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DISCLAIMER

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KeyLogic Systems, Inc.’s contributions to this work were funded by the National Energy Technology Laboratory under the Mission Execution and Strategic Analysis contract (DE-FE0025912) for support services.
2017 LCA Work

**Journal Publications**
- Updated Petroleum Baseline (November, 2016)
- Low-carbon fuels from EOR (In preparation)
- Comparison of Industrial & Power CO2 Capture (in preparation)

**Major Reports & Tools**
- Update to Natural Gas LCA
- Baseline Power Updates
- Solid-oxide fuel-cell Power LCA
- Life Cycle GHG Model for CO2-EOR Applications
- Update to Grid Mix Explorer & Upstream Dashboard

**Ongoing Work**
- CO2 Utilization LCA Guidance Documents
- Environmental Life Cycle Analysis of Algae to Biofuels
- Support for Federal LCA Commons
- Support for DOE Loan Program Office

**Emerging Work**
- Development of an Electricity Baseline for the U.S.
- Implementation of Consequential LCA for Energy Systems
- Development of Energy Sustainability Metrics for Energy Systems
- Creation of Power System Construction Inventories

Work can be accessed at: [www.netl.doe.gov/lca](http://www.netl.doe.gov/lca)
Energy Life Cycle Analysis
Cradle-to-grave environmental footprint of energy systems

Mission
Develop and utilize the LCA framework and methods to support the evaluation of sustainable energy systems both in and outside of the Department of Energy

Vision
A world-class research and analysis team that integrates results which inform and recommend sustainable energy strategy and technology development
Life Cycle Analysis Team

**Tim Skone** – 18 years  
Federal Team Lead  
BS Chemical Engineering | P.E. Env. Engr.

**Greg Cooney** – 10 years  
Contractor Team Lead  
MS Env. Engr. | BS Chem. Engr.

**James Littlefield** – 17 years  
Natural gas, system & process design  
BS Chemical Engineering

**Joe Marriott** – 12 years  
Senior Advisor  
PhD Environmental Engr. & Public Policy

**Matt Jamieson** – 8 years  
Power systems, CO₂-enhanced oil recovery  
BS Mechanical Engineering

**Michele Mutchek** – 5 years  
Loan program office, federal LCA commons  
MS Civil/Env/Sust Engr | BS Env Sciences

**Michelle Krynock** – 2 years  
Natural gas, fuel cells, coal  
BS Civil/Env Engr & Public Policy

**Derrick Carlson** – 7 years  
I/O LCA, Energy efficiency  
PhD/MS Civ/Env Engr| B.S. Chemistry

**Dan Augustine** – 1 year  
Natural gas, visual analytics  
BS Energy Engineering

**Ambica Pegallapati** – 5 years  
Biofuels, bioreactor development  
PhD Env Engr| B.S. Civil Eng.

**Greg Zaimes** – 4 years  
Energy analysis; transportation fuels  
PhD Civ/Env Eng; B.S. Physics

**Mid-level LCA** – 2-5 years  
Energy/environment  
BS/MS Science or Engineering

**Junior-level LCA** – 1-3 years  
Energy/environment  
BS Science or Engineering
Cooney, G.; Littlefield, J.; Marriott, J.; & Skone, T. J.
- CO₂-EOR is a GHG-intensive way of extracting crude compared to conventional extraction methods
- Linking EOR with anthropogenic CO₂ yields a benefit due to the displacement of uncaptured electricity

Cooney, G., Jamieson, M., Marriott, J., Bergerson, J., Brandt, A., Skone, T.
- 98.1 vs. 96.2 g CO₂e/MJ gasoline (-2%) for 2005 to 2014
- Changing baseline values lead to potential compliance challenges with frameworks such as the EISA Section 526

Ongoing Work
- Adding CO₂ capture to refineries
- Full environmental inventory for the Petroleum Baseline
- Using field EOR data to inform models
- Inclusion of biofuels in U.S. transportation consumption

Collaborators
Recent Natural gas-related LCA Work

Synthesis of recent ground-level methane emission measurements from the US natural gas supply chain (2017)
Littlefield, J.; Marriott, J.; Schivley, G.; Skone, T. J.
• Overall Result: 1.7% CH₄ emission rate across the NG life cycle
• Emission reduction opportunities: Pneumatic devices - widespread use in production and gathering stages; Unassigned” emissions (observed, but not fully understood); Gathering Systems (new to emissions inventories, but highly aggregated)

Littlefield, J.; Marriott, J.; Schivley, G.; Cooney, G.; Skone, T. J.
• Emphasizes the importance of boundary selection when expressing CH₄ emission rates and comparing NG to other energy sources
• Includes use of technology warming potential as a method for comparing cumulative radiative forcing

Ongoing Work
• Creating a 2016 baseline for natural gas produced in the U.S.
• Collaboration with ONE Future
• Improved uncertainty characterization

Collaborators
Recent Coal-related LCA Work

Schivley, G.; Ingwersen, W.; Marriott, J.; Hawkins, T.; Skone, T. J.

- 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

Understanding the Contribution of Mining and Transportation to the Total Life Cycle Impacts of Coal Exported from the United States (2016)
Mutchek, M.; Cooney, G.; Pickenpaugh, G.; Marriott, J.; Skone, T. J.

- Emissions from coal mining activities are more significant in Australia and Indonesia than PRB
- PRB disadvantages: longer transport distance, lower heating value
- Non-GWP impact categories are driven by emissions from diesel combustion (transport and mining) and affected by differences in diesel regulations between exporting countries

Ongoing Work
- Creating a regionalized 2017 baseline for coal produced in the U.S.
- Options for energy in the North Slope of Alaska
- Updated advanced power plant design LCAs

Collaborators
Life Cycle Baseline for Electricity in the U.S.

- **Bottom-up, regional and multi-scale full environmental characterization of power generation and consumption in the U.S.**
  - Builds on expertise used to develop the 2005 and 2014 baselines for petroleum fuels
  - Collaboration with EPA, NREL, USDA as part of the Federal Interoperability Workgroup

- **Development occurring in two phases:**
  - Phase 1: September, 2017
  - Phase 2: FY18 into FY19

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**Interregional Electricity Trade:** Mapping of electricity imports/exports, accounting for international trade with Mexico and Canada, as well as transmissions losses.

**NERC & eGRID Subregion:** Environmental impacts of electricity generation and consumption for North American Electricity Reliability Corporation (NERC) and eGRID subregions.

**U.S. Electricity Baseline:** A static description of the environmental footprint of U.S. electricity in the current year.
Educing scientific community on the environmental value of CO₂-EOR and geologic storage opportunities

- LCA Conference, October 2016
- RIC Technical Seminar, March 2017
- Energy Modeling Forum, April 2017
- LCA Conference, September 2017

New NETL Reports and Models for 2017

- Public CO₂-EOR LCA Model (Winter 2017)
- Enhanced Hydrocarbon Assessment Journal Article (pending)
LCA Support of CO₂ Utilization

Design Basis for CO₂-enhanced Algal Biofuels

Design Basis for Clathrate-based Industrial Desalination

Guidance documents for designing, performing, and interpreting LCAs for CO₂ utilization projects
Recent & Ongoing Natural Gas LCA Work

- **Overall result**: 1.7% CH\(_4\) emission rate across NG life cycle
- **Emission reduction opportunities**
  - Pneumatic devices - widespread use in production and gathering stages
  - “Unassigned” emissions (observed, but not fully understood)
  - Gathering Systems (new to emissions inventories, but highly aggregated)
- **Research opportunities**
  - Improve activity data on pneumatic devices throughout supply chain
  - Identify drivers and regional variability for unassigned emissions
  - Disaggregate gathering emissions at the category level to individual system components

Collaboration with ONE Future

1. Leverage ONE Future’s best management practices
2. Emphasize the value of industry participation in identifying emission reduction opportunities
3. Establish benchmarks for assessing the value of CH\(_4\) reduction opportunities and what they mean at the national scale
LCA of Carbon Capture Systems

Large scale thermoelectric power generation to small scale industrial CO₂ sources

- **Comparative analysis of carbon capture for ammonia production and petroleum refining**
  - Compared on a carbon dioxide abated functional unit as products are not comparable
  - Carbon capture from each industry is compared with carbon capture for electric power production
  - Next phase will include cement and steel

![Graph showing LCA of Carbon Capture Systems](image)

Functional unit is **1kg carbon dioxide abated**. SCPC results from NETL baseline.
Economic Input-Output LCA Modeling

Power Plant Construction Profiles

- EIO-LCA offers an easy and reliable method to estimate construction emissions for power plants and expand inventory.
- Construction, design, processing, and other services are included.
- While construction represents <1% of many impacts for a fossil power plant, this is unlikely to be true with the adoption of CCS & renewables.
  - For SCPC w/ CCS - construction is ~5% of the operational CO₂ emissions.

<table>
<thead>
<tr>
<th>Item No.</th>
<th>Description</th>
<th>EIO-LCA Sector</th>
</tr>
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<tbody>
<tr>
<td>7</td>
<td>Ductwork, Ducting, &amp; Stacks</td>
<td>Air purification and ventilation equipment manufacturing</td>
</tr>
<tr>
<td>7.1</td>
<td>Steam TG &amp; Accessories</td>
<td>Air purification and ventilation equipment manufacturing</td>
</tr>
<tr>
<td>7.2</td>
<td>Turbine Plant Auxiliaries</td>
<td>Ready-mix concrete manufacturing</td>
</tr>
<tr>
<td>7.3</td>
<td>Condenser &amp; Auxiliaries</td>
<td>Turbine and turbine generator set units manufacturing</td>
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<tr>
<td>7.4</td>
<td>Steam Piping</td>
<td>Turbine and turbine generator set units manufacturing</td>
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<tr>
<td>7.5</td>
<td>TG Foundations</td>
<td>Turbine and Turbine generator set units manufacturing</td>
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<td>7.6</td>
<td>Steam TG &amp; Accessories</td>
<td>Iron, steel pipe and tube manufacturing from purchased steel</td>
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<td>7.7</td>
<td>Turbine Plant Auxiliaries</td>
<td>Ready-mix concrete manufacturing</td>
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<td>Condenser &amp; Auxiliaries</td>
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<td>7.10</td>
<td>TG Foundations</td>
<td>Ready-mix concrete manufacturing</td>
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</tbody>
</table>

\[ y = 0.6812x + 4.3417 \]
\[ R^2 = 0.95 \]
Background:
- Applicants must “avoid, reduce, or sequester” GHG emissions
  - Advanced Fossil
  - Renewable Energy and Efficient Energy
- Compares GHG emissions to a business-as-usual (BAU) scenario

Analysis:
- Suggest BAU product or technology
- Calculate life cycle GHG emissions for the applicant and BAU
- Include all products in the comparison

NETL provided analysis for over a dozen projects in the past year

Sample Comparison

<table>
<thead>
<tr>
<th></th>
<th>Product A</th>
<th>Product B</th>
<th>Product C</th>
<th>Advanced Technology</th>
</tr>
</thead>
<tbody>
<tr>
<td>GHG Emissions</td>
<td>140 kg CO₂e/unit</td>
<td>110 kg CO₂e/unit</td>
<td>21% reduction</td>
<td></td>
</tr>
</tbody>
</table>

http://energy.gov/lpo/innovative-clean-energy-projects-title-xvii-loan-program
Citations and Links to Recent Work


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