atmospheric removals	kg atmospheric CO_2 captured and stored	c = 1; g = 0.20 $\text{kg CO}_2\text{e} = \frac{a+b-c+f-g}{c} = \frac{0.40+0.05-1.00+0.01-0.20}{1.00} = -0.74$
3	Co-Product Accounting: Separate avoided and atmospheric removals	kg atmospheric CO_2 captured and stored	c = 1; g = 0.20 $\text{removed kg CO}_2\text{e} = \frac{a+b-c+f}{c} = -0.54$ $\text{avoided kg CO}_2\text{e} = \frac{-g}{c} = -0.20$

Interpretation: Negative emissions

DOE FECM Best Practices

- ☑ For systems with co-products, when system expansion is used to manage multiple outputs, report **avoided emissions and atmospheric removals separately** in the results
- ☑ When a DAC facility includes capture of CO_2 from on-site fossil fuel combustion or other non-atmospheric CO_2, **separately report that amount** from the atmospheric CO_2 captured

DOE/NETL CO2U LCA Guidance Toolkit

- CO2 utilization LCA guidance and tool package for Carbon Utilization Program primary research projects
- Improving **clarity and specificity** of existing ISO guidance.
- Ensuring **accuracy** of LCAs developed by technical personnel who are new to the framework.
- Minimizing **effort** needed to complete LCAs.
- Participation in global **harmonization** community.

Toolkit available at netl.doe.gov/LCA/CO2U

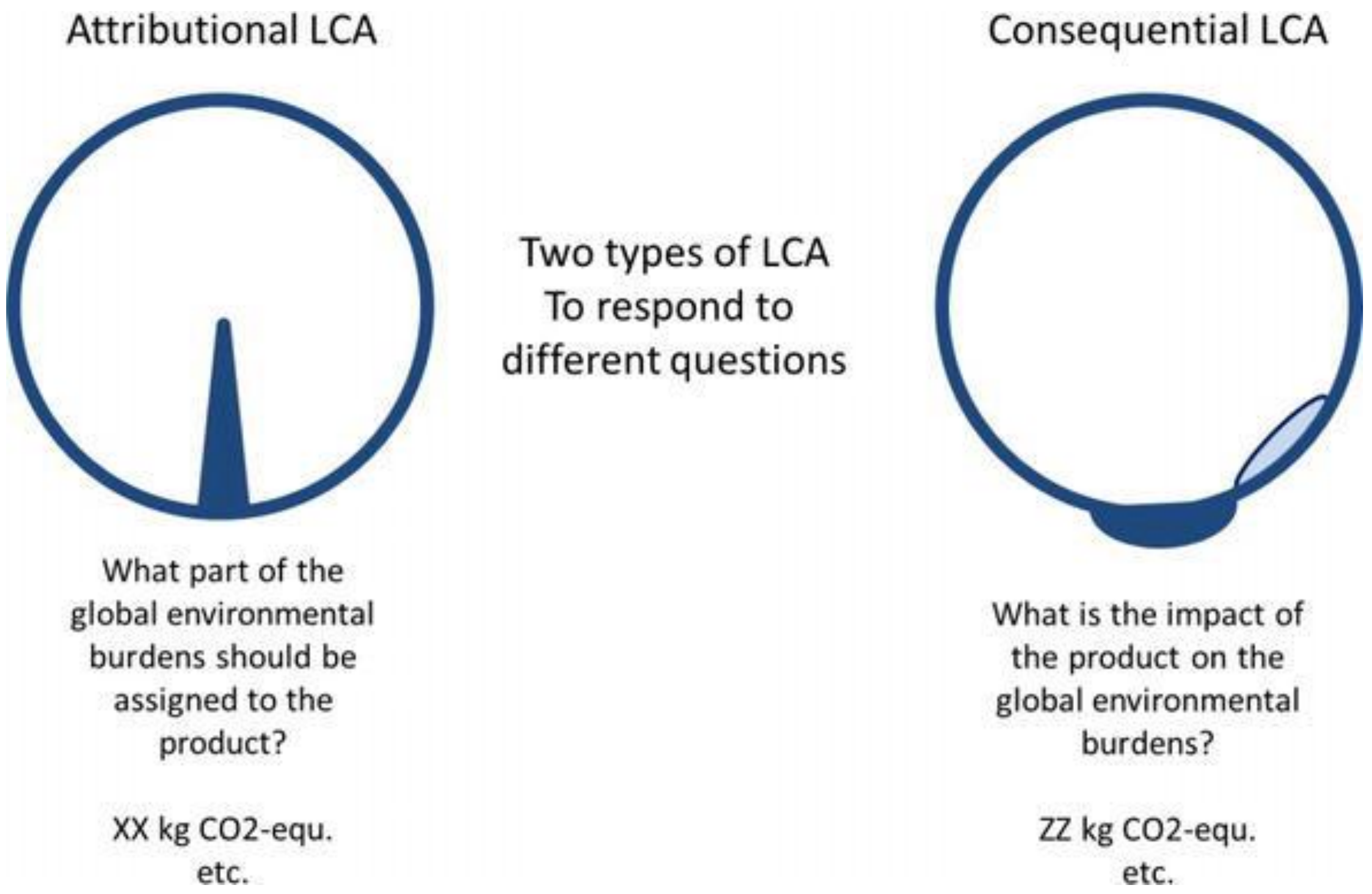
Contributions to Global Discussion

- The FECM/NETL LCA Team has been participating in numerous global workgroups to ensure CO2U LCA is consistent:
  - International CCU Assessment Harmonization Group
  - American Center for Life Cycle Assessment (ACLCA) and Society of Environmental Toxicology and Chemistry (SETAC) LCA of Emerging Technologies Workgroup

- The collaboration with the International CCU Assessment Harmonization Group has resulted in several peer-reviewed articles in Frontiers in Climate:
  - Life-Cycle and Techno-Economic Assessment of Early-Stage Carbon Capture and Utilization Technologies – A Discussion of Current Challenges and Best Practices
  - Adapting Technology Learning Curves for Prospective Techno-Economic and Life Cycle Assessment of Emerging Carbon Capture and Utilization Pathways
  - Why Terminology Matters for Successful Rollout of Carbon Dioxide Utilization Technologies

International CCU Assessment Harmonization Group Participants

Attributional and consequential LCA



Source: Ekvall (2019), Weidema (2012)

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Thank You

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DACS LCA Best Practices:
www.energy.gov/fecm/best-practices-LCA-DACS

DOE/NETL CO2U LCA Toolkit
www.netl.doe.gov/lca/co2u