Using Life Cycle Analysis to Inform Energy Policy

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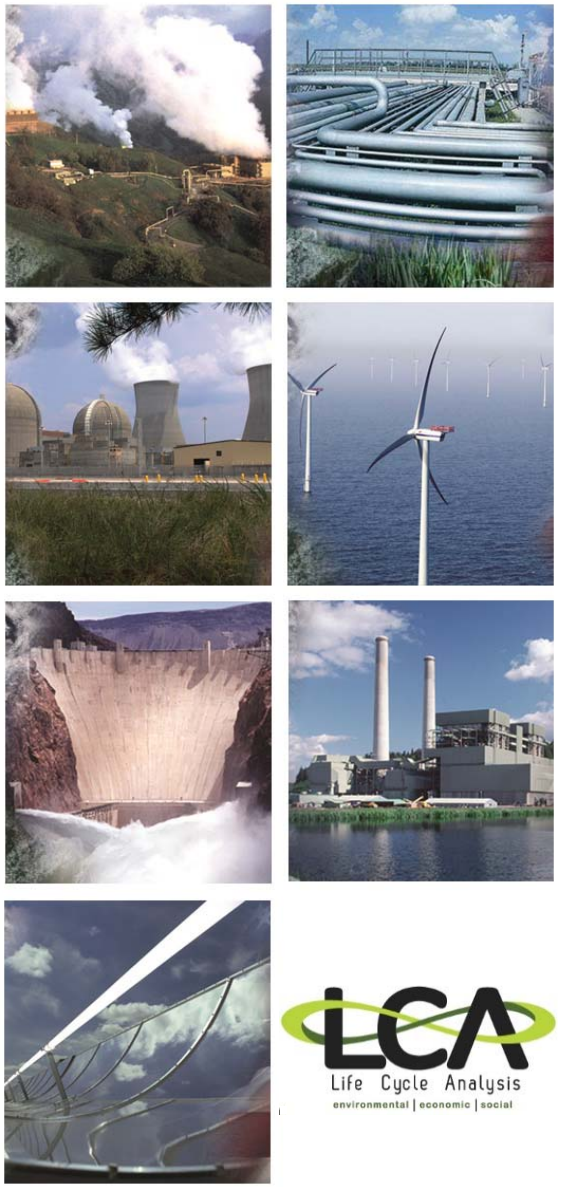
OFFICE OF FOSSIL ENERGY

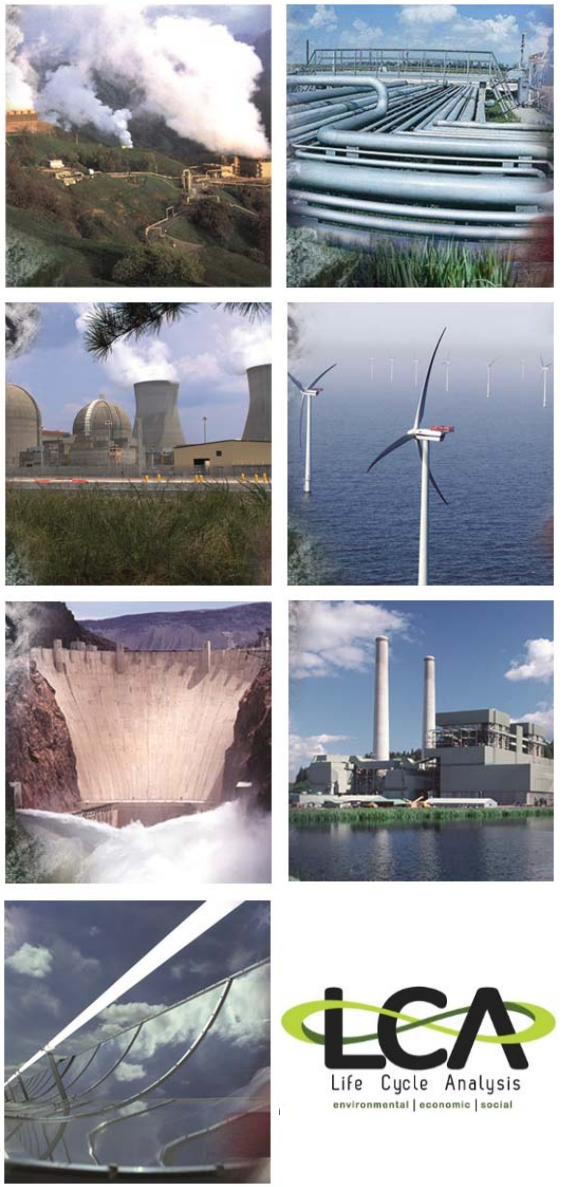
LCA is well suited for energy analysis

- 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



LCA answers are sensitive to the question asked

- **Purpose of the analysis**
  - Comparing two technology options
  - Evaluating impact of a policy on entire system
- **Boundaries and function considered**
  - Coal: production of feedstock vs. delivered electricity
  - Natural gas: all annual domestic or marginal shale only
- **Metrics evaluated**
  - Greenhouses gases: 20 or 100 year GWPs, inclusion of timing and feedback effects
  - Economic, environmental, and human health metric results may favor different options; and relative importance of each may differ among technologies



Potential trade-off between usefulness and uncertainty

The more complete the picture, the more uncertain it becomes

LCA Life Cycle Analysis environmental | economic | social

LCA at NETL meets both internal and external objectives

1. Produce LCAs of energy systems

- Inform and defend technology programs, and identify opportunities for R&D
- Baseline different energy technologies
- Understand technology strengths and weaknesses from a life cycle perspective

2. Improve LCA methods

- Expand environmental inventory
- Characterize both variability and multiple types of uncertainty
- Build flexible models
- Enhance interpretation and comparability of inventory results without losing depth and transparency

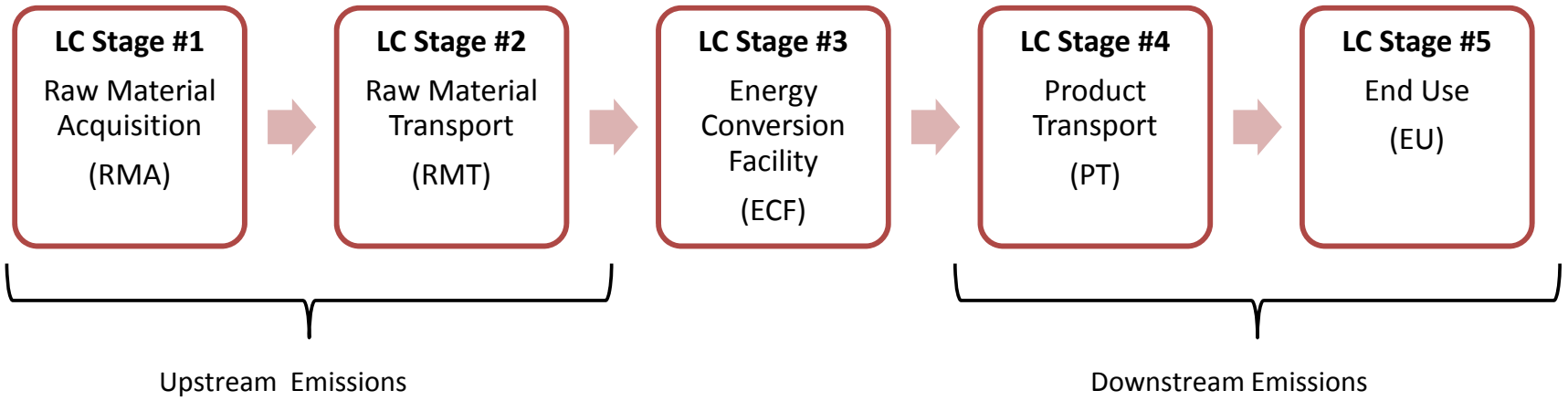
3. Inform energy policy decision-makers

NETL's LCA program has generated both high-profile results and productive collaborations

- **Analysis**
  - Petroleum Baseline (2009)
  - Technology Assessment Reports (2012)
  - Natural Gas LCA (2011-2013)
- **Collaboration**
  - LCA of Alternative Jet Fuel
    with DOD, FAA, EPA, academia
  - DOE LCA Workgroup
    with NREL, Argonne, LBNL, PNNL, BNL
  - LCA Digital Commons, OpenLCA software
    with EPA, USDA, USACE, academia

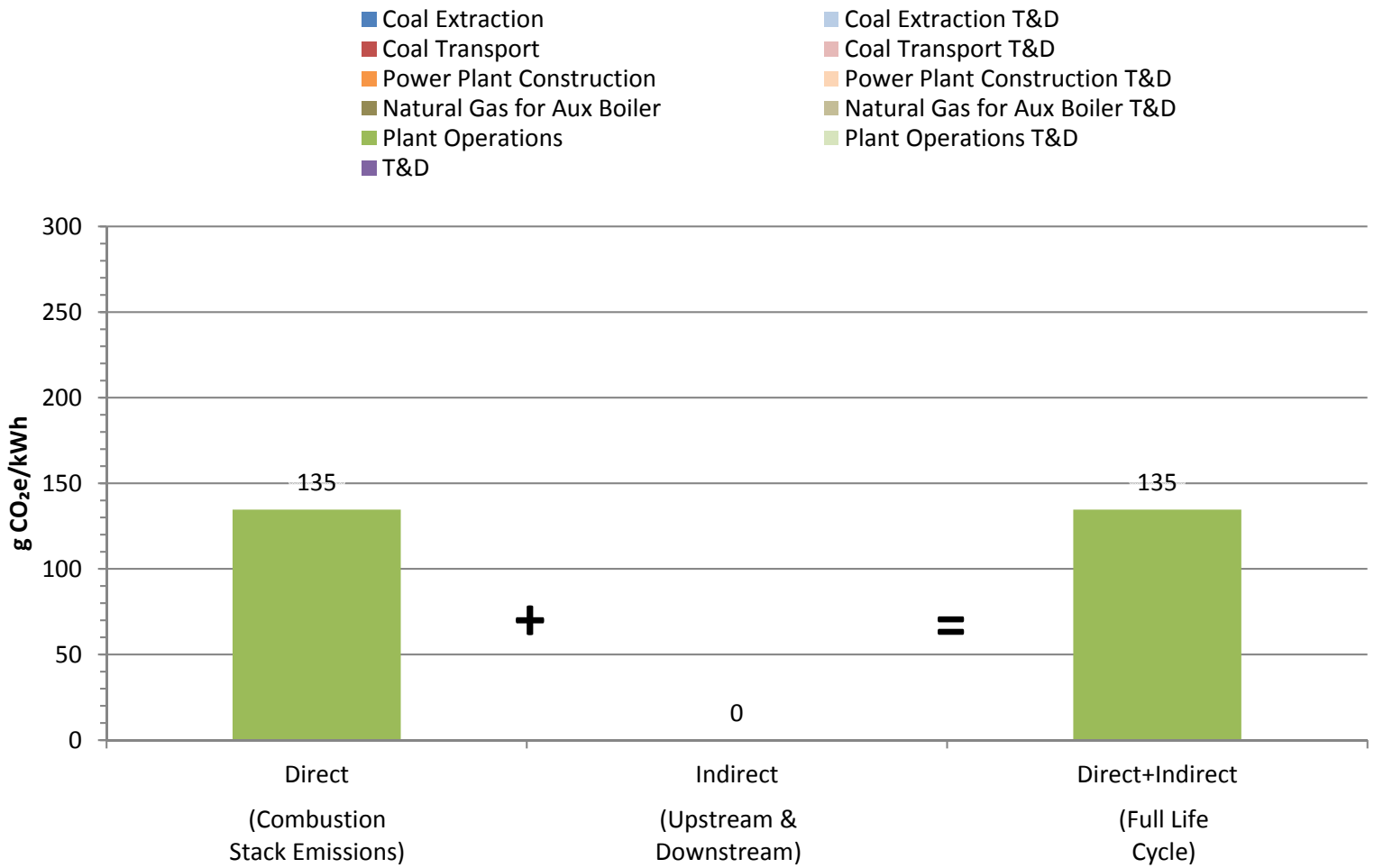
NETL approaches each LCA systematically to ensure comparability and transparency

- **Compilation and evaluation of the inputs, outputs, and potential environmental impacts of a product or service throughout its life cycle, from raw material acquisition to final disposal**



- **Ability to compare different options depends on functional unit (denominator)**
  - 1 MWh of electricity delivered to the end user
  - 1 MJ of fuel combusted

LCA shows the importance of each portion of the life cycle



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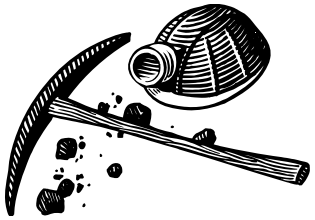

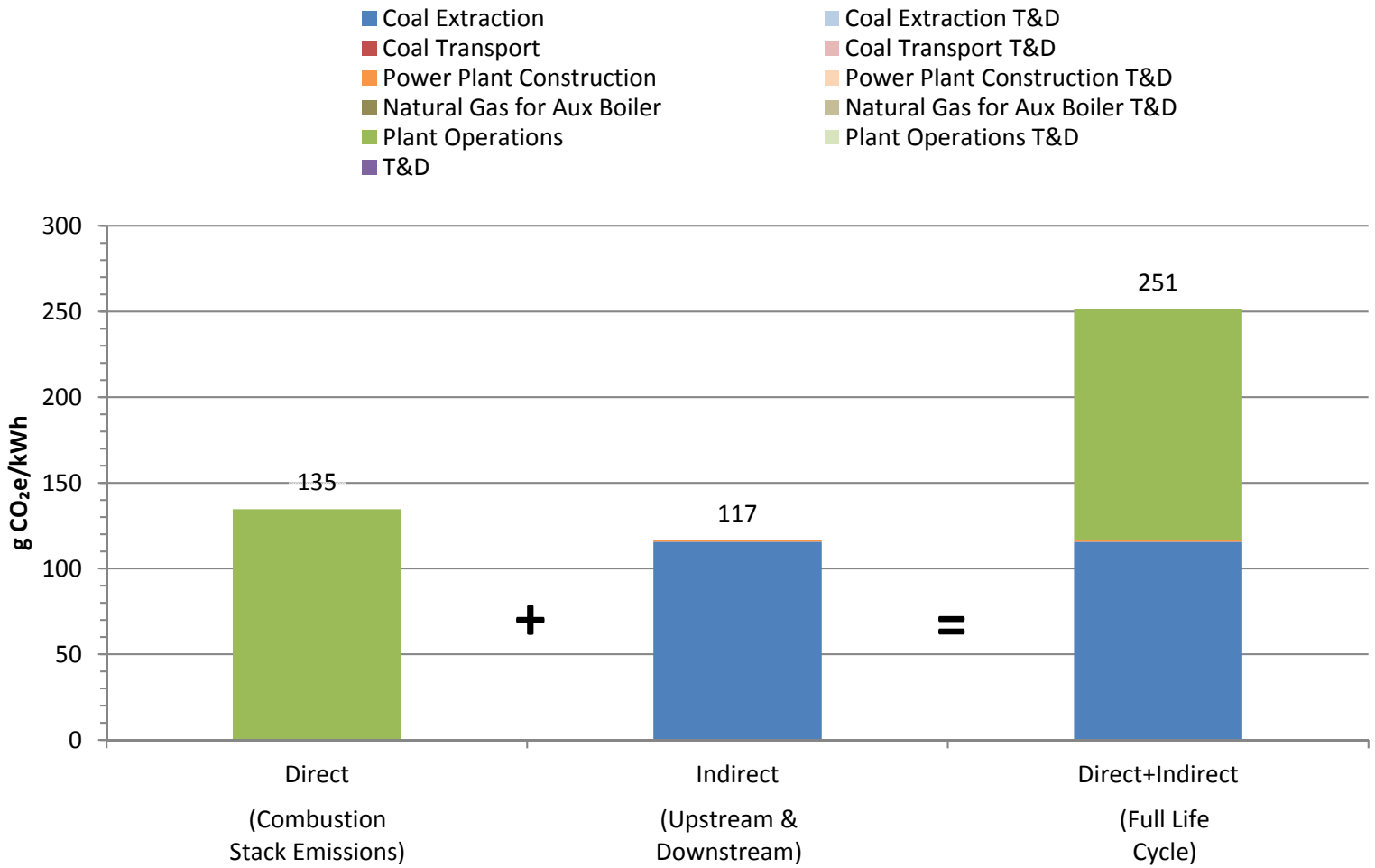

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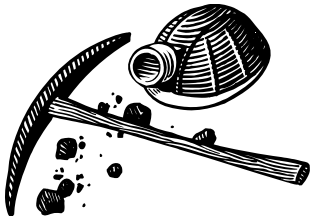

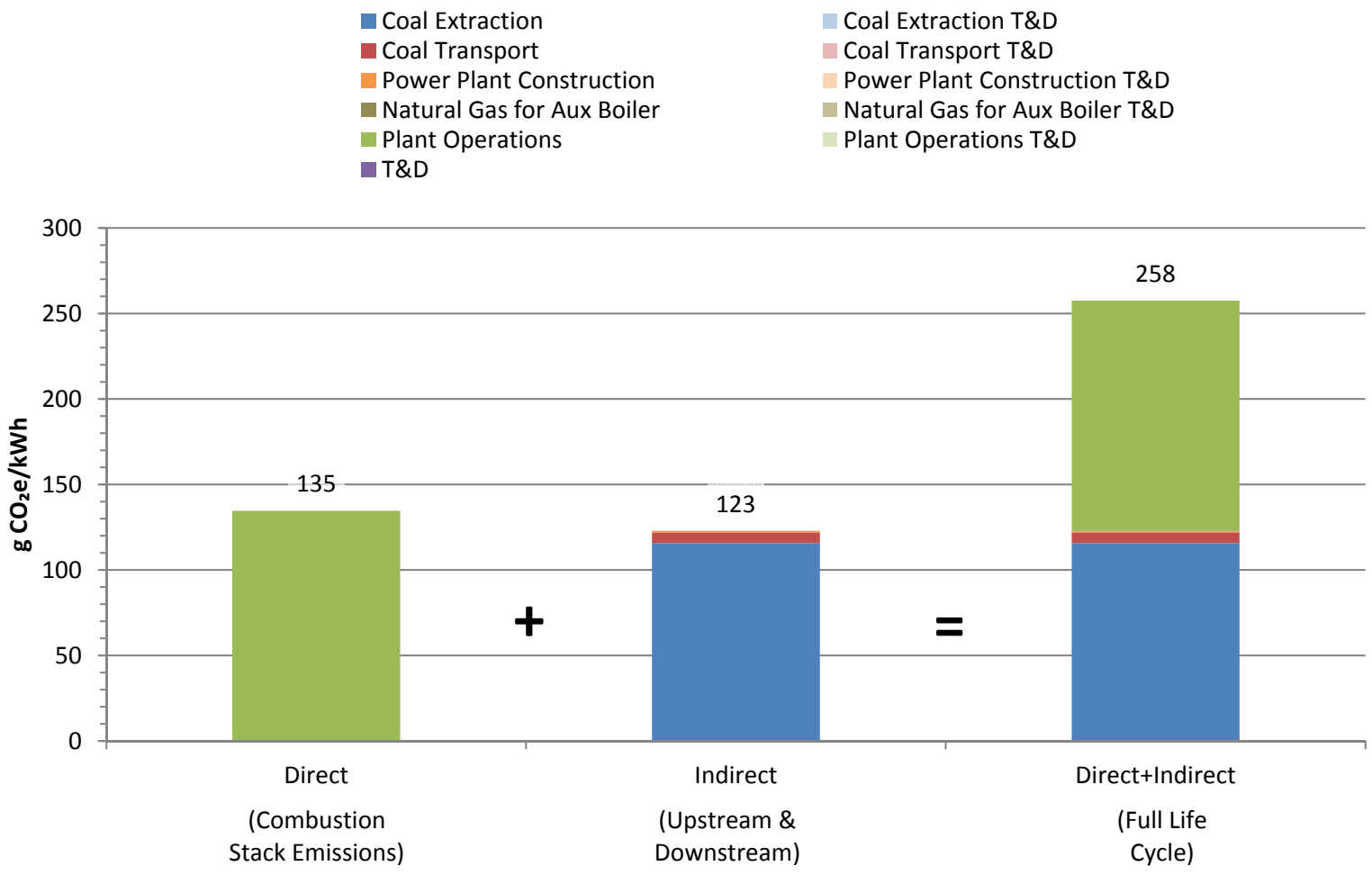

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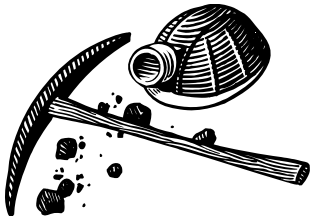
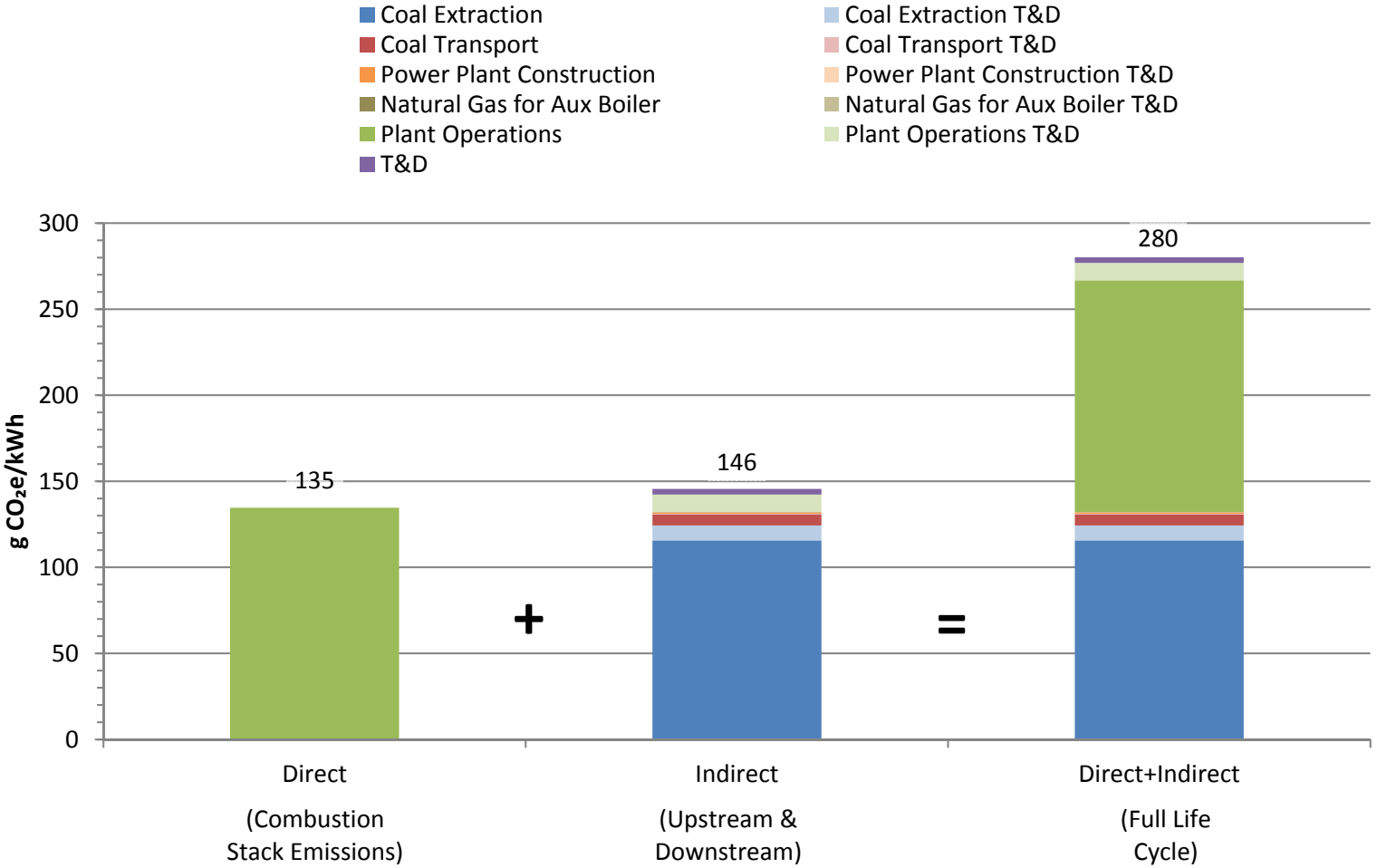
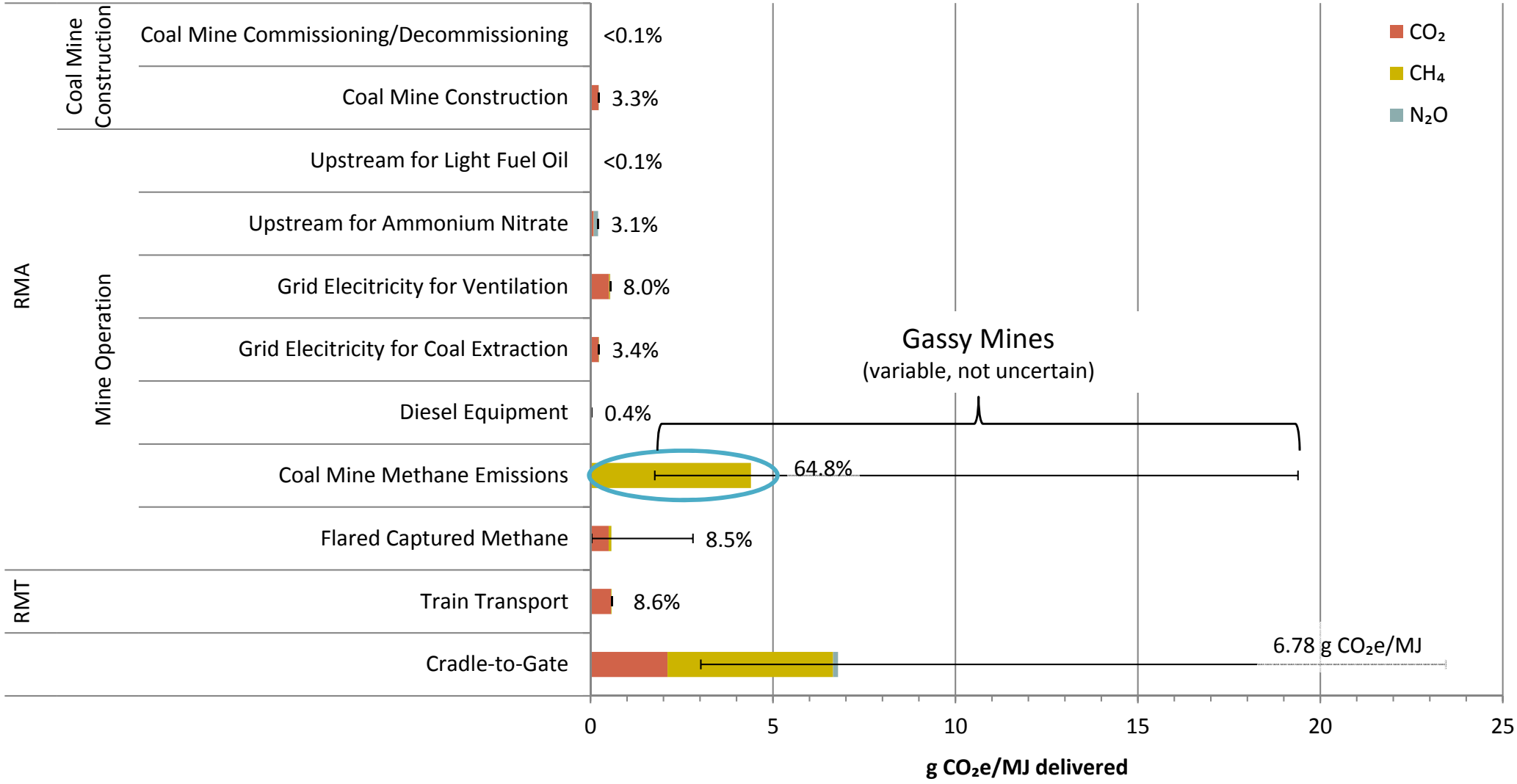


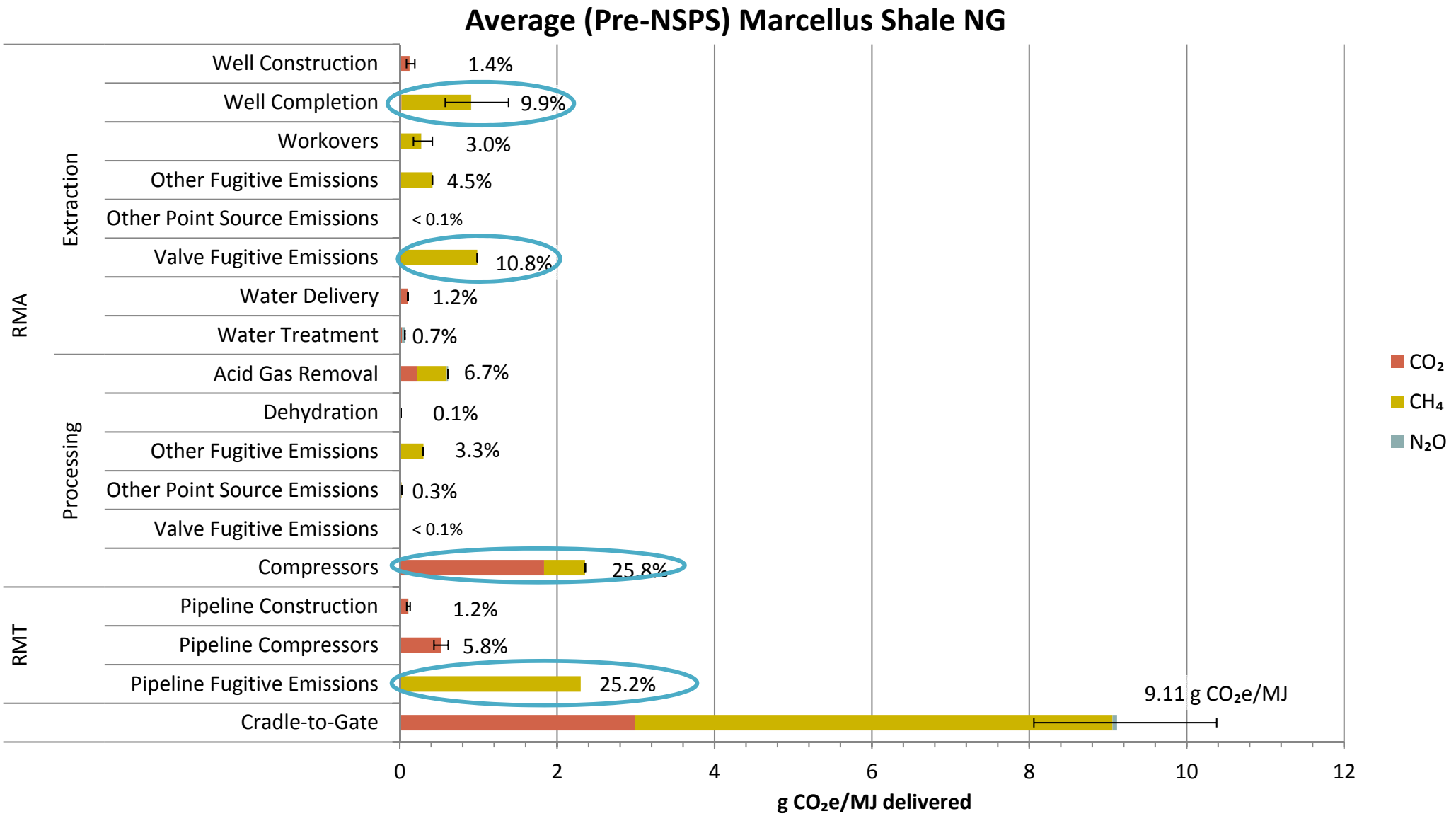


Depth of analysis can identify opportunities for improvement throughout the supply chain

Extraction and Transport of U.S. Average Coal



Depth also allows tuning of results given small or large changes to policy



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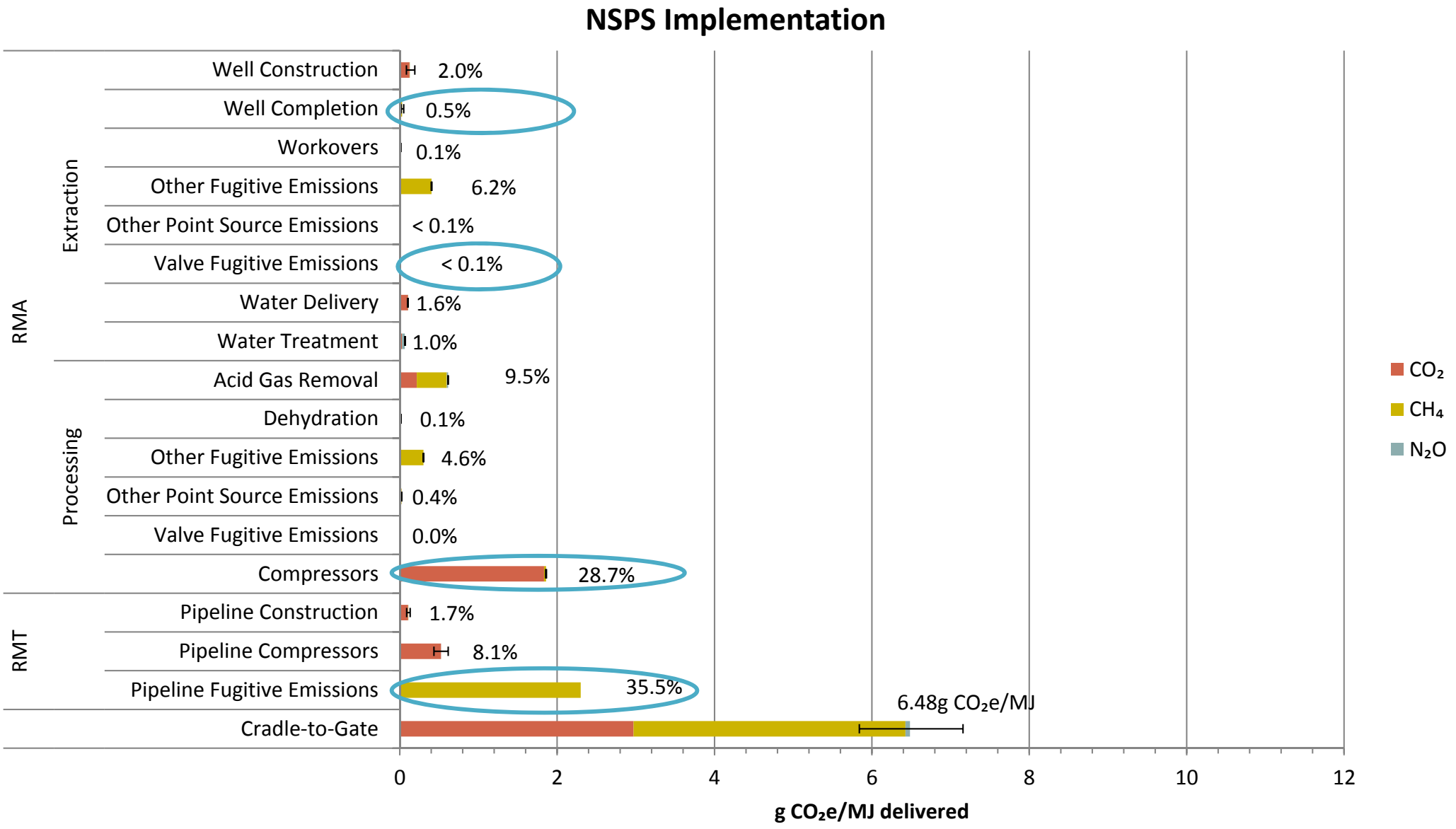
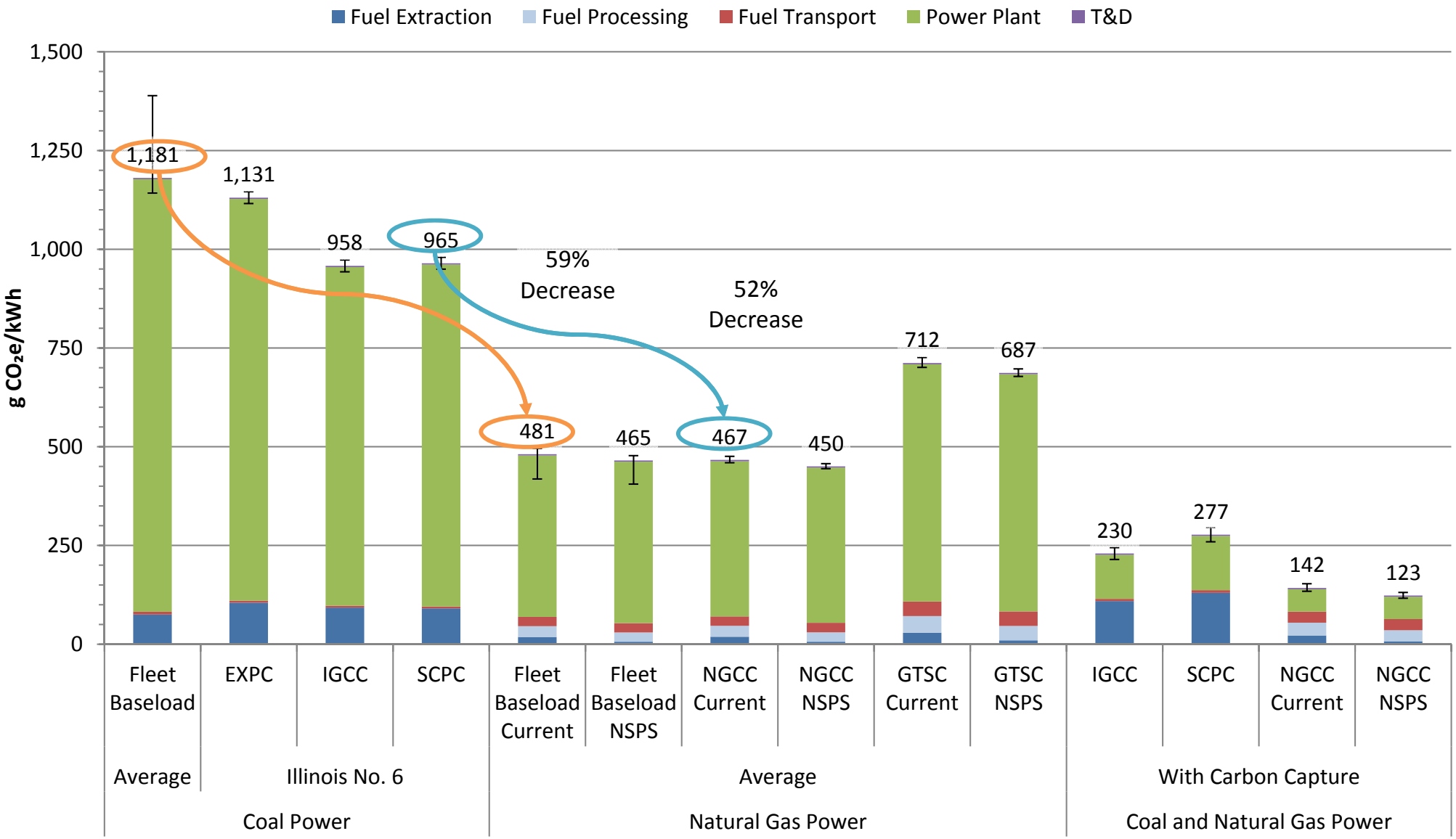
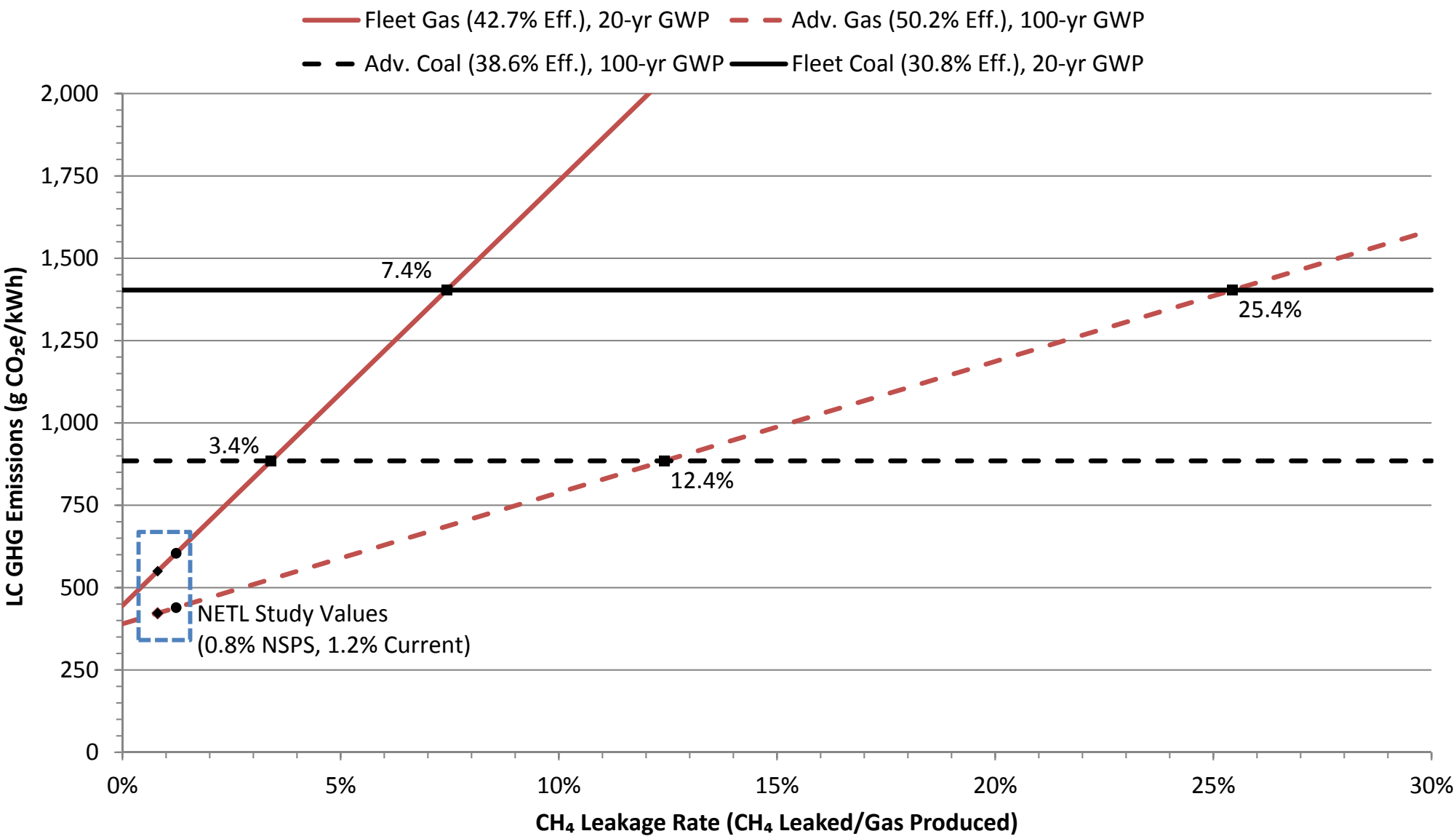


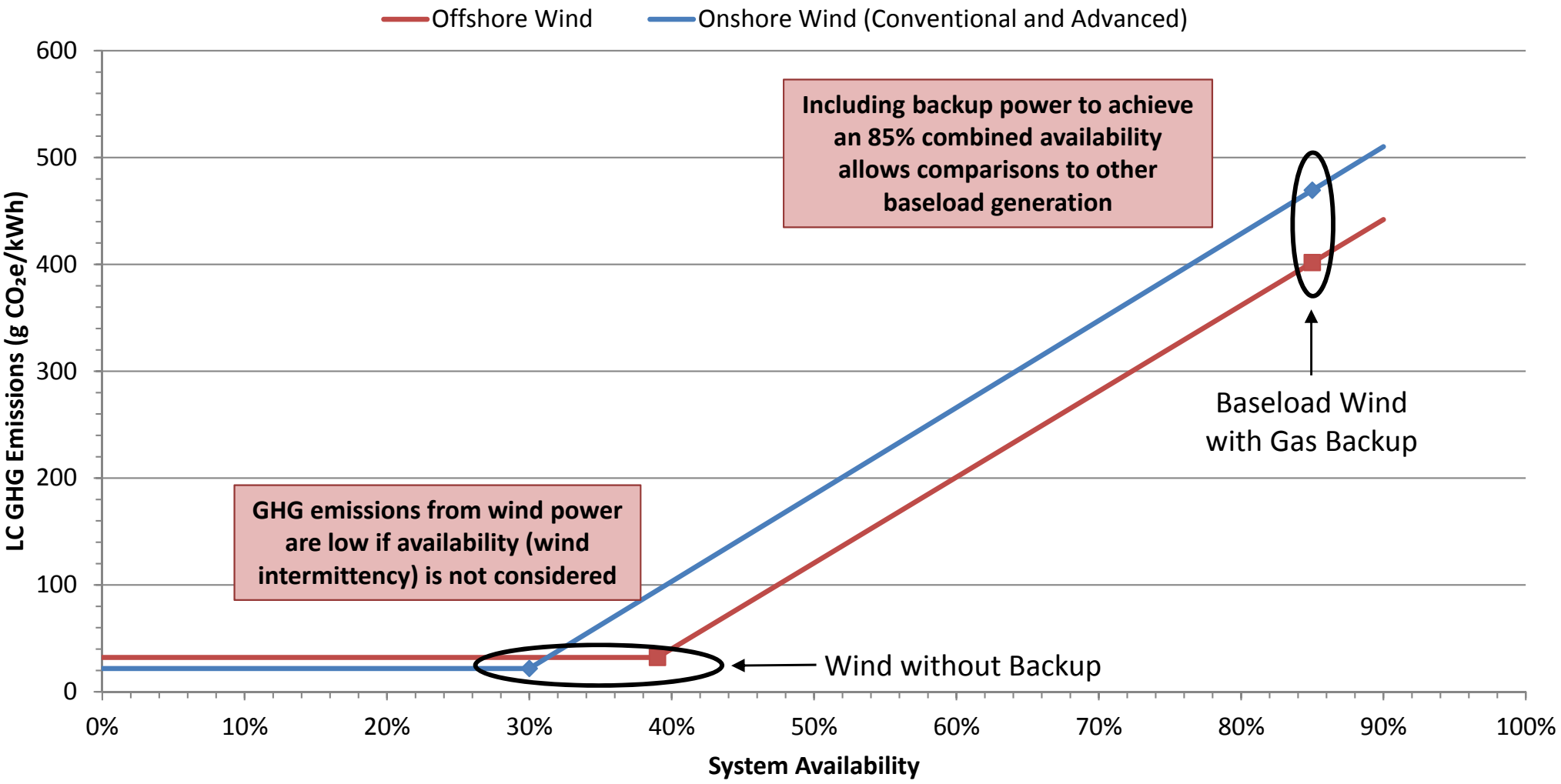
Different energy sources should be compared based on a common function



Choosing a common function allows uncertain information to be examined in context

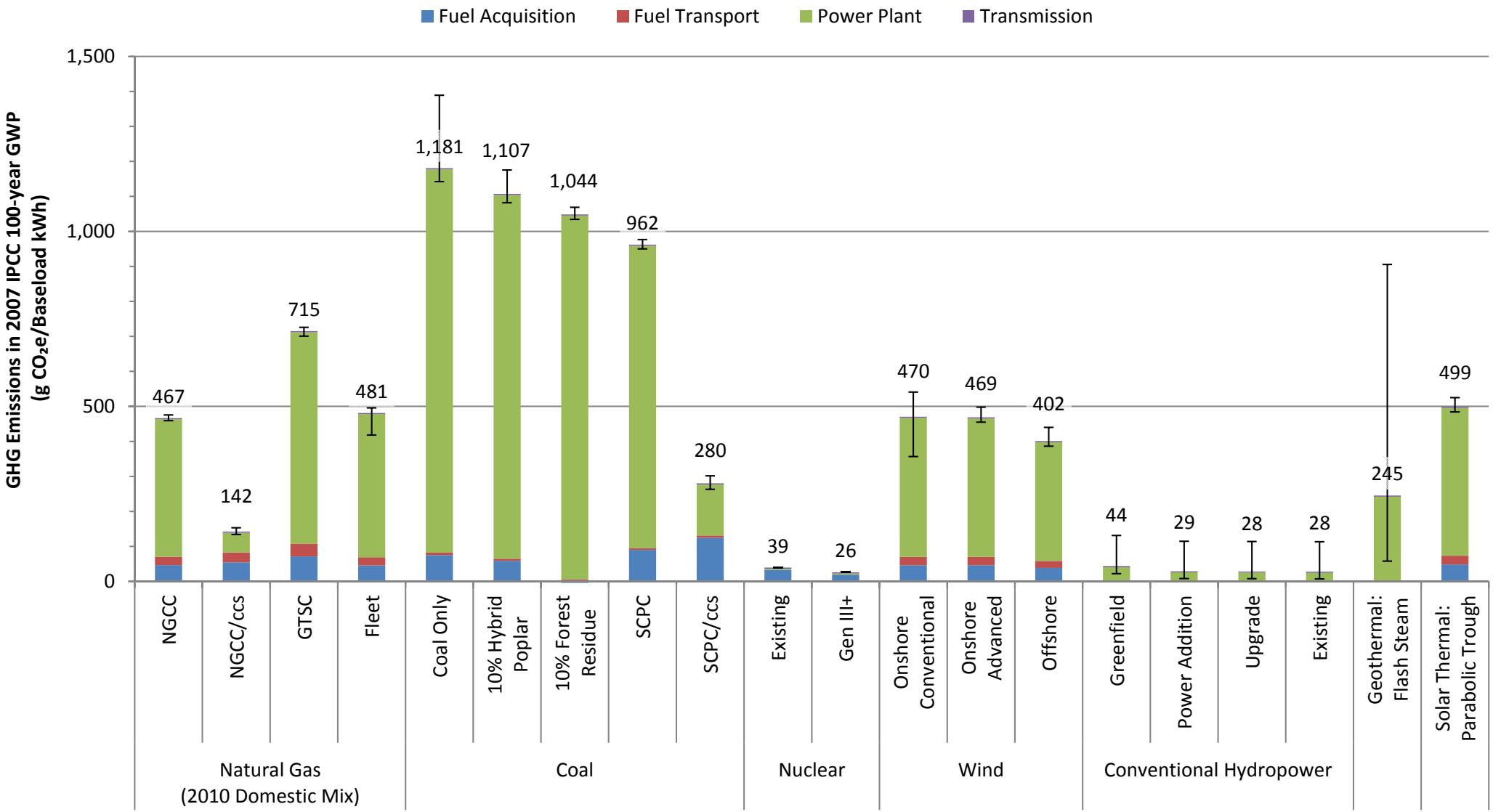


Clear definition of function leads to appropriate boundary choices



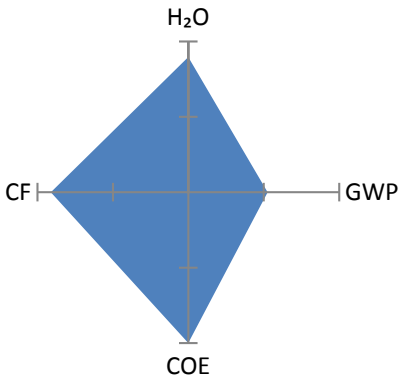
A "kWh-when-available" provides a different service than a baseload kWh

This consistent approach allows comparisons among disparate technologies

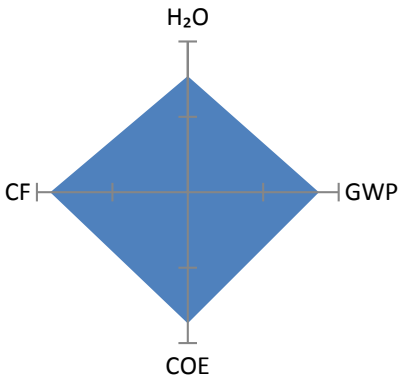


GHG emissions are not the only metric that provide a basis for comparison

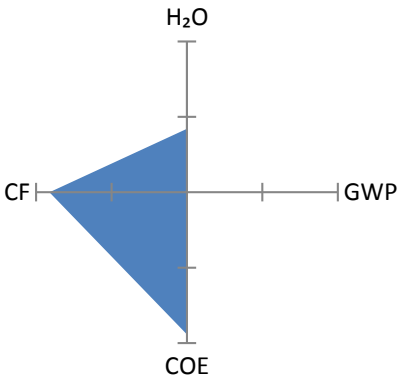
Natural Gas, Combined Cycle



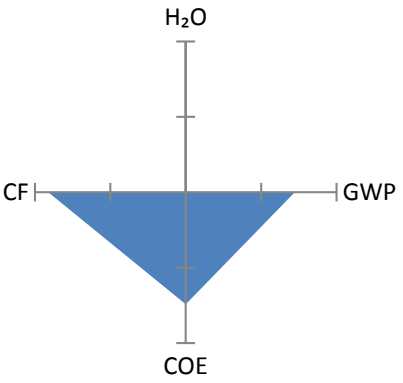
Natural Gas, Comb. Cycle w/ Carbon Capture



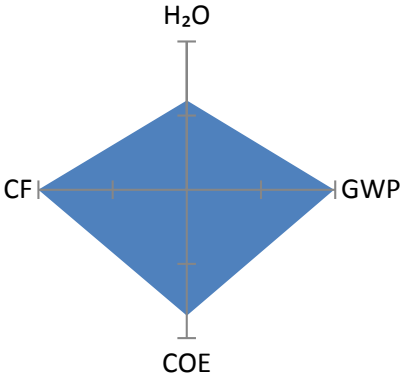
Advanced Coal

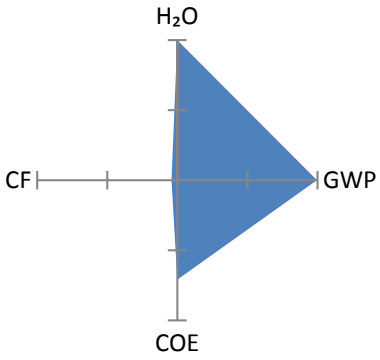


Advanced Coal, w/ Carbon Capture

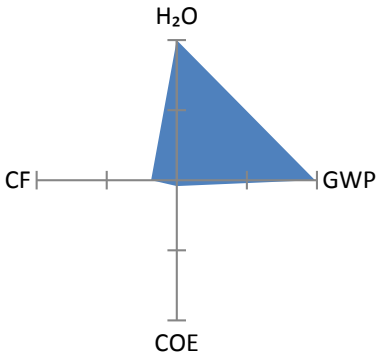


New Nuclear





Wind, Onshore



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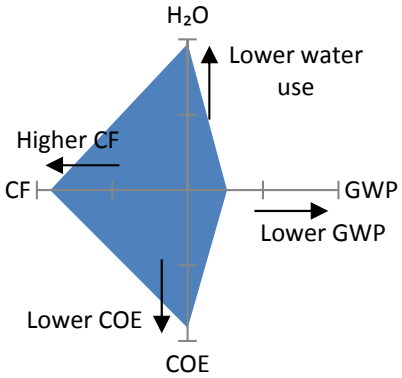
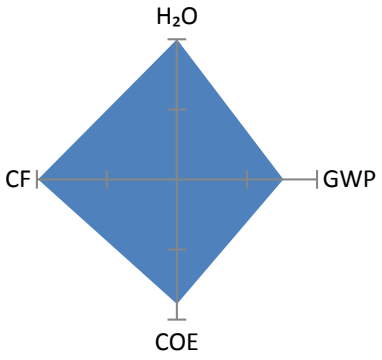
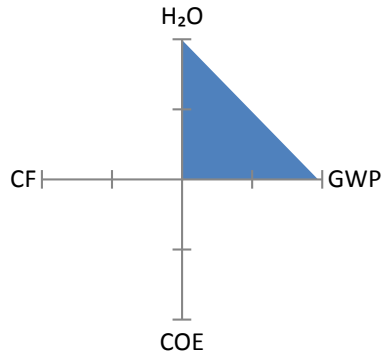


Natural Gas, Simple Cycle



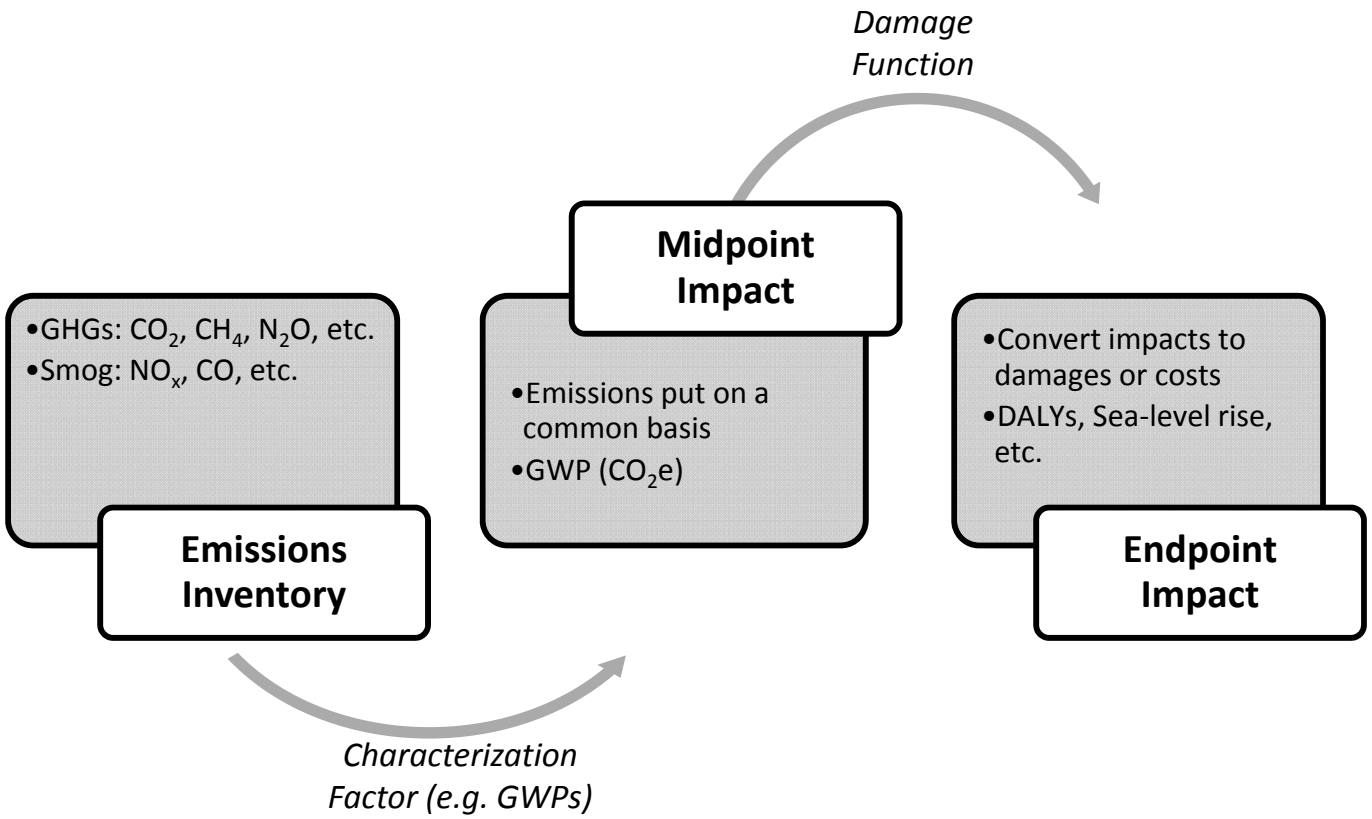
Geothermal



Solar Thermal

Spokes represent preferability of each metric relative to other technologies shown – the larger the shaded area, the more preferable the technology

LCIA maps *inventory* to *impact*, increasing usefulness, but also uncertainty



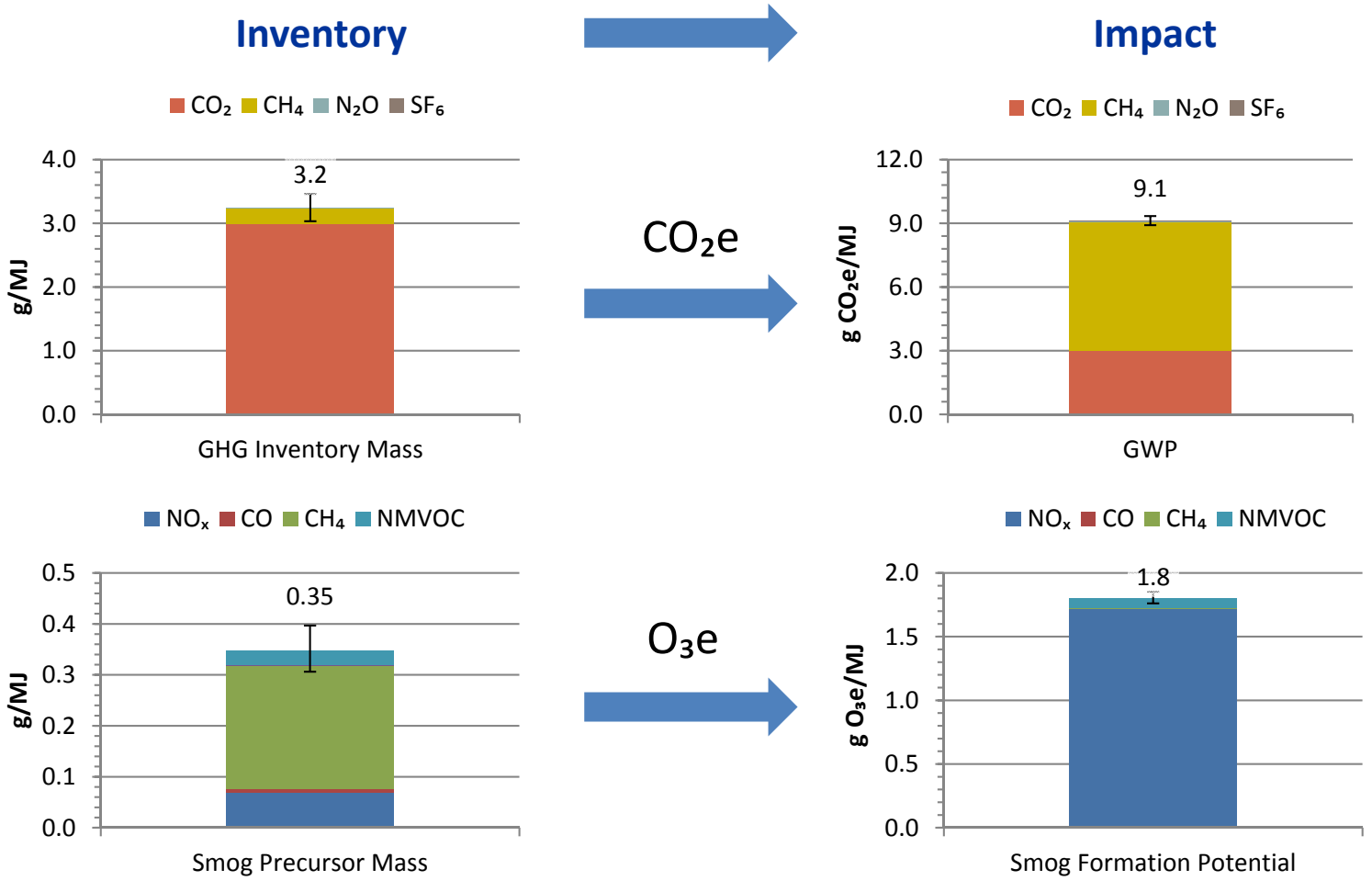
Impact Categories

- **Global Warming Potential (CO_2e)**
  - Increase in Earth's average temperature
- **Ozone Depletion (CFC-11e)**
  - Thinning of ozone layer in the stratosphere
- **Acidification (SO_2e)**
  - Increased concentration of H ions
- **Photochemical Smog Formation (O_3e)**
  - Ground-level ozone (smog)
- **Respiratory Effects ($PM_{2.5}e$)**
  - Health impacts caused by inhalation of PM
- **Toxicity**
  - Impacts to human health (cancer and non-cancer) and ecosystem
- **Ionizing Radiation**
  - Impacts on health, due to discharges of radioactive material
- **Resource Depletion**
  - Reduced future availability of a resource, due to use now
- **Eutrophication (Ne)**
  - Increase in nutrients (primarily N and P) in an aquatic system

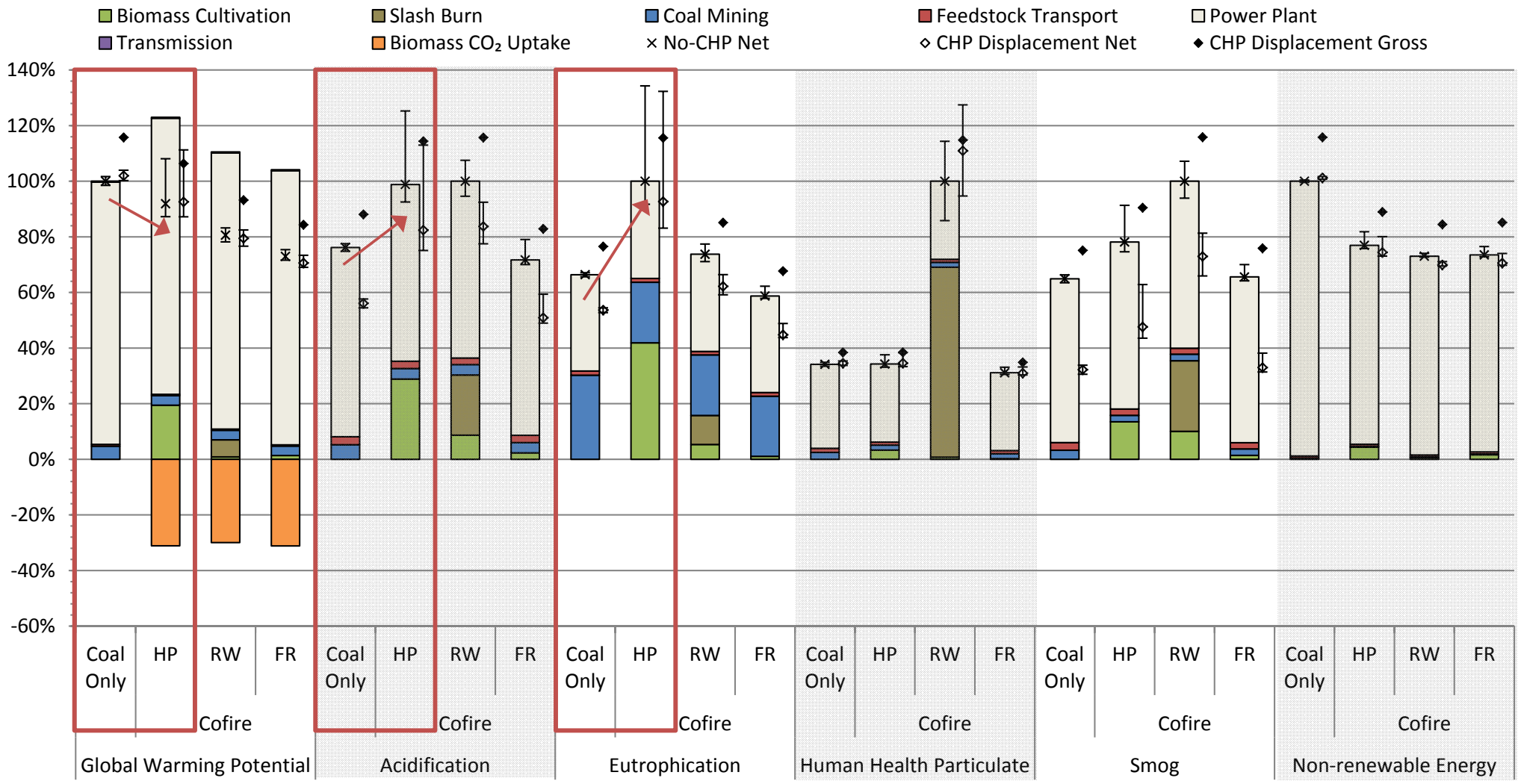
Results from impact assessment can change the importance of inventory items

Natural Gas Extraction from Marcellus Shale

The impacts associated with certain inventory items, such as CH_4 and NO_X, are critical to understanding the complete environmental footprint of natural gas extraction



Results for different impact categories can change which option is preferred



Normalized impact assessment results for a 500 MW coal & biomass co-fired, combined heat & power facility

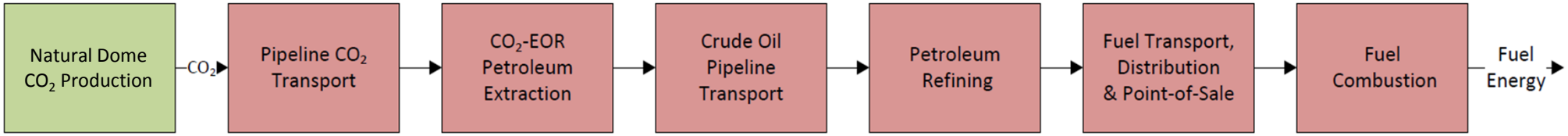
Life cycle results depend on whether you're studying *attributes* or *consequences*

	Attributional	Consequential
Purpose	*Regulatory compliance, Corporate footprint*	*Policy implications*
Goal	What are the environmental burdens of a particular product?	How does new system change the world around it?
Functional unit	Single product	Multiple products (within a defined world)
Boundaries	Truncated (to isolate burdens of a single product)	Expanded (to include indirect effects)
Uncertainty	Methods for isolating a single product can arbitrarily shift burdens between systems	Extent to which system alters the world around it

Both types of analyses – attributional and consequential – are valid LCA approaches; context of a study must be known before determining which one is appropriate

CO_2-Enhanced Oil Recovery provides examples of attributional and consequential analysis

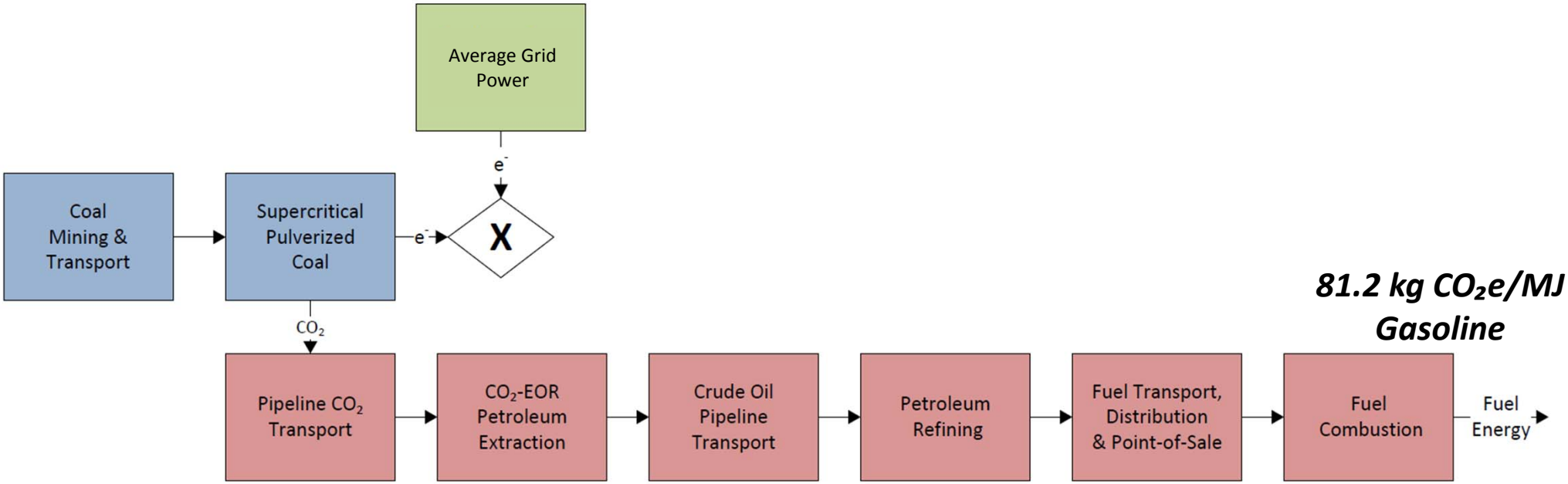
EOR *attributional* approach: Natural dome CO_2 to produced fuel



75.5 kg CO_2e/MJ Gasoline

Consequential approach: Advanced Coal CO_2 to fuel

New coal power substitutes for average grid power



81.2 kg CO_2e/MJ Gasoline

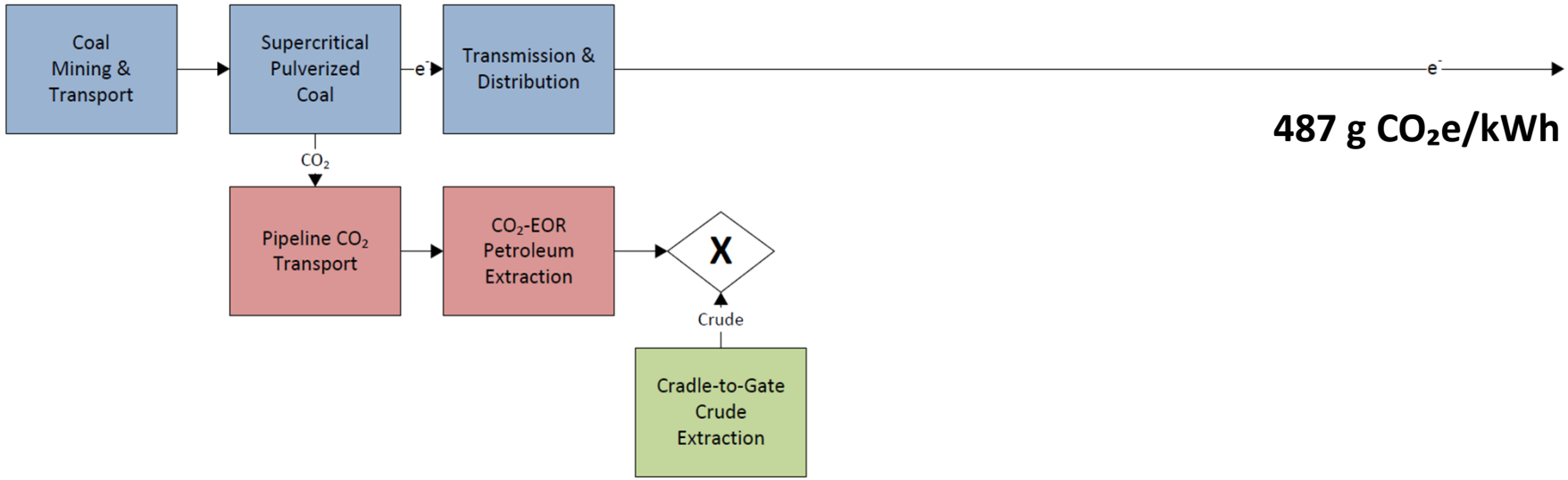
With consequential analysis, a change in perspective can change preferences

Attributional approach: Advanced coal power with sequestered CO_2

280 g CO_2e/kWh

Consequential approach: Advanced coal power with CO_2 to EOR

Reduces oil imports



487 g CO_2e/kWh

With consequential analysis, a change in perspective can change preferences

Attributional approach: Advanced coal power with sequestered CO_2

280 g CO_2e/kWh

Consequential approach: Advanced coal power with CO_2 to EOR

Existing source of CO_2 displaced with power plant captured CO_2

166 g CO_2e/kWh

Creating useful – or understanding existing – LCA results requires well-defined questions

- **What was the purpose of the analysis?**
  - Comparing two technology options
  - Evaluating impact of a policy on entire system
- **What function do the systems provide?**
  - Coal: production of feedstock vs. delivered electricity
  - Natural gas: all annual domestic or marginal shale only
- **What metrics are of interest?**
  - Greenhouses gases: 20- or 100-year GWPs, inclusion of timing and feedback effects
  - Economic, environmental, and human health metric results may favor different options; relative importance of each may differ among technologies

With LCA – as with any analysis – the more complete the picture, the more uncertain it becomes

Contact Us

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