The Challenge of Co-product Management for Large-scale Energy Systems: Power, Fuel and CO_2

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Co-product Management

Determining who's responsible for their slice of the pie!

Energy Allocation

Mass Allocation

Attributional versus Consequential LCA

System Expansion

Model Uncertainty

Displacement

Economic Allocation

Exergy Allocation

1 + 1 = 2

Marginal versus Average

Electricity, Fuel, CO_2

Virtual Partitioning

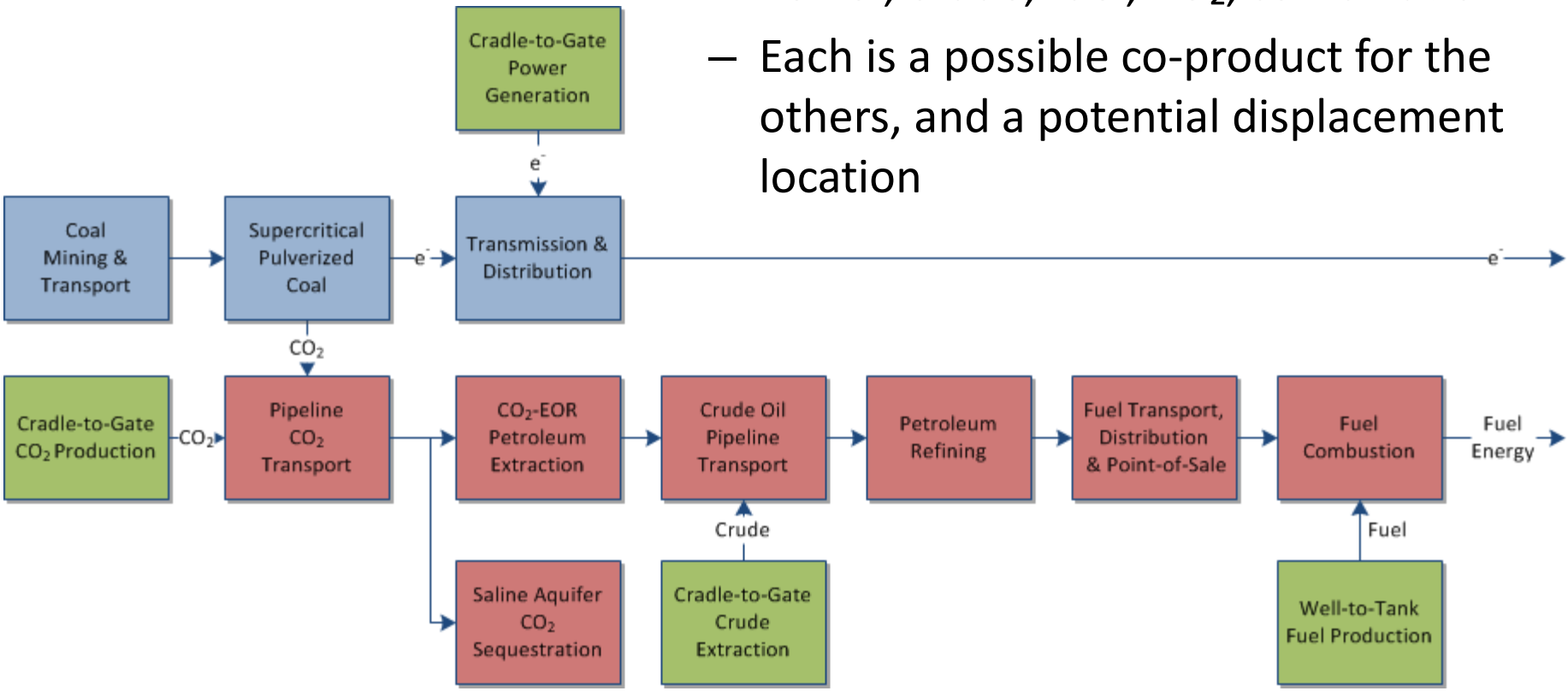
Dependent or Independent Markets

One Plant or Large Scale Implementation (change)

Full System: Advanced Coal Power with CO_2 Capture, sent to EOR or Aquifer

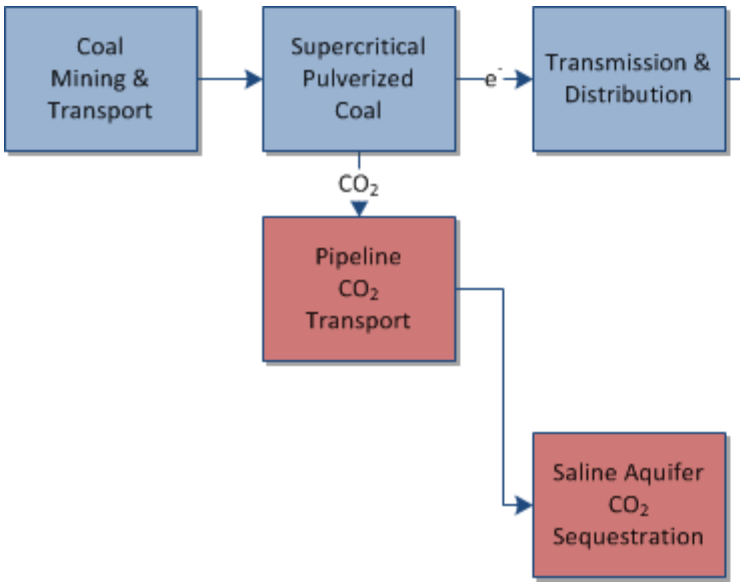
Possible functional units:

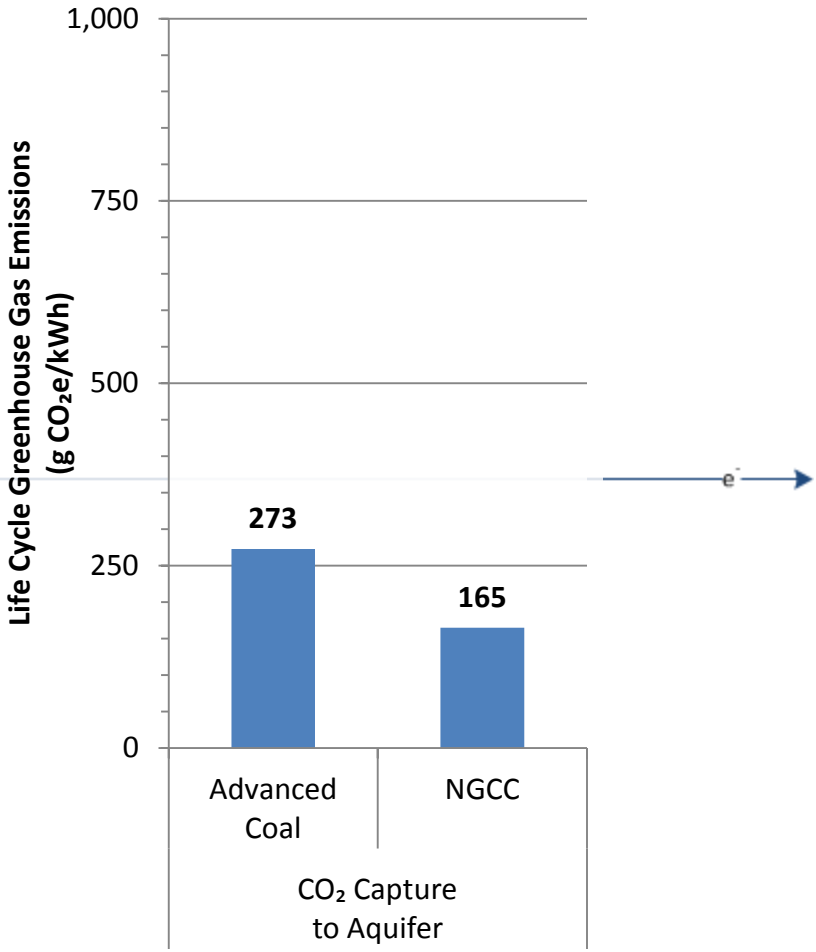
- Power, crude, fuel, CO_2, *combination*
- Each is a possible co-product for the others, and a potential displacement location



Simplest Version: Power is the Only Product, CO_2 is a Waste

Although CO_2 is a 2nd tracked flow, it is defined as a waste, so product of interest is assigned all the burdens of waste storage and management



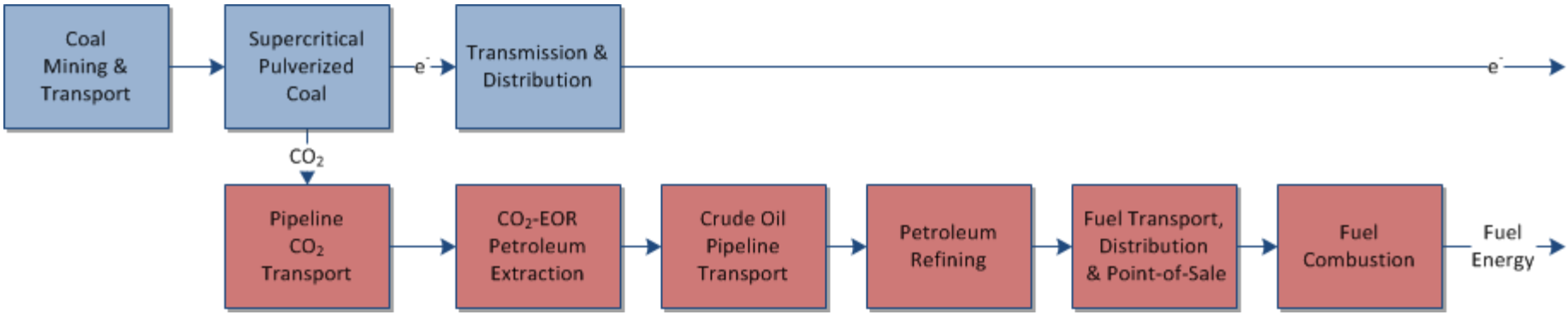


Captured CO_2 sent to Enhanced Oil Recovery

2 Products, Perform Co-product Allocation

- **Electricity has no mass or volume, entities are economically independent, so *energy* only physical basis for allocation**

- **Issue: 1 MJ of electricity ≠ 1 MJ of fuel, combusted**
  - Could choose an end use for each and measure exergy, but this ignores all other possible end uses and the differences in end use efficiency

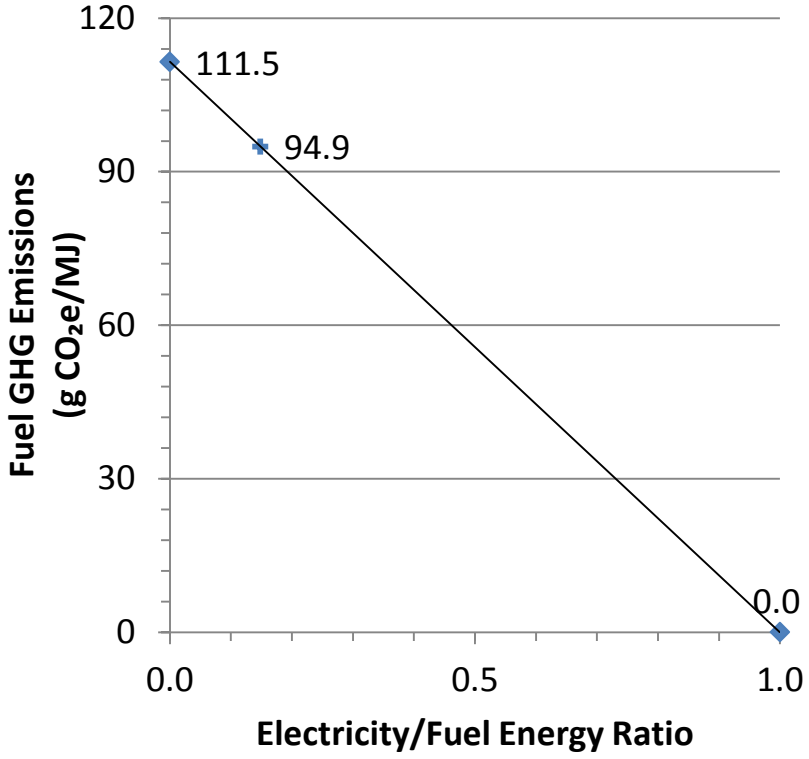


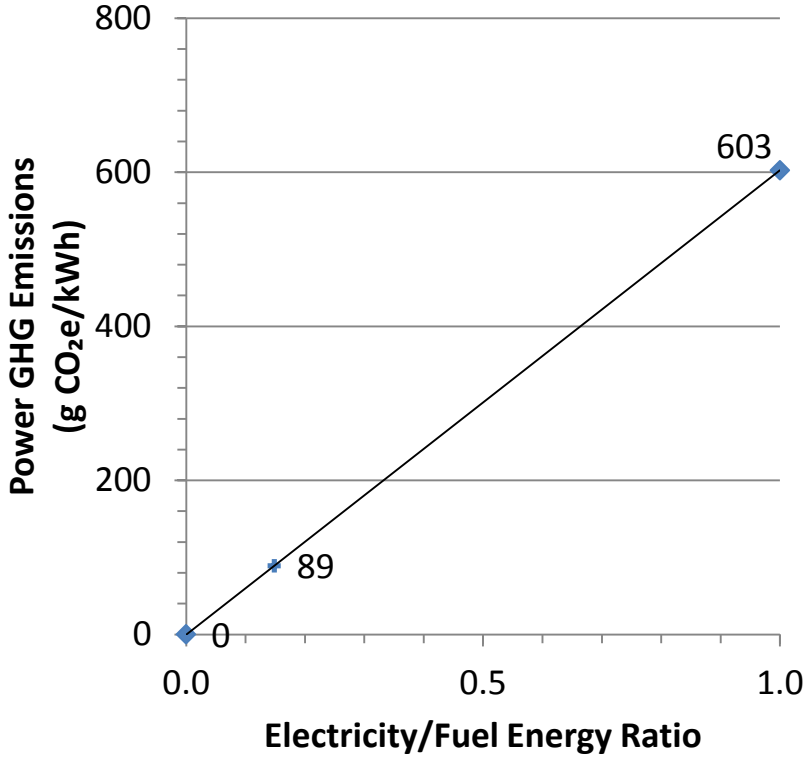
If end uses (and associated efficiencies) are not explicitly chosen, an implicit choice has been made:

1 MJ electricity = 1 MJ fuel, combusted

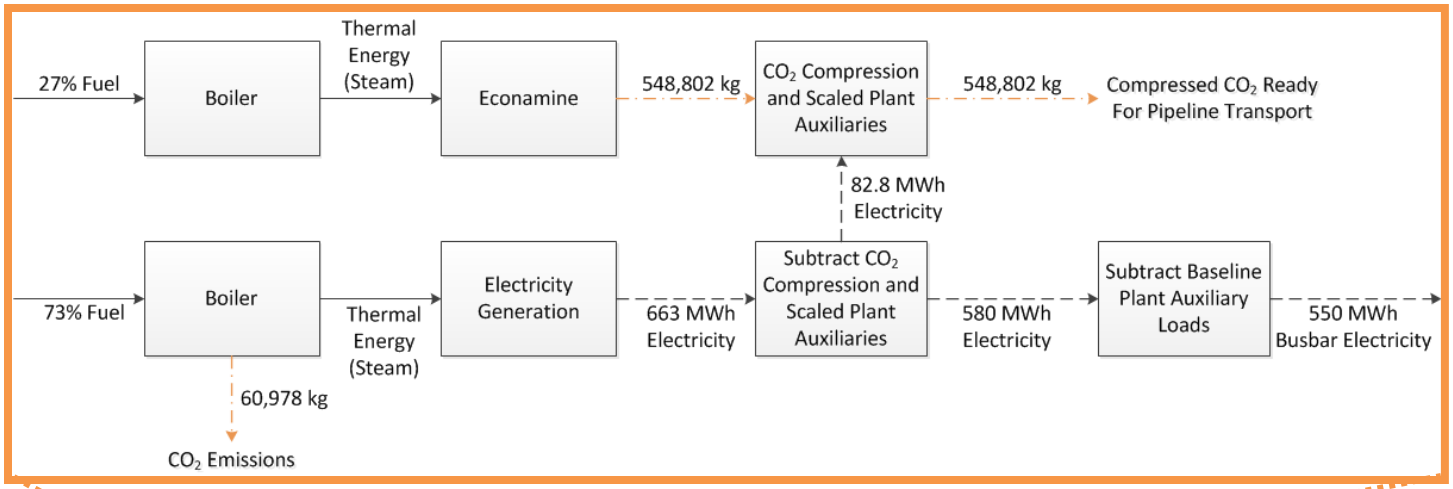
Energy Allocation Uncertainty Handled Parametrically

Uncertainty about useful work contained in 1 MJ of coal-fired power or combusted fuel leads to uncertainty bounds wide enough to render the result useless



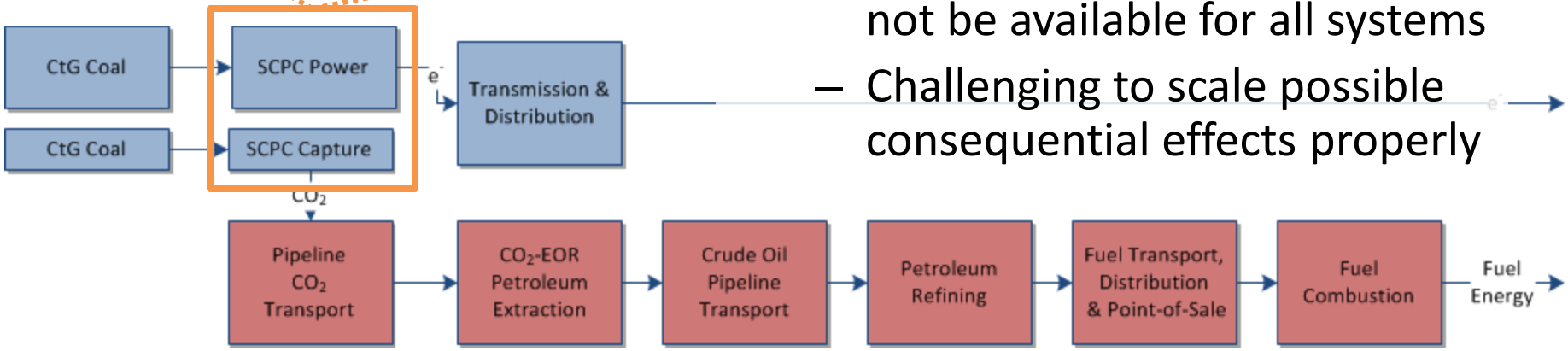


By Partitioning the Power Plant, Another Energy Allocation Option Appears



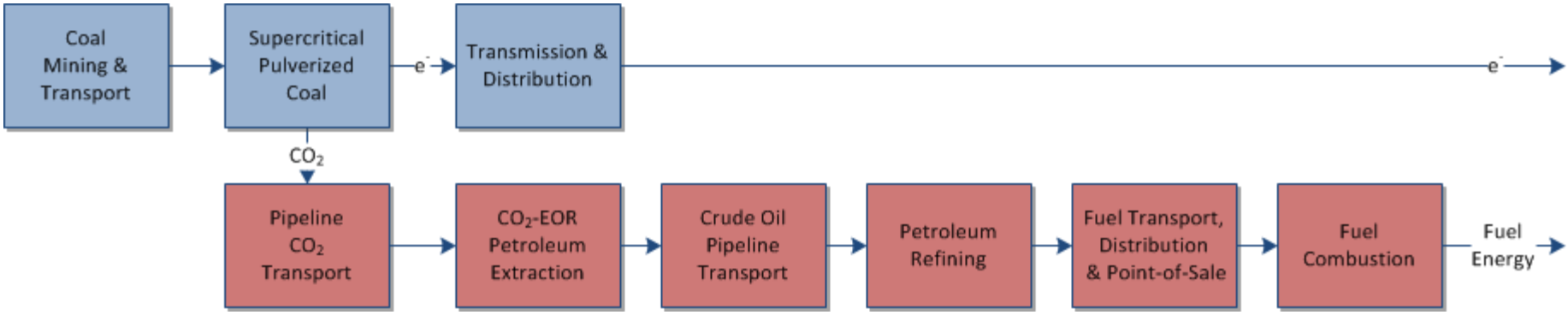
Potential issues:

- Partitioning information may not be available for all systems
- Challenging to scale possible consequential effects properly



Use System Expansion, no Displacement

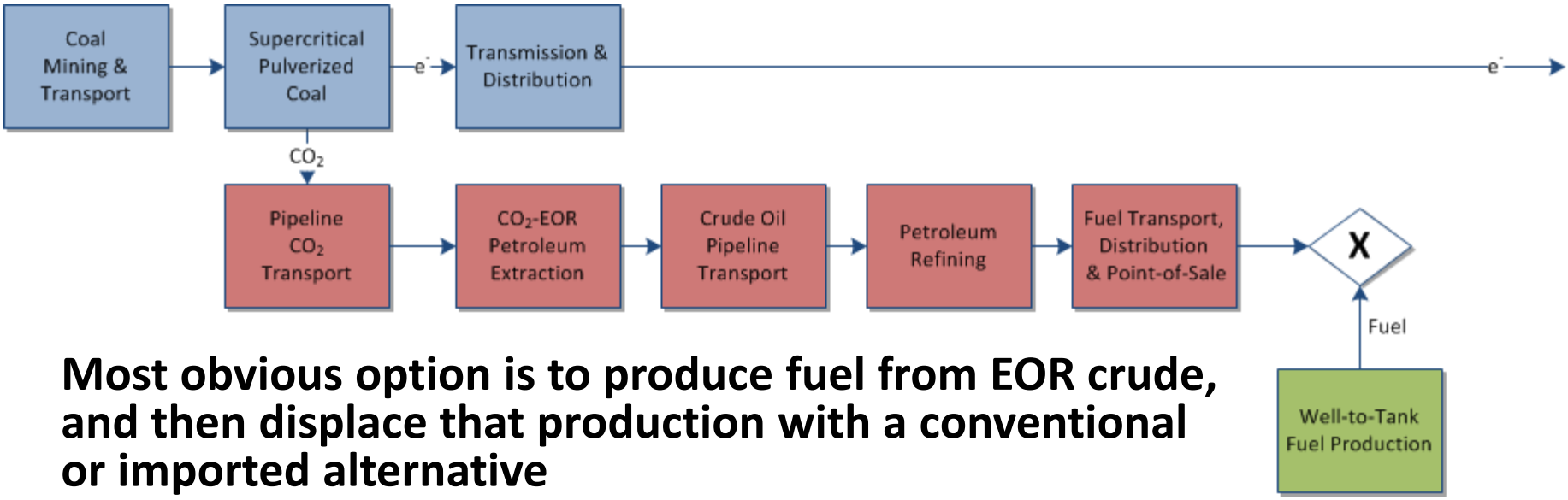
- **Expand boundary to include both products, redefine functional unit to be 1 MJ and *X* MJ fuel (or vice versa)**
- **Results impossible to compare to systems which produce products in a different proportion**



For Large-scale Energy Systems Displacement Calculations Need to be Handled Systematically

Any displacement credit has three components

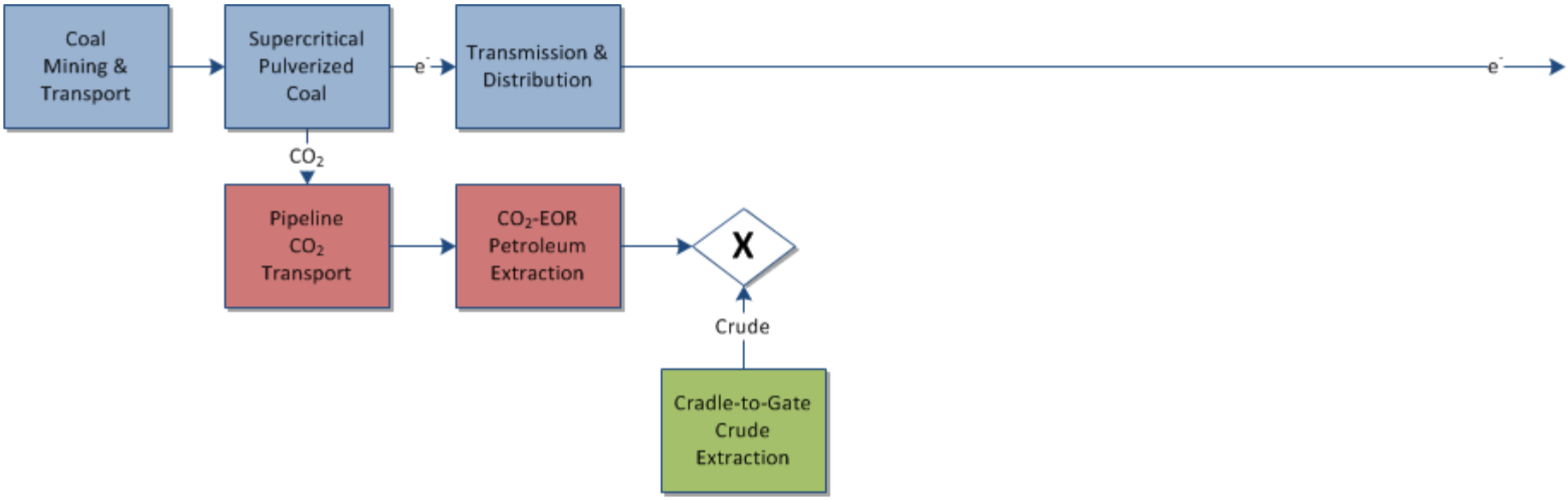
1. Location in the system the displacement occurs (end use, finished product, feedstock)
2. Which option gets displaced (highest marginal cost, average, highest GHG)
3. What percent of it gets displaced (all, none, other)



Most obvious option is to produce fuel from EOR crude, and then displace that production with a conventional or imported alternative

A Simpler Displacement Location is Not Always Better

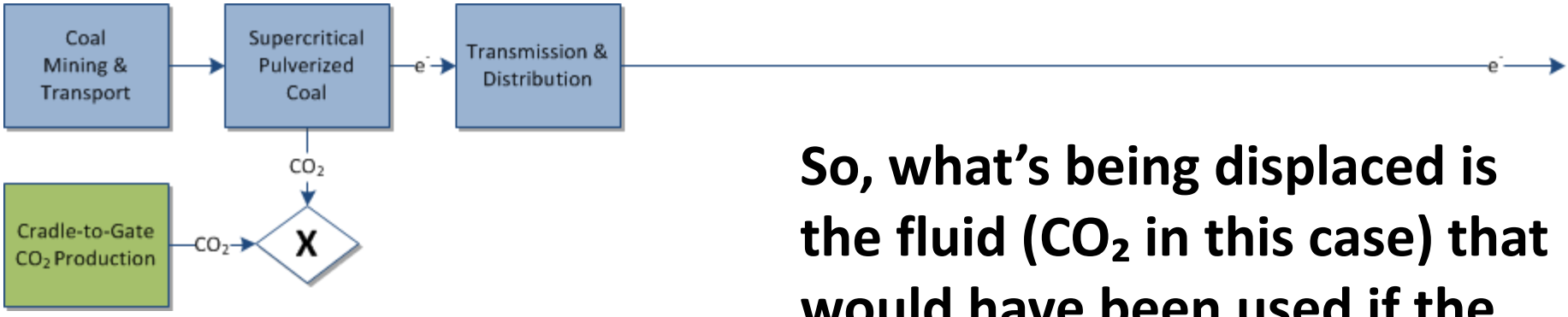
- **Seemingly easy argument for removing refining, delivery and combustion blocks: Processes are identical for displaced or EOR crude, so balance would be the same**
- **But markets (and potential displacement effects) are different for crude oil and finished fuels**



Case for Removing the EOR Block Entirely

Argument for displacing here hinges on an existential case rather than an economic one:

Domestic EOR crude production will happen regardless of the existence of this power plant

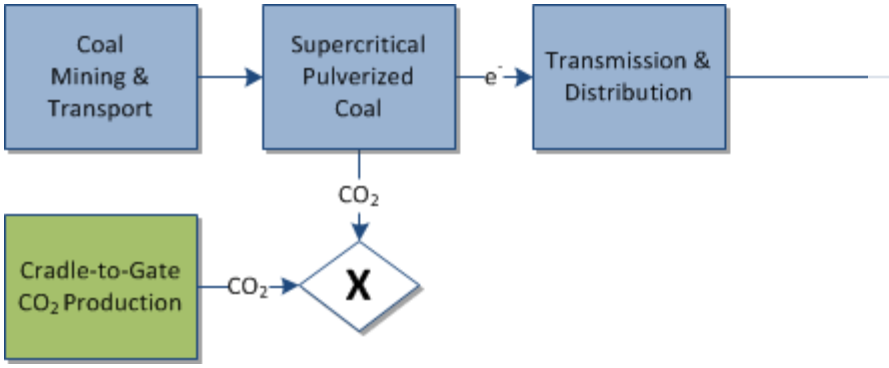


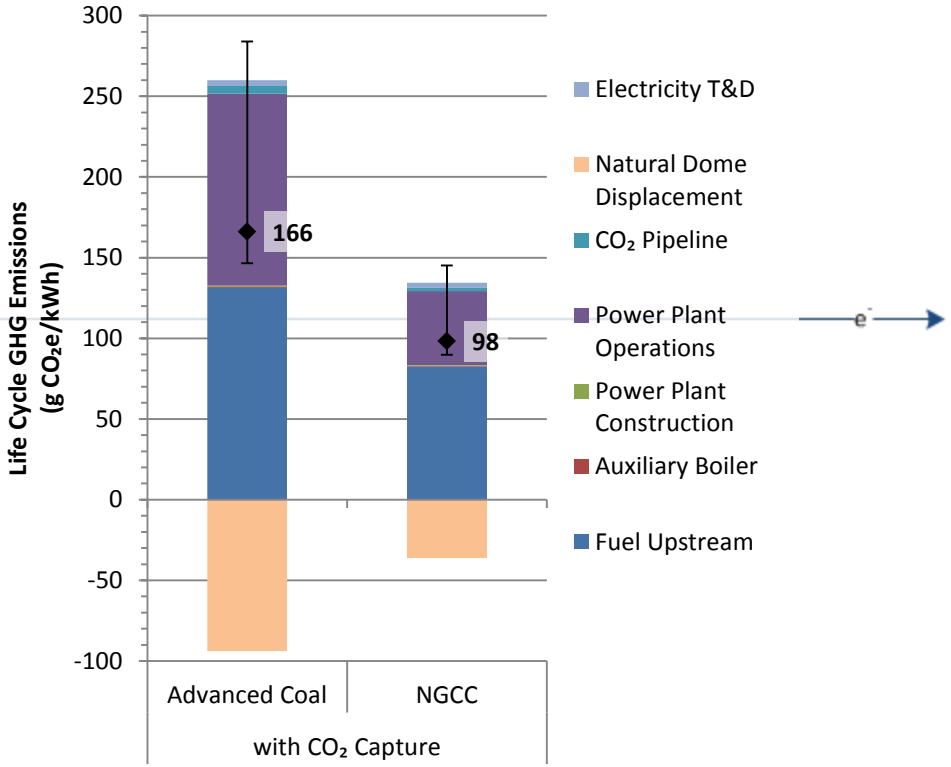
So, what's being displaced is the fluid (CO_2 in this case) that would have been used if the power plant didn't exist

Apply Displacement of Captured CO_2

- **Advanced coal with carbon capture likely exists in a world where generators would take just about any price – or even pay – to get rid of CO_2**
- **Strong case for displacement of natural dome CO_2 production**

Scenario	Location	Option	%
Low Exp. Val. High	User Gate	Natural Dome	0% 100% 100%

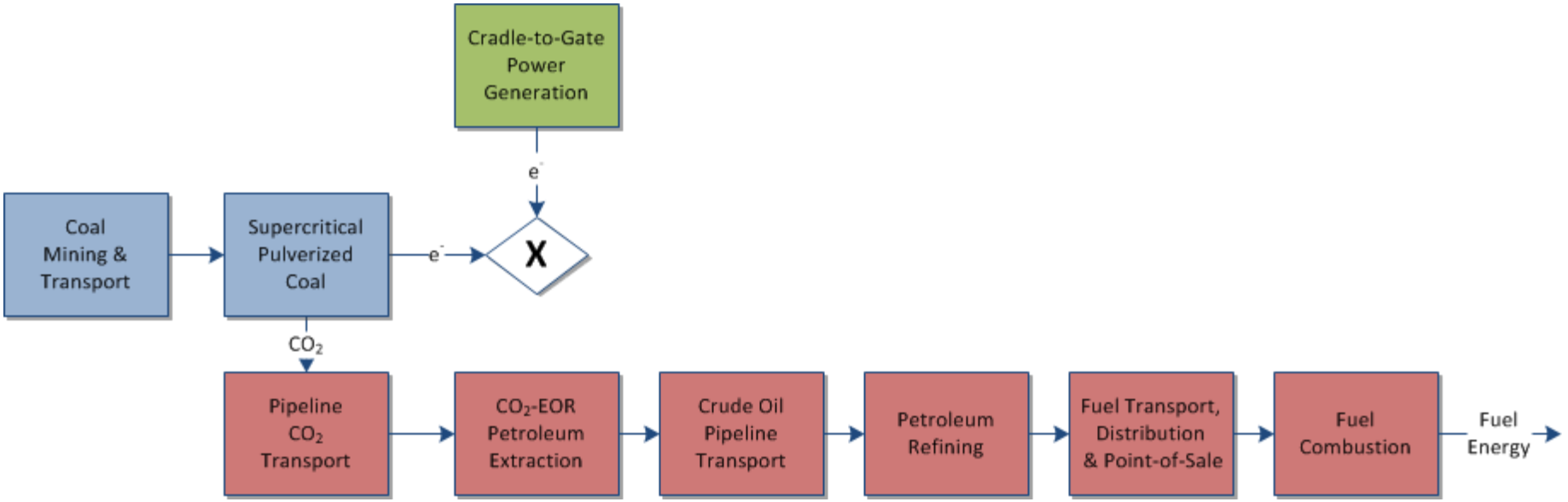




Functional Unit of 1 MJ Fuel from EOR

Need to Displace the Power Production

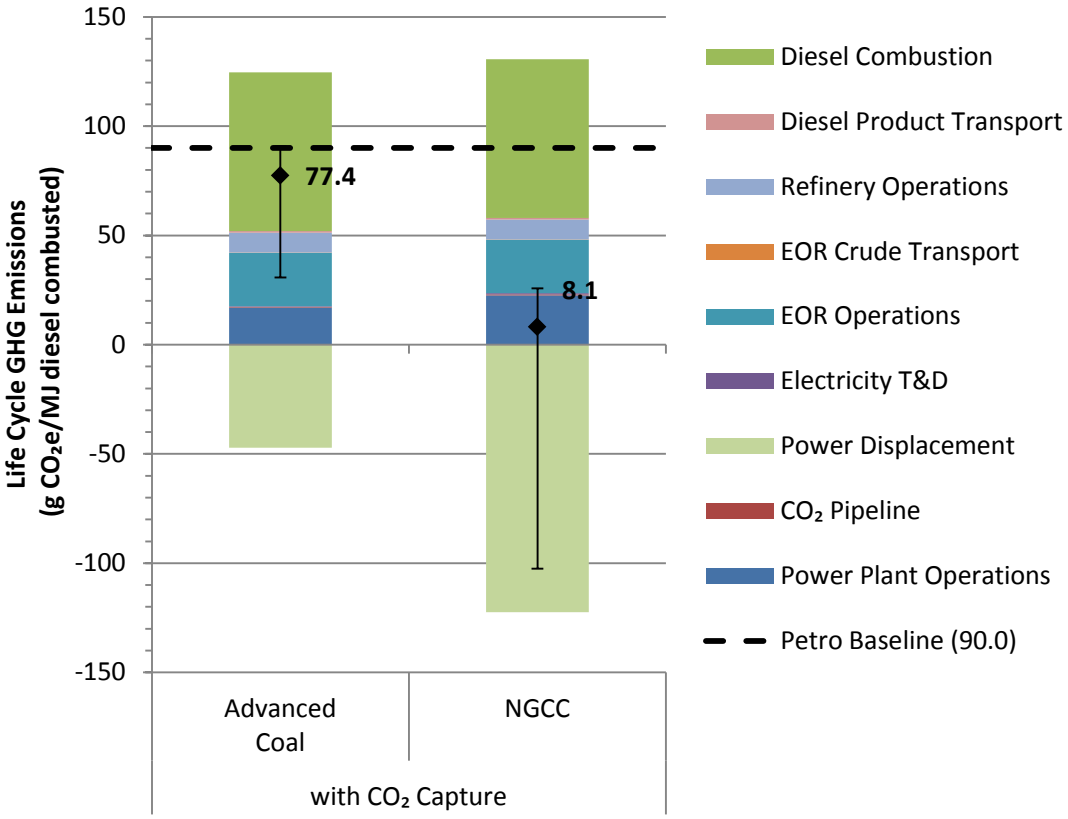
- **Assume that demand is relatively inelastic w.r.t. changes in supply**
- **Could displace anything from wind at 15 g/kWh to retiring coal at 1,300 g/kWh**
- **Narrowing the range of this displacement credit requires careful thought about the long-run marginal change to the grid induced by new power generated, and testing of the range's impact on conclusions being made in the study**

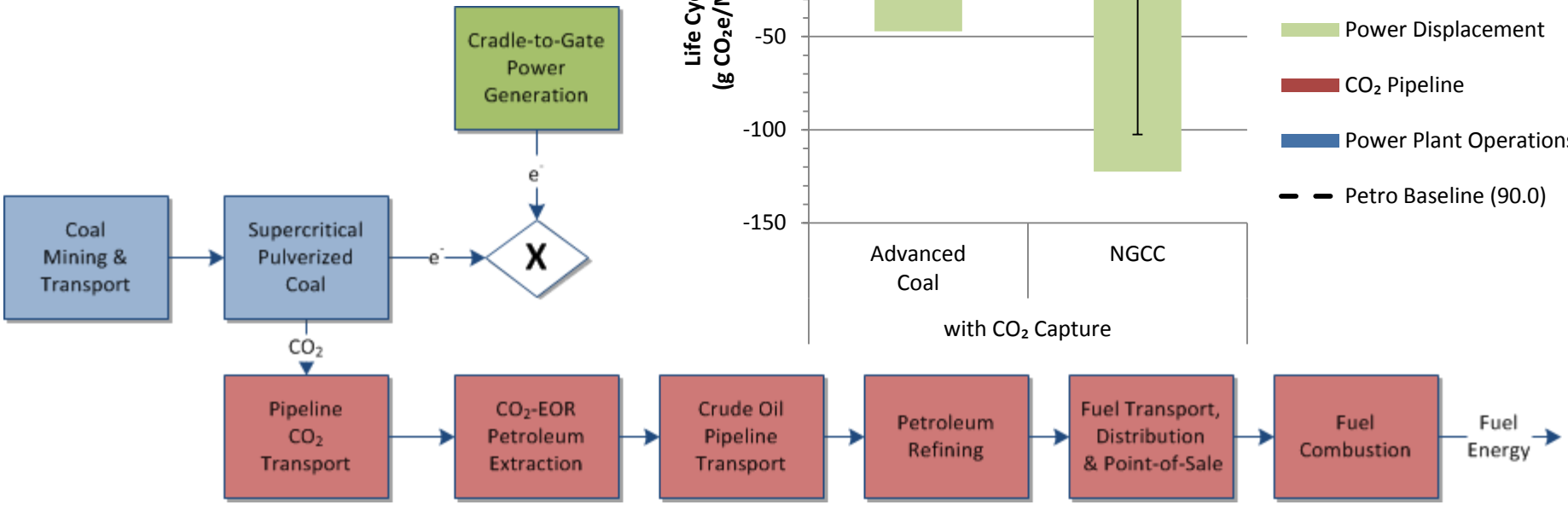


Functional Unit of 1 MJ Diesel Fuel from EOR

Need to Displace the Power Production

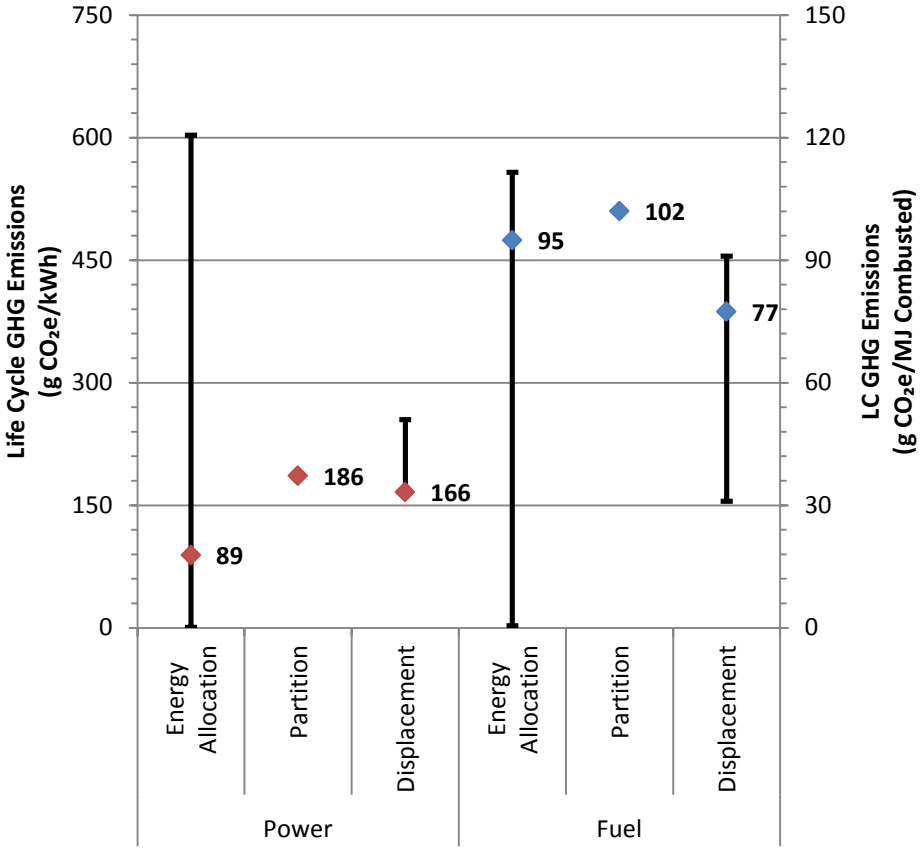
Scenario	Location	Option	%
Low Exp. Val. High	Busbar	AEO 2035 U.S. Grid 2010 U.S. Net Grid Fleet Coal	100%





Co-product Management Decisions are Critical for Large-scale Energy Systems

In many cases, differences between co-product management choices are far greater than any underlying technical uncertainty



- **Uncertainty about end-use application renders energy allocation useless**
- **Partitioning has very high attributional certainty, but isn't reproducible for all systems, and hampers consequential analysis**
- **For large scale energy systems, displacement requires careful consideration of the consequential effects of the system: choose location, process option and magnitude very carefully**

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