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

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

  LC Stage #1
  Raw Material Acquisition (RMA)

  LC Stage #2
  Raw Material Transport (RMT)

  LC Stage #3
  Energy Conversion Facility (ECF)

  LC Stage #4
  Product Transport (PT)

  LC Stage #5
  End Use
  Not Included in Power LCA

  Upstream Emissions

  Downstream Emissions

- 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**
  - $\text{CO}_2, \text{CH}_4, \text{N}_2\text{O}, \text{SF}_6$
- **Criteria Air Pollutants**
  - $\text{NO}_x, \text{SO}_x, \text{CO}, \text{PM}10, \text{Pb}$
- **Air Emissions Species of Interest**
  - $\text{Hg}, \text{NH}_3, \text{radionuclides}$
- **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  - Withdrawn water, consumption, water returned to source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)
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)
5. Baseline Analysis of Subbituminous Coal and Biomass to Gasoline (Indirect Liquefaction by Methanol Synthesis) Revision 2 (Under Review)
8. Gate-to-Gate Life Cycle Inventory and Model of CO₂-Enhanced Oil Recovery (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
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

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.

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

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Figure 1. Life Cycle Stage Definition

Figure 2. Power LCAT Screenshot

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

the ENERGY lab
Website: www.netl.doe.gov
Customer Service: 1-800-553-7681
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
• Accounts for different CO₂ sources, gas processing technologies, crude oil recovery rates, and other variables
• GHG results are sensitive to crude oil recovery rate and CO₂ injection pressure
• Displacement is caused by co-products and contributes to most of study uncertainty
• Helps answer questions related to U.S. energy security
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
  – CO₂-EOR systems produce electricity (when power plants are the CO₂ 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 necessarily 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.
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**
  - Augment with NETL CO₂ 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