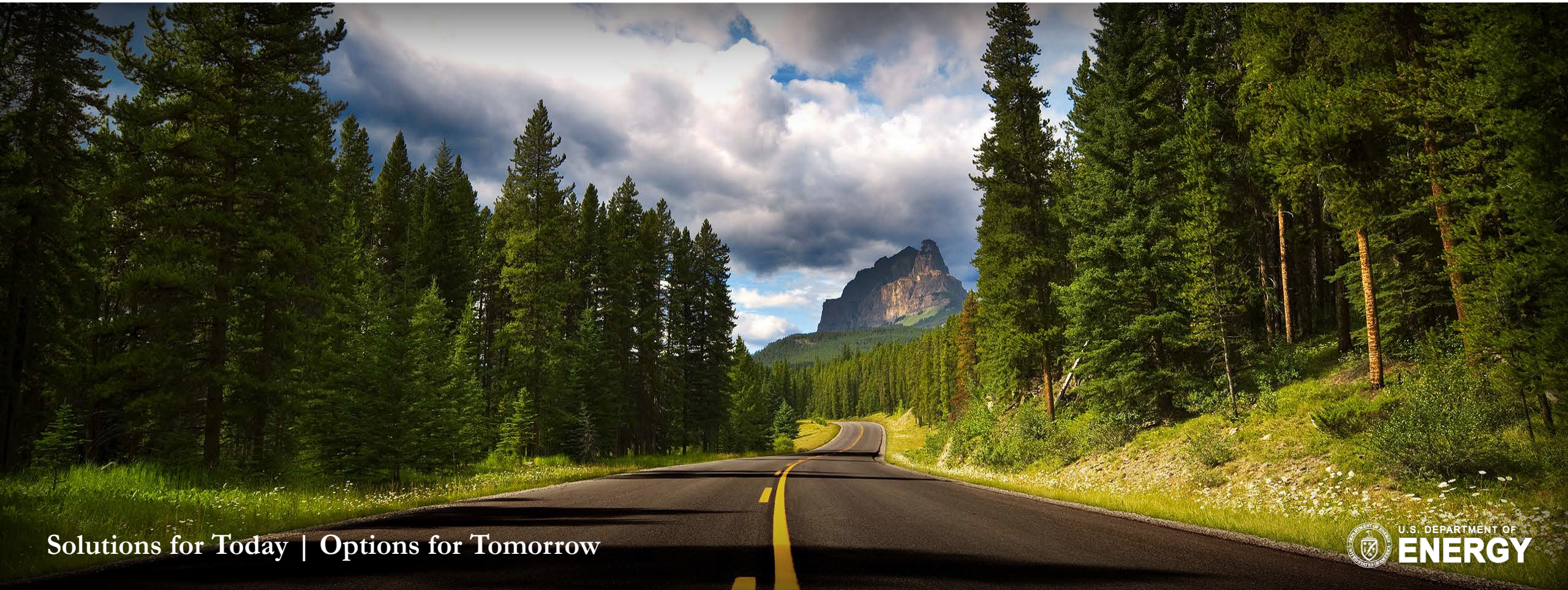


# CO2 Utilization Life Cycle Analysis (LCA) Guidance at the U.S. Department of Energy



Greg Cooney, NETL LCA Team

Carbon Dioxide Utilization Summit: February 27-28<sup>th</sup>, 2019



Solutions for Today | Options for Tomorrow



# Disclaimer and Attribution

## DISCLAIMER

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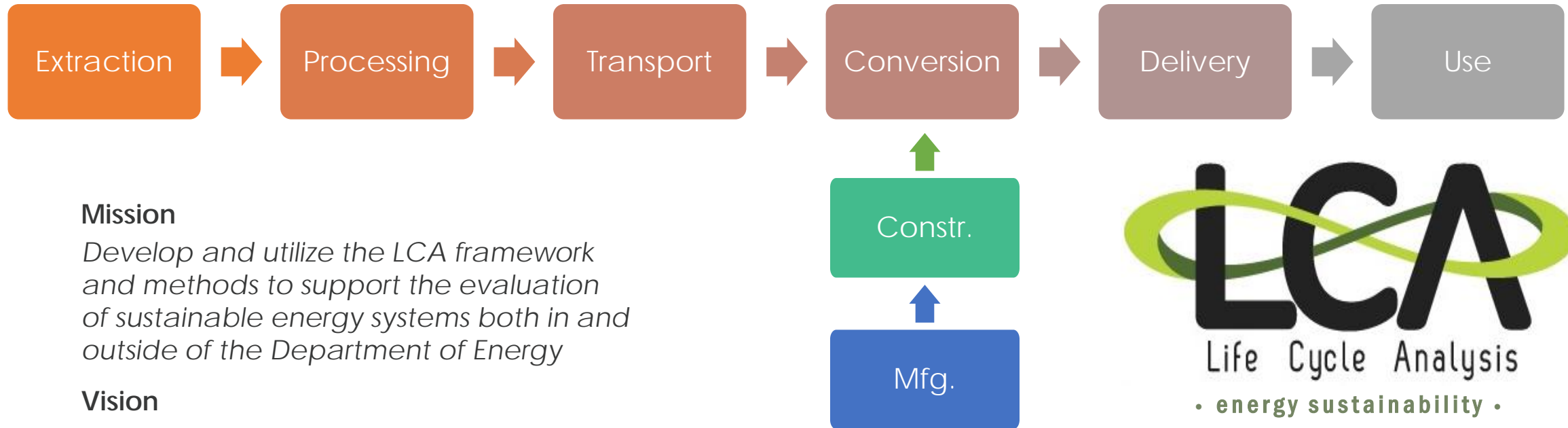
## Attribution

KeyLogic Systems, Inc.'s contributions to this work were funded by the National Energy Technology Laboratory under the Mission Execution and Strategic Analysis contract (DE-FE0025912) for support services.

# Outline

- **Life Cycle Analysis (LCA) at U.S. DOE NETL**
- **CO2U LCA in U.S. Federal Programs and Policy**
  - FOAs and 45Q
- **CO2U LCA Guidance Document Project**
  - Who, What, Why?
- **CO2U LCA Methods**
  - Carbon Accounting vs. LCA – Why do we include the source of CO<sub>2</sub>?
  - System Definition
  - Upstream CO<sub>2</sub> and Electricity Co-Product Determination

# Energy Life Cycle Analysis at NETL



## Mission

*Develop and utilize the LCA framework and methods to support the evaluation of sustainable energy systems both in and outside of the Department of Energy*

## Vision

*A world-class research and analysis team that integrates results which inform and recommend sustainable energy strategy and technology development*



# Life Cycle Analysis Team

**Tim Skone** – 20 years  
Federal Team Lead  
BS Chem Engr | P.E. Env. Engr



**Greg Cooney** – 10 years  
Contractor Team Lead  
MS Env Engr | BS Chem Engr



**James Littlefield** – 17 years  
Natural gas, system & process design  
BS Chemical Engineering



**Matt Jamieson** – 9 years  
Power systems, CO<sub>2</sub>-EOR  
BS Mechanical Engineering



**Michele Mutchek** – 6 years  
Loan program office, CO<sub>2</sub>U  
MS Civil/Env/Sust Engr | BS Env Sci



**Michelle Krynock** – 4 years  
Natural gas, fuel cells, coal  
BS Civil/Env Engr & Public Policy



**Derrick Carlson** – 7 years  
I/O LCA, Energy efficiency  
PhD/MS Civ/Env Engr | BS Chem



**Greg Zaimes** – 4 years  
Energy analysis; fuels  
PhD Civ/Env Eng; BS Physics



**Selina Roman-White** – 1 year  
Energy/environment  
BS Chem. Engr.



**Joseph Chou** – 1 year  
Energy/environment  
MS Civil & Env Engr



**Srijana Rai** – 1 year  
Energy/environment  
MS Civil & Env Engr

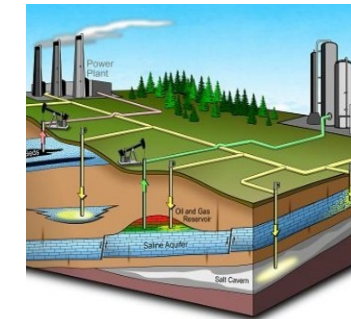
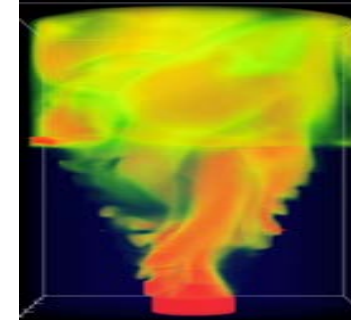


**Joe Marriott** – 12 years  
Senior Advisor  
PhD Env Engr & Public Policy



# LCA is Well Suited for Energy Analysis

- Draws a more complete picture than one focused solely on stack or tailpipe emissions
- Allows direct comparison of dramatically different options based on function or service
- Includes methods for evaluating a wide variety of emissions and impacts on a common basis
- Brings clarity to results through systematic definition of goals and boundaries



# CO2U LCA Requirements in U.S. Federal Programs and Policy

- DOE Funding Opportunity Announcements (FOAs)
  - LCA (GHG analysis) required for funding recipients under the Carbon Use and Reuse Program
  - “The FOA objective is to secure applications that will support the Carbon Storage program’s efforts to **develop technologies that utilize CO<sub>2</sub> from coal-fired power plants as a reactant to produce useful products without generating additional CO<sub>2</sub> or greenhouse gas (GHG) emissions validated via a product life cycle analysis (LCA).** Awards made from this FOA will validate the concept, estimate the technology cost, and demonstrate that the carbon lifecycle of the products offer a true carbon reduction.”

# CO2U LCA Requirements in U.S. Federal Programs and Policy

- **26 USC 45Q: Credit for carbon oxide sequestration (aka, 45Q)**
  - LCA (GHG analysis) required for tax credit (non-EOR utilization)
  - “(B) Measurement
    - (i) In general For purposes of determining the amount of qualified carbon oxide utilized by the taxpayer under paragraph (2)(B)(ii) or (4)(B)(ii) of subsection (a), such amount shall be equal to the metric tons of qualified carbon oxide which the taxpayer demonstrates, **based upon an analysis of lifecycle greenhouse gas emissions** and subject to such requirements as the Secretary, in consultation with the Secretary of Energy and the Administrator of the Environmental Protection Agency, determines appropriate, were—
      - (I) captured and permanently isolated from the atmosphere, or
      - (II) displaced from being emitted into the atmosphere,
        - through use of a process described in subparagraph (A).”



# The “Who?” “What?” and “Why?” of the U.S. DOE CO2U LCA Guidance Project

## Who?

- The LCA team at the National Energy Technology Laboratory at the U.S. DOE
- In collaboration with other researchers and Office of Fossil Energy at the DOE



[www.netl.doe.gov/lca](http://www.netl.doe.gov/lca)

# The “Who?” “What?” and “Why?” of the U.S. DOE CO2U LCA Guidance Project

## What?

- Guidance
- Tools
  - openLCA template
  - Excel template
- NETL Data
  - Unit process database
  - Algae pathway example

1. Introduction – Goals and How-to
2. Overview of LCA
3. Using openLCA
4. Using graph generating Excel tool
5. Using the GHG analysis documentation Excel template
6. Reporting structure

# The “Who?” “What?” and “Why?” of the U.S. DOE CO2U LCA Guidance Project

## What?

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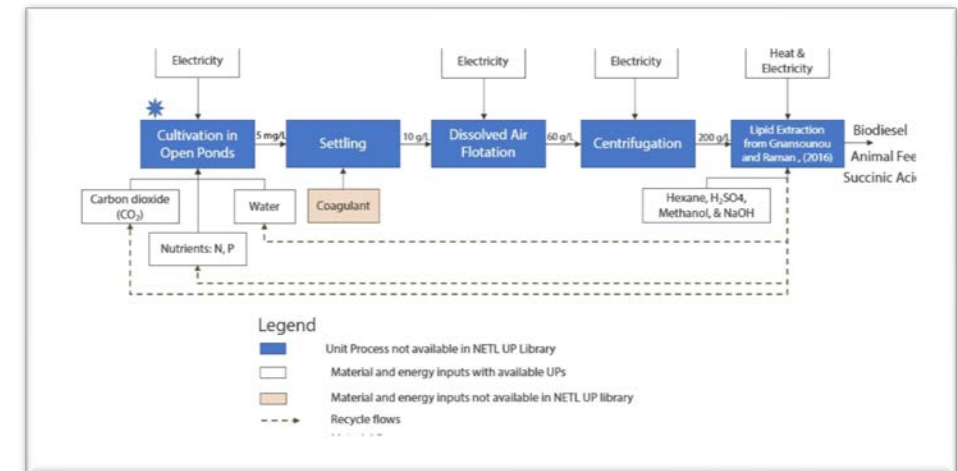
Units included in orange are either for data entry, included in that one automatically produced and should not be adjusted, or those UPs are based on one year of process operation. Recycled manufacturing construction UPs are based on the lifetime of the constructed item. Portion UPs are based on distance traveled or mass or volume x distance traveled. Red units for data collection include y, kg, kWh, m<sup>3</sup>, MJ, km, and gpc.

Process UP is the name of the unit process

Type of UP & Unit

Unit Name	Units
Energy Flow	Amount Units Amount per Factor Units Amount per Reference Flow Units
Material Flow	Amount Units Amount per Factor Units Amount per Reference Flow Units

Unit Name	Units	Amount per Factor	Units	Amount per Reference Flow	Units	Percent of Total	Col-Of-Other UPs	Recycled Flows	Carbon Intensity	Mass Output Input	Units
Energy Input Flow	Amount Units	0.001	0.001	0.001	0.001	0.001	Yes	Flows Input to Other UPs	Carbon Content (kg)	Mass Output Input	Units
Material Input Flow	Amount Units	0.001	0.001	0.001	0.001	0.001	Yes	Flows Input to Other UPs	Carbon Content (kg)	Mass Output Input	Units
Additional rows as necessary											



# The “Who?” “What?” and “Why?” of the U.S. DOE CO2U LCA Guidance Project

## Why?

- To provide technical support to U.S. federal funding recipients
- To influence the development of consistent, robust analyses for policy decisions
- To provide value to the LCA community

**CO<sub>2</sub> UTILIZATION LIFE CYCLE ASSESSMENT GUIDANCE DOCUMENT**

AT THE U.S. DEPARTMENT OF ENERGY

**WHAT IS LCA?**  
Life cycle assessment/analysis (LCA) is a technique that quantifies the comprehensive environmental impacts of a product or service over its lifetime (ISO 2006)

**WHAT IS THE VALUE OF LCA FOR CO<sub>2</sub> UTILIZATION PROJECTS?**

- Technology Improvement:** Identify sources and magnitude of impact to the environment across the value chain (Opportunity Analysis)
- Environmental Performance Benchmarking:** Compare environmental trade-offs on an equal basis (Technology Evaluation)
- Public/Investor Acceptance:** Communicate a complete understanding of environmental trade-offs to air, water, solid waste, and competing technologies (R&D/Commercialization Strategy)
- Meeting Funding Requirements:** Various government and non-governmental organizations require an environmental life cycle analysis (Project Requirement)

**WHO IS DEVELOPING IT?**  
The guidance document is being developed by the LCA team at the National Energy Technology Laboratory (NETL). Additionally, DOE held a workshop with principal investigators (PIs) receiving funding under a Funding Opportunity Announcement (FOA) and CO<sub>2</sub> utilization LCA subject matter experts to get feedback on the direction of the guidance document.

**THE GUIDANCE DOCUMENT**

**WHY IS IT BEING DEVELOPED?**  
The guidance document is being developed to help simplify the process of LCA and improve consistency in communicating results. The guidance document will be rolled out to a group of PIs receiving funding under FOAs that require LCA.

**WHAT IS IN IT?**

**Guidance:** Background on LCA and guidance on how to conduct an LCA for CO<sub>2</sub> utilization projects

**Tools:**

- NETL spreadsheet model for a simple GHG analysis populated with data and an example LCA
- openLCA model (www.openlca.org) populated with data and an example LCA

**NETL Data:**

- Comparison cases that make the same product and do not use CO<sub>2</sub> (state-of-the-art alternatives)
- Upstream and downstream processes including upstream CO<sub>2</sub> product, electricity, natural gas, fuels and fuel combustion, steel, concrete, and transportation

**CO<sub>2</sub> UTILIZATION LCA POINTS OF INTEREST**

**Methods:** When CO<sub>2</sub> is captured from a power plant and used as a feedstock for a carbon utilization process, the CO<sub>2</sub> should be treated as an intermediate product and a co-product management method should be applied to the electricity from the power plant

**Time Scales:** The carbon in carbon-based fuels enter the atmosphere as CO<sub>2</sub> soon after production during combustion, while the carbon in building products may be sequestered in a building for the life of that building or longer

**Hotspots:** CO<sub>2</sub> utilization processes can be energy intensive, potentially negating the benefit of CO<sub>2</sub> utilization; energy efficiency is an area of improvement for CO<sub>2</sub> utilization projects

**Impact Categories:** CO<sub>2</sub> utilization LCA tends to focus on GHGs, because of the CO<sub>2</sub> co-product; analyses that include other impact categories related to water, human health, etc. are needed

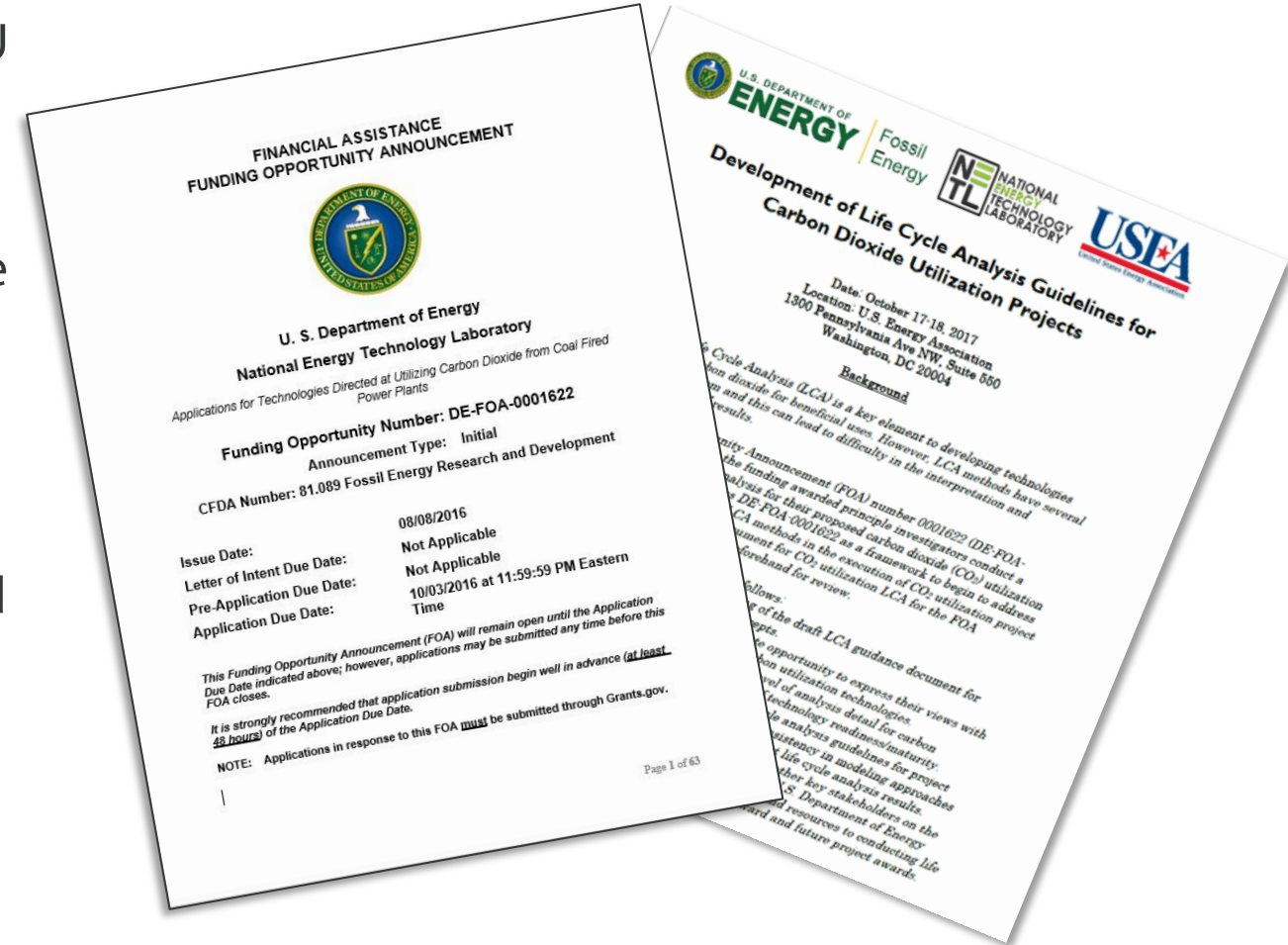
**The Guidance Document will be available in the Fall of 2018 at [www.netl.doe.gov/LCA](http://www.netl.doe.gov/LCA)**

**CONTACT INFORMATION**  
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michele.mutchek@netl.doe.gov

U.S. DEPARTMENT OF ENERGY | NETL NATIONAL ENERGY TECHNOLOGY LABORATORY

# This Project Responds to Funding Requirements and Will Be Released Soon

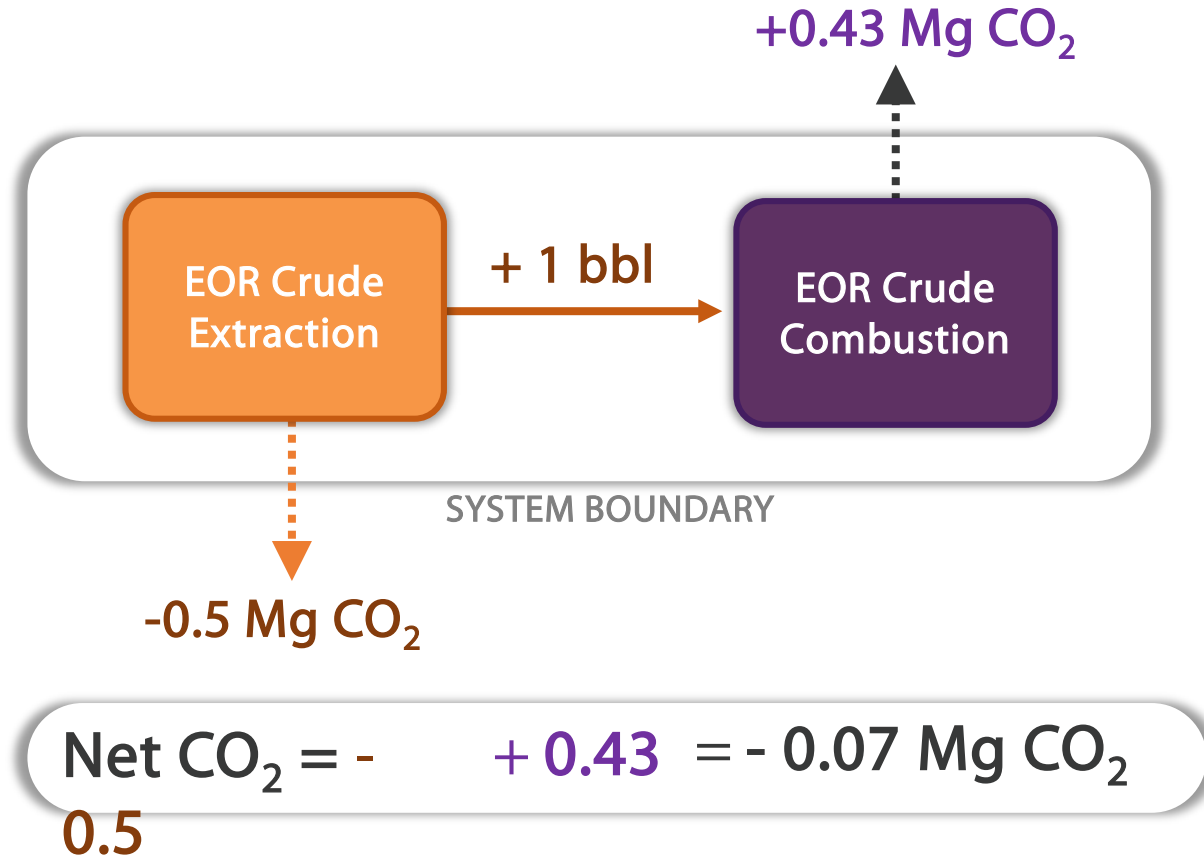
- 2016
  - Funding Opportunity Announcement for CO<sub>2</sub>U projects establishes requirement for life cycle greenhouse gas (GHG) analysis
- 2017
  - August - First exploratory draft of the guidance document is completed
  - October - A workshop was held in D.C. with subject matter experts and CO<sub>2</sub>U project principal investigators
- 2018
  - Second draft of guidance document is finalized based on stakeholder feedback
- 2019
  - March - Guidance document will be released to the public



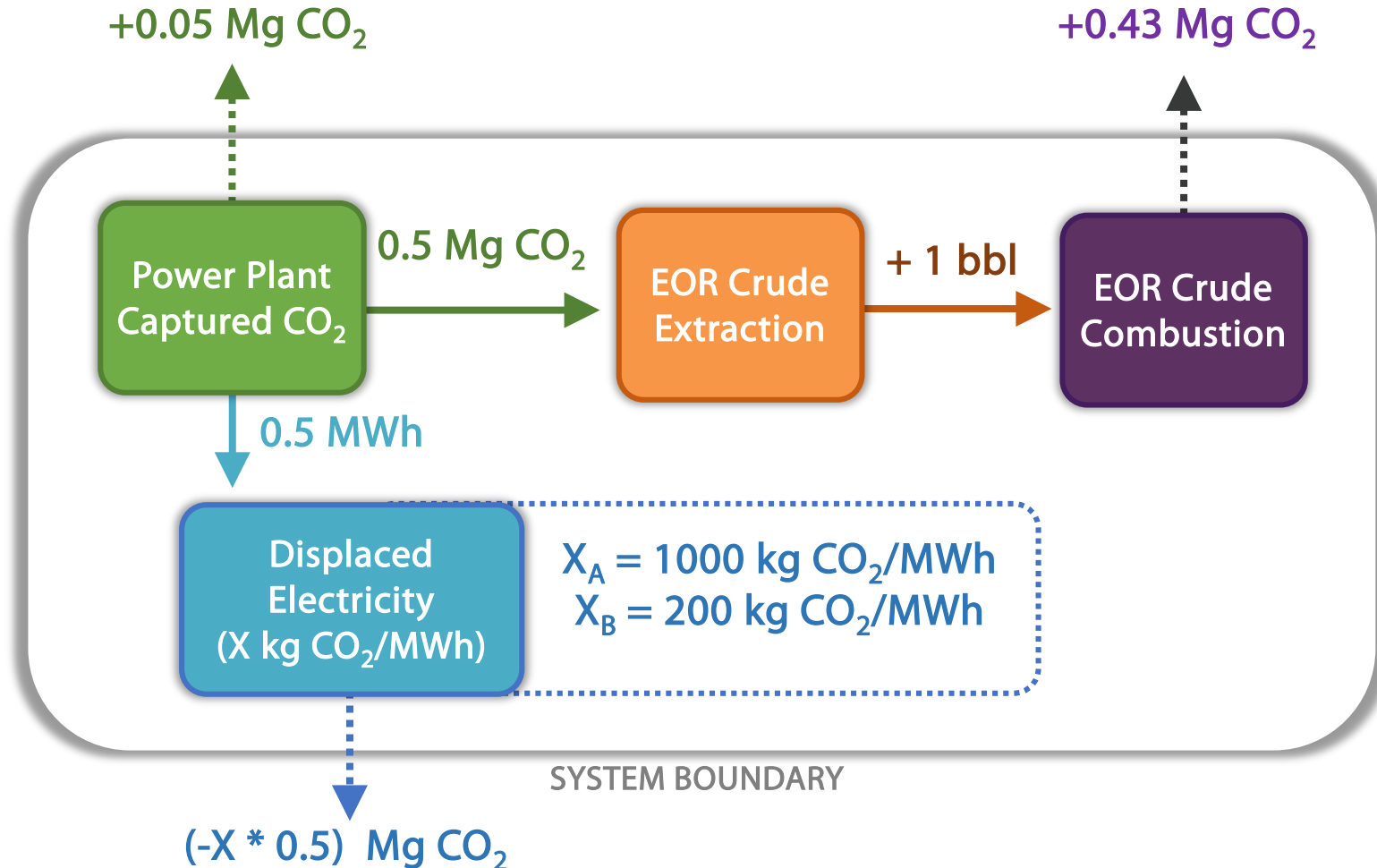
# Carbon Accounting vs. LCA – Why do we include the source of CO<sub>2</sub>?

- We are not directly reducing the amount of CO<sub>2</sub> in the atmosphere, rather, we are relying on an indirect reduction in those emissions
  - Reduction is a consequence of choosing one option over another
  - If a captured power plant is deployed, it will displace (retire from the existing market or be built in lieu of) some other method of generating electricity (most likely one that is more GHG intensive)
- Capturing CO<sub>2</sub> alone yields an improvement in a comparative context relative to another technology option
- In the near-term, this line of thinking is important to quantifying the size of the benefit

# CARBON BALANCE ACCOUNTING A P P R O A C H



# LCA ACCOUNTING APPROACH

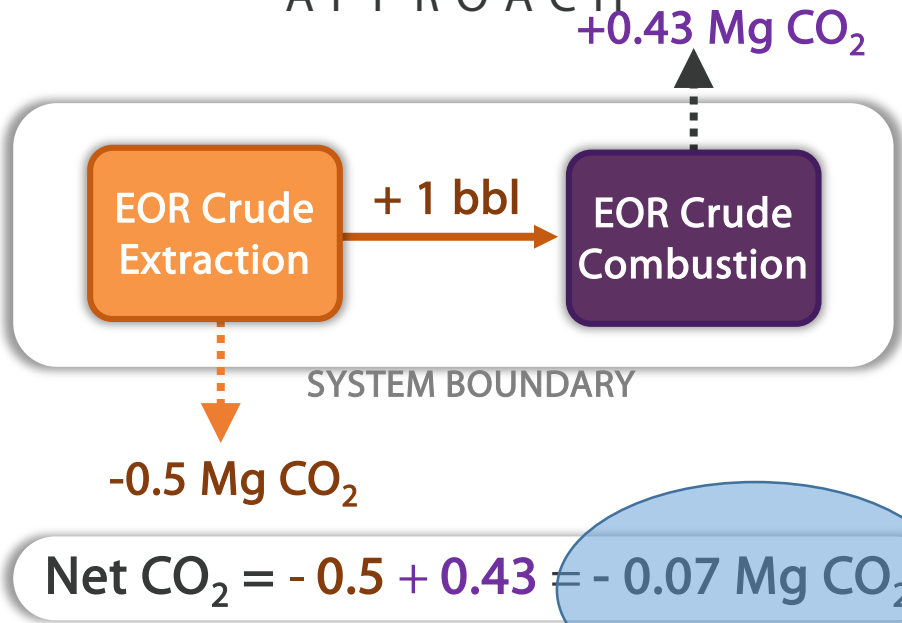


$$\text{Net CO}_2 \text{ [A]} = + 0.43 + 0.05 - ([0.5] \times 1.0) = - 0.02 \text{ Mg}$$

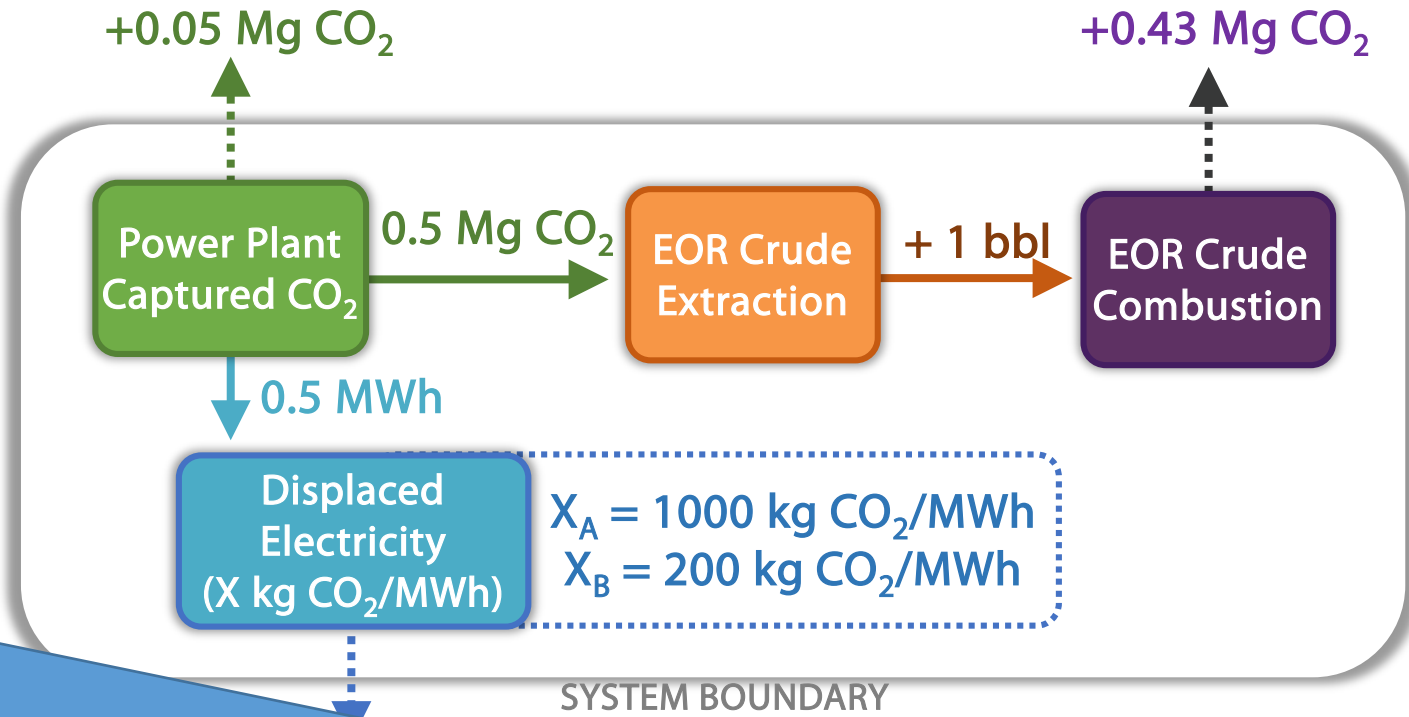
$$\text{Net CO}_2 \text{ [B]} = + 0.43 + 0.05 - ([0.5] \times 0.2) = + 0.38 \text{ Mg}$$



# CARBON BALANCE ACCOUNTING APPROACH



# LCA ACCOUNTING APPROACH



$\text{Net CO}_2 [\text{A}] = +0.05 - ([0.5] \times 1) + 0.43 = -0.02 \text{ Mg}$   
 $\text{Net CO}_2 [\text{B}] = +0.05 - ([0.5] \times 0.2) + 0.43 = +0.38 \text{ Mg}$

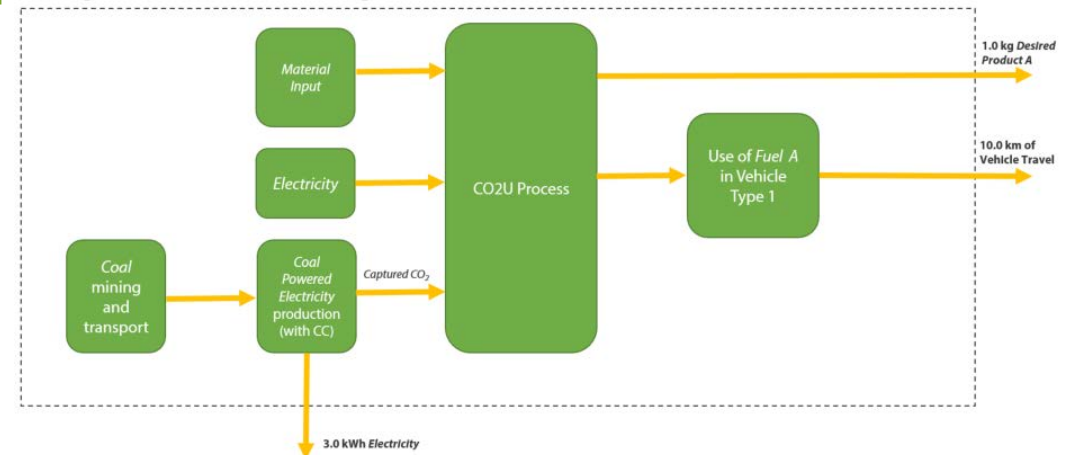
For reference, the GHG emissions for the extraction and combustion U.S. average crude, based on a characterization of the various technologies composing the mix are 0.49 Mg CO<sub>2</sub>/bbl.

# The LCA Guidance Makes Recommendations Related to Methods, Data, and Tools

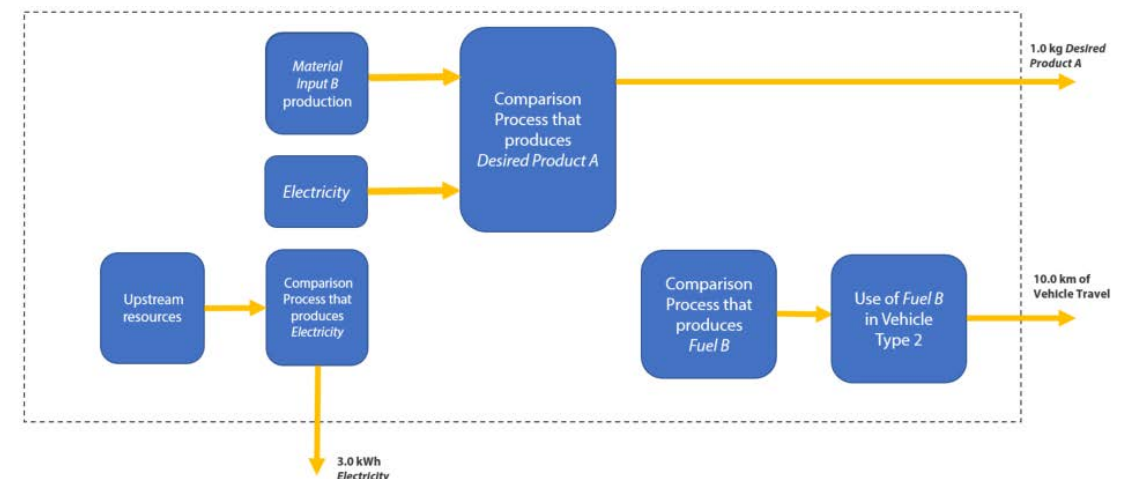
## Recommendations on:

- Determining the comparison system
- Establishing the system boundaries
- What modeling/reporting platform(s) to use
- What upstream CO<sub>2</sub> profiles to use
- And more...

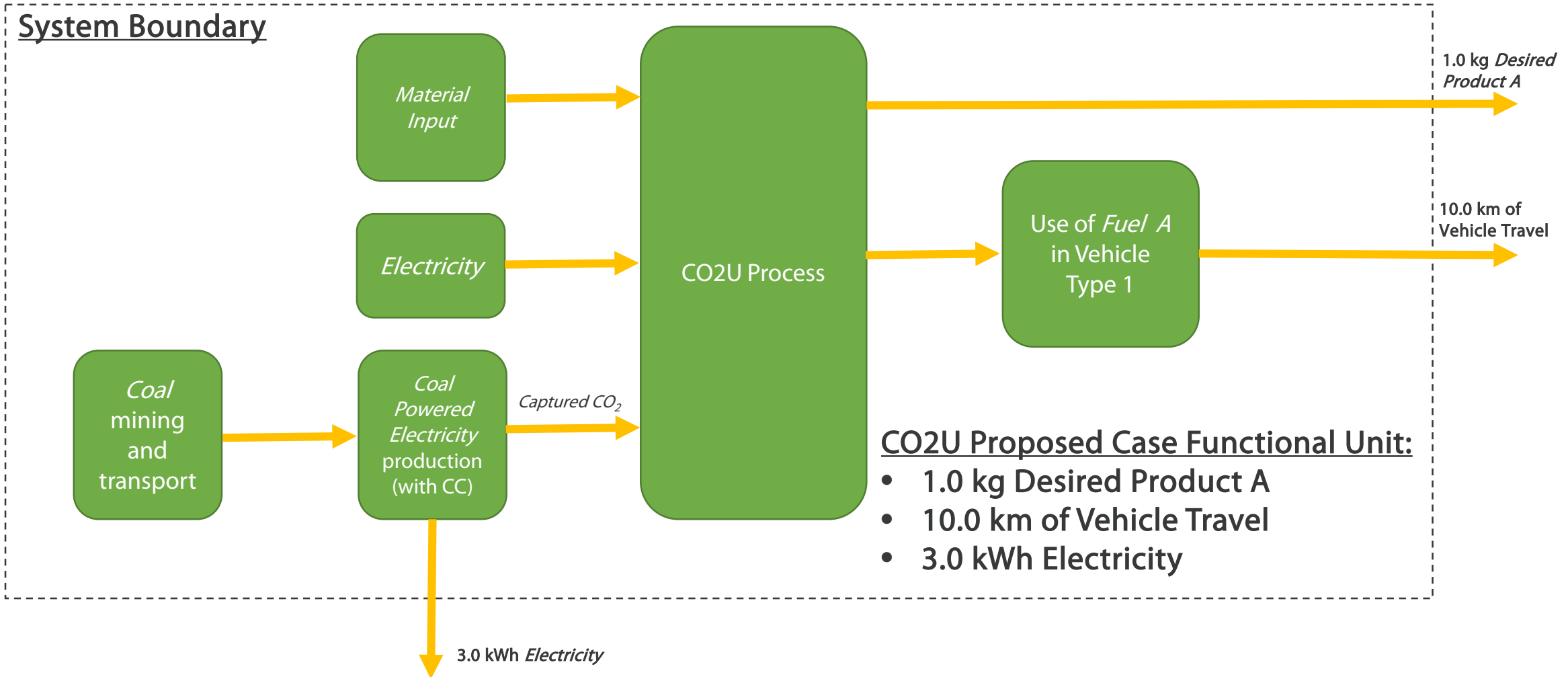
## Proposed Case



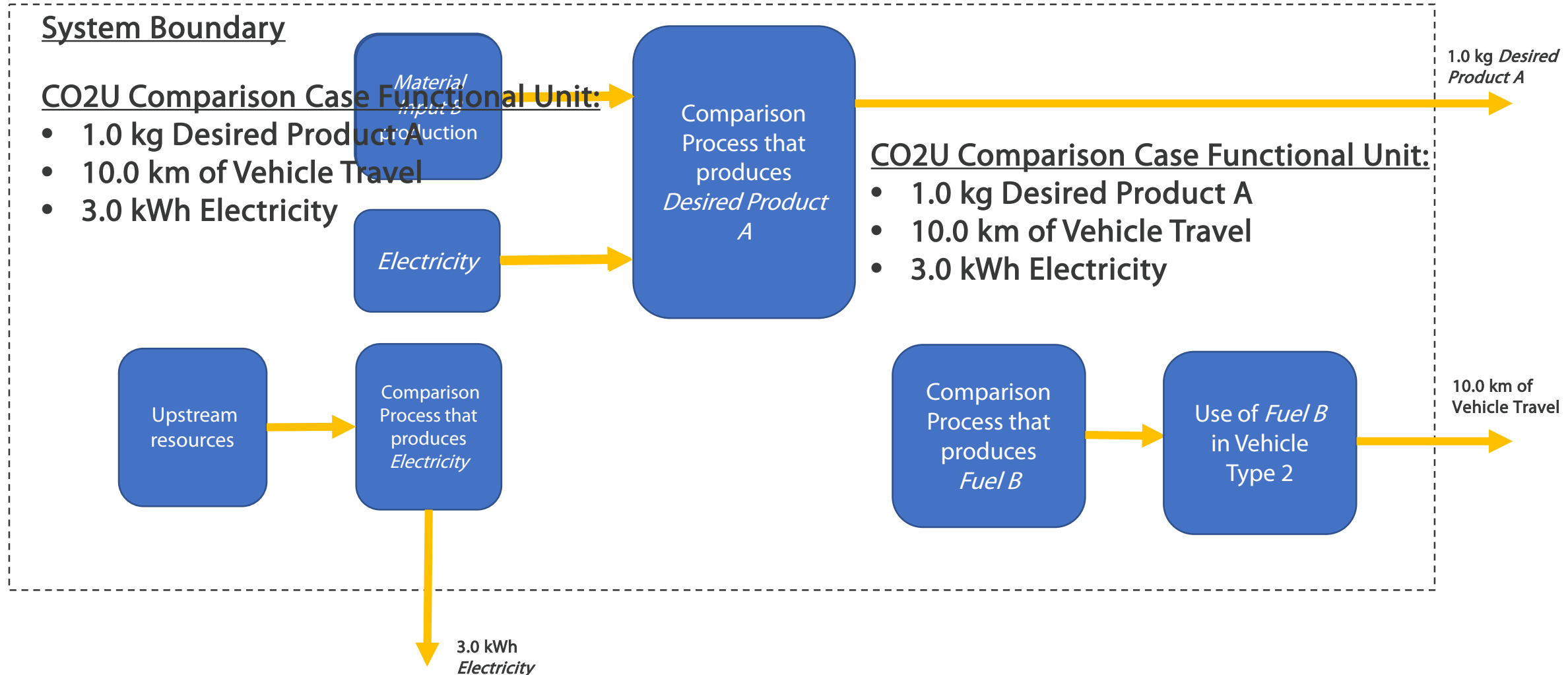
## Comparison Case



# Example CO<sub>2</sub>U Proposed Case



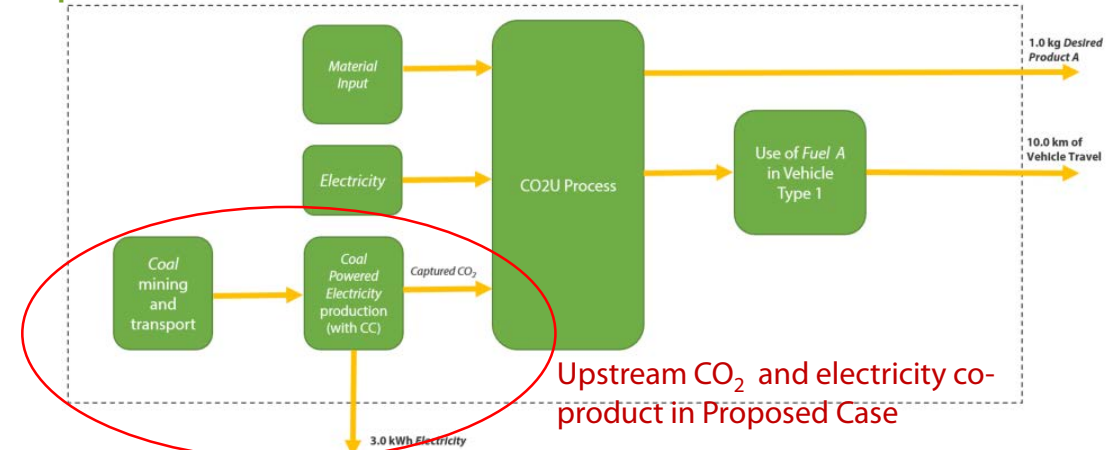
# Example CO2U Comparison Case



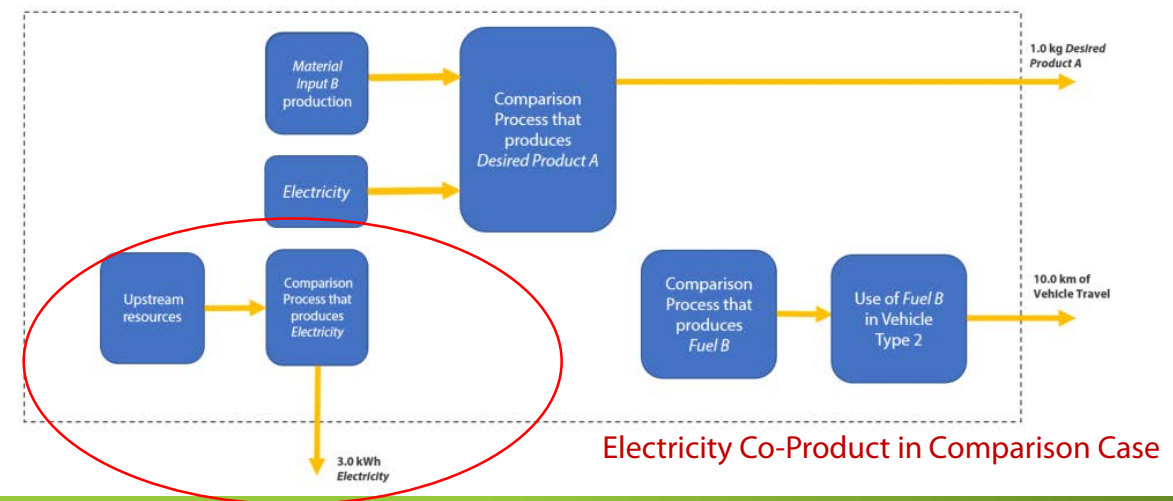
# One Area of Method Development is Upstream CO<sub>2</sub> and Electricity Co-Product Determination

- Including upstream CO<sub>2</sub> in the boundary – results in an electricity co-product in the system boundary
- What should be the source of the electricity in the comparison case?
- How do we maintain functional equivalence between the cases?

## Proposed Case



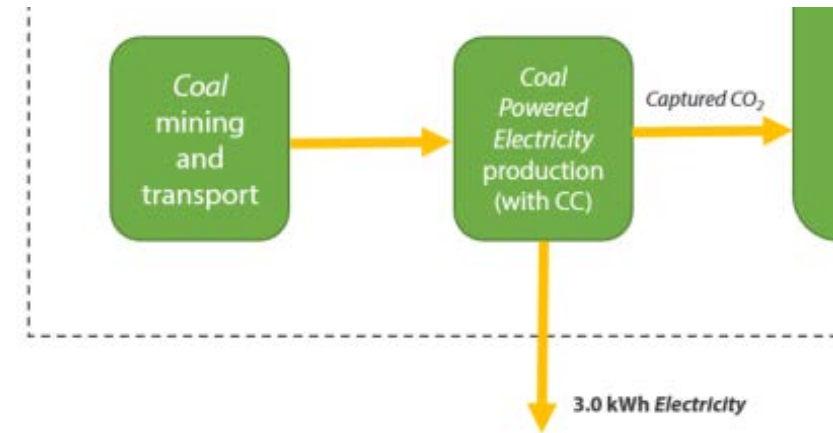
## Comparison Case



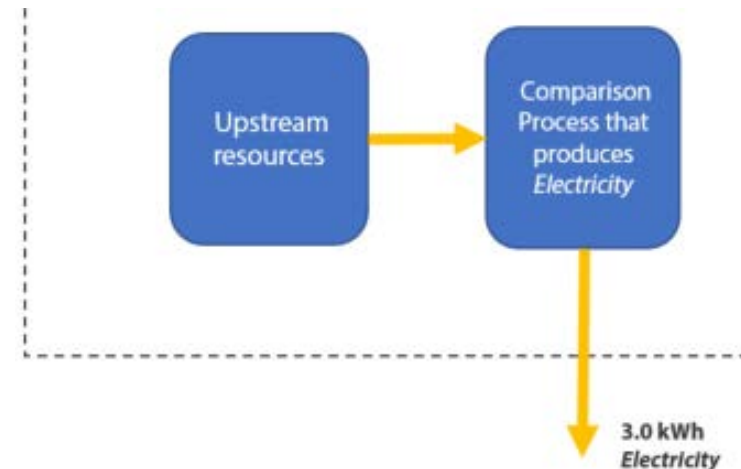
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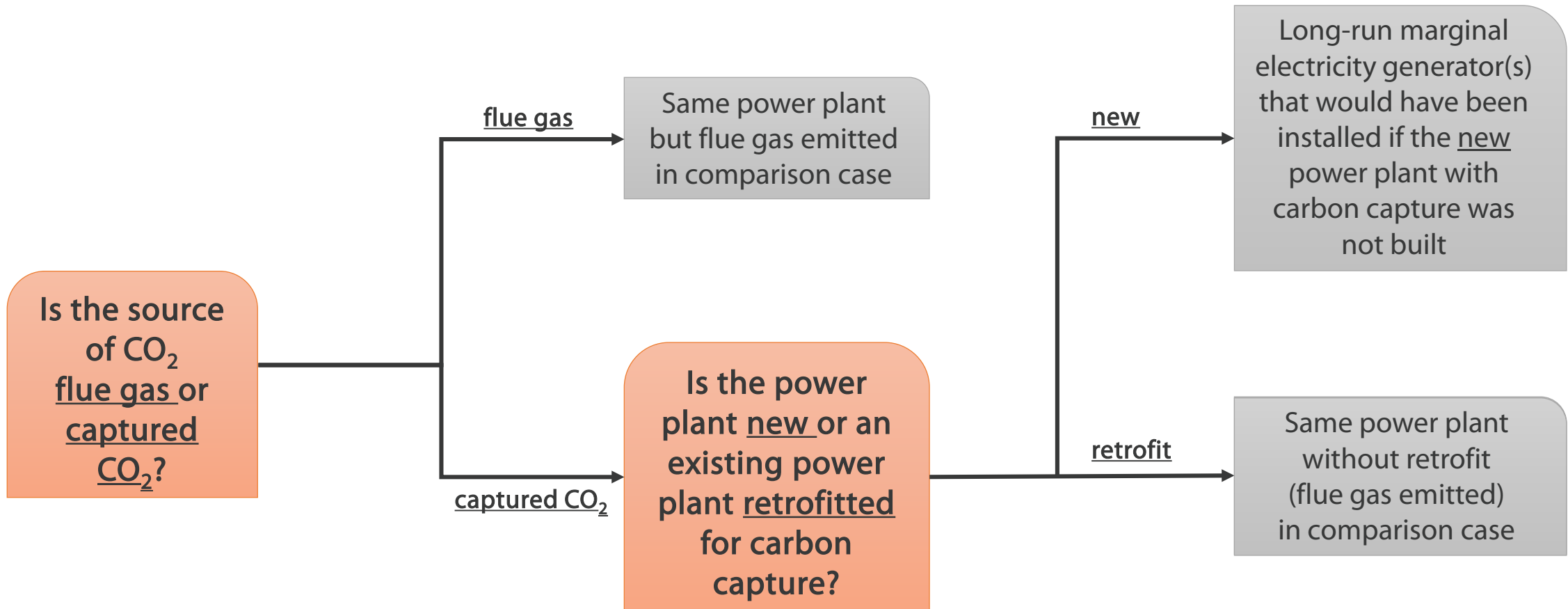
## Proposed Case



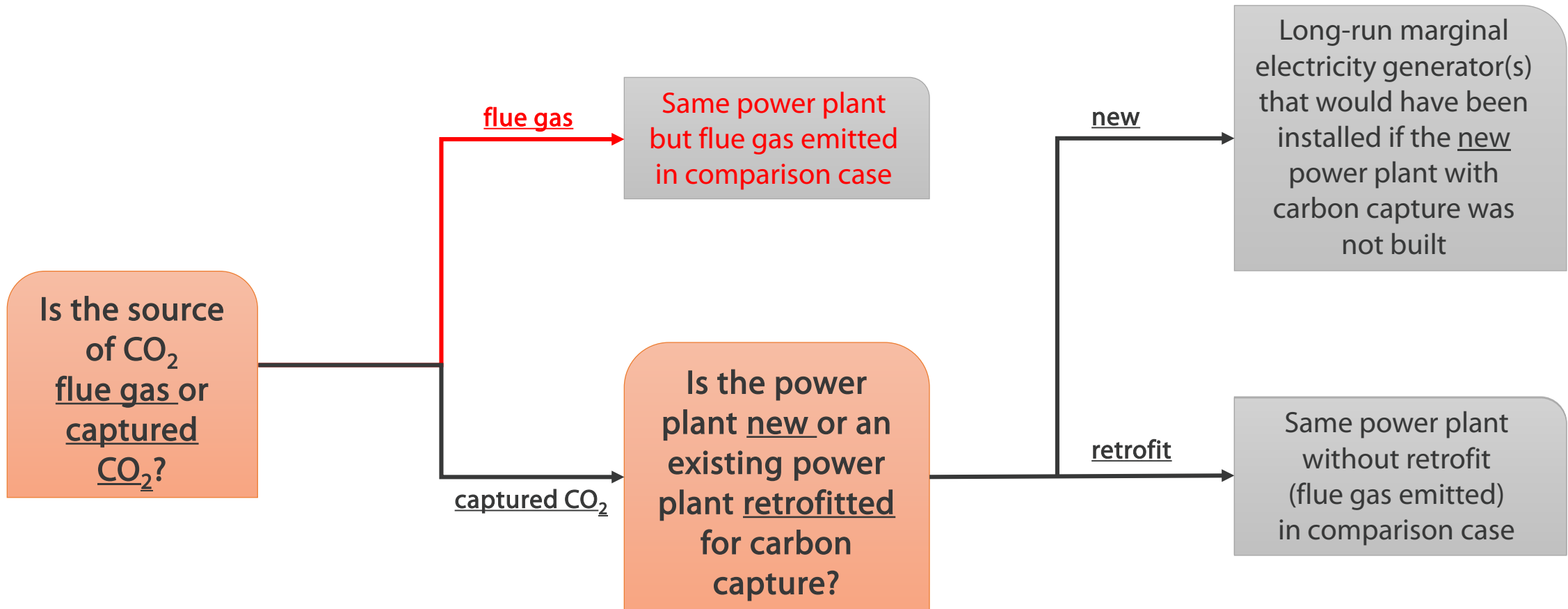
## Comparison Case



# The Electricity in the Comparison Case Depends on How the CO<sub>2</sub> Is Procured for CO<sub>2</sub>U



# What If the Source of the CO<sub>2</sub> Is Flue Gas?

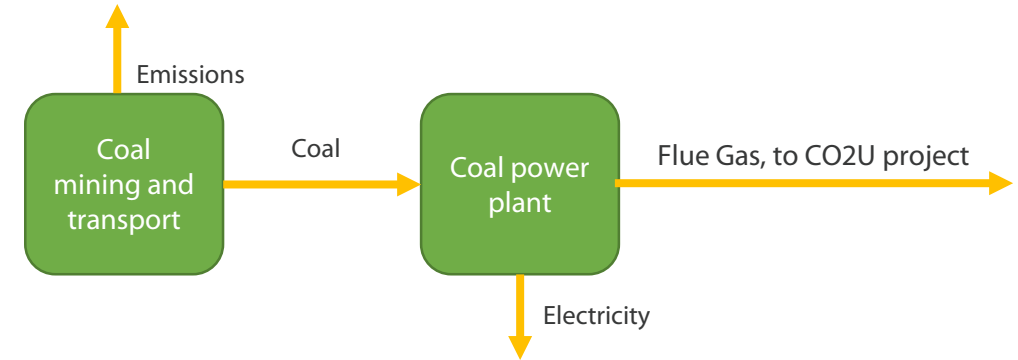




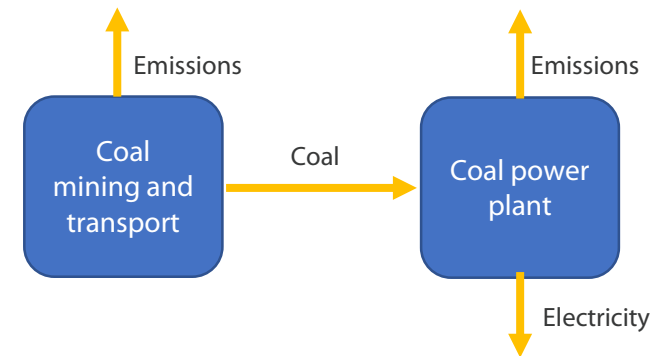
# What If the Source of the CO<sub>2</sub> Is Flue Gas?

- Assume diversion of flue gas for alternative use does not affect the net electricity output the power plant prior to diversion of the flue gas
- Comparison case is the same power plant with the CO<sub>2</sub> being emitted rather than used

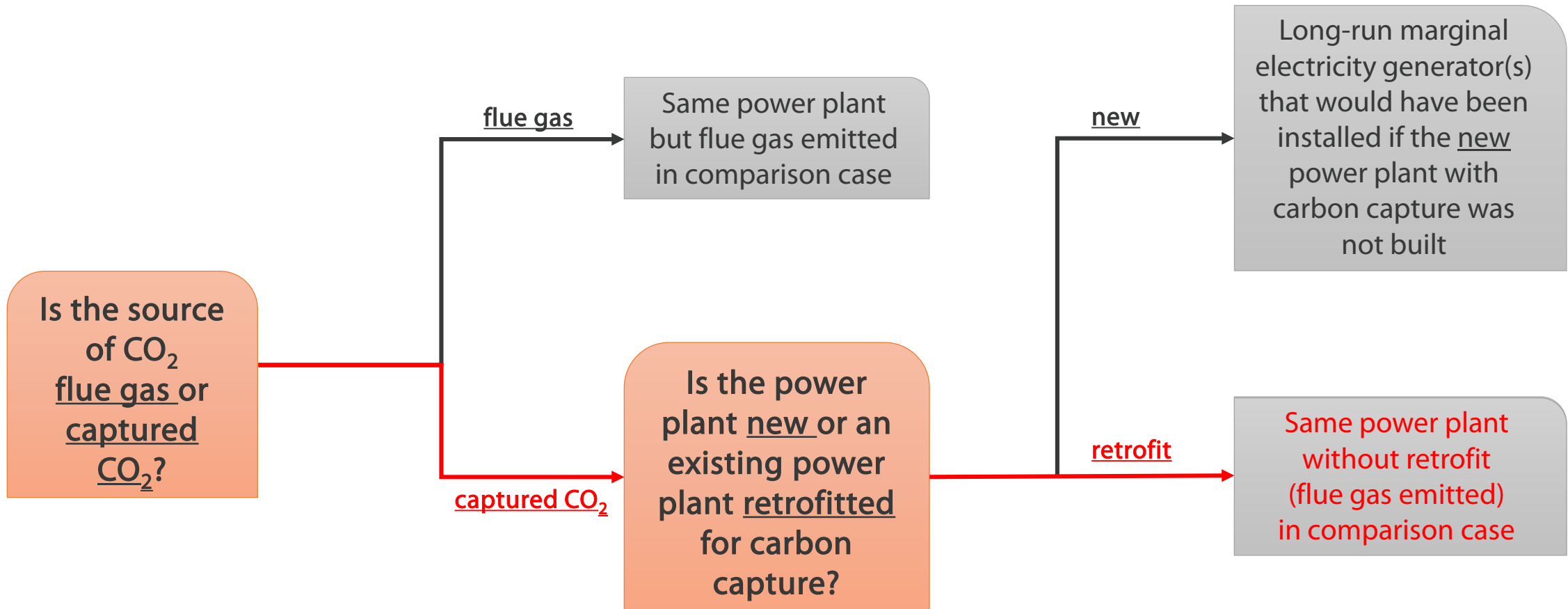
## Upstream CO<sub>2</sub> in Proposed Case



## Electricity Co-product in Comparison Case



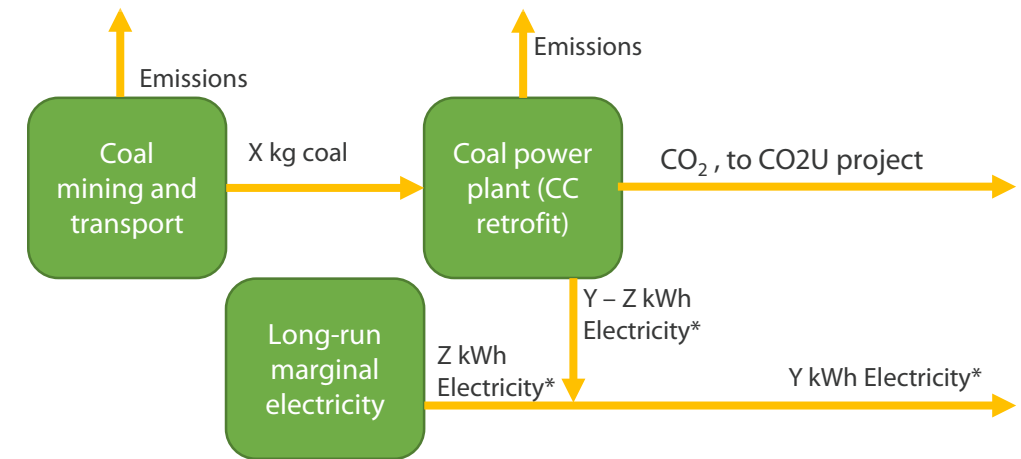
# What If the Source of the CO<sub>2</sub> Is Captured CO<sub>2</sub> From a Retrofitted Power Plant?



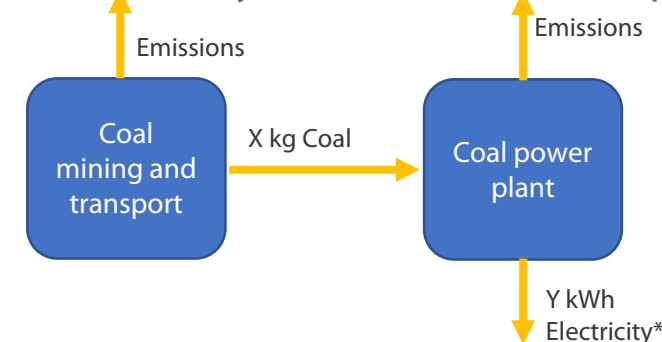
# What If the Source of the CO<sub>2</sub> Is Captured CO<sub>2</sub> From a Retrofitted Power Plant?

- IF, retrofitting the power plant results in a decrease in the net power output, then the “Proposed CO<sub>2</sub>U Case” will require “make-up” electricity
- “Make-up” electricity shall be equal to the electricity consumption mix (marginal supplier) in the geographical area defined in the study scope

## Upstream CO<sub>2</sub> in Proposed Case



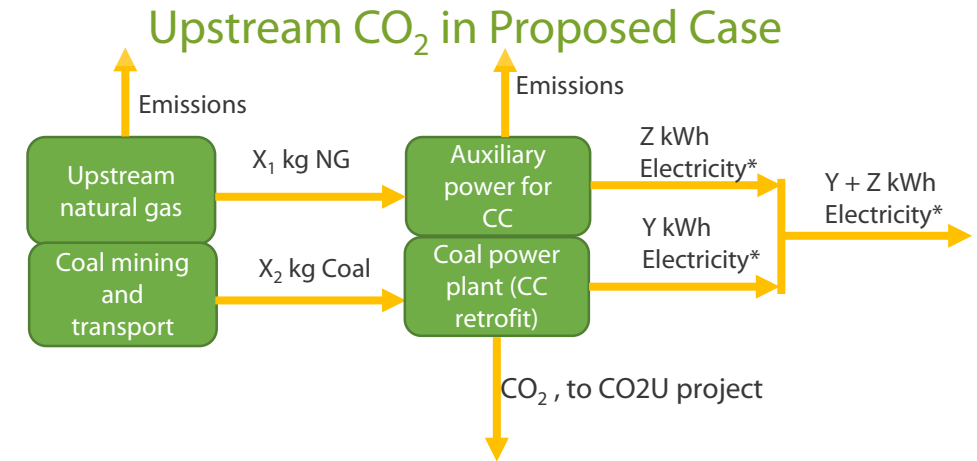
## Electricity Co-Product in Comparison Case



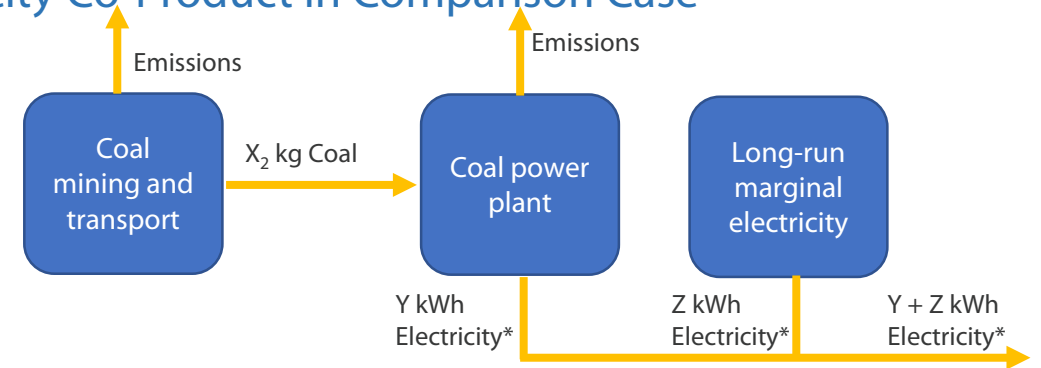
\*The carbon capture plant loses some of its capacity to run the carbon capture equipment, so make-up electricity in the proposed case is required to have the same amount of electricity output.

# What If the Source of the CO<sub>2</sub> Is Captured CO<sub>2</sub> From a Retrofitted Power Plant?

- IF, retrofitting the power plant **DOES NOT** result in a change in the net power output, then assume external source of heat and power to operate the carbon capture and compression system (e.g., Petra Nova)
- IF, the auxiliary power system produces excess electricity, in turn increasing the net power output of the “Proposed CO<sub>2</sub>U Case”, then additional “make-up” electricity has to be added to the “Comparison Case” to ensure system equivalence

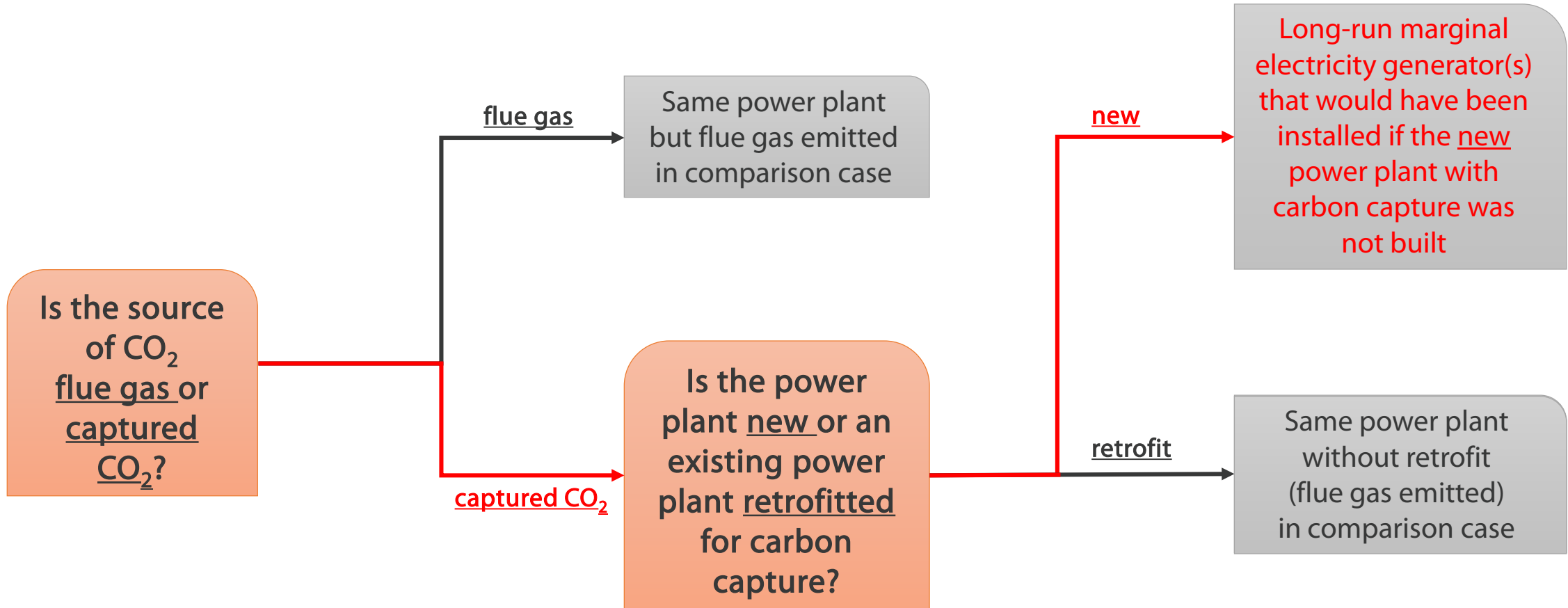


## Electricity Co-Product in Comparison Case



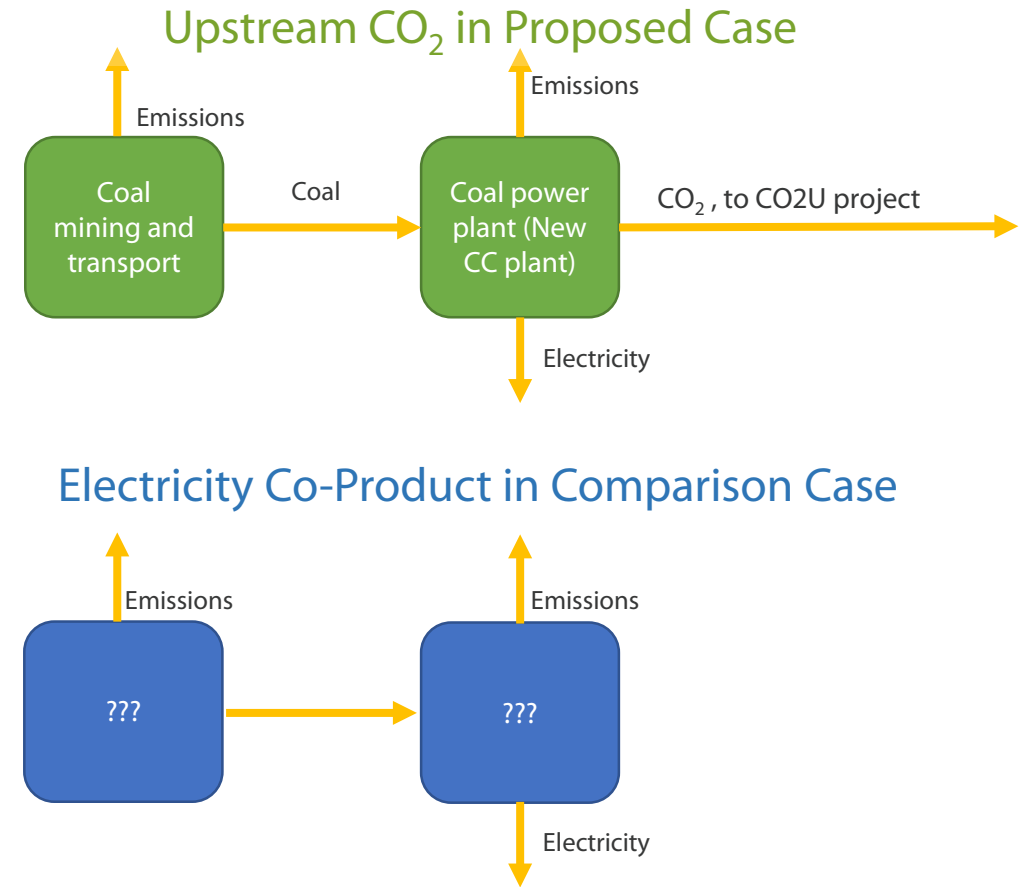
\*The carbon capture plant gains capacity by installing auxiliary power to run the carbon capture equipment, so make-up electricity in the comparison case is required to have the same amount of electricity output.

# What If the Source of the CO<sub>2</sub> Is Captured CO<sub>2</sub> From a New Power Plant?



# What If the Source of the CO<sub>2</sub> Is Captured CO<sub>2</sub> From a New Power Plant?

- The comparison case is determined based on the long-run marginal electricity generator(s) that would have been installed if the new power plant with carbon capture was not built
- The electricity generator(s) are determined using capacity expansion modelling for the on-line (start) year of the power plant for the stated geographical scope of the study



# What If the Source of the CO<sub>2</sub> Is Captured CO<sub>2</sub> From a New Power Plant?

1. Determine year of proposed CO<sub>2</sub>U project deployment (same as power plant on-line [start] year)
2. Compile mix of technologies composing capacity additions for that year
3. Develop weighted emission factors

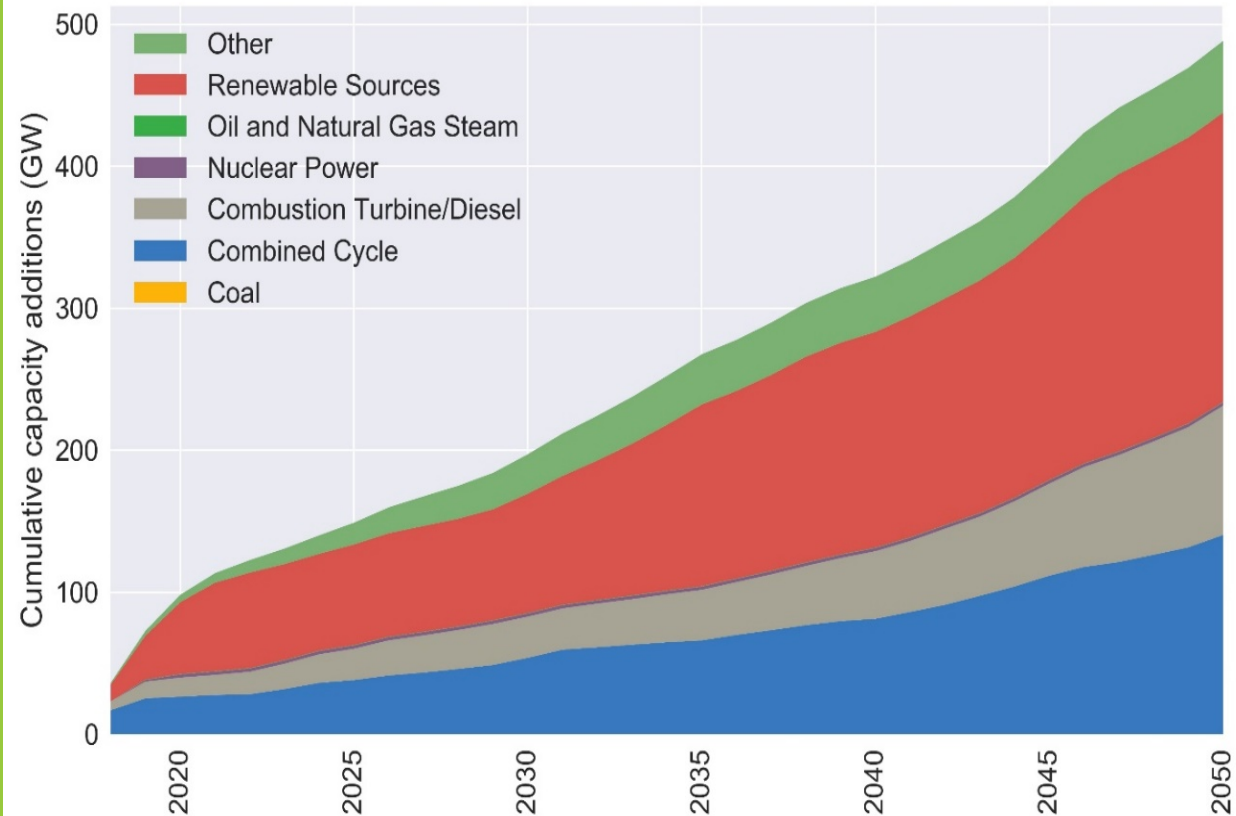
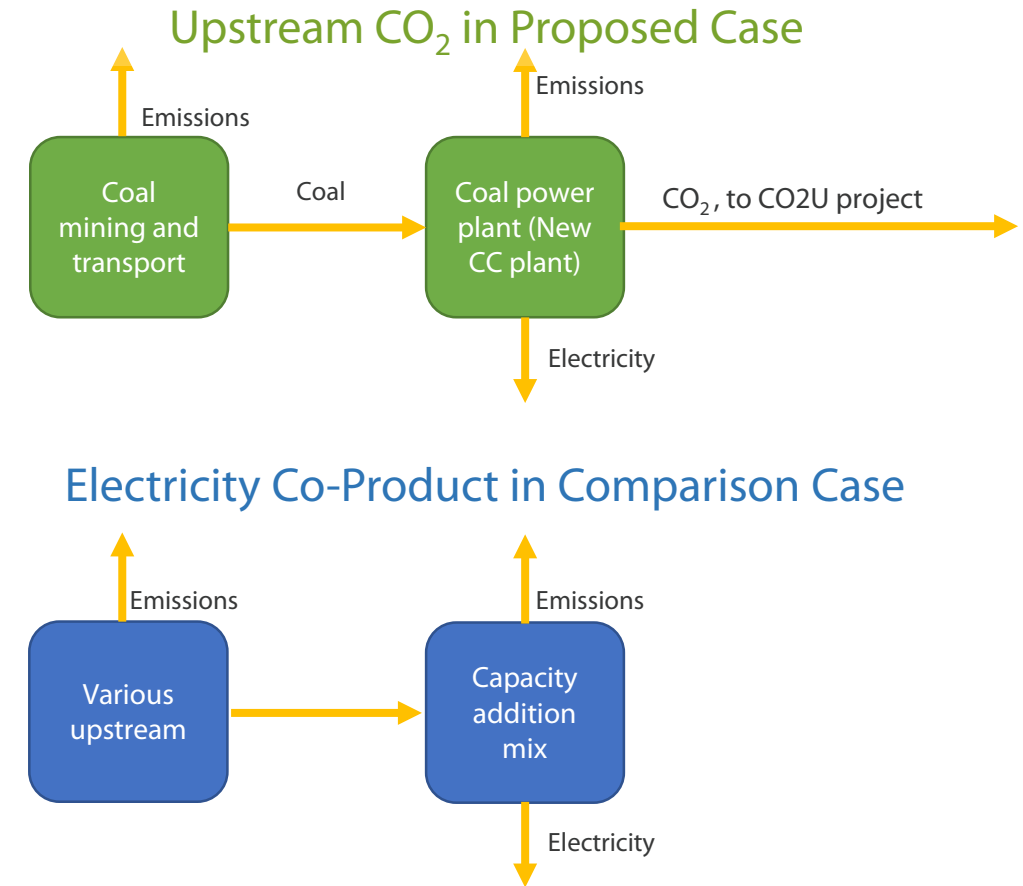


Figure 1. Cumulative capacity additions in the U.S. electric sector, based on the U.S. EIA's Annual Energy Outlook 2018, reference scenario. Source: EIA Annual Energy Outlook 2018, Electricity Generating Capacity

# What If the Source of the CO<sub>2</sub> Is Captured CO<sub>2</sub> From a New Power Plant?

1. Determine year of proposed CO<sub>2</sub>U project deployment (same as power plant on-line [start] year)
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# Conclusions

- CO<sub>2</sub>U systems are unique in that they combine two sectors (electricity and CO<sub>2</sub>U product)
- Consistent LCA approaches are necessary to ensure comparability and fairness
- The goal of the NETL CO<sub>2</sub>U Guidance is to determine the environmental preferability of utilizing captured carbon to produce products – this necessitates a consequential LCA approach



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