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LCA
Life Cycle Analysis
environmental | economic | social



A Life Cycle Analysis Perspective of CCUS – *Goal and Scope Definition*

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National Energy Technology Laboratory

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Advancing energy options to fuel our economy, strengthen our security, and improve our environment

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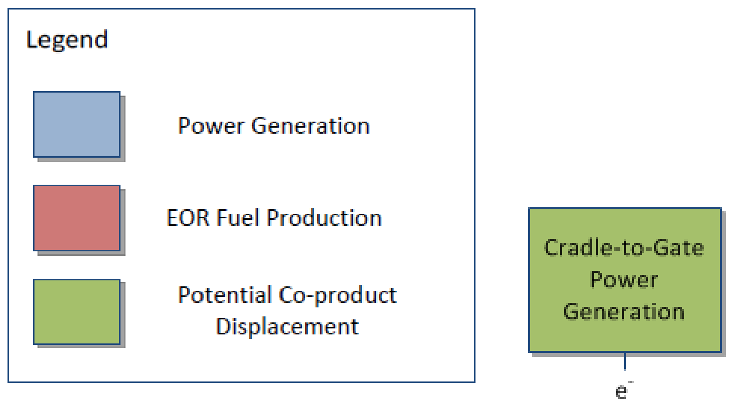
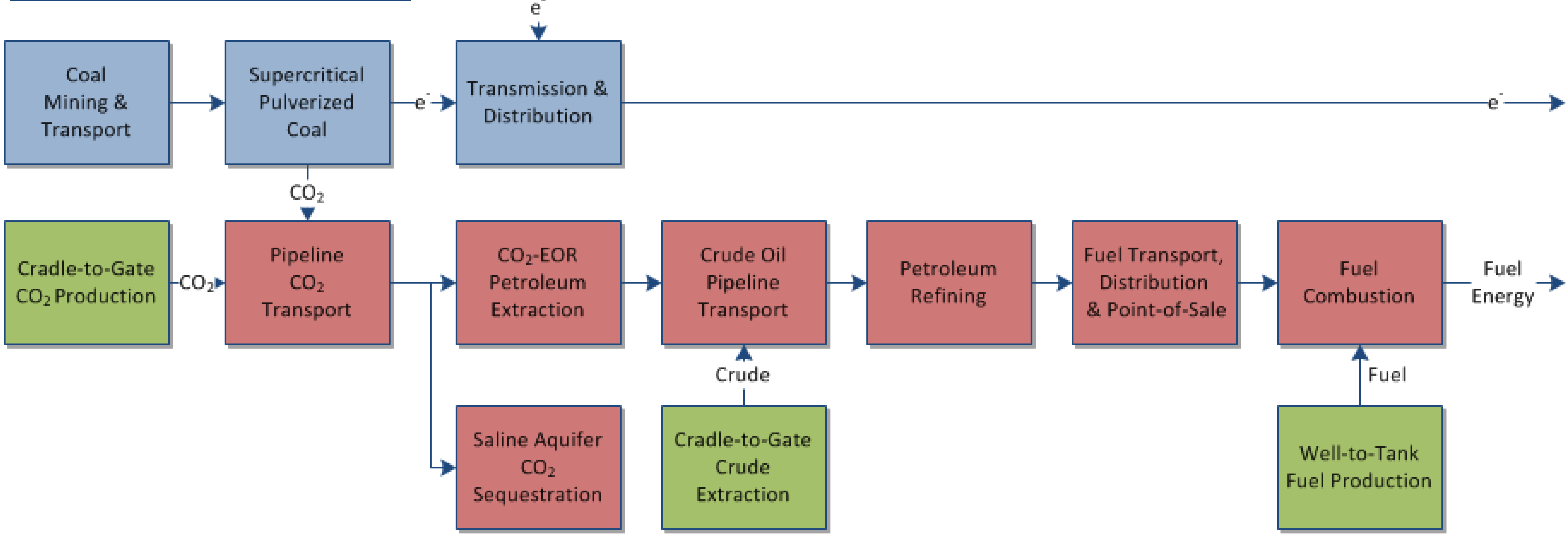
CCUS create a very complex life cycle system to model - with varying objectives

Possible products from this system:

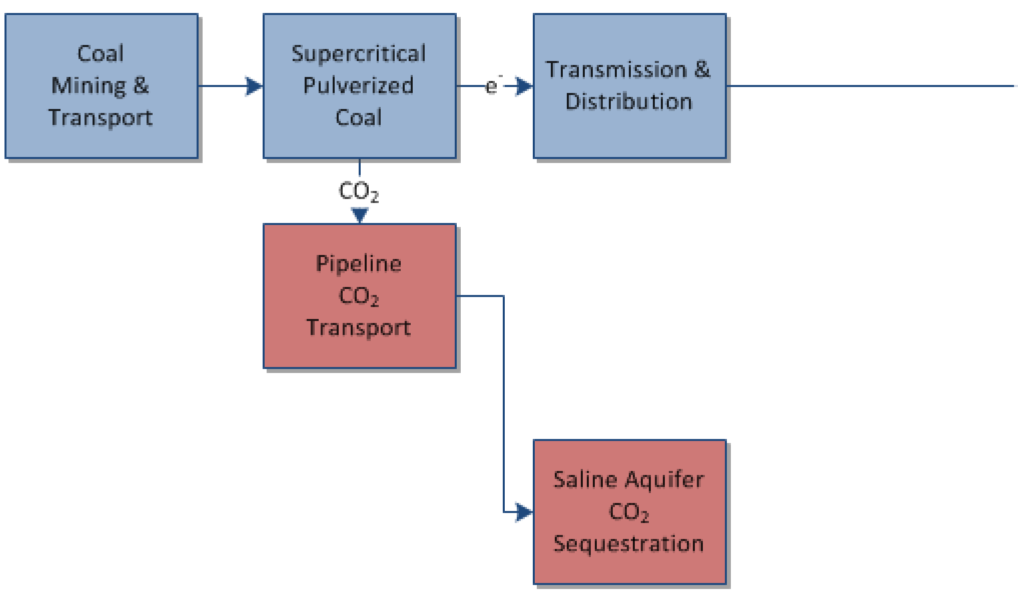
- Electricity
- Crude oil
- Refined fuel
- Captured CO_2
- *Some combination of the above*

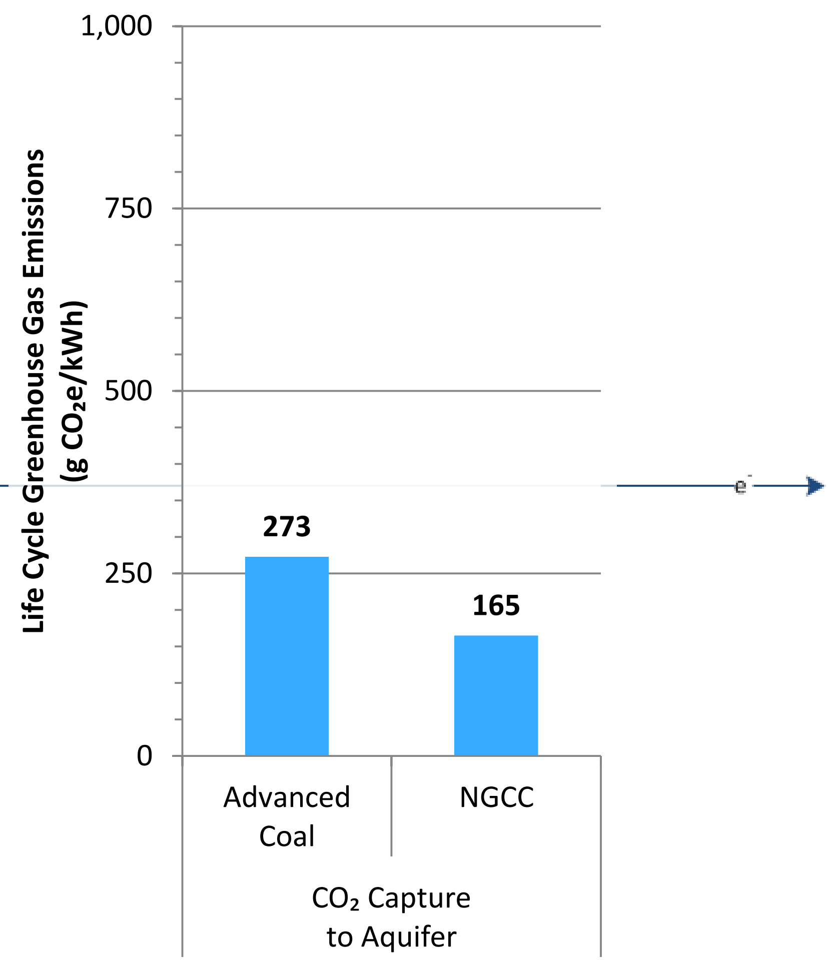




Simplest scenario: power is the only product, CO_2 is a waste and managed in a saline aquifer

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



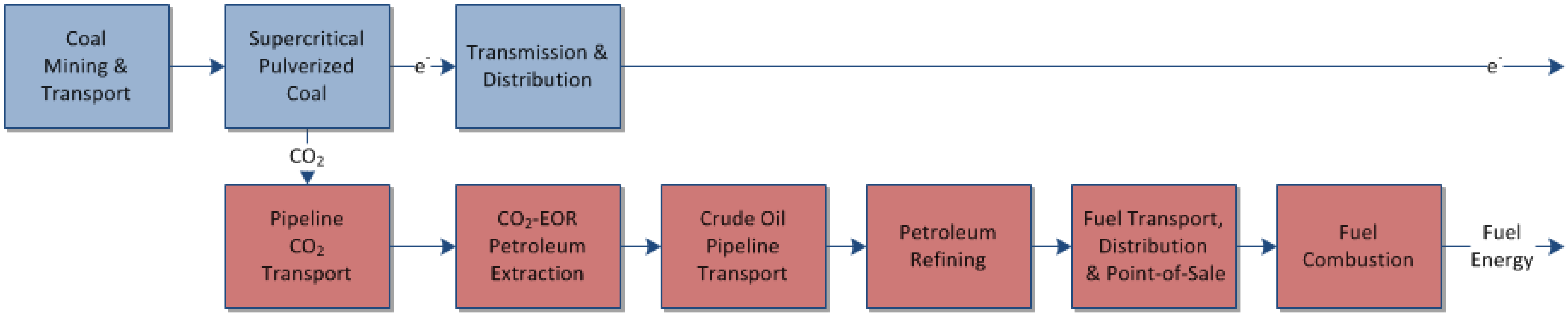


LCA of complex systems requires co-product management to apportion burdens

- **The objective of LCA is to assign ownership of environmental burdens to a single function**
- **When more than one product exits the system boundary of an LCA, it is necessary to redefine the system boundaries or apply an assignment that splits life cycle burdens between products**
- **NETL has studied the system (captured fossil power coupled with CO_2-EOR extensively and recommends system expansion with displacement**
  - System expansion alters system boundaries to include all co-products
  - With displacement, the system receives a credit for the GHGs emitted via the conventional product route for co-products
  - This analysis expands the boundaries of the system to include displacement of one of the co-products, leaving us with the desired product (power or fuel)

One option is to expand the system to include both electricity and fuel as products

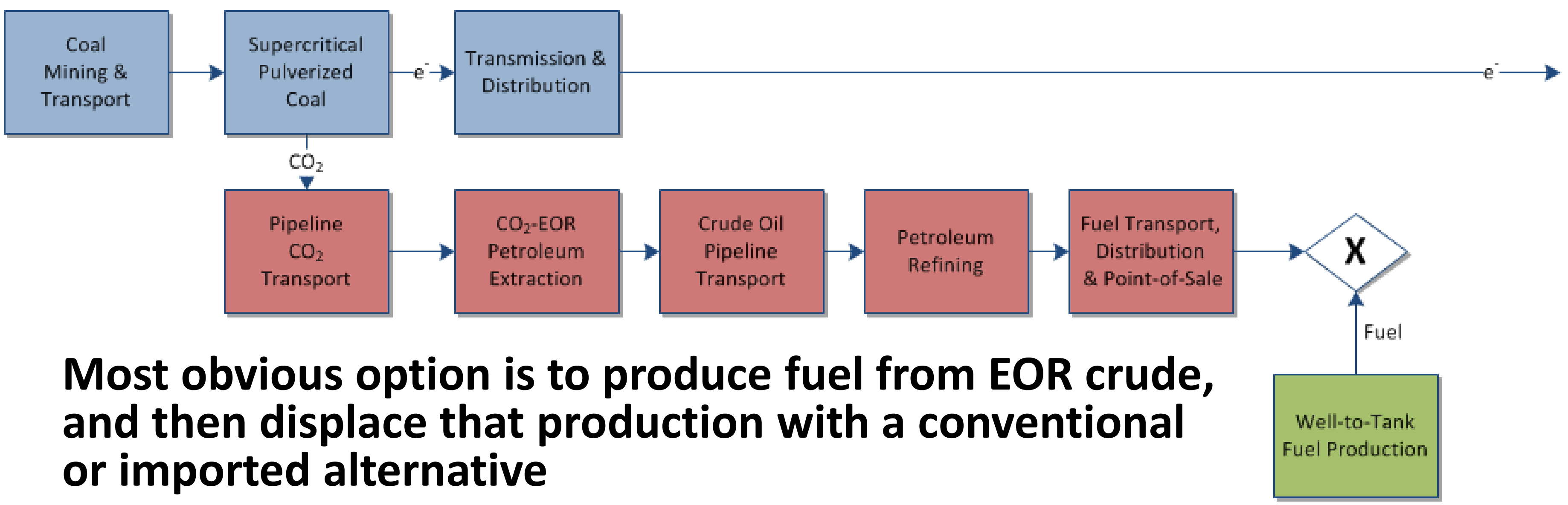
- **Expand boundary to include both products, redefine functional unit to be 1 MJ and *X* MJ fuel (or vice versa)**
- **Results impossible to compare to systems which produce products in a different proportion**
  - For example, for the same amount of CO_2 to EOR, natural gas combined cycle generates 2.5x power of a coal plant



For large-scale energy systems, displacement calculations need to be handled systematically

Any displacement credit has three components

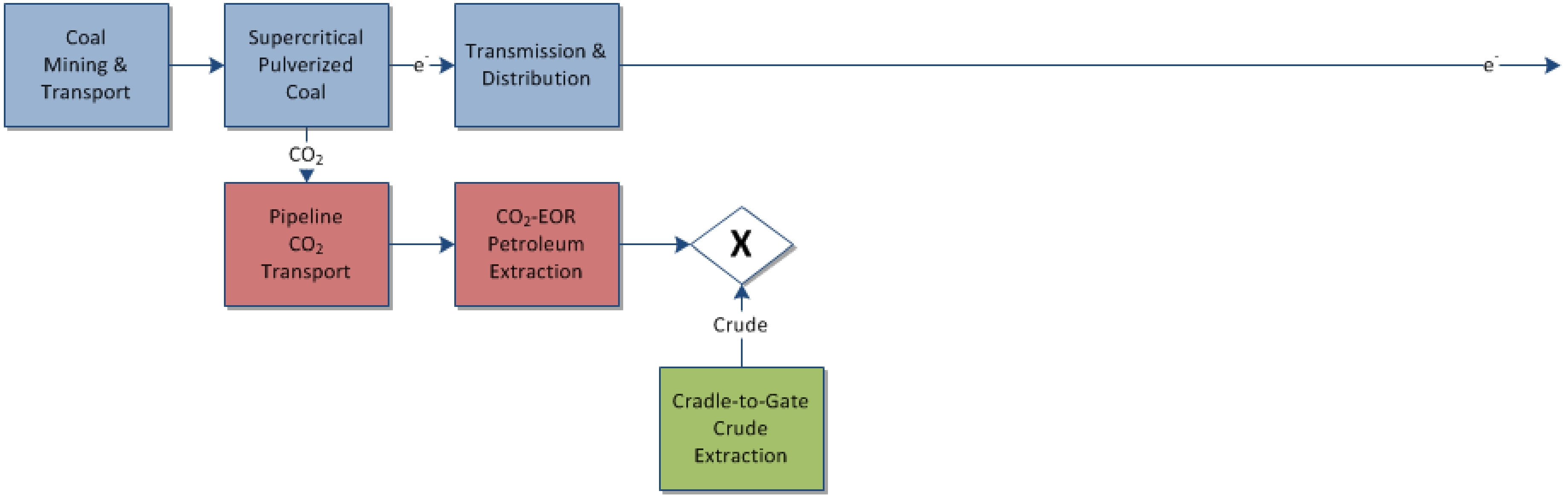
1. Location in the system the displacement occurs (end use, finished product, feedstock)
2. Which option gets displaced (highest marginal cost, average, highest GHG)
3. What percent of it gets displaced (all, none, other)



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 in the supply chain is not always better

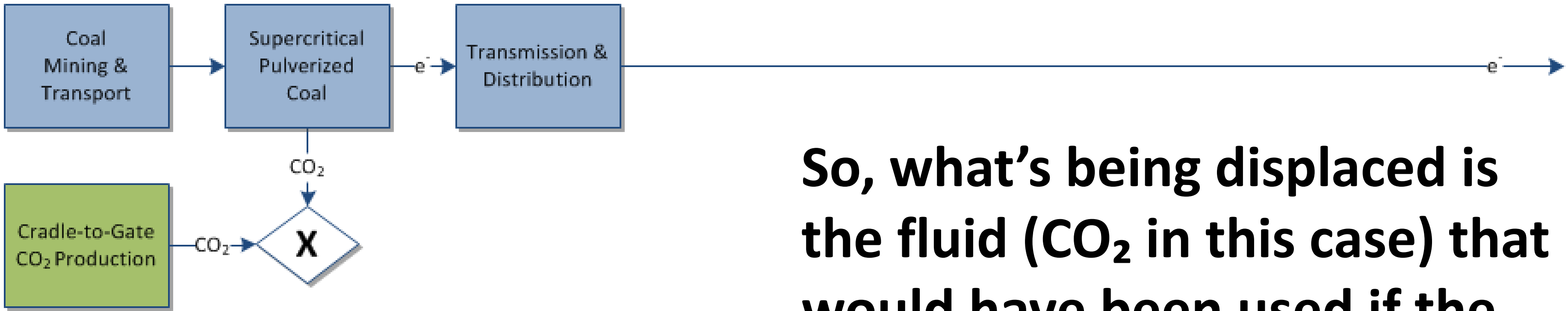
- **Seemingly easy argument for removing refining, delivery and combustion blocks: Processes are identical for displaced or EOR crude, so balance would be the same**
- **But markets (and potential displacement effects) are different for crude oil and finished fuels**



Yet another option for displacement – the case for removing the EOR block entirely

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

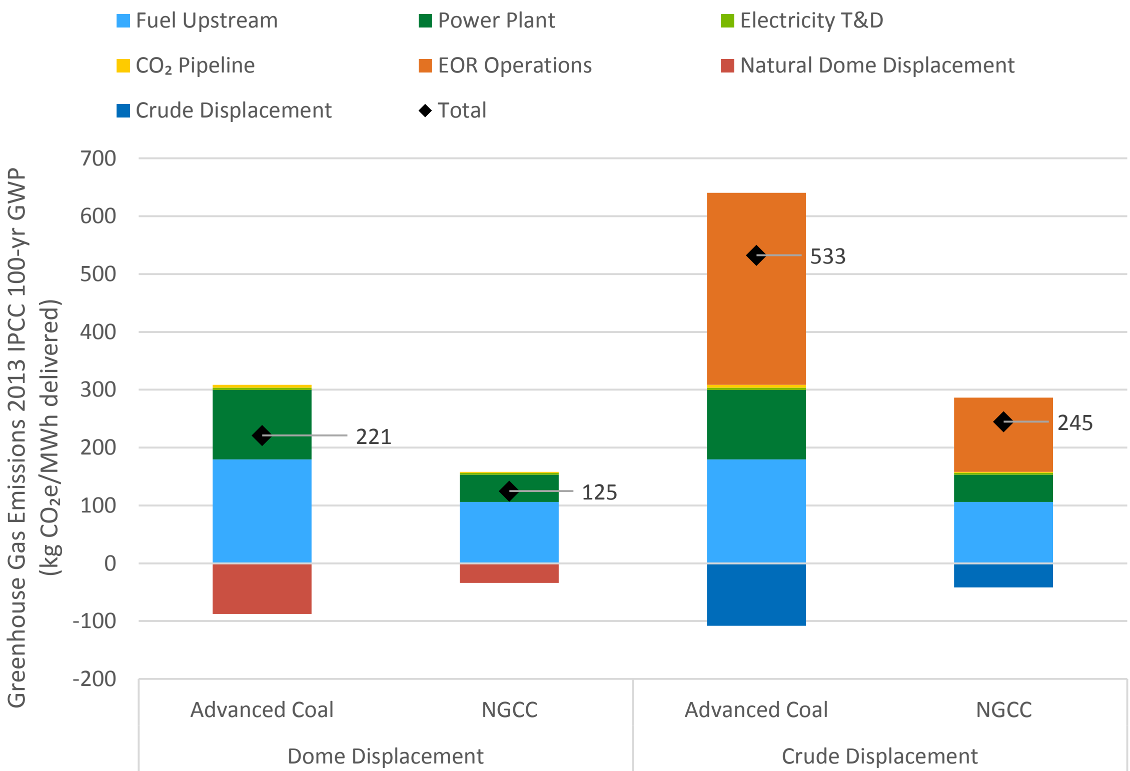
Domestic EOR crude production will happen regardless of the existence of this power plant



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

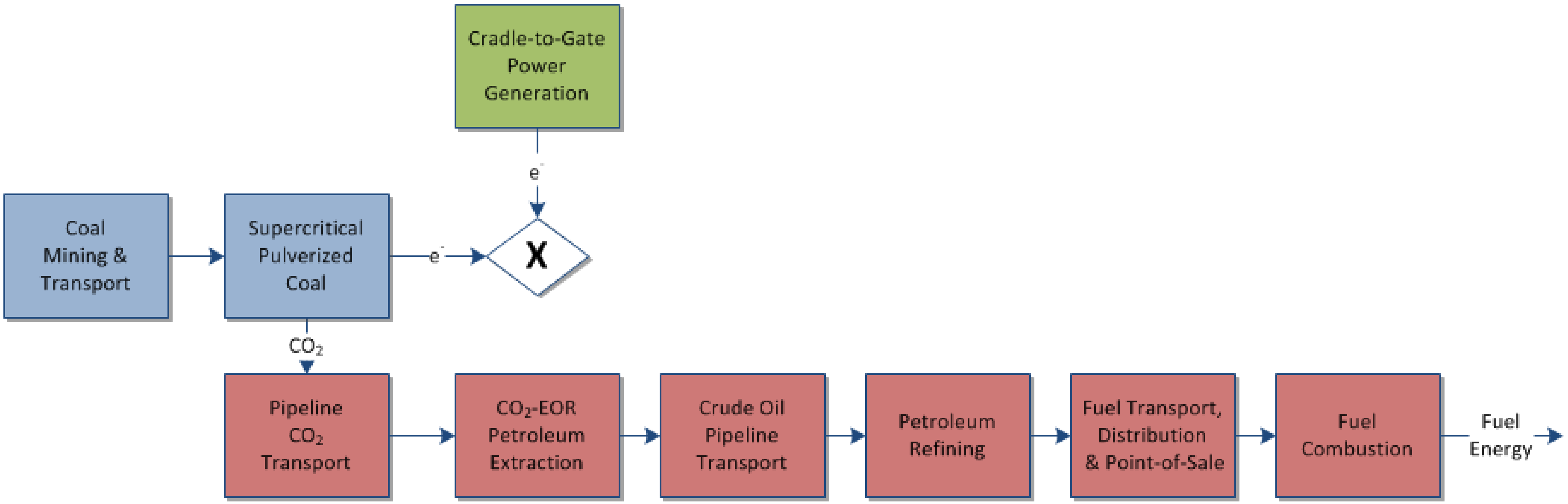
With displacement applied, LCA results can be generated and compared across technologies

- **Advanced coal with carbon capture may 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**



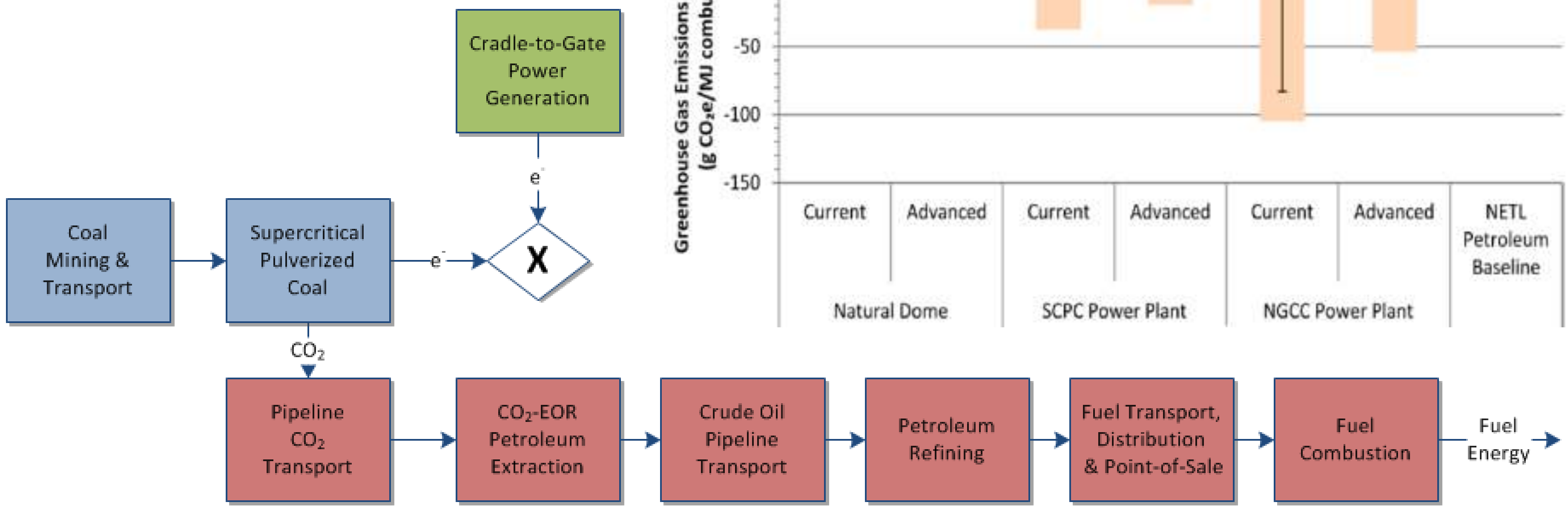
If the product of interest is fuel produced via EOR, need to displace the electricity co-product

- Assume that demand for electricity is relatively inelastic w.r.t. changes in supply
- Could displace anything from wind at 15 g CO_2e/kWh to retiring coal at 1,300 g CO_2e/kWh
- Narrowing the range of this displacement credit requires careful thought about the long-run marginal change to the grid induced by new power generation, and testing of the range's impact on conclusions being made in the study



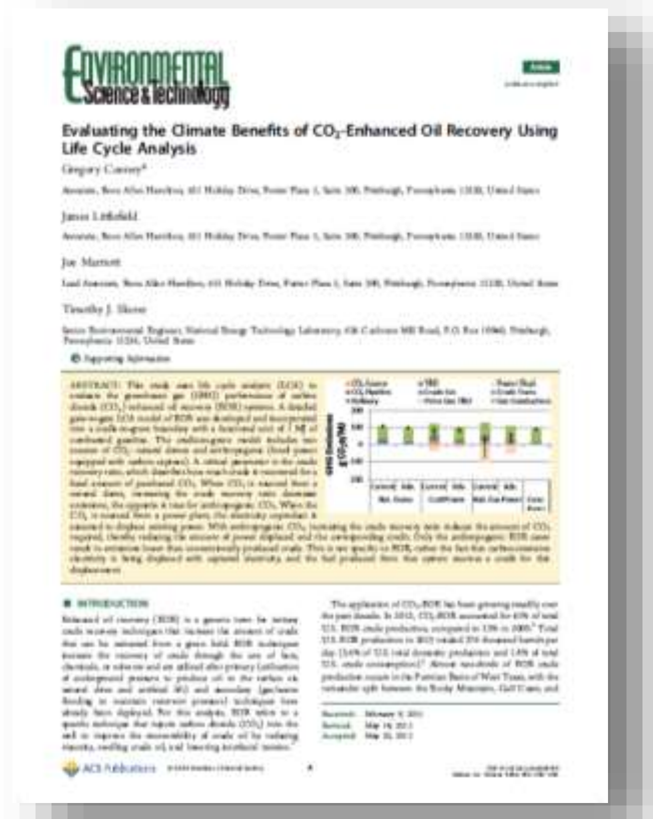
With the co-product managed, compare fuel from EOR with CO_2 from various sources (natural/fossil)

Improvements in the efficiency of EOR crude production reduces the life cycle GHGs for dome EOR, but increases for fossil EOR (displaces less power)



Evaluating the Climate Benefits of CO_2-Enahanced Oil Recovery Using Life Cycle Analysis

- **Detailed models are necessary to give confidence to broader system applications**
- **CO_2-EOR is a GHG-intensive way of extracting crude compared to conventional extraction methods**
- **Linking EOR with anthropogenic CO_2 yields a benefit due to the displacement of uncaptured electricity**
- **Crude recovery impacts depend on the source of CO_2 (natural vs. fossil)**
- **Inefficient CO_2 generators are best (NGCC vs. SCPC): increasing efficiency will increase the amount of power generated per unit of CO_2 captured and sent to EOR**


Environmental Science & Technology

Evaluating the Climate Benefits of CO_2-Enhanced Oil Recovery Using Life Cycle Analysis

Cooney, G., Littlefield, J., Marriott, J., & Skone, T. J. (2015). Evaluating the Climate Benefits of CO2-Enhanced Oil Recovery Using Life Cycle Analysis. *Environmental Science & Technology*, 49(12), 7491-7500. doi: 10.1021/acs.est.5b00700

Other NETL CCUS-related publications

- **Gate-to-Gate Life Cycle Inventory and Model of CO_2-Enhanced Oil Recovery *(Sept. 2013)***
  - Full process detail and comparison of four gas processing technologies
- **Gate-to-Grave Life Cycle Analysis Model of Saline Aquifer Sequestration of Carbon Dioxide *(Sept. 2013)***
  - Parameterized operation of a hypothetical saline aquifer and supporting activities
- **Cradle-to-Gate Life Cycle Analysis Model for Alternative Sources of Carbon Dioxide *(Sept. 2013)***
  - Three potential sources considered: natural dome, ammonia production, natural gas processing
- **All reports accessible via:**

  www.netl.doe.gov/LCA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Cradle-to-Gate Life Cycle Analysis Model for Alternative Sources of Carbon Dioxide

September 30, 2013

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