NETL

Driving Innovation ♦ Delivering Results

LCA
Life Cycle Analysis
environmental | economic | social

Overview of Energy LCA at NETL

LCA @ DOE Special Session

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U.S. DEPARTMENT OF ENERGY | National Energy Technology Laboratory

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Overview of Energy Life Cycle Analysis at NETL
(The Agenda)

- **Purpose of LCA at NETL**
- **NETL Modeling Approach**
- **Recently Published LCA Work**
- **How to Access NETL's LCA Work**

Purpose of Life Cycle Analysis at NETL

- **Produce Energy System LCAs**
  - Inform and defend the Technology Programs
  - Baseline different energy system technologies
  - Understand technology strengths and weaknesses when viewed from a life cycle perspective
  - Identify opportunities for R&D innovation
    (through depth and transparency of analysis)

- **Improve LCA methods**
  - Expand inventory
  - Characterize uncertainty and variability
  - Build flexible and dynamic models
  - Keep data collection and modeling current with state-of-the-art LCA

- **Enhance interpretation and comparability of inventory results without losing depth and transparency**
  - Stochastic simulation of life cycle inventory
  - Tools to explore uncertainty and variability

Research, Model, Document…Repeat

- **Life Cycle Inventory (LCI) data is developed from a wide range of sources from primary to secondary data**
  - The type of data used depends on the "use" of the data within the analysis being conducted
- **All data and calculations are documented in NETL's standardized unit process spreadsheet and documentation formats for quality assurance review**
- **Unit processes are imported into the GaBi Life Cycle Assessment Software (PE International)**
- **Unit processes are assembled (modeled) to represent the scope of the LCA of interest**
- **Results are evaluated, significant data contributions are improved, and finally study results are documented**

2015 LCA Work

- **Journal Publications**
- **Natural Gas Update**
- **NG Resource Intensity Model**
- **EDF Bottom-up Synthesis**
- **Federal Data Interoperability Progress**
- **Forecast of Petroleum Baseline**
- **DOE LPO Support**
- **U.S. Coal Exports**
- **CBTL Jet Fuel Analysis**
- **Advanced Fossil Power Baseline LCAs**

Work can be accessed at:
www.netl.doe.gov/lca

Publications: NG CH_4 emissions

- *Using Common Boundaries to Assess Methane Emissions: a Life Cycle Evaluation of Natural Gas and Coal Power Systems* (pending publication in Journal of Industrial Ecology)
- Emphasizes importance of boundary selection when expressing CH_4 emission rates and comparing NG to other energy sources

Boundary	Upstream Emissions (g CH_4) Extraction	—	Processing	—	Transmission	—	Distribution	NG Exiting Boundary (g)	Loss Rate	Emission Rate
Cradle-to-Extraction	4.7							1,086	0.5%	0.43%
Cradle-to-Processing	4.7	+	2.6					1,020	6.6%	0.71%
Cradle-to-Transmission	4.7	+	2.6	+	5.2			1,005	7.9%	1.24%
Cradle-to-Distribution	4.7	+	2.6	+	5.2	+	4.5	1,000	8.4%	1.70%
Processing Only (GtG)			2.6					1,020	6.1%	0.25%
Transmission Only (GtG)					5.2			1,005	1.5%	0.52%
Distribution Only (GtG)							4.5	1,000	0.5%	0.45%
	Numerator							*Denominator*		

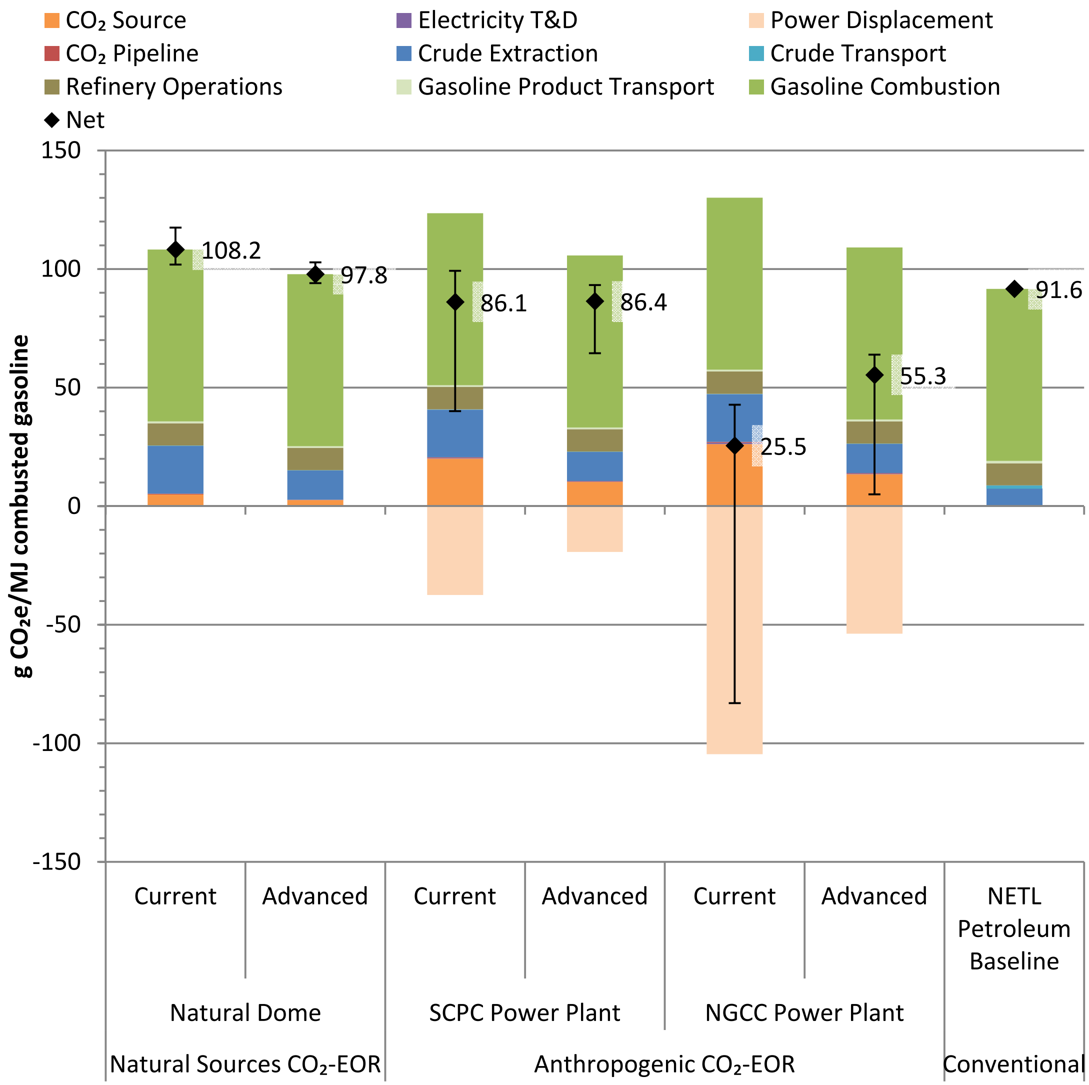
Evaluating the Climate Benefits of CO_2-Enhanced Oil Recovery Using Life Cycle Analysis – ES&T

Background:

- Cradle-to-grave boundary with a functional unit of 1 MJ of combusted gasoline
- Two sources of CO_2: natural domes and anthropogenic (fossil power equipped with carbon capture)
- Critical parameter: crude recovery ratio - how much crude is recovered per unit CO_2

Analysis Results:

- Natural CO_2: increasing crude recovery ratio decreases emissions
- Anthropogenic CO_2: electricity co-product is assumed to displace existing power; increasing the crude recovery ratio reduces the amount of CO_2 required, thereby reducing the amount of power displaced
- Only the anthropogenic EOR cases result in emissions lower than conventionally produced crude
- Carbon-intensive electricity is being displaced with captured electricity, and the fuel produced from that system receives a credit for this displacement.



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

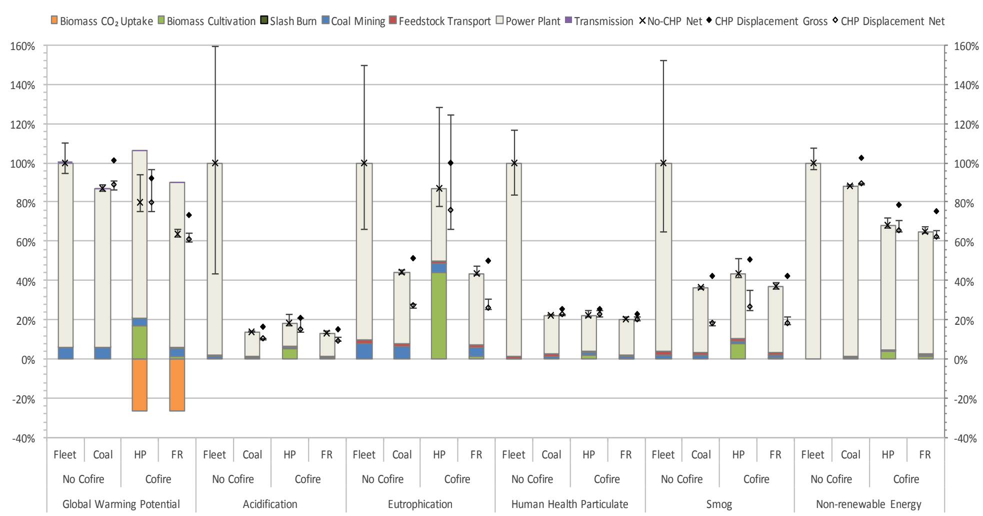
Identifying/quantifying environmental tradeoffs inherent in GHG reduction strategies for coal-fired power – ES&T

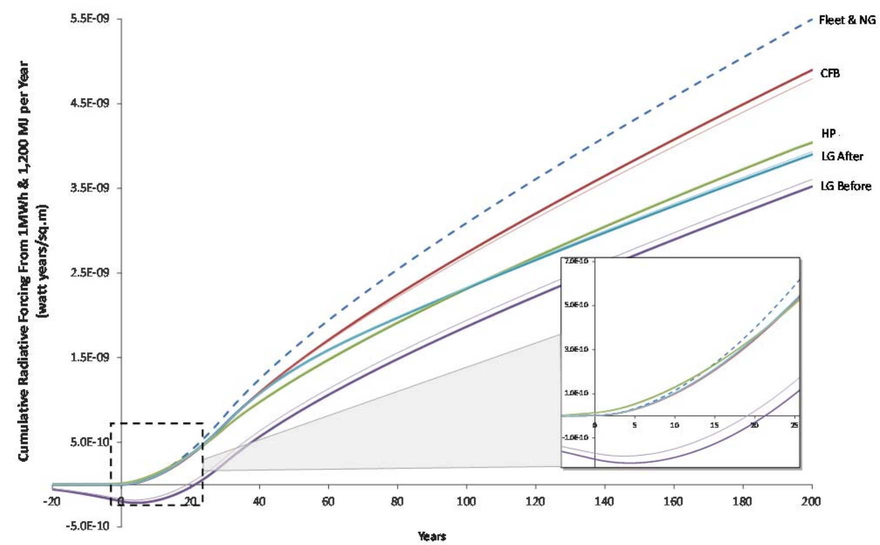
Background:

- Co-firing biomass with coal can help reduce CO_2 emissions
- Need to investigate other environmental impacts
- How does growth time affect climate impact

Analysis Results:

- Upgrading boiler & environmental controls reduces all impacts
- Intensive biomass (hybrid poplar) can increase some impacts
- Modeling decisions (growth before or after burning) makes a difference for climate impacts when accounting for emission timing

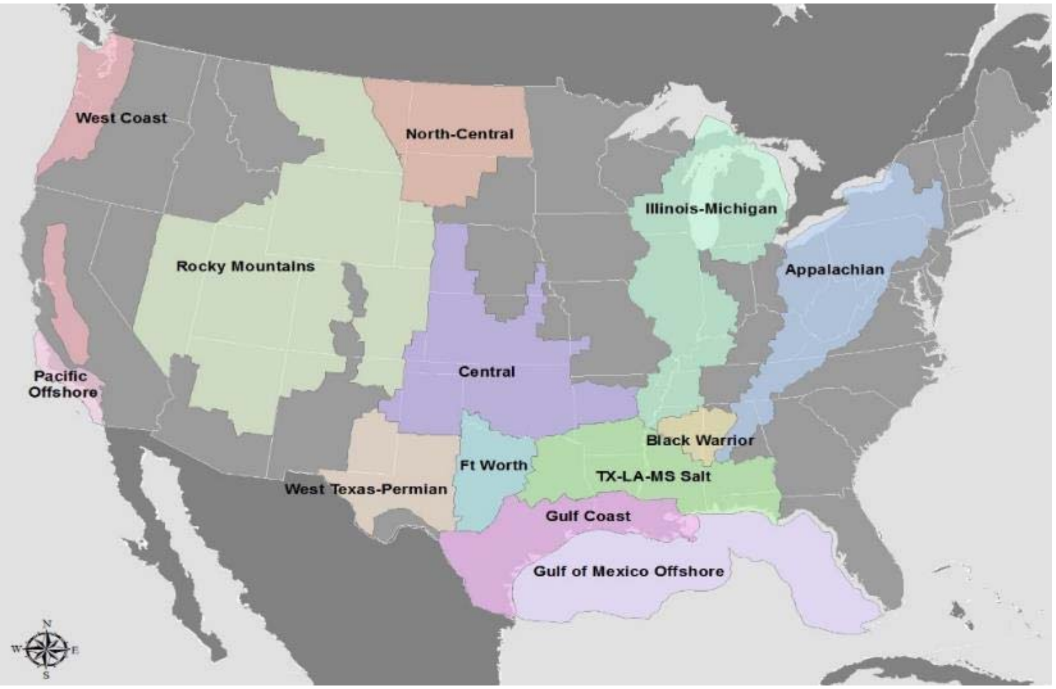




Schivley, G., Ingwersen, W. W., Marriott, J., Hawkins, T. R., & Skone, T. J. (2015). Identifying/Quantifying Environmental Trade-offs Inherent in GHG Reduction Strategies for Coal-Fired Power. Environmental Science & Technology, 49(13), 7562–7570. doi:10.1021/acs.est.5b01118

Natural Gas Modeling Updates

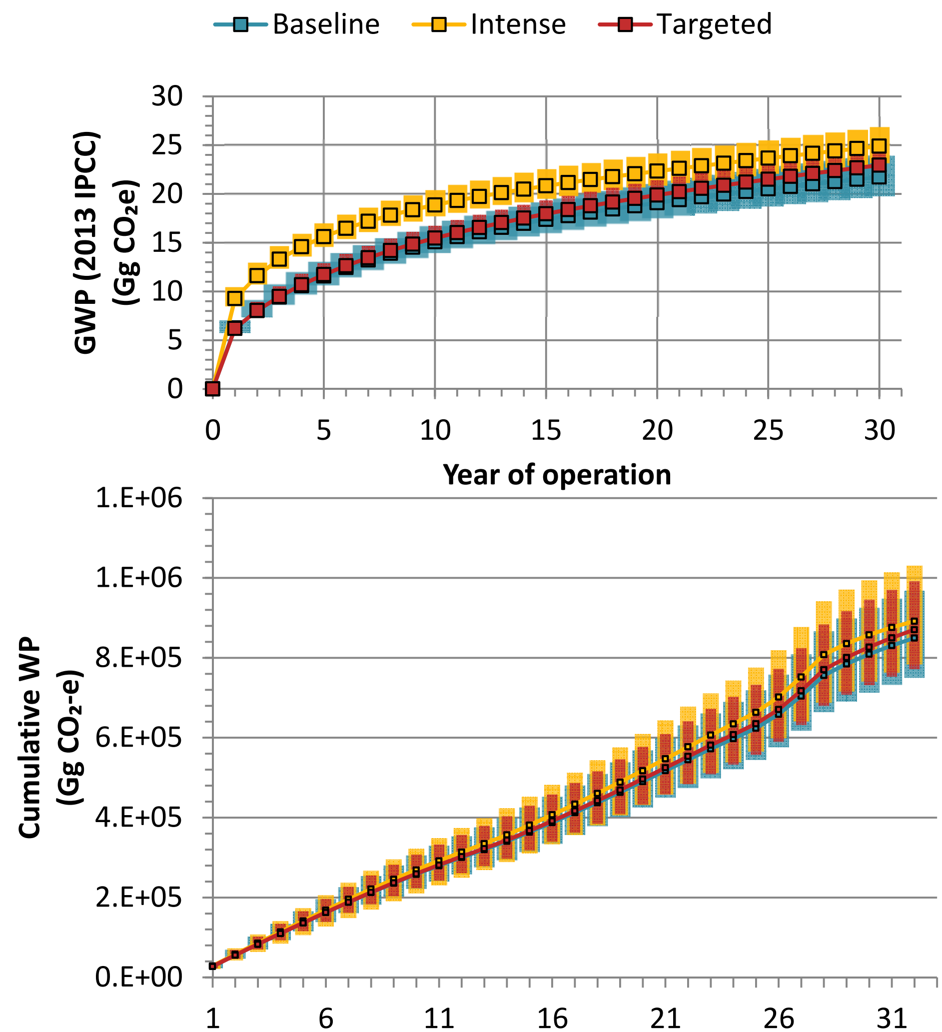
- **Regional variability:** from 7 technologies to 30 techno-regions



- **Enhanced parameterization:** unconventional completions, liquids unloading, and production fugitives
- **Monte Carlo simulation:** prevents unlikely parameter pairings

Well Impact Model & Resource Intensity Model

- **Well Impact Model generates yearly impacts (TRACI 2.1) for natural gas wells**
  - Monte-Carlo enabled
  - More granularity for well construction
  - Currently tuned for hydraulically fractured Barnett shale wells
- **Resource Intensity Model scales impact model results to play-level**

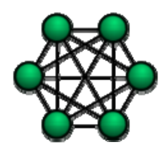


EDF bottom-up synthesis of NG supply chain (extraction through distribution)

- We are working with EDF (Environmental Defense Fund) to analyze *observed* CH_4 emissions
- Our life cycle model is an ideal platform for validating *observed* and *estimated* emissions
- Bottom-up approach: individual processes are compiled to represent an interconnected system
- Potential insight on why bottom-up NG studies consistently have lower CH_4 emission rates than top-down studies

Measure

Estimate



Model

Validate

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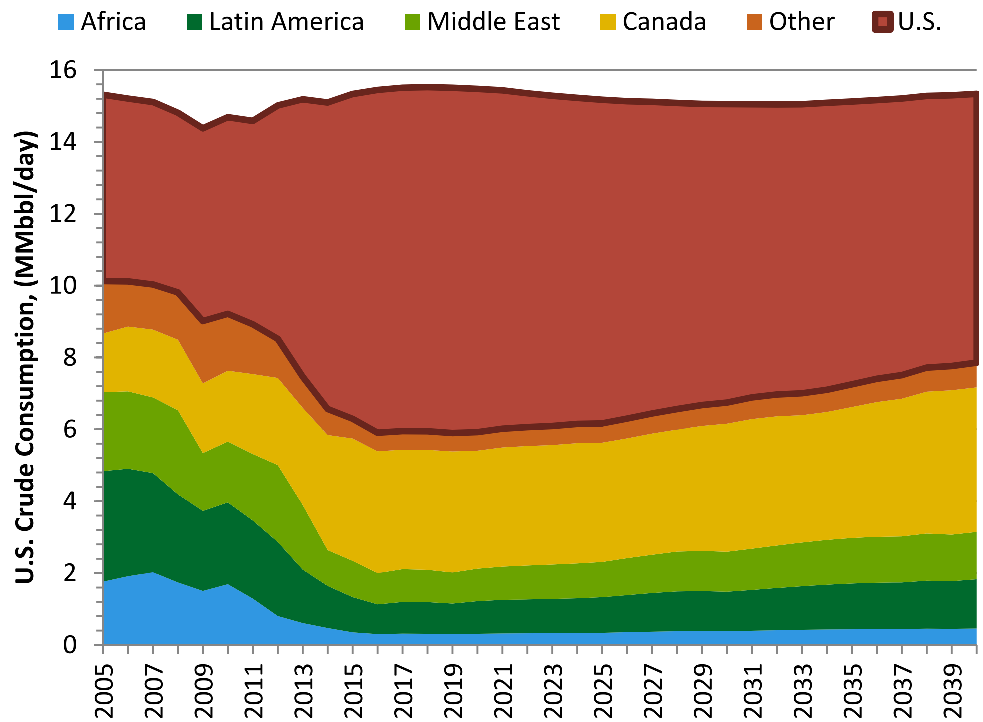
Federal LCA Commons

- **The Federal LCA Commons is a collaboration among U.S. federal agencies to combine their LCA inventories and tools into an open access, usable product (lcacommons.gov)**
- **NETL is working with NREL and USDA to translate NETL's coal database into openLCA format and publish the database on NREL's website before the end of 2015.**

US Army Corps of Engineers®

Developing the Approach for a New Petroleum Baseline; Evaluating Out to 2040

- **Significant changes since 2005 baseline analysis:**
  - Known changes to crude oil mix (source, extraction method, and quality)
  - Transition to ultra low sulfur diesel, increasing refinery hydrogen demand
- **Utilize publicly available and peer-reviewed tools to inform the life cycle impacts of extraction and refining (OPGEE and PRELIM)**
- **Evaluate to understand uncertainty in long-term comparisons of alternative fuels projects to the petroleum baseline**
- **Potential policy implications (EISA Section 526; RFS2)**
- **Working through extraction and transport; next step - refining**

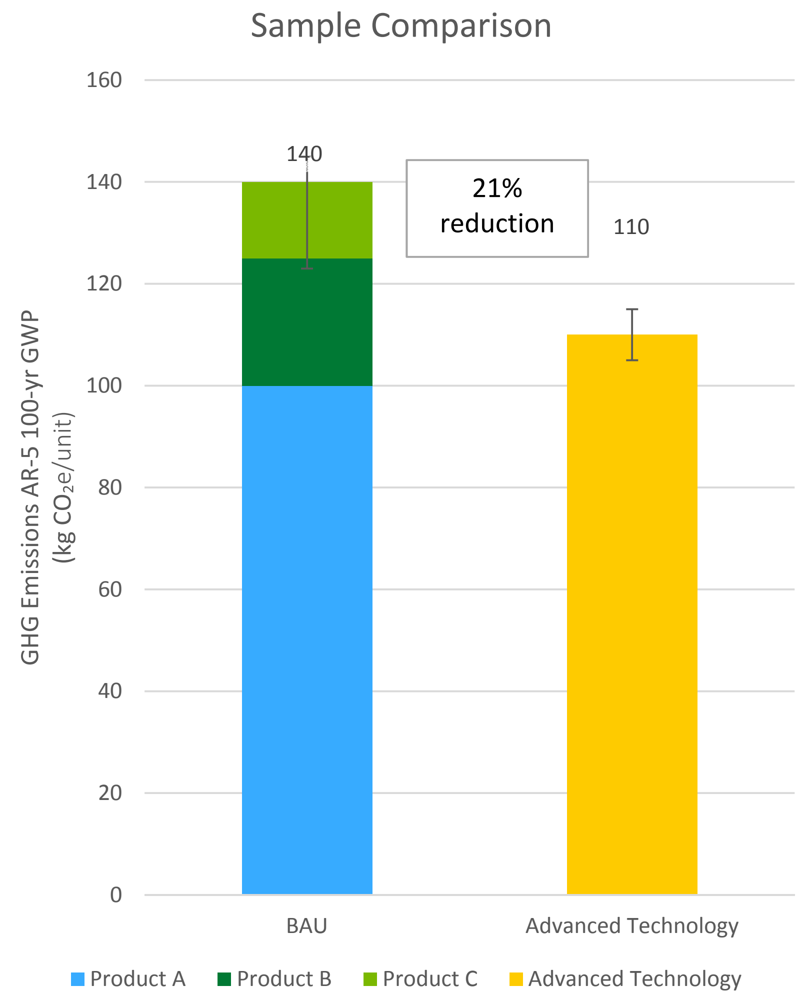


- U.S. domestic share peaks at 62% in 2016
- Tight oil accounts for 50% of U.S. domestic production by 2015
- EOR share of production doubles over the forecast period
- Canadian imports increase; all other imports drop off

1 EIA. (2013). AEO 2014 Interactive Table Viewer. US Department of Energy Retrieved January 2, 2014, from http://www.eia.gov/oiaf/aeo/tablebrowser/
2 EIA. (2013). Petroleum & Other Liquids Data. US Department of Energy Retrieved January 2, 2014, from http://www.eia.gov/petroleum/data.cfm
3 Canadian Association of Petroleum Producers. (2013). Crude Oil Forecast, Markets & Transportation. (2013-0013). Alberta, Canada: CAPP

DOE Loan Program Office GHG Analysis

- **Background:**
  - Applicants must "avoid, reduce, or sequester" GHG emissions
    - Advanced Fossil
    - Renewable Energy and Efficient Energy
  - NETL compares GHG emissions to a business-as-usual (BAU) scenario
- **NETL Analysis:**
  - Suggest BAU product or technology
  - Calculate life cycle GHG emissions for the applicant and BAU
  - Include all products in the comparison



U.S. Coal Exports - LC GHG comparison of PRB coal to foreign export competitors in the Asian market

Background:

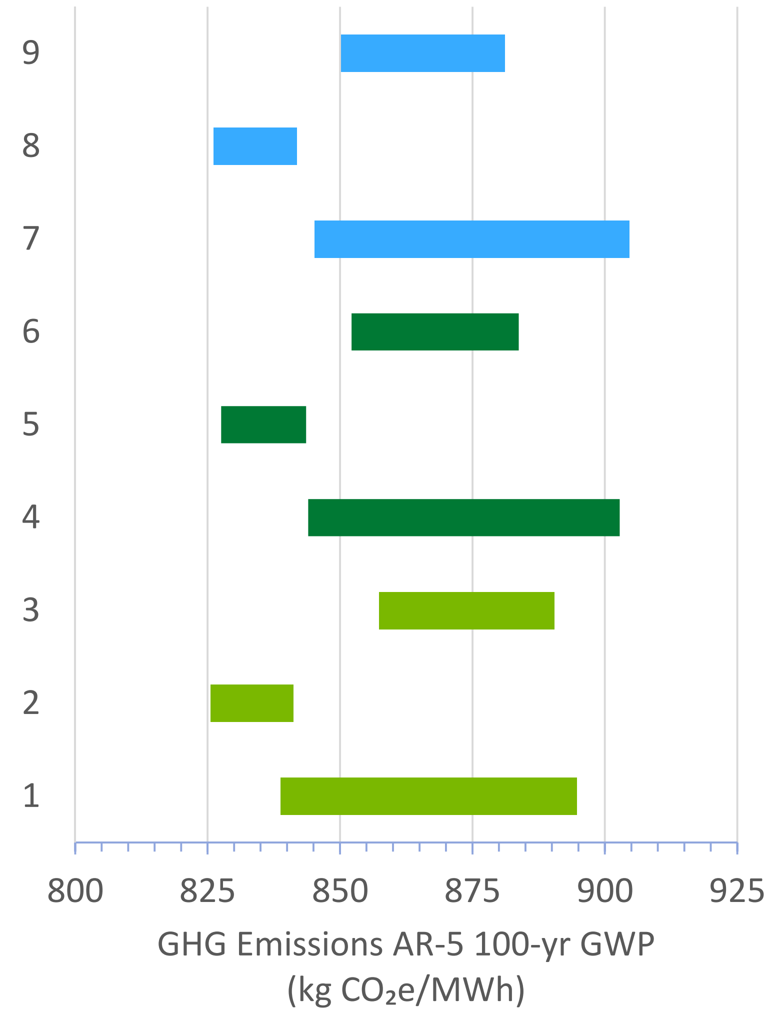
- Sources: U.S. (PRB), Australia, Indonesia
- Destinations: Japan, Korea, Taiwan

GHG Analysis:

- Emissions associated with coal mining activities are much more significant in Australia and Indonesia than PRB
- Coal from Australia has lowest emissions; Indonesia and PRB comparable
- PRB disadvantages: longer transport distance (mine to terminal, terminal to plant) and lower heating value

TRACI 2.1 Analysis:

- Global Warming Potential (GWP) is the only impact category where the coal sources are essentially even
- Non-GWP impact categories are driven by emissions from diesel combustion (transport and mining)
- As a result of the longer transport distances required to ship PRB coal to the destination in Asia, it tends to have higher impacts in the associated categories



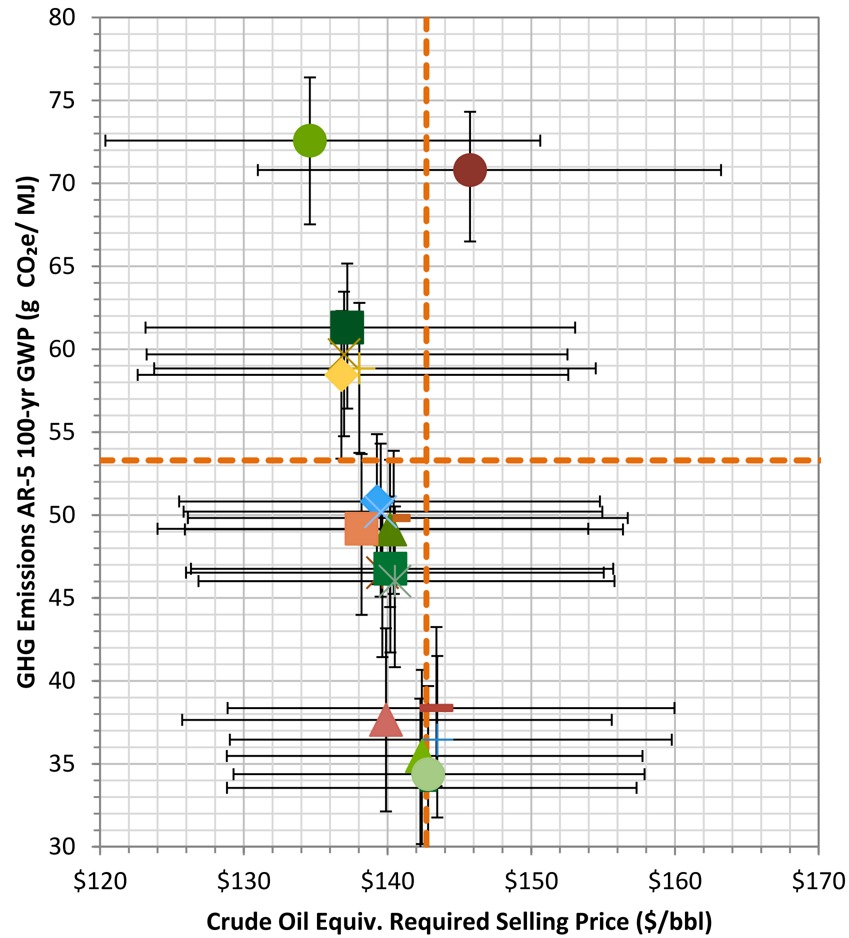
CCAT CRADA: TEA and LCA modeling support for coal and biomass to liquid fuels for alternative jet fuel

Background:

- Entrained Flow Gasifier and Transport Reactor Integrated Gasifier configurations operating on coal and biomass with Fischer-Tropsch (F-T) fuels production
- Combinations of coal and biomass were tested at both Wilsonville and EERC test facilities to “validate” the modeled results

CRADA Products:

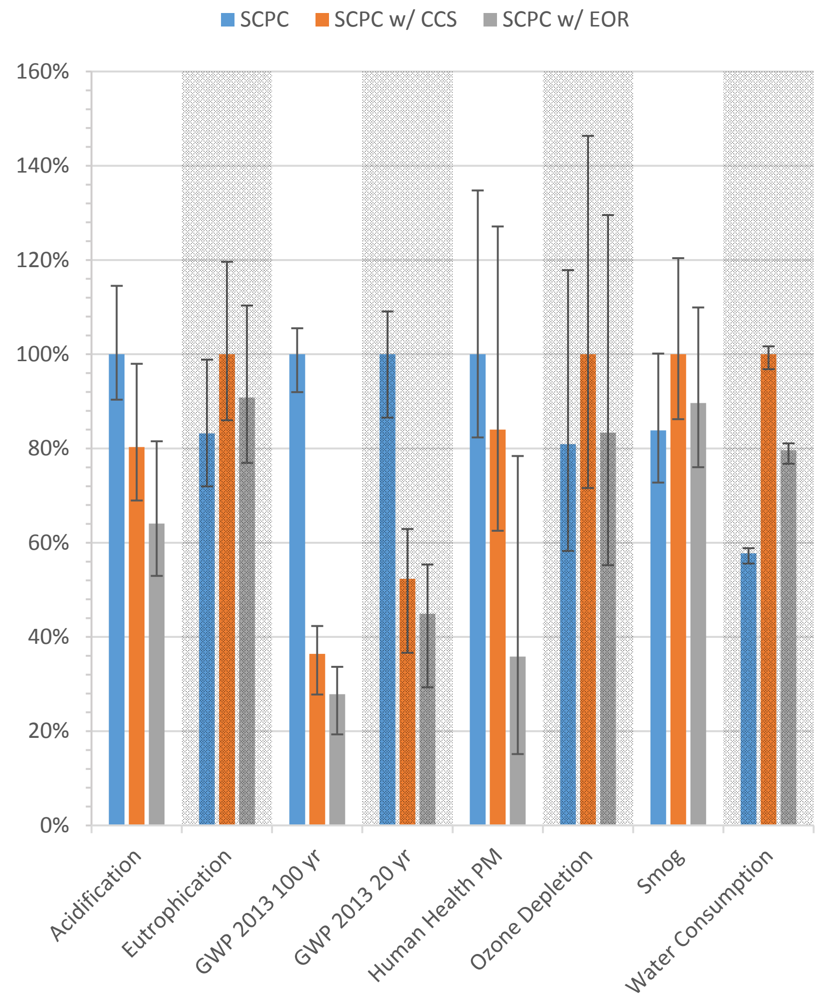
1. Comprehensive Analysis of Coal and Biomass Conversion to Jet Fuel: Oxygen Blown, Transport Reactor Integrated Gasifier (TRIG) and Fischer-Tropsch (F-T) Catalyst Configurations Modeled and Validated Scenarios
2. Comprehensive Analysis of Coal and Biomass Conversion to Jet Fuel: Oxygen Blown, Entrained-Flow Gasifier (EFG) and Fischer-Tropsch (F-T) Catalyst Configurations Modeled and Validated Scenarios
3. NETL CBTL Jet Fuel Model
4. Fischer-Tropsch Black Box Model
5. Coal and Biomass to Liquids (CBTL) Greenhouse Gas Screening and Optimization Tool



Connecticut Center for Advanced Technology, Inc.

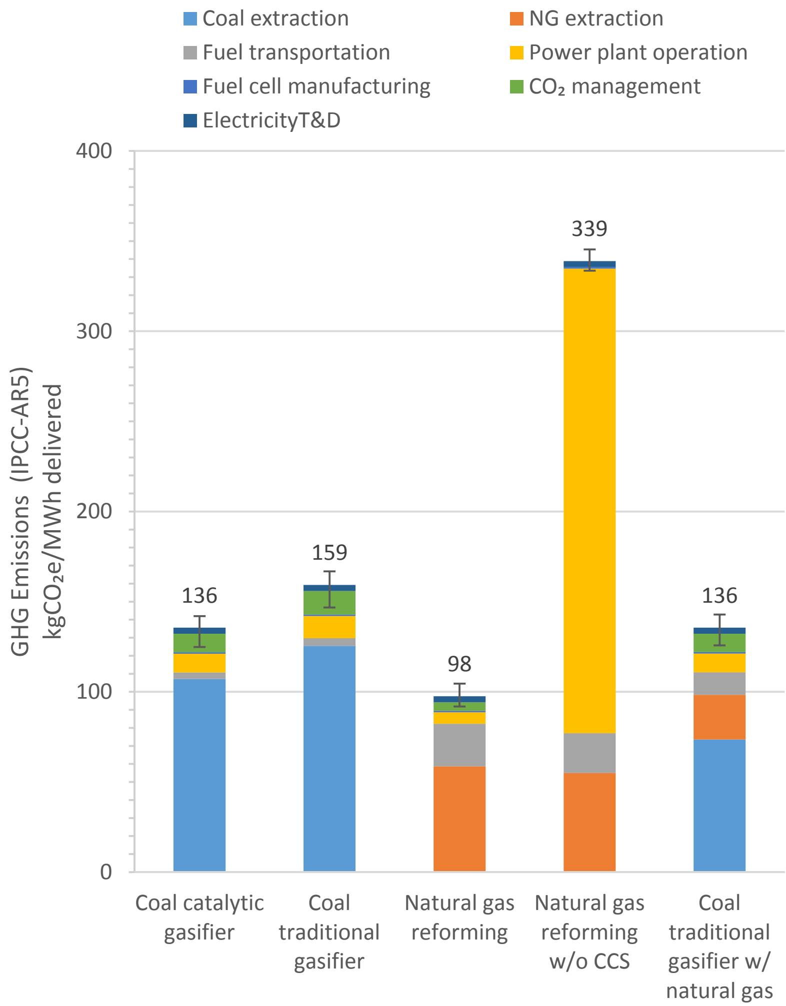
Advanced Fossil Power Baseline LCAs

- **NETL has updated power plant baseline studies – the baseline LCA studies have been updated based on the new reports:**
  - Sub-critical pulverized coal
  - Supercritical pulverized coal
  - Natural gas combined cycle
  - Oxycombusted pulverized coal
- **New LCA studies include life cycle impact results**



Solid Oxide Fuel Cell Screening LCA

- **Screening LCA performed for simulated plants using coal, natural gas, or both**
- **GWP for plants with CO_2 capture dominated by upstream impacts**
- **Fuel cell manufacturing based on existing LCA (Karakoussis et al., 2000) – model shows little sensitivity to these impacts**



Karakoussis, V., Brandon, N. P., Leach, M., & Vorst, R. v. d. (2000). The environmental impact of manufacturing planar and tubular solid oxide fuel cells. Journal of Power Sources, 101.

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