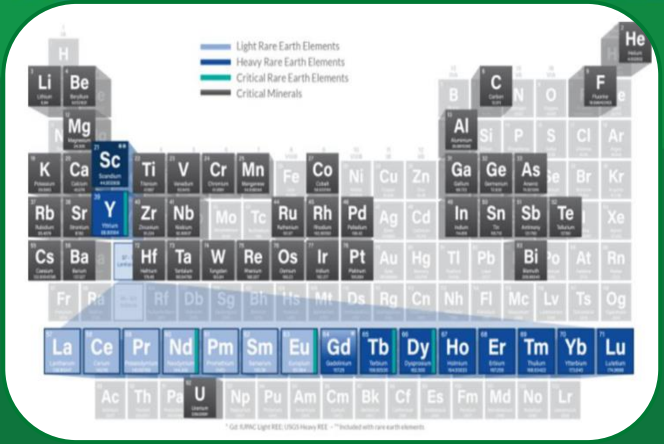
U.S. DEPARTMENT OF
ENERGY
Fossil Energy and Carbon Management

Best Practices for LCA of DACS

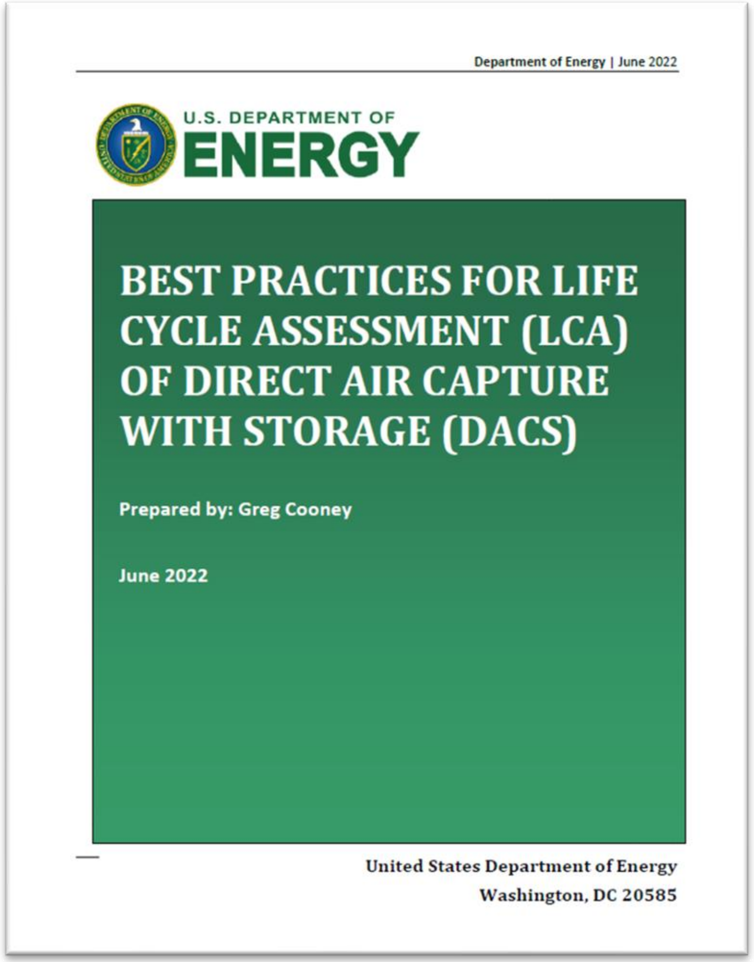
USEA Webinar
Presented by Greg Cooney
July 28, 2022





Purpose and Motivation

- CDR is necessary to limit warming
- LCA is well-suited to evaluate CDR
- ISO standards exist (14040/14044), but lack specificity
- Audiences: developers, federal funding awardees, policymakers and regulators, entities interested in evaluating CDR procurement, and potential host communities
- Not exclusive to current leading solvent and sorbent tech



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

Prepared by: Greg Cooney

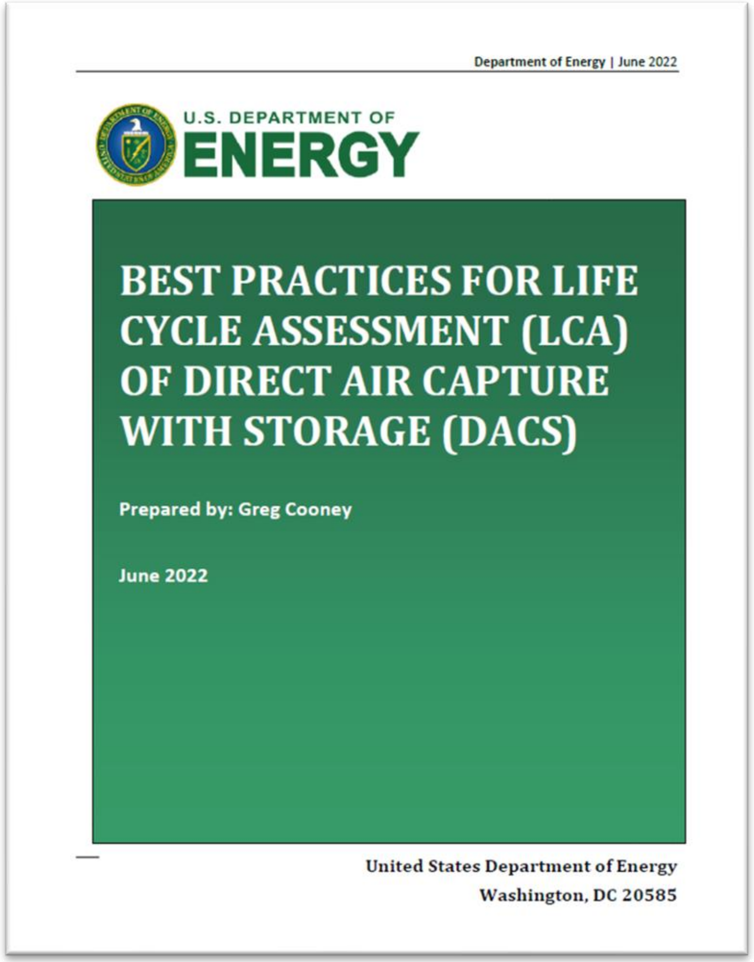
June 2022

United States Department of Energy
Washington, DC 20585

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

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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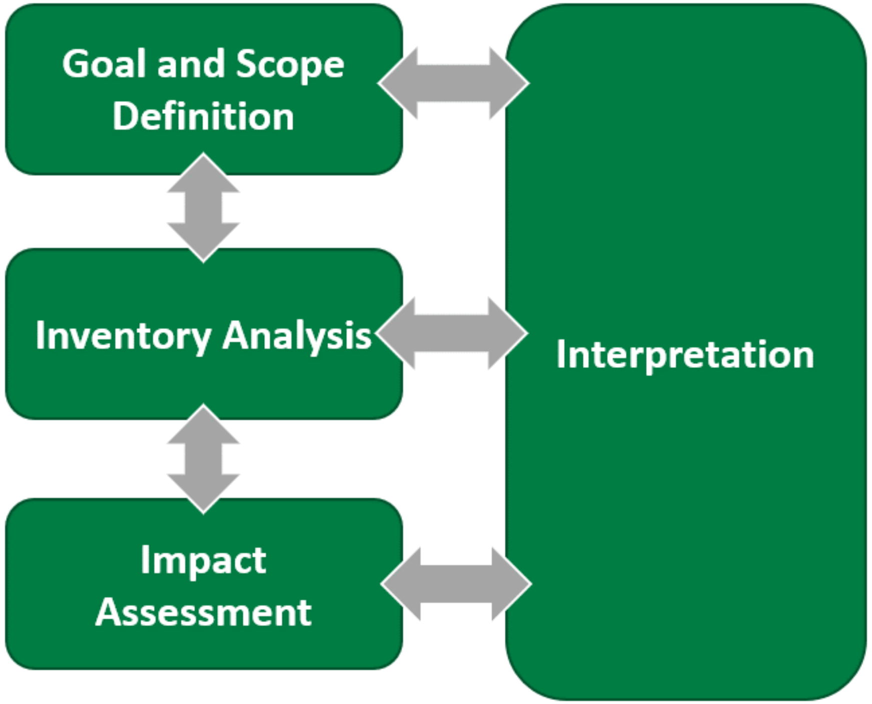
Document Structure

- Each life cycle stage is broken down into the key decisions per ISO
- Document is not a replacement for ISO 14040/14044
- Within each LCA stages:
  - Background on key decisions
  - Relevance to the application of LCA to DACS
  - Recommended best practices

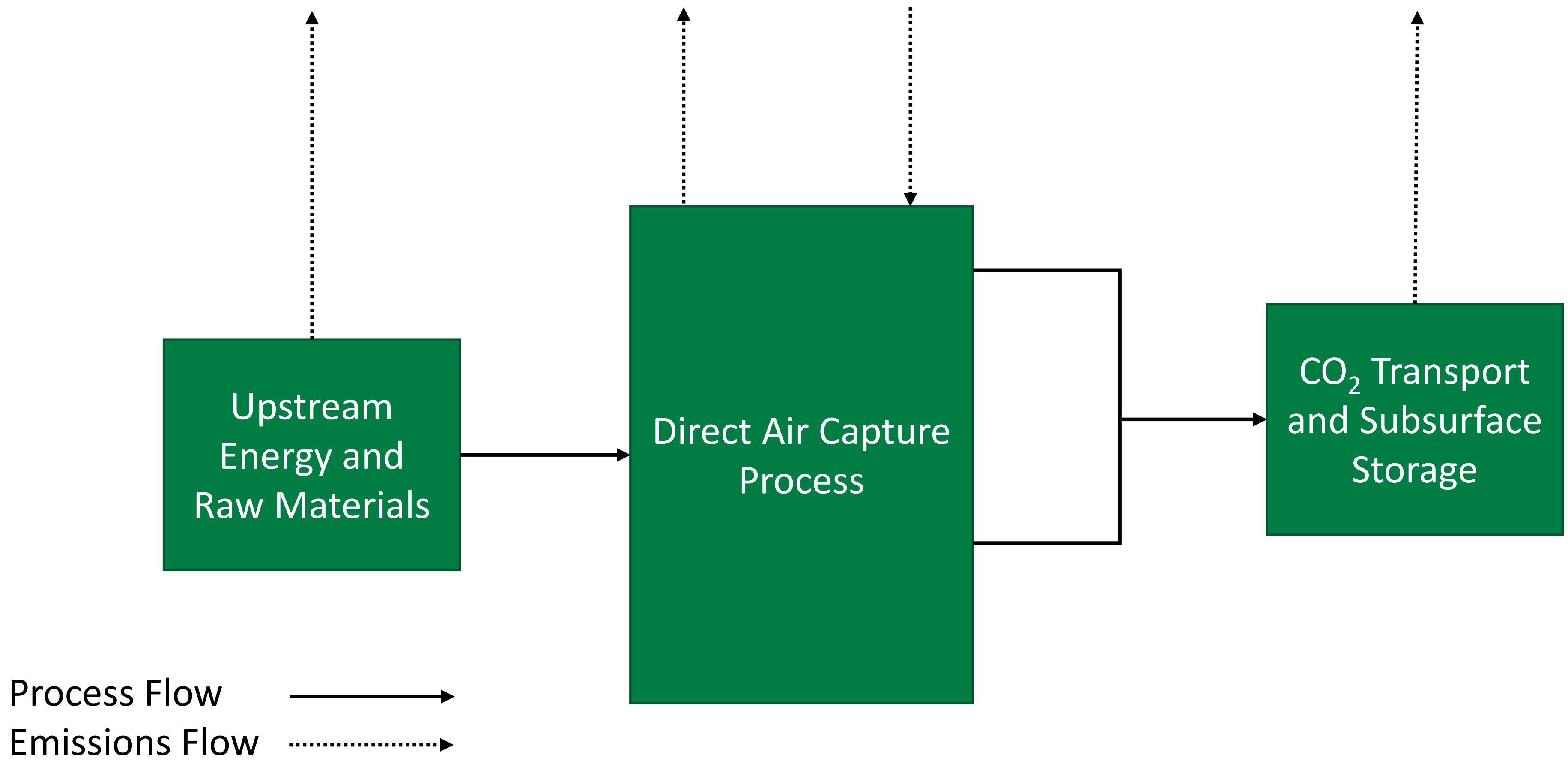


Adapted from ISO 14040 (2006)

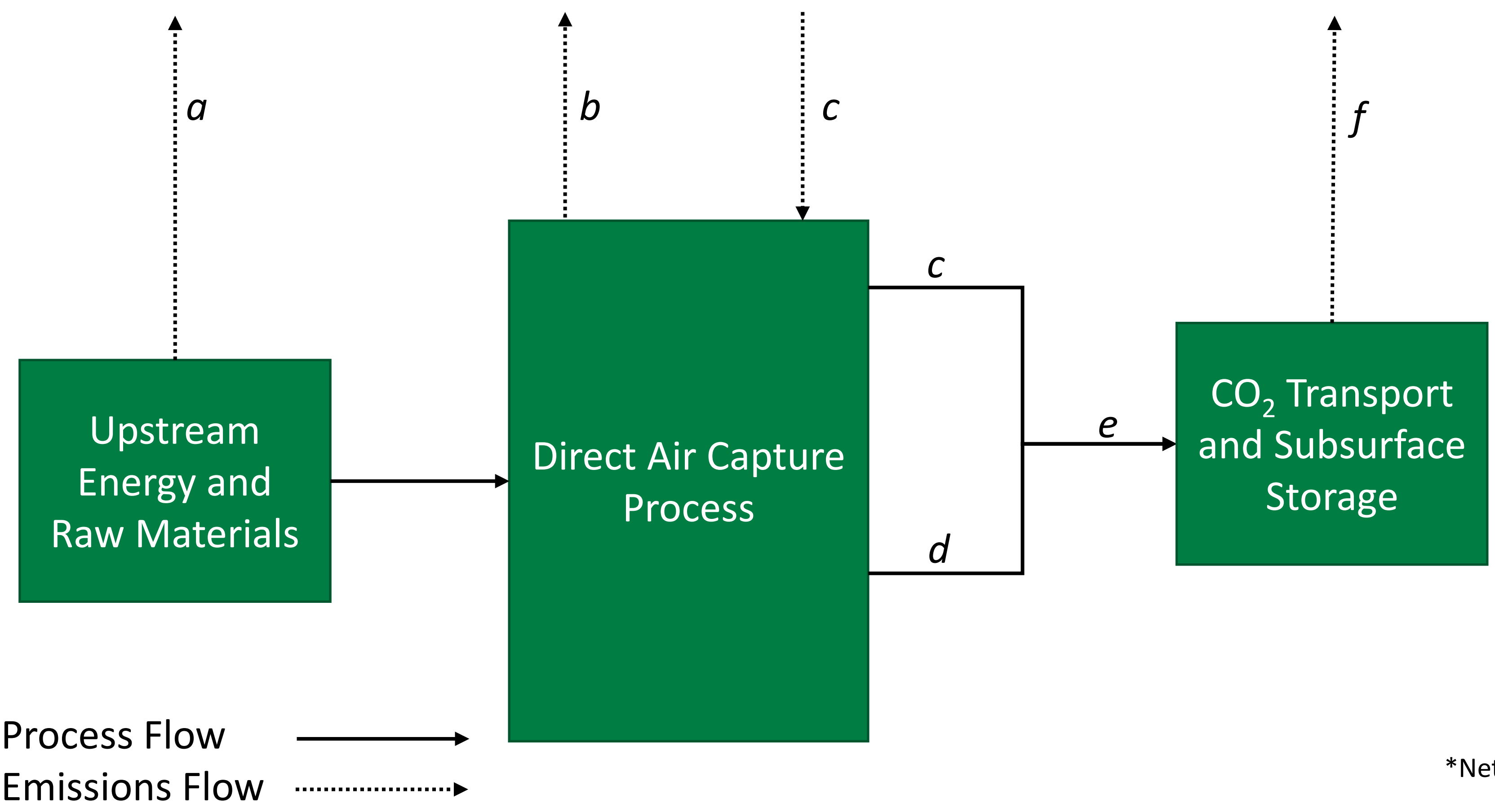
Discussion topics for today

- Clarity and consistency in functional unit definition
- System boundary definition
- LCI data consistency/representativeness
- Negative emissions accounting
- Sensitivity and uncertainty analysis

Goal & Scope: Functional Unit



Goal & Scope: Functional Unit



	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

Goal & Scope: Functional Unit

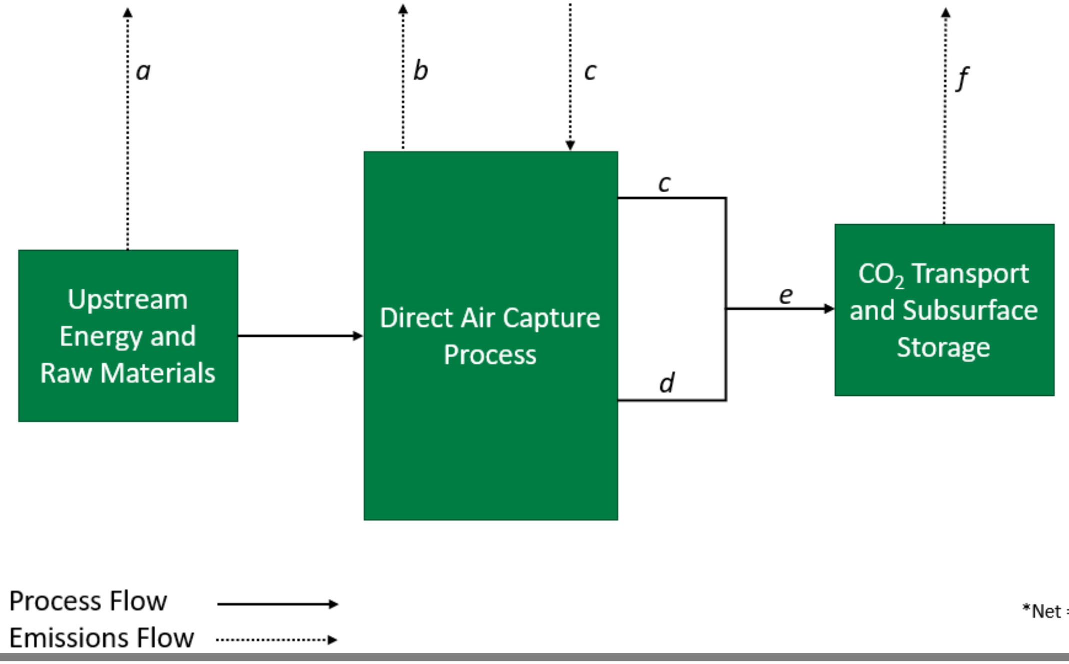
Potential Functional Units

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



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Goal & Scope: Functional Unit

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 $\text{kg } CO_2e = \frac{a+b-c}{c} = \frac{0.40+0.05-1.00}{1.00} = \mathbf{-0.55}$
3	kg CO_2 captured from the atmosphere and permanently stored	Cradle-to-grave	
4	net kg CO_2e captured from the atmosphere and permanently stored	Cradle-to-grave	

Goal & Scope: Functional Unit

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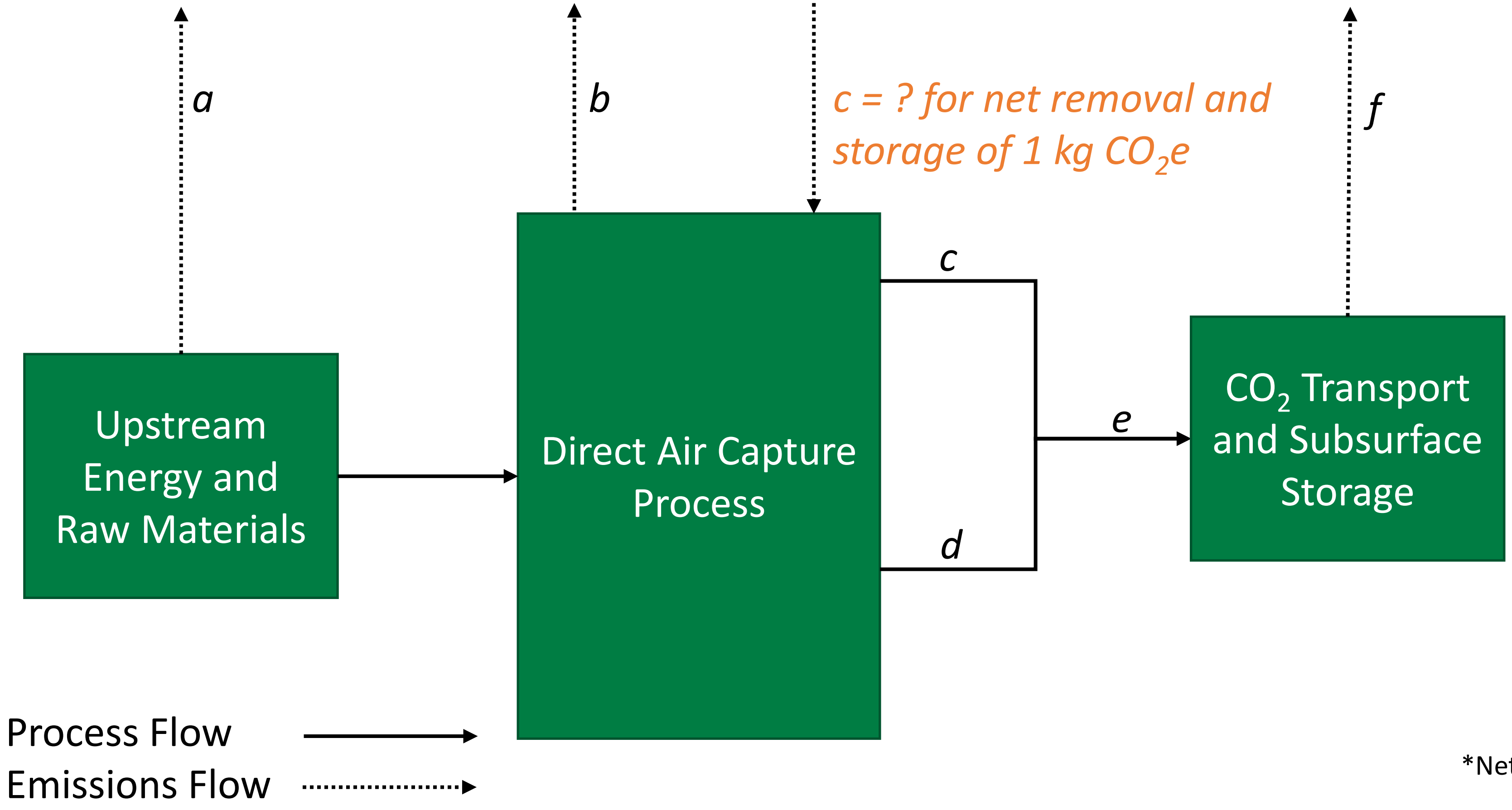
3	kg CO_2 captured from the atmosphere and permanently stored	Cradle-to-grave	c = 1 kg $CO_2e = \frac{a+b-c+f}{c} = \frac{0.40+0.05-1.00+0.01}{1.00} = \mathbf{-0.54}$
4	net kg CO_2e captured from the atmosphere and permanently stored	Cradle-to-grave	

Goal & Scope: Functional Unit



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4	net kg CO_2e captured from the atmosphere and permanently stored	Cradle-to-grave	$\text{Scale up factor } c' = \frac{-1}{FU\ 3\ Result} = \frac{-1}{-0.54} = \mathbf{1.85}$ $\text{kg } CO_2\text{e} = \frac{c'(a+b+f)-c'}{1} = \frac{0.85-1.85}{1} = \mathbf{-1}$

Goal & Scope: Functional Unit

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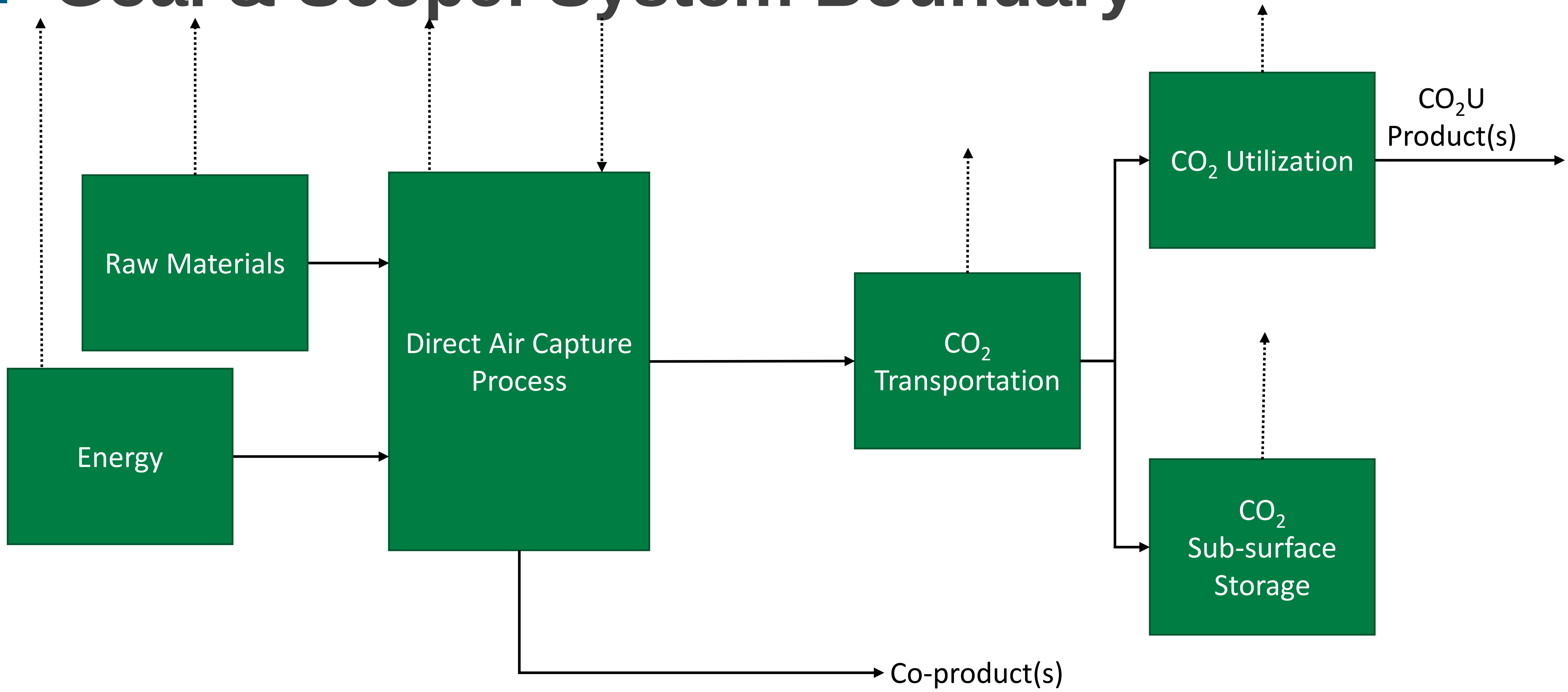
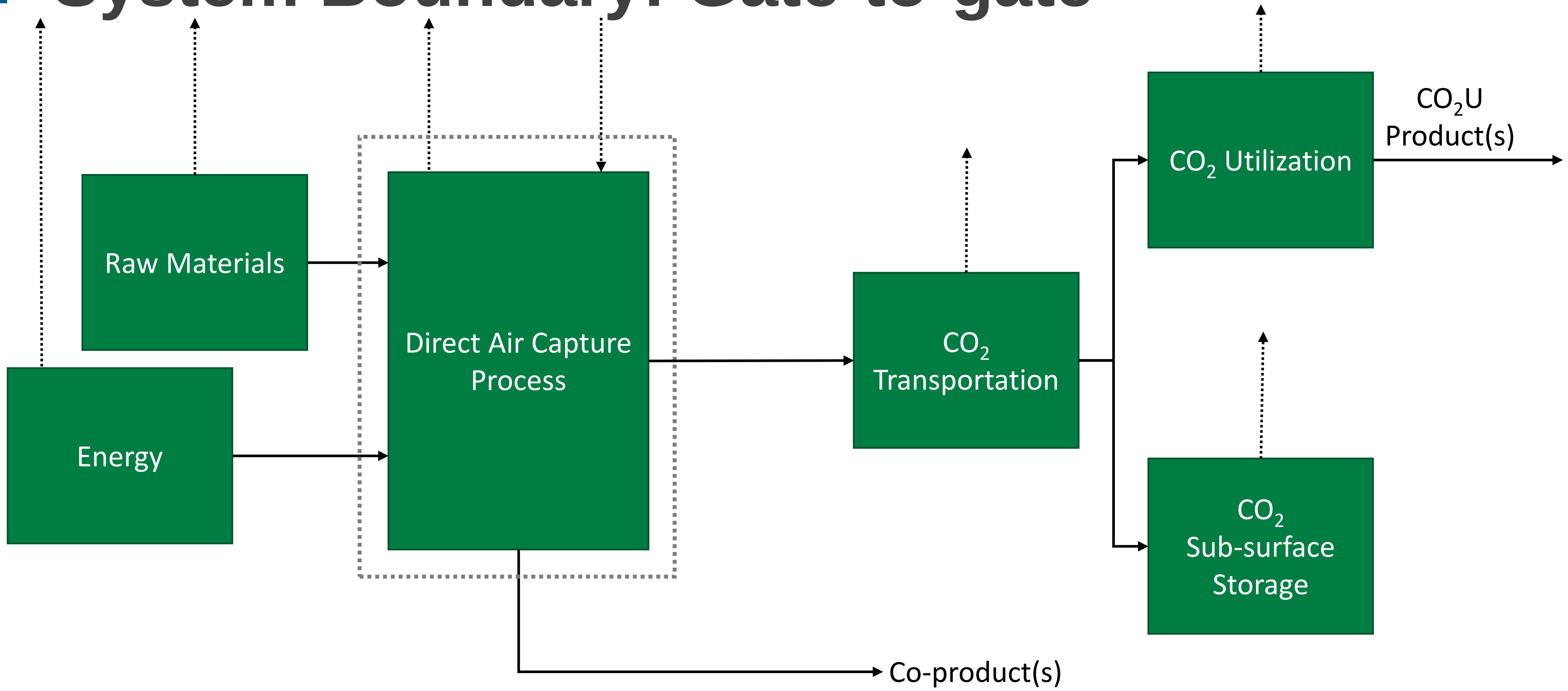
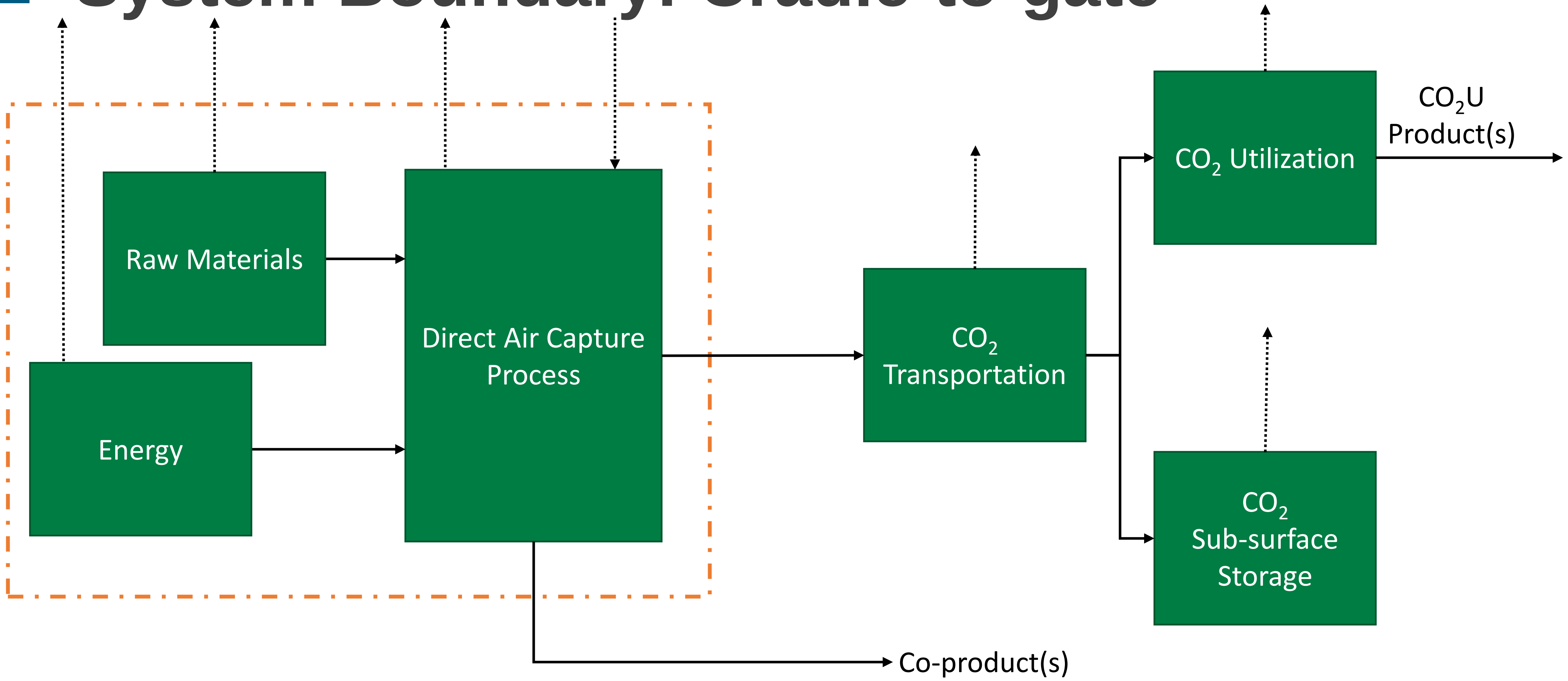
Goal & Scope: System Boundary



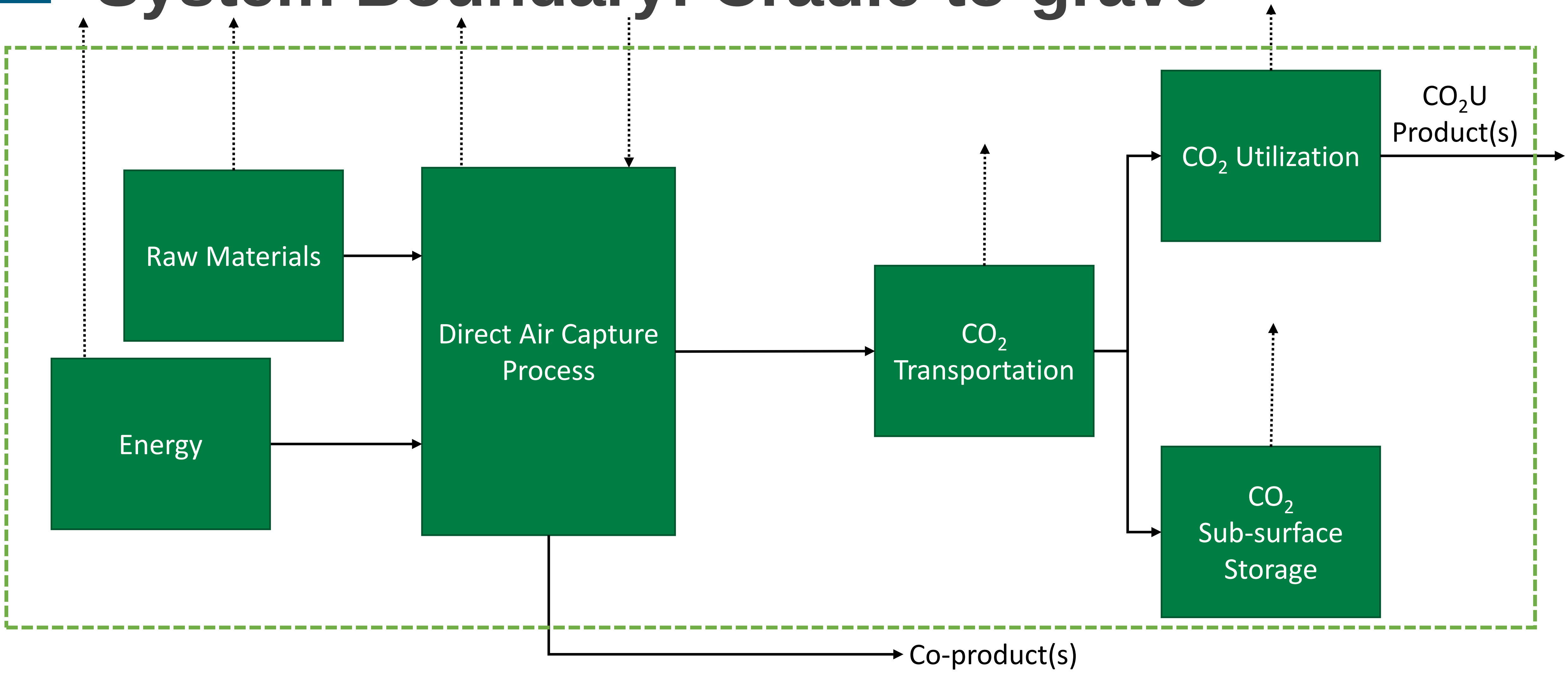
System Boundary: Gate-to-gate



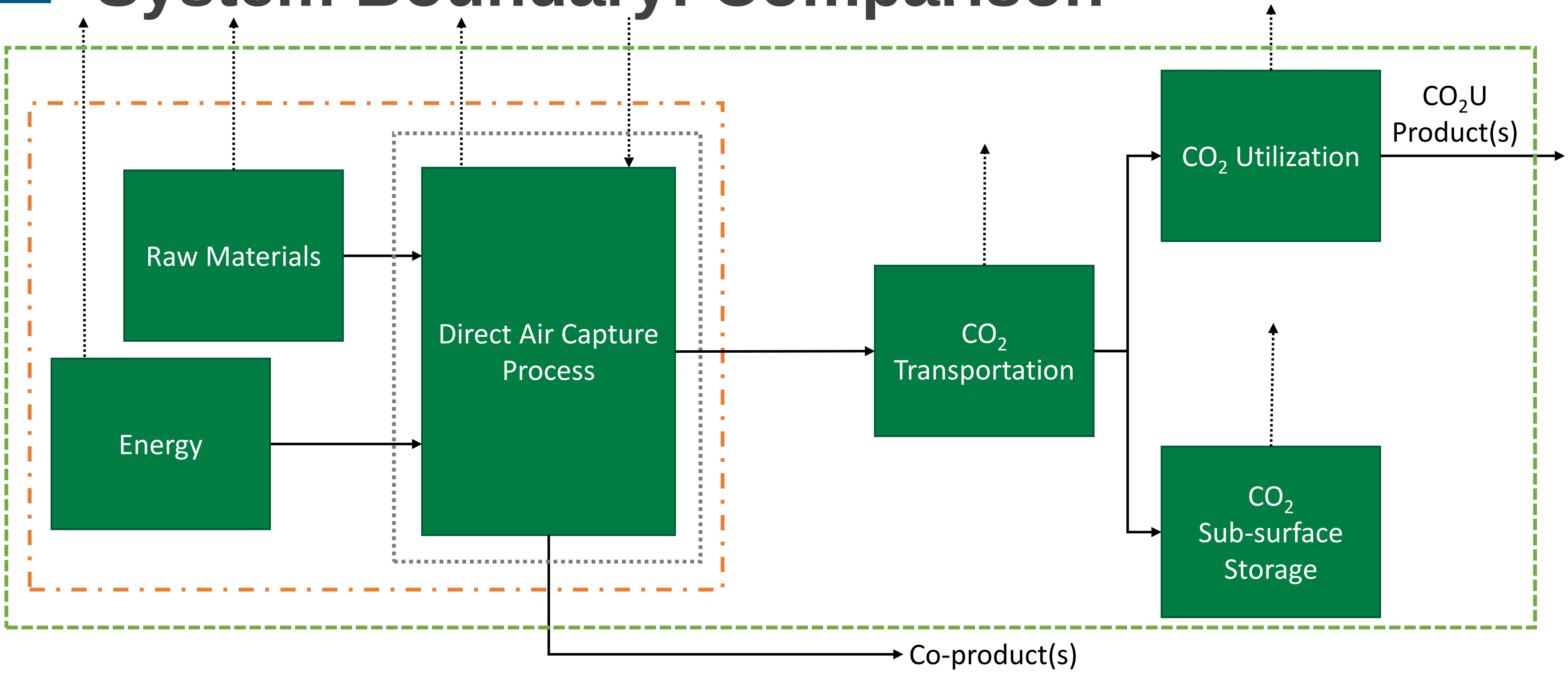
System Boundary: Cradle-to-gate



System Boundary: Cradle-to-grave



System Boundary: Comparison



Functional Unit and System Boundary

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

Life Cycle Inventory: Data Collection

- Facility Operations
- Consumables
  - Utilities – heat, electricity
  - Process chemicals
  - Water
- Non-Consumables
  - Capital equipment
  - Site construction
  - Initial process fluids

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<u>DOE and other Federal Resources</u>

NETL (National Energy Technology Laboratory)

- Natural gas model
- Saline aquifer storage model
- U.S. Electricity Baseline

Argonne National Laboratory

- Greenhouse gases, Regulated Emissions and Energy use in Technologies (GREET) model

Federal LCA Commons

- U.S. Life Cycle Inventory (USLCI) database
- Federal agency LCI data submission

EPA

- Environmentally-Extended Input-Output (USEEIO) Models

Life Cycle Inventory: Data Collection

FECM Best Practices
☑ Define LCA scenarios with a **direct tie to process and cost engineering model (i.e., TEA)** scenarios such that they characterize the underlying facility operating envelope
☑ Report **physical quantities for process inputs and outputs** (e.g., MJ energy, kg materials) in addition to the associated inventory of emissions (e.g., kg emission)
☑ Utilize a modeling approach that provides the best data that is available to represent these activities corresponding to the **stage of development**
☑ **Update representation** of design and underlying LCI data as **technology matures** and nears deployment
☑ When multiple potential sources/types are being evaluated as part of the design, **develop separate LCA scenarios** for each

Life Cycle Impact Assessment

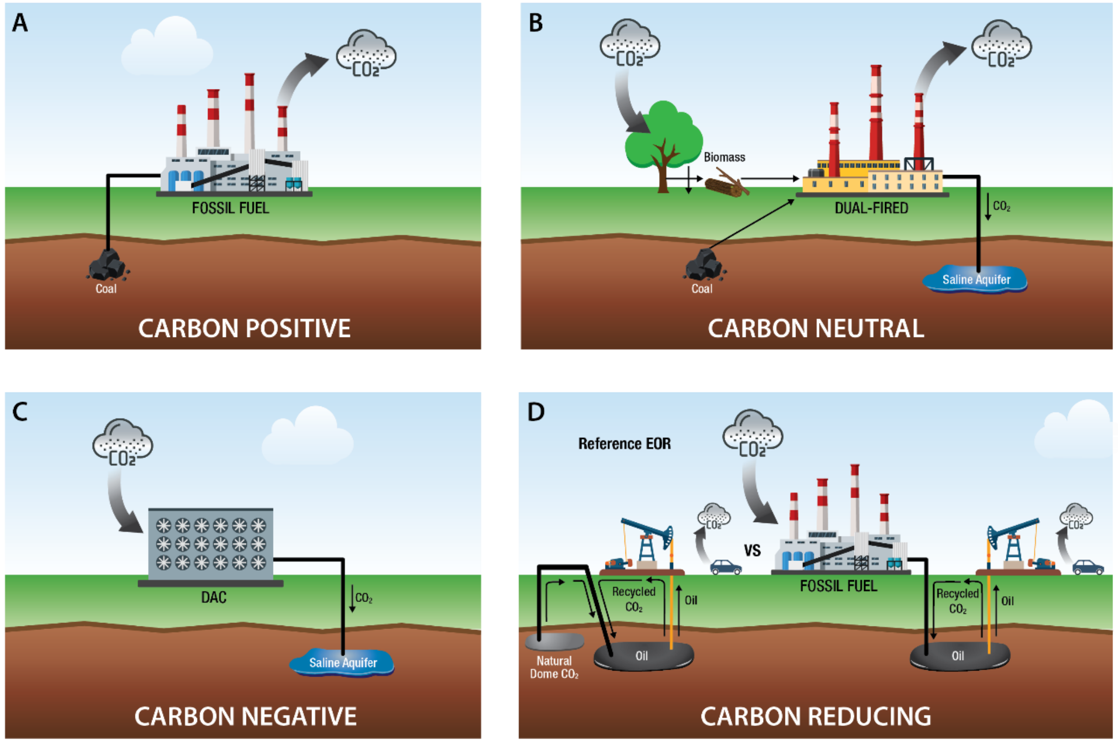
FECM Best Practices

- ☑ Utilize the **EPA's Tool for Reduction and Assessment of Chemicals and Other Environmental Impacts (TRACI)** version 2.1 method for LCIA to characterize the following impact categories (additional impact methods and impact categories may also be reported): ozone depletion, acidification, eutrophication, smog formation, human health particulate, human health cancer, human health noncancer, ecotoxicity
- ☑ Utilize the **IPCC AR6 GWP characterization factors** for translation of GHG emissions to Global Warming Potential impacts as a replacement for the factors in TRACI (IPCC, 2021), and adopt future IPCC GWP characterization factors as they are released.

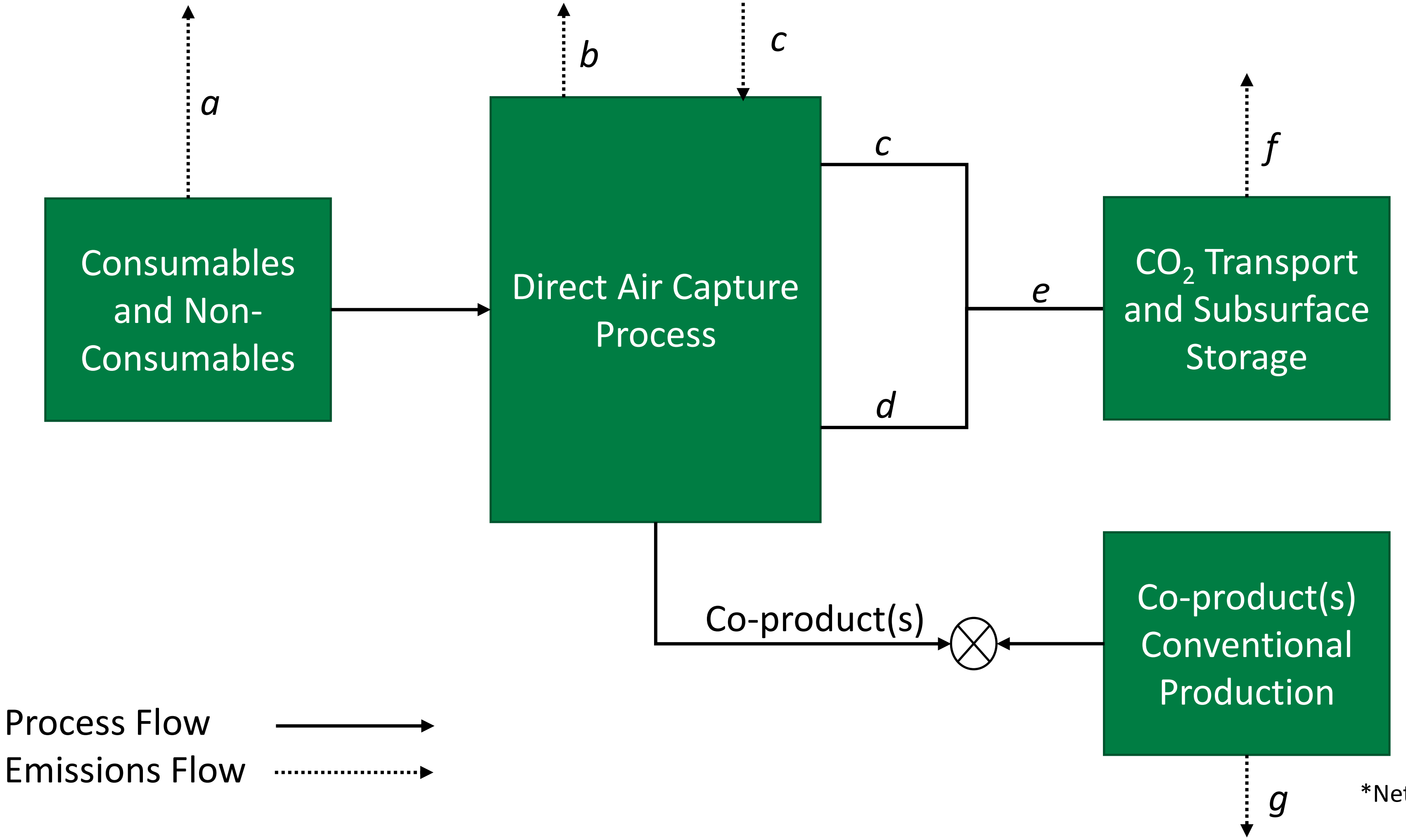
Interpretation: Negative emissions

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



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

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

Interpretation: Sensitivity and Uncertainty

- LCA is a data-intensive framework

- Requires decisions from the analyst about the representation of the system under study affect results

- Uncertainty and variability in these decisions manifest from a variety of sources

LCI Data Category	Parameters for Analysis
DAC Operation	Technical operating performance (TEA case alignment)
	Co-product management method and displacement value (if applicable)
Consumables – Electricity	Electricity source
Consumables – Heat	Heat source
Consumables – Natural Gas	Natural gas supply chain – methane intensity
Consumables – Process chemicals and water	Key process material inputs (e.g., solvent makeup, other supporting chemicals)
Non- Consumables	Capital equipment Process chemicals/catalysts

Interpretation: Sensitivity and Uncertainty

FECM Best Practices

- ☑ Use of **bounding** analysis to inform key decision points
- ☑ Use of standard modeling **scenarios** (defined in table)
- ☑ Use of **sensitivity analysis** to understand the dependence of key parameters

Thank You

We would like to thank the following reviewers for their feedback on a draft version of the Best Practices:

- Emily Grubert – Deputy Assistant Secretary, U.S. Department of Energy Office of Carbon Management
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- Derrick Carlson and Matt Jamieson – National Energy Technology Laboratory
- Dwarakanath Ravikumar and Eric C. D. Tan – National Renewable Energy Laboratory

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Thank You

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