NATIONAL ENERGY TECHNOLOGY LABORATORY

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

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Office of Strategic Energy Analysis and Planning

LCA XII, Tacoma, WA

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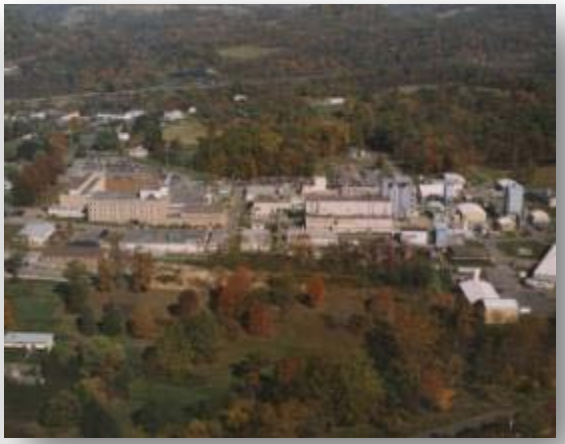
U.S. DEPARTMENT OF ENERGY

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

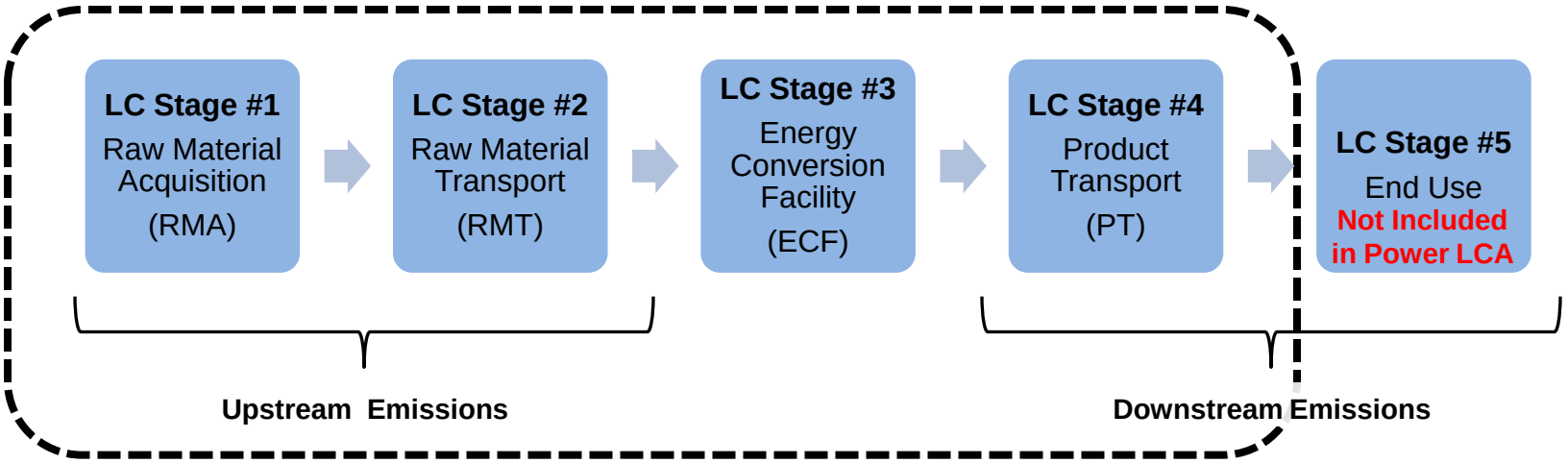
1. **Produce Energy System LCAs**
   - Inform and defend the Technology Programs
   - Baseline different energy system technologies
   - Understand technology strengths and weaknesses when viewed from a life cycle perspective
   - Identify opportunities for R&D innovation (through depth and transparency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

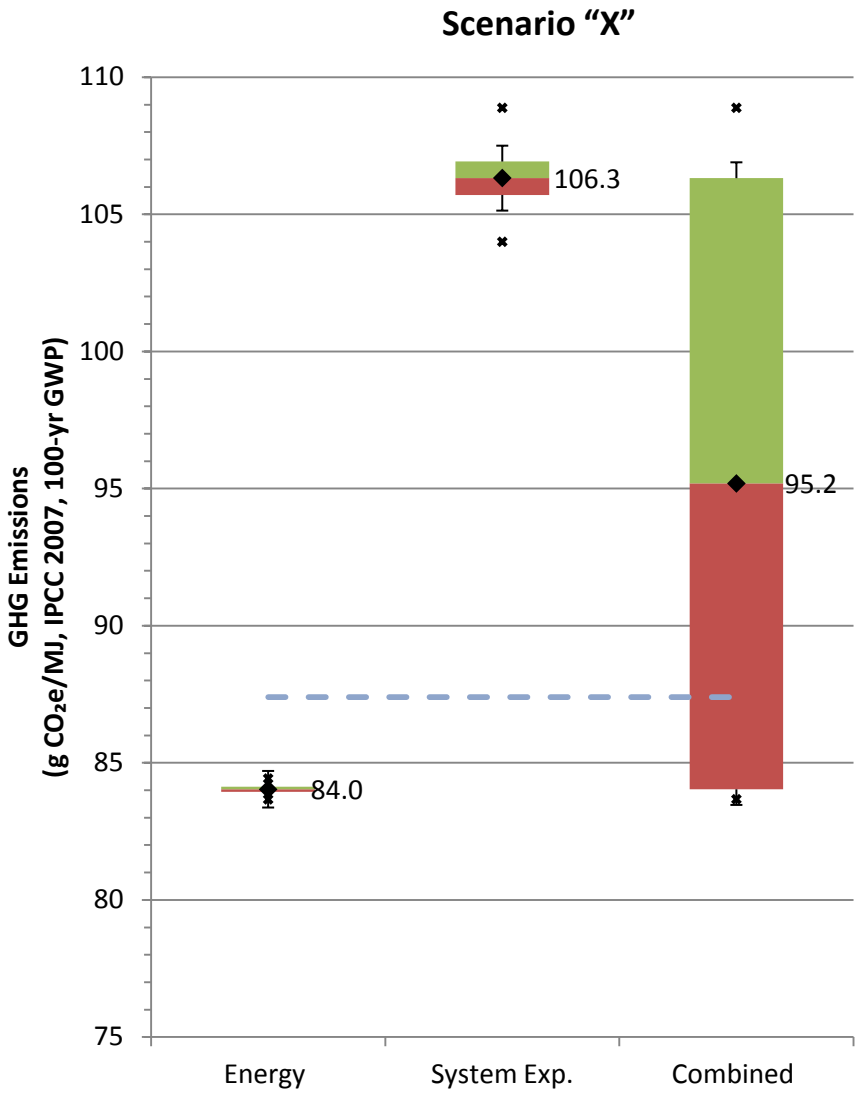
Research, Model, Document…Repeat

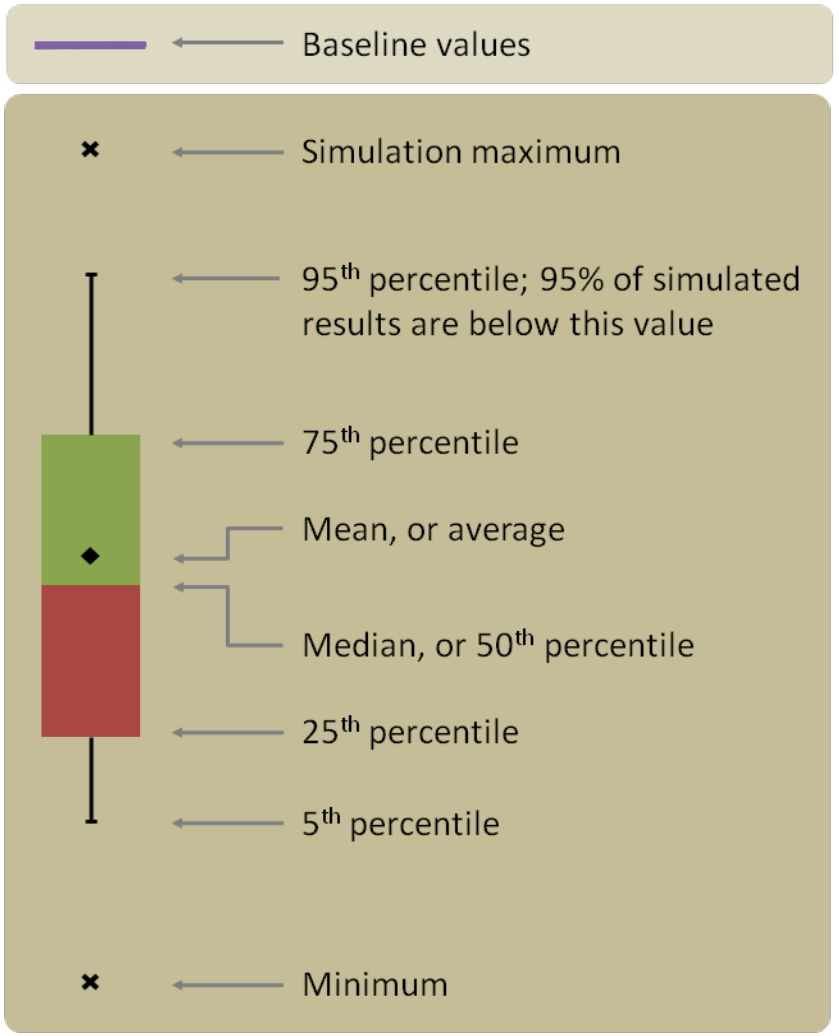
- **Life Cycle Inventory (LCI) data is developed from a wide range of sources from primary to secondary data**
  - The type of data used depends on the “use” of the data within the analysis being conducted
- **All data and calculations are documented in NETL’s standardized unit process spreadsheet and 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**

Example of Model Uncertainty (allocation)





Recently Published LCA Work
2012 Technology Assessment Reports

1. Natural Gas (NGCC and GTSC)
2. Pulverized Coal and Biomass Cofiring
3. Nuclear (existing, upgrade, & new)
4. Wind (with and without back-up)
5. Hydropower (existing, upgrade, & new
6. Solar Thermal
7. Geothermal (flash steam)

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

Unit Process Documentation

- Two primary documents – the process documentation file (DF) and the data summary sheet (DS)
- DS contains all of the parameters, inputs, and outputs for a given system as well as background data, calculations and quality scores
- DF contains major assumptions and data sources that are the basis for each of the unit processes
- All unit processes go through a full QA check prior to addition to the library

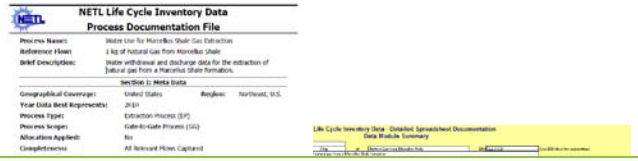


Figure 2. DF/DS Unit Process Documentation Screenshots

NETL Unit Process Library

- Now available on the NETL Energy Analysis website
- 300 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

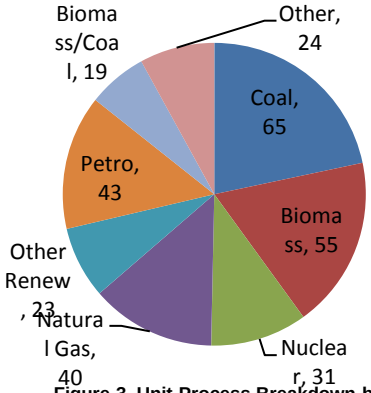


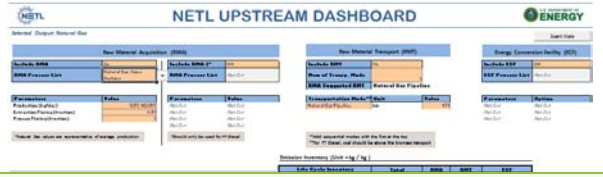
Figure 3. Unit Process Breakdown by Technology

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

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

Upstream Dashboard Tool

- Now available on the NETL Energy Analysis website
- Provides users access to stage-wise life cycle



Published LCA Product Library

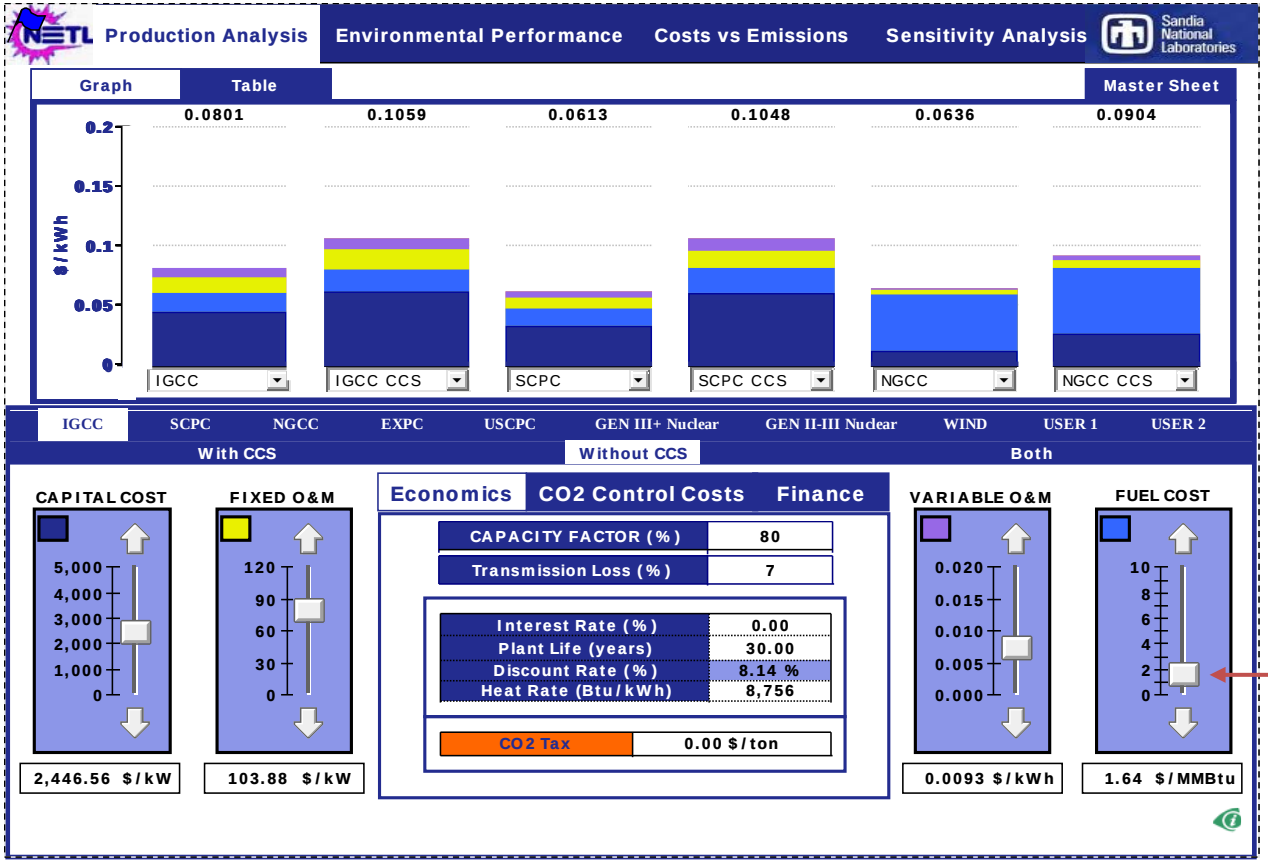
- Role of Alternative Energy Sources Technology Assessments (2012):
  - -Coal/Biomass Co-firing
  - -Geothermal
  - -Hydropower
  - -Natural Gas
  - -Nuclear
  - -Solar Thermal
  - -Wind
  - - Technology Compilation
- NETL Upstream Dashboard Tool (2012)
- Life Cycle Greenhouse Gas Analysis of Advanced 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)
- Life Cycle Analysis: Integrated Gasification Combined Cycle (IGCC) Power Plant (2010)
- Life Cycle Analysis: Supercritical Pulverized Coal (SCPC) Power Plant (2010)
- An Evaluation of the Extraction, Transport, and Refining of Imported Crude Oils and the Impact on Life Cycle Greenhouse Gas Emissions (2009)
- Development of Baseline Data and Analysis of Greenhouse Gas Emissions of Petroleum-Based Fuels: Report and Model (2008)

LCA reports and products can be accessed at:
www.netl.doe.gov/energy-analyses

NETL unit processes can be accessed at:

www.netl.doe.gov/LCA

Power Life Cycle Analysis Tool (Power LCAT)



Included Technologies:

- IGCC
- IGCC/ccs
- EXPC
- EXPC/ccs
- EXPC/ccs + RP
- SCPC
- SCPC/ccs
- NGCC
- NGCC/ccs
- Onshore Wind
- Gen III+ Nuclear

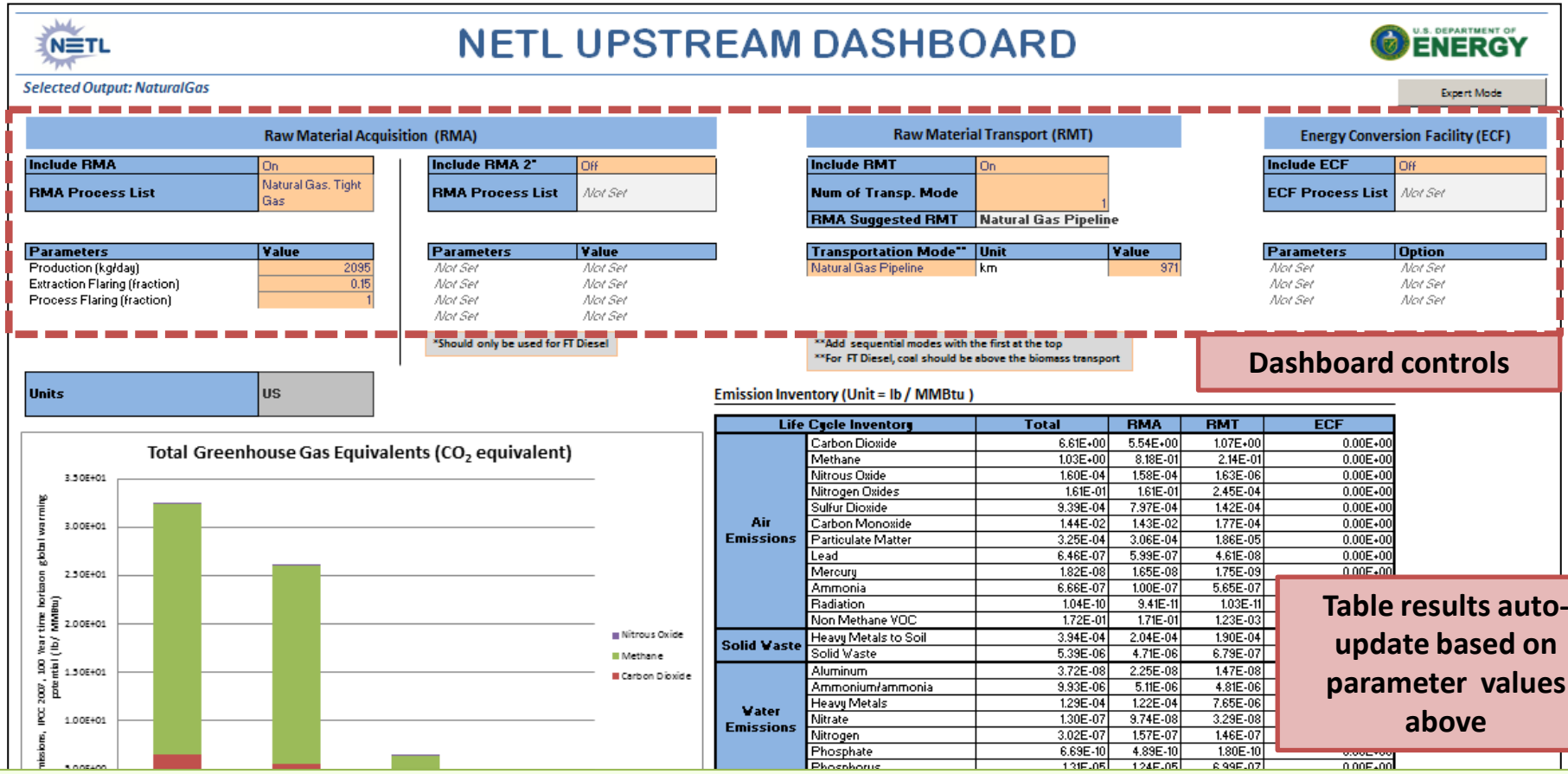
Sliders allow user to control assumptions and see results update in real time

Power LCAT can be accessed at:

www.netl.doe.gov/energy-analyses

Search Term "LCAT"

The Upstream Dashboard Tool



NETL UPSTREAM DASHBOARD

U.S. DEPARTMENT OF ENERGY

Selected Output: NaturalGas

Expert Mode

Raw Material Acquisition (RMA)

Include RMA	On
RMA Process List	Natural Gas. Tight Gas

Parameters	Value
Production (kg/day)	2095
Extraction Flaring (fraction)	0.15
Process Flaring (fraction)	1

Include RMA 2*	Off
RMA Process List	Not Set

Parameters	Value
Not Set	Not Set
Not Set	Not Set
Not Set	Not Set
Not Set	Not Set

*Should only be used for FT Diesel

Raw Material Transport (RMT)

Include RMT	On
Num of Transp. Mode	1
RMA Suggested RMT	Natural Gas Pipeline

Transportation Mode**	Unit	Value
Natural Gas Pipeline	km	971

**Add sequential modes with the first at the top
**For FT Diesel, coal should be above the biomass transport

Energy Conversion Facility (ECF)

Include ECF	Off
ECF Process List	Not Set

Parameters	Option
Not Set	Not Set
Not Set	Not Set
Not Set	Not Set

Dashboard controls

Units	US

Total Greenhouse Gas Equivalents (CO_2 equivalent)

Emission Inventory (Unit = lb / MMBtu)

Life Cycle Inventory		Total	RMA	RMT	ECF
Air Emissions	Carbon Dioxide	6.61E+00	5.54E+00	1.07E+00	0.00E+00
	Methane	1.03E+00	8.18E-01	2.14E-01	0.00E+00
	Nitrous Oxide	1.60E-04	1.58E-04	1.63E-06	0.00E+00
	Nitrogen Oxides	1.61E-01	1.61E-01	2.45E-04	0.00E+00
	Sulfur Dioxide	9.39E-04	7.97E-04	1.42E-04	0.00E+00
	Carbon Monoxide	1.44E-02	1.43E-02	1.77E-04	0.00E+00
	Particulate Matter	3.25E-04	3.06E-04	1.86E-05	0.00E+00
	Lead	6.46E-07	5.99E-07	4.61E-08	0.00E+00
	Mercury	1.82E-08	1.65E-08	1.75E-09	0.00E+00
	Ammonia	6.66E-07	1.00E-07	5.65E-07	
	Radiation	1.04E-10	9.41E-11	1.03E-11	
	Non Methane VOC	1.72E-01	1.71E-01	1.23E-03	
Solid Waste	Heavy Metals to Soil	3.94E-04	2.04E-04	1.90E-04	
	Solid Waste	5.39E-06	4.71E-06	6.79E-07	
Water Emissions	Aluminum	3.72E-08	2.25E-08	1.47E-08	
	Ammonium/ammonia	9.93E-06	5.11E-06	4.81E-06	
	Heavy Metals	1.29E-04	1.22E-04	7.65E-06	
	Nitrate	1.30E-07	9.74E-08	3.29E-08	
	Nitrogen	3.02E-07	1.57E-07	1.46E-07	
	Phosphate	6.69E-10	4.89E-10	1.80E-10	
	Phosphorus	1.31E-05	1.24E-05	6.99E-07	0.00E+00

Table results auto-update based on parameter values above

Upstream Dashboard Tool can be accessed at:

www.netl.doe.gov/energy-analyses

Search Term "Dashboard"

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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