LCA at the Department of Energy (DOE), National Energy Technology Laboratory (NETL)

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Strategic Energy Analysis and Planning Division

October 2, 2013

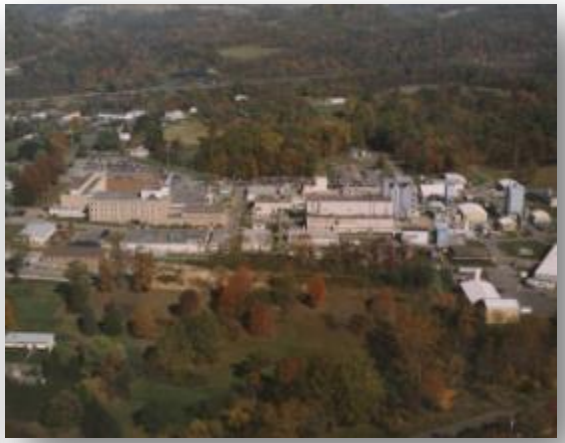
LCA XIII, Orlando, FL

National Energy Technology Laboratory

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

Oregon

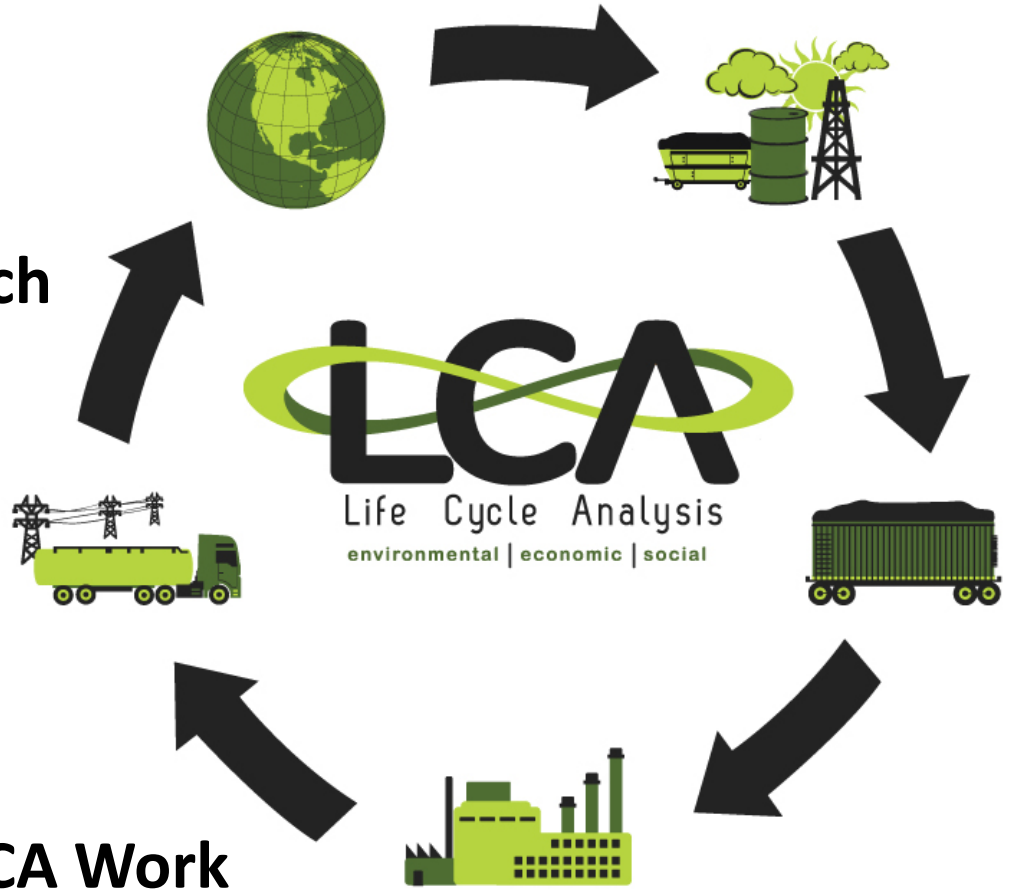
Pennsylvania



West Virginia

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

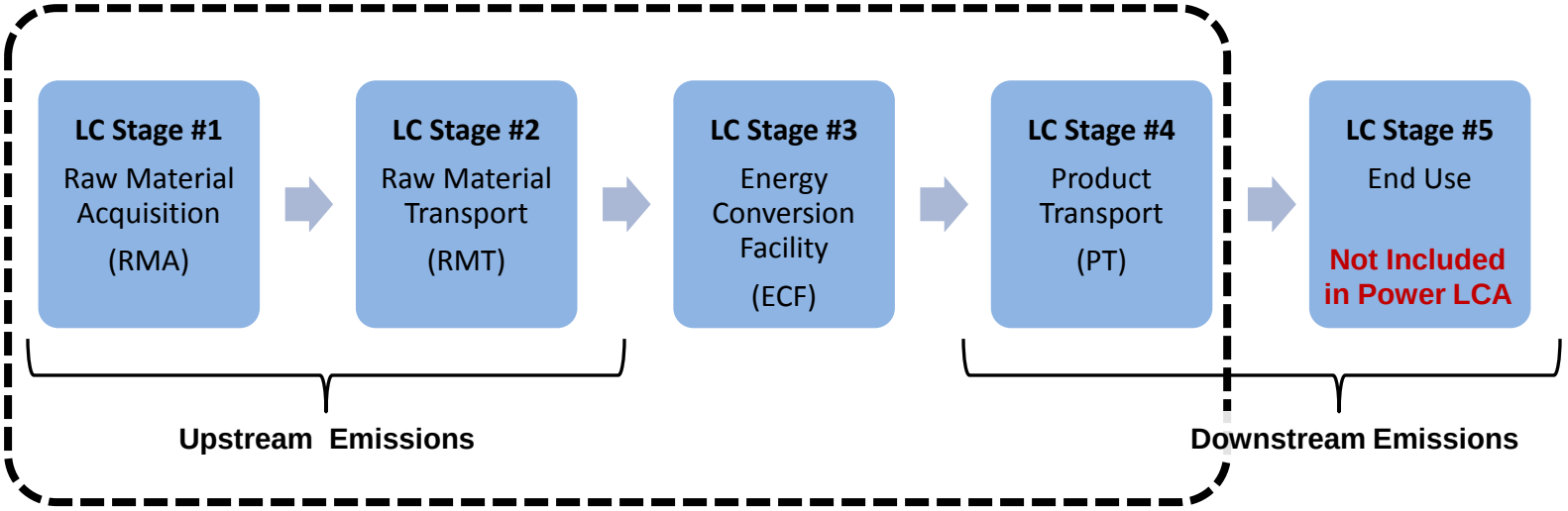
1. **Produce Energy System LCAs**
   - Inform and defend the Technology Programs
   - Baseline different energy system technologies
   - Understand technology strengths and weaknesses when viewed from a life cycle perspective
   - Identify opportunities for R&D innovation (through depth and transparency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

2. **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

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

NETL Life Cycle Analysis Approach

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



- **The ability to compare different technologies depends on the functional unit (denominator); for power LCA studies:**
  - 1 MWh of electricity delivered to the end user

NETL Life Cycle Study Metrics

- **Greenhouse Gases**
  - CO_2, CH_4, N_2O, SF_6
- **Criteria Air Pollutants**
  - NO_X, SO_X, CO, PM10, Pb
- **Air Emissions Species of Interest**
  - Hg, NH_3, radionuclides
- **Solid Waste**
- **Raw Materials**
  - Energy Return on Investment
- **Water Use**
  - Withdrawn water, consumption, water returned to source
  - Water Quality
- **Land Use**
  - Acres transformed, greenhouse gases
- **Life Cycle Cost**
  - Cost of Electricity (COE), Total Overnight Cost (TOC)

Converted to Global Warming Potential using IPCC 2007 100-year CO_2 equivalents

CO_2 = 1
CH_4 = 25
N_2O = 298
SF_6 = 22,800

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**

Uncertainty Matters when Comparing Alternatives

- **Data Uncertainty (or Variability) – does the data accurately represent what was modeled, is there variability in the key parameters**

- **Model Uncertainty – introduced by choices the LCA Practitioner makes; e.g., the choice of allocation procedure, impact assessment method, etc.**

- **Scenario Uncertainty – applied when multiple design options or implementation strategies are possible**

2013 LCA Work

1. Production of Zero Sulfur Diesel Fuel from Domestic Coal: Configurational Options to Reduce Environmental Impact (Under Review)
2. Synergistic Production of Transport Fuels (Diesel, Jet, Gasoline) from Coal (Under Review)
3. CTL Pathway Study (Under Review)
4. Cost and Performance Baseline for Fossil Energy Plants Volume 4: Coal-to-Liquids via Fischer-Tropsch Synthesis (Under Review)
5. Baseline Analysis of Subbituminous Coal and Biomass to Gasoline (Indirect Liquefaction by Methanol Synthesis) Revision 2 (Under Review)
6. Analysis of Natural Gas-to Liquid Transportation Fuels via Fischer-Tropsch (2013)
7. Recommendations for Assessing the Environmental Performance and Costs of CO_2-EOR Systems (Under Review)
8. Gate-to-Gate Life Cycle Inventory and Model of CO_2-Enhanced Oil Recovery (2013)
9. Gate-to-Grave Life Cycle Analysis Model of Saline Aquifer Sequestration of Carbon Dioxide (2013)
10. Cradle-to-Gate Life Cycle Analysis Model for Alternative Sources of Carbon Dioxide (2013)

Reports & Presentations can be accessed at:

www.netl.doe.gov/energy-analyses

From Unit Processes to Completed LCAs: NETL Life Cycle Analysis Library

the ENERGY lab
Website: www.netl.doe.go
Customer Service: 1-800-553-7681

Life Cycle Analysis at NETL

- Methodology includes the critical analysis of scope, assumptions, level of detail, data quality, interpretation of results, etc.
- Purpose is to perform and publish a transparent LCA
- NETL LCA studies are ISO 14040 compliant

Figure 1. Life Cycle Stage Definition

Power Systems LCA Tool (Power LCAT)

- A high-level dynamic model that calculates production costs and tracks environmental performance for a range of electricity generation technologies
- Joint effort between Sandia National Laboratories (SNL) and the National Energy Technology Laboratory (NETL)
- Allows for quick sensitivity analysis on key technical and financial assumptions, such as: capital, O&M, and fuel costs; interest rates; heat rates; etc.

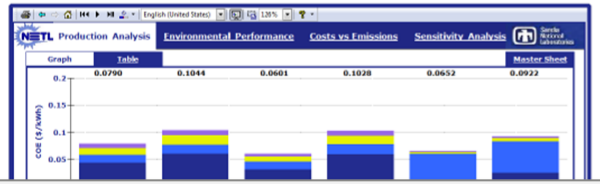
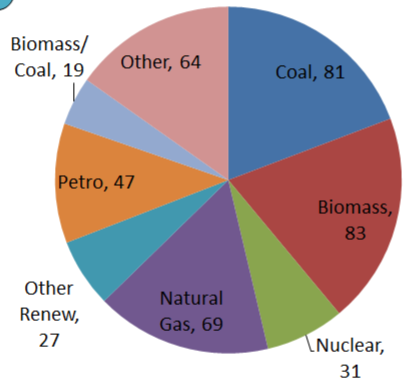


Figure 2. Power LCAT Screenshot

NETL Unit Process Library

- Available on the NETL Energy Analysis website, complete with full documentation
- 420 unit processes are contained in the NETL library
- Includes unit processes from all 5 life cycle stages and a range of technologies
- Rollup unit processes represent a collection of smaller unit processes that provide cradle-to-gate inventory results for a more complex process (e.g. production of hybrid poplar or refined diesel fuel)

NETL unit processes can be accessed at:
www.netl.doe.gov/LCA



"Other" includes: water processing, CO_2 management, and generic transport processes

"Other Renew." includes: ethanol, geothermal, hydro, solar thermal, and wind

Figure 3. Unit Process Breakdown by Technology

Upstream Dashboard Tool

- Updating with Monte Carlo analysis in 2013
- Provides users access to stage-wise life cycle emissions, water emissions, and water and energy use

NETL LCA Product Library

- Production of Zero Sulfur Diesel Fuel from Domestic Coal: Configurational Options to Reduce Environmental Impact (Under Review)
- Synergistic Production of Transport Fuels (Diesel, Jet, Gasoline) from Coal (Under Review)
- CTL Pathway Study (Under Review)
- Cost and Performance Baseline for Fossil Energy Plants Volume 4: Coal-to-Liquids via Fischer-Tropsch Synthesis (Under Review)
- Baseline Analysis of Subbituminous Coal and Biomass to Gasoline (Indirect Liquefaction by Methanol Synthesis) Revision 2 (Under Review)
- Analysis of Natural Gas-to Liquid Transportation Fuels via Fischer-Tropsch (2013)
- Recommendations for Assessing the Environmental Performance and Costs of CO_2-EOR Systems (Under Review)
- Gate-to-Gate Life Cycle Inventory and Model of CO_2-Enhanced Oil Recovery (Under Review)
- Gate-to-Grave Life Cycle Analysis Model of Saline Aquifer Sequestration of Carbon Dioxide (Under Review)
- Cradle-to-Gate Life Cycle Analysis Model for Alternative Sources of Carbon Dioxide (Under Review)
- Role of Alternative Energy Sources Technology Assessments (2012):
  - -Coal/Biomass Co-firing
  - -Geothermal
  - -Hydropower
  - -Natural Gas
  - -Nuclear
  - -Solar Thermal
  - -Wind
  - - Technology Compilation
- NETL Upstream Dashboard Tool (2012; 2013 Update)
- Life Cycle Greenhouse Gas Analysis of Advanced Jet Propulsion Fuels: Fischer Tropsch Based SPK-1 Case Study: Report and Model (2012)
- Life Cycle Greenhouse Gas Inventory of Natural Gas Extraction, Delivery, and Electricity Production (2011)
- Life Cycle Analysis: Ethanol from Biomass (2011)
- Life Cycle Analysis: Existing Pulverized Coal (EXPC) Power Plant (2010)
- Life Cycle Analysis: Natural Gas Combined Cycle (NGCC) Power Plant (2010; 2013 Update)
- Life Cycle Analysis: Integrated Gasification Combined Cycle (IGCC) Power Plant (2010; 2013 Update)

NETL unit processes can be accessed at:

www.netl.doe.gov/LCA

Life Cycle Impact Assessment (LCIA)

- **Reviewed TRACI, ReCiPe, Impact 2002+ and EDIP**
  - NETL will use TRACI 2.1 with some modifications, may use ReCiPe as a second method
- **Modifications and Additions**
  - Modify Human Health Particulates
    - Actual impacts vary by release height and population density
    - Factors are available from EPA
  - Scale Water Use by Geography
    - Location of withdrawal/use is as important as quantity
    - NETL can increase internal capabilities with training by outside SMEs
  - Remove Resource Depletion
    - Category doesn't account for new oil/gas resources
  - Expand GWP Inventory
    - Ozone precursors
    - Black carbon, sulfur and nitrate aerosols
  - Add Cumulative Energy Demand Metric
    - Captures total energy use in system
    - Develop factors for new resources like tight oil and tar sands
    - At most 5% different from ReCiPe fossil depletion factors
  - Include Significant Toxic Emissions
    - Report list of emissions and results separately due to high uncertainty

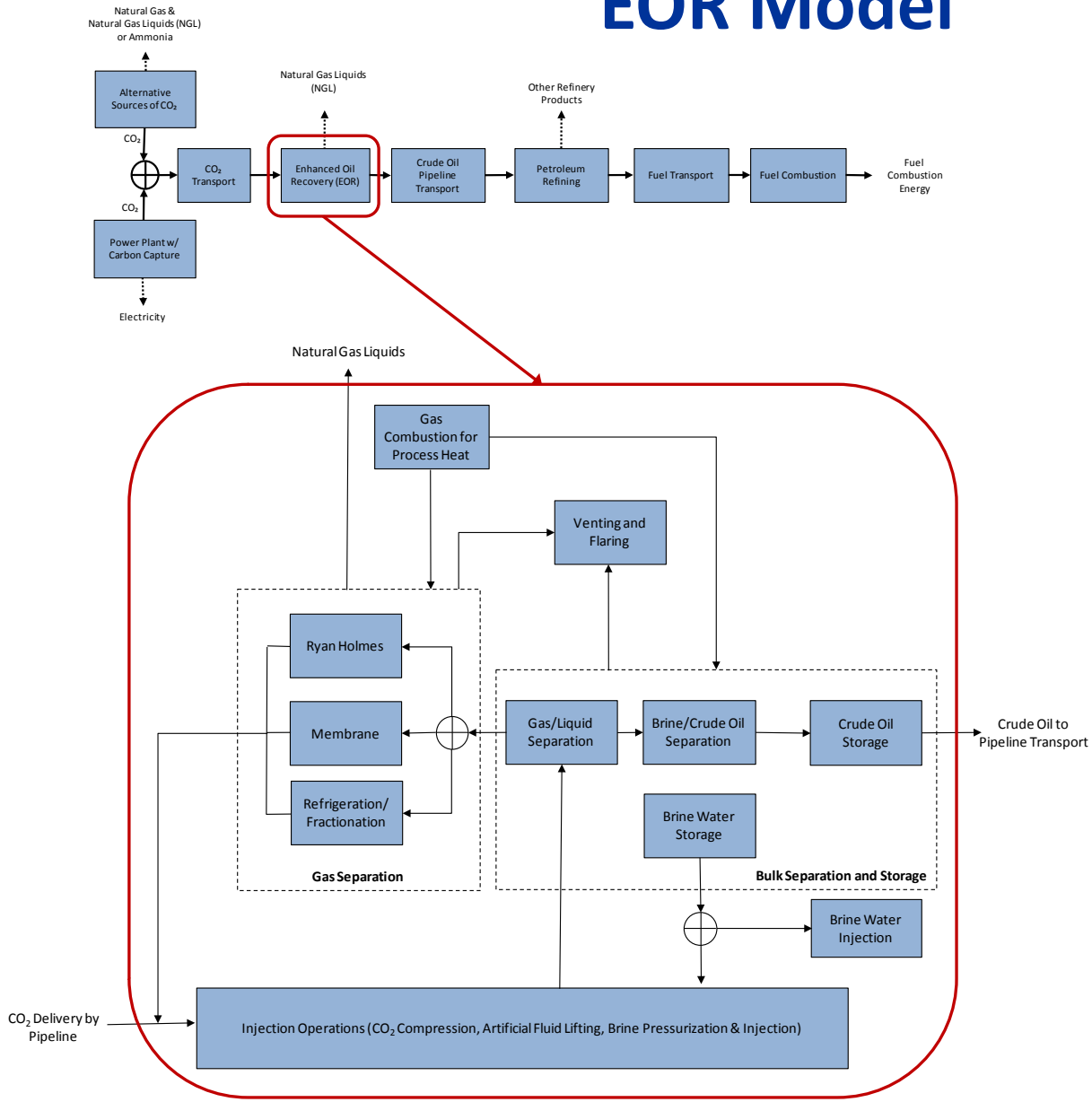
TRACI is the only method with data specific to the U.S.

In use by many U.S.-based institutions and agencies

NETL Transition to openLCA Modeling Platform

- **Conducted an extensive review of available LCA software**
  - Goal: Evaluate ways of making NETL's LCA work, especially unit processes, models and tools, more accessible and transparent to the public & more efficient to perform
  - Evaluation categories included: interoperability, features, ease of use, visualization, support, cost, maintenance, analysis time, data, transparency, and LCA community integration and impact
- **NETL's evaluation of the key advantages of openLCA**
  - Open Source
    - Increased transparency for internal and external users
    - Ability to share models without worrying about licenses
    - Full access for key stakeholders
  - Enhanced Analysis
    - Monte Carlo uncertainty analysis
    - Data pedigree matrix
    - LCIA sub-categories
  - LCA Community of Practices
    - EPA, USDA, etc.
    - Drive tool development
- **NETL plans to transition existing models to openLCA over the next year**

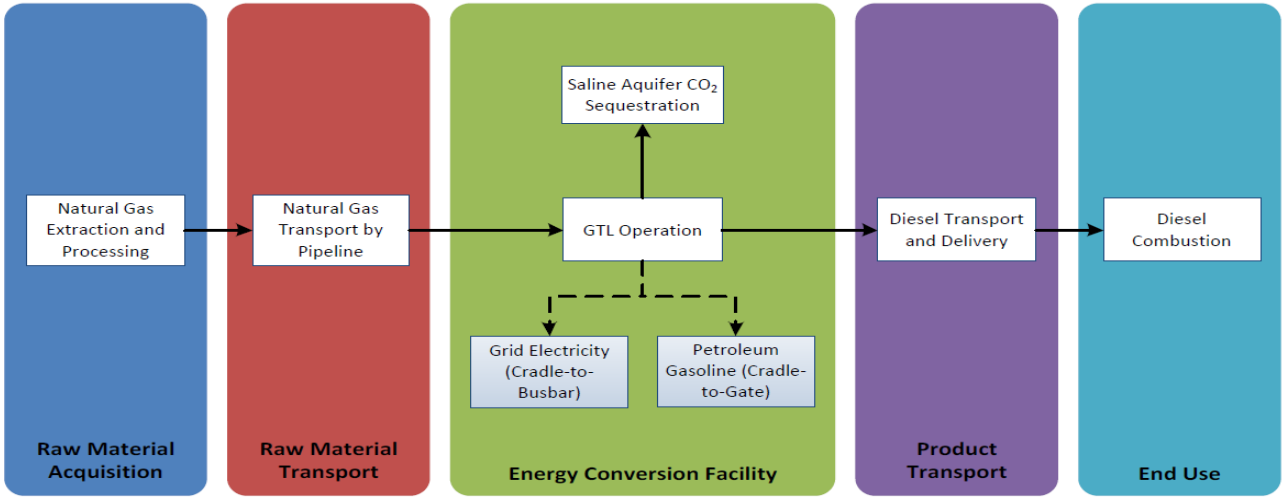
EOR Model

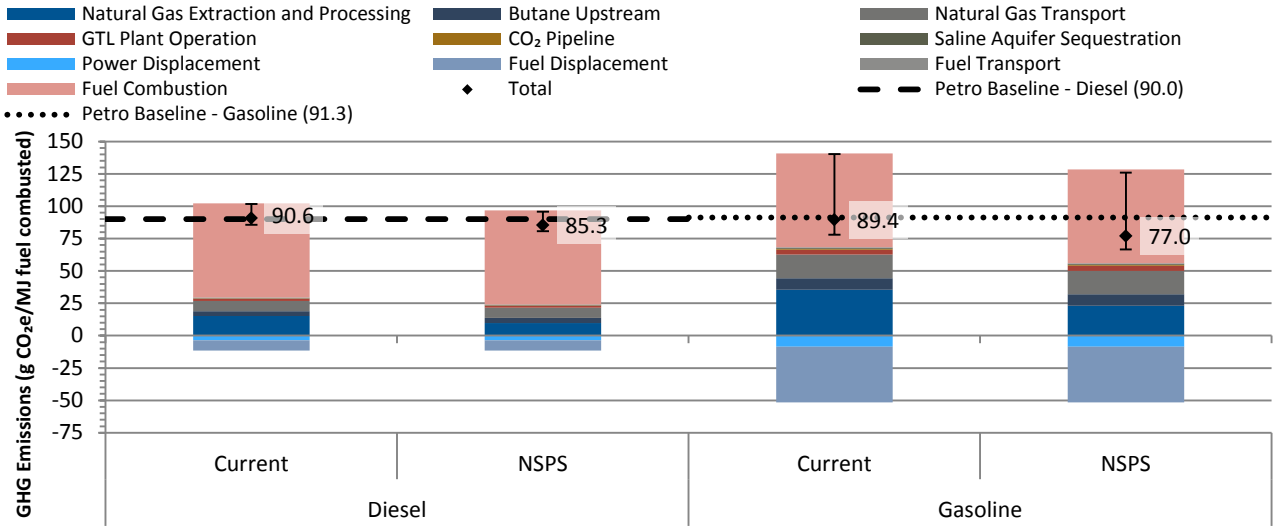


- Accounts for different CO_2 sources, gas processing technologies, crude oil recovery rates, and other variables
- GHG results are sensitive to crude oil recovery rate and CO_2 injection pressure
- Displacement is caused by co-products and contributes to most of study uncertainty
- Helps answer questions related to U.S. energy security

Fossil Fuels 2 Session
10/2/13 3:00-4:30 PM

Application of LCA to advanced fuel systems such as natural gas-to-liquids (GTL)





- Functional unit of 1 MJ of combusted diesel or gasoline
- Upstream natural gas based on a detailed model
- GTL co-products are managed with displacement
- Improved upstream natural gas practices can push life cycle GHG emissions below petroleum baseline
- Uncertainty straddles the baseline

Fossil Fuels 1 Session
10/2/13 1:00-2:30 PM

Integrated energy systems often produce a mix of material and energy co-products

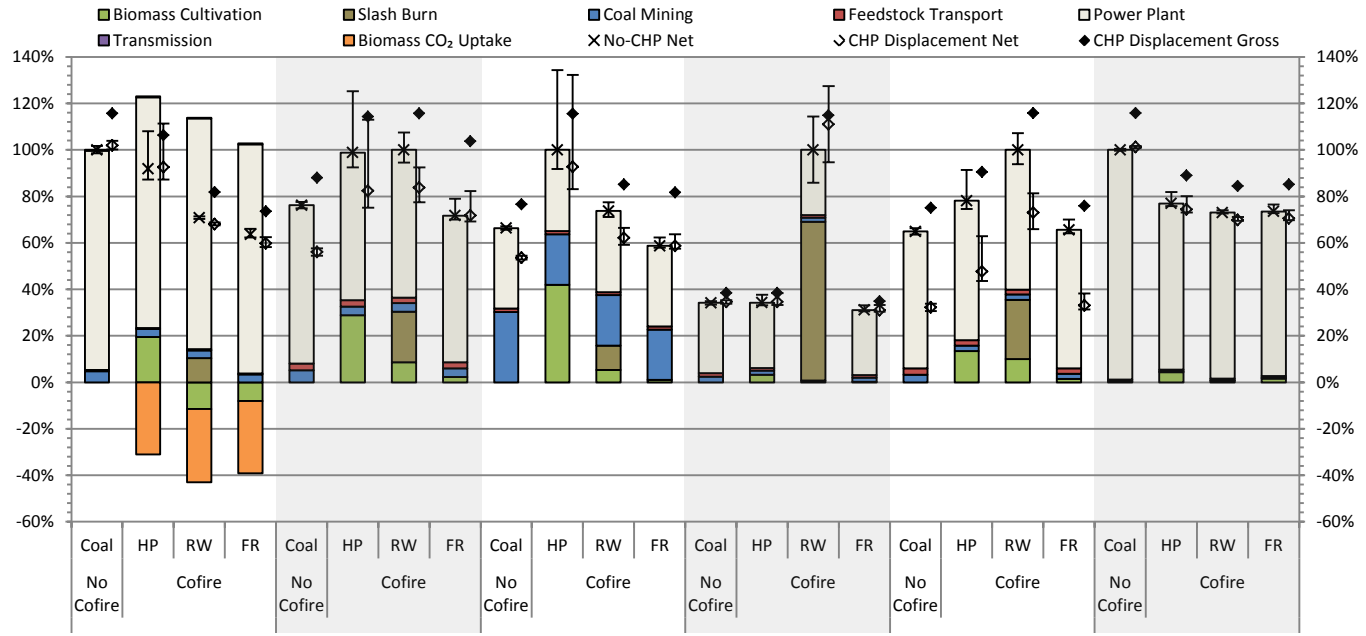
- Examples
  - Thermochemical conversion plants (GTL, CTL, CBTL) produce fuels and electricity
  - CO_2-EOR systems produce electricity (when power plants are the CO_2 source) and fuels (from refined EOR crude)
- Allocation?
  - Mass allocation is not possible with electricity as a co-product
  - Economic allocation is possible, but costs are relative and societal values reflected by prices do not necessary indicate relative environmental burdens of co-products
  - Energy allocation is possible if all co-products can be expressed on an energy basis, but does not account for differences in *useful* energy
- Displacement?
  - Large scale energy systems can affect demand for competing products
  - Displacement considers broader consequences of co-production

Displacement is more appropriate than allocation for large scale energy systems because they affect conventional routes to energy production.

Fossil Fuels 2 Session
10/2/13 3:00-4:30 PM

Co-fire Combined Heat and Power (CHP)

- **Joint project with EPA's National Risk Management Research Laboratory (NRMRL)**
- **Examination of coal-only and co-fire with three biomass types**
  - Hybrid poplar
  - Roundwood
  - Forest residue



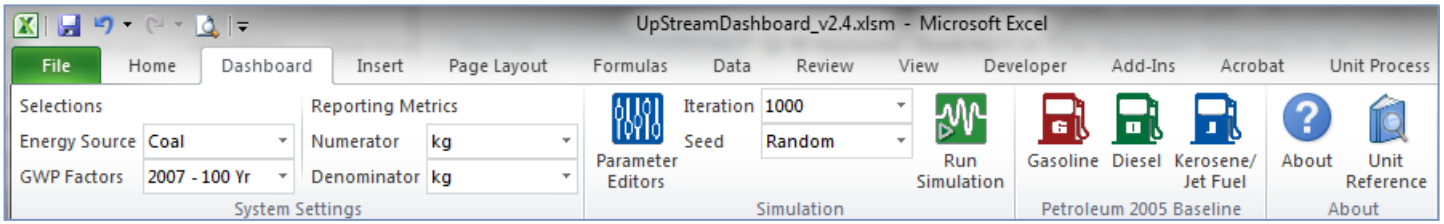
Biofuel feedstocks reduce GHG emissions, but may increase other impacts.

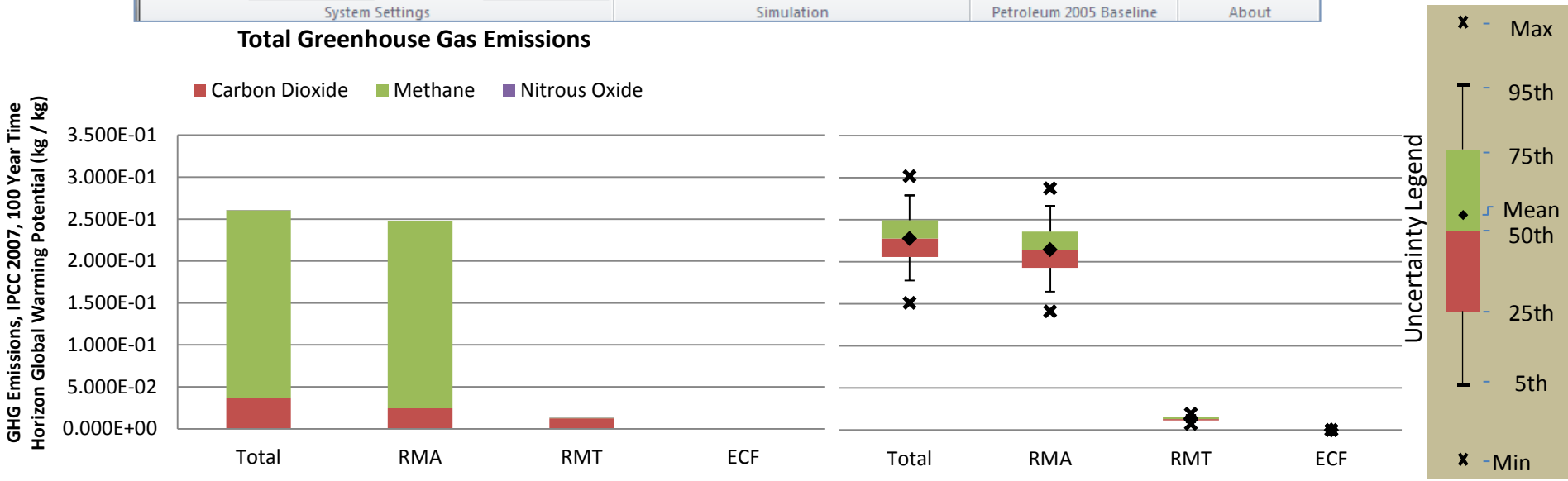
CHP generally reduces impacts across all impact categories.

Electricity Session
10/2/13 8:30-10:00 AM

Upstream Dashboard Update

- **Added uncertainty through Monte Carlo simulation**
- **Updated and cleaned the user interface with ribbon design**

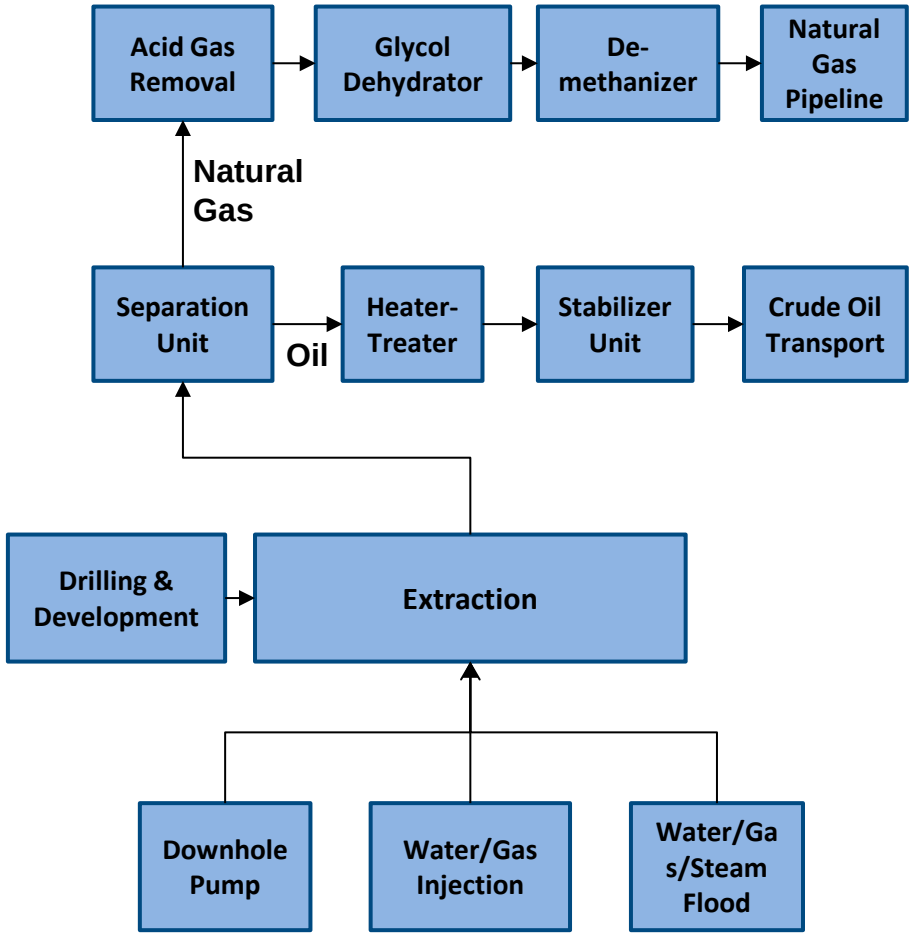




Upstream Dashboard Tool can be accessed at:
www.netl.doe.gov/energy-analyses (Search Term "Dashboard")

Improvements to NETL Petroleum Baseline – Translation of Crude Extraction Processes

- **Oil Production Greenhouse Gas Emissions Estimator (OPGEE)**
  - Created by Stanford University Dept. of Energy Resources Engr. (Adam Brandt)
  - Based on bottom-up engineering calculations to capture variability in crude extraction emissions
- **Create modular unit processes based on the stages in OPGEE**
  - Seven main stages: (1) Exploration, (2) Drilling and Development, (3) Production and Extraction, (4) Separation and Surface Processing, (5) Maintenance and Workovers, (6) Waste Treatment and Disposal, (7) Crude Product Transport
  - Augment with NETL CO_2 EOR work
  - Addition of non-GHG emissions to provide a more complete inventory



How to Access NETL's LCA Work

- **NETL Energy Analyses Website, Search for "LCA"**
  - www.netl.doe.gov/energy-analyses

- **Email the NETL LCA Team with Questions**
  - LCA@NETL.DOE.GOV

- **Collaborate with NETL on Energy Related LCA Studies**
  - Contact Tim Skone, 412-386-4495 or skonet@netl.doe.gov

Contact Information

Office of Fossil Energy

www.fe.doe.gov

NETL

www.netl.doe.gov

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