Overview of the U.S. Department of Energy (DOE) Bioenergy Technologies Office (BETO) and its National Laboratories

IEA Bioenergy Task 45: Triennium 2019-2021
Work area interests and potential contributions

Patrick Lamers
IEA Bioenergy Task 45 Kick-off Meeting
Stockholm, Sweden | February 27, 2019
Office of Energy Efficiency and Renewable Energy (EERE)

**Sustainable TRANSPORTATION**
- Office of Transportation
- Vehicle Technologies Office
- Fuel Cell Technologies Office
- Bioenergy Technologies Office

**Renewable ELECTRICITY GENERATION**
- Office of Renewable Power
- Geothermal Techn. Office
- Solar Energy Techn. Office
- Wind Energy Techn. Office
- Water Power Techn. Office

**Energy Saving HOMES, BUILDINGS, & MANUFACTURING**
- Office of Energy Efficiency
- Advanced Manufacturing O.
- Building Technologies Office
- Fed. Energy Mgmt Program
- Intergovernmental, etc.
BETO’s Critical Program Areas

Production & Harvesting
- **Feedstock Supply & Logistics**
  Works to reduce the cost, improve the quality, and increase the volume of sustainable feedstocks available for delivery to a biorefinery.
- **Advanced Algal Systems**
  Focuses on improving the productivity of algal biomass and enhancing the efficiency of cultivation and harvesting.

Conversion & Refining
- **Conversion**
  Develops technologies to convert non-food feedstocks into biofuels, bioproducts, and biopower.
  Conducts separations, materials compatibility evaluations, and technoeconomic-driven verification tests.

Distribution & End Use
- **Advanced Development & Optimization**
  Reduces investment risk in bioenergy production by developing technologies that will enable efficient and reliable operations of integrated biorefineries and addressing the final links of the supply chain to promote demand for end products.

Strategic Analysis & Crosscutting Sustainability
Strategic Analysis & Crosscutting Sustainability

**Strategic Goal:** to understand and enhance the *positive economic, social, and environmental effects and reduce potential negative impacts* of bioenergy production activities.

**Approaches:**

- Develop and maintain analytical tools, models, methods, and datasets to support science-based quantification and improved decision-making
- Ensure high-quality, consistent, reproducible, peer-reviewed analyses
- Research and develop sustainable system designs that increase bioenergy production while enhancing economic and environmental outcomes
- Ensure broad engagement with other agencies and stakeholders

Enhancing the economic and environmental benefits of a growing bioeconomy.
Interagency efforts: U.S. Biomass R&D Board

- The Biomass Research and Development Act of 2000 established the Interagency Biomass R&D Board.

- The BR&D Board facilitates coordination among federal government agencies that affect the research, development, and deployment of biofuels and bioproducts.
“Realizing the full benefits of the bioeconomy requires commitment to rigorous science-based quantification of benefits and impacts across multiple environmental, social, and economic dimensions.

This will enable the development of technologies and practices that deliver the benefits of renewable energy and the bioeconomy, while maintaining healthy communities and natural ecosystems.”
U.S. DOE National Laboratory System

Office of Science Laboratories
1. Ames Laboratory
   Ames, Iowa
2. Argonne National Laboratory
   Argonne, Illinois
3. Brookhaven National Laboratory
   Upton, New York
4. Fermi National Accelerator Laboratory
   Batavia, Illinois
5. Lawrence Berkeley National Laboratory
   Berkeley, California
6. Oak Ridge National Laboratory
   Oak Ridge, Tennessee
7. Pacific Northwest National Laboratory
   Richland, Washington
8. Princeton Plasma Physics Laboratory
   Princeton, New Jersey
9. SLAC National Accelerator Laboratory
   Menlo Park, California
10. Thomas Jefferson National Accelerator Facility
    Newport News, Virginia

Other DOE Laboratories
1. Idaho National Laboratory
   Idaho Falls, Idaho
2. National Energy Technology Laboratory
   Morgantown, West Virginia
   Pittsburgh, Pennsylvania
   Albany, Oregon
3. National Renewable Energy Laboratory
   Golden, Colorado
4. Savannah River National Laboratory
   Aiken, South Carolina

NNSA Laboratories
1. Lawrence Livermore National Laboratory
   Livermore, California
2. Los Alamos National Laboratory
   Los Alamos, New Mexico
3. Sandia National Laboratory
   Albuquerque, New Mexico
   Livermore, California

BETO A&S support:
- ANL
- INL
- NREL
- ORNL
- PNNL
- NREL-Systems Integration (SI)

Map: https://science.energy.gov/laboratories/
Pictures: https://www.energy.gov
More information: https://www.energy.gov/national-laboratories
NREL-Systems Integration (NREL-SI)

- Independent, strategic, systems-level expertise to BETO Portfolio Management
  - Technical Evaluation (Lead: Craig Brown)
  - Systems-Level Planning (Lead: Amy Schwab)
  - **Systems-Level Analysis** (Lead: Patrick Lamers)

- Systems-Level Analysis Tasks
  - Direct support of A&S program management (Kristen Johnson, Alicia Lindauer)
  - Quick turn-around / integration support and analysis for A&S portfolio
  - Focused, in-depth analysis on pre-defined, select topics

- Cross-supply chain, cross-program, cross-sector

- Close operating partnership with BETO

- Independent, arms-length relationships with national labs (incl. NREL)
IEA Bioenergy
Task 45
# Country: United States

<table>
<thead>
<tr>
<th>Name</th>
<th>Role in Task 45*</th>
<th>Affiliation</th>
<th>Expertise; previous Task involvement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kristen Johnson</td>
<td>NTL</td>
<td>U.S. Department of Energy (DOE) Bioenergy Technologies Office (BETO)</td>
<td>DOE BETO Program Lead Crosscutting Sustainability Previous U.S. NTL Task 38</td>
</tr>
<tr>
<td>Patrick Lamers</td>
<td>NTL alternate</td>
<td>NREL-Systems Integration (NREL-SI)</td>
<td>DOE BETO Analysis &amp; Sustainability Program Support Previous alternate NTL for Tasks 38 &amp; 40</td>
</tr>
</tbody>
</table>

* Roles: TL=Task Leader; WPL=WP Leader; NTL=National Team Leader; A=Associate
## Interest Task 45 WP1

<table>
<thead>
<tr>
<th>Work Package 1</th>
<th>Role*</th>
<th>Relevant projects/programs in country or own organization</th>
</tr>
</thead>
<tbody>
<tr>
<td>Topic 1: StandMeth Update</td>
<td>C</td>
<td>Previous Task 38 work, ongoing LCA work at ANL &amp; NREL</td>
</tr>
<tr>
<td>Topic 2: StandMeth Expansion, system-level approaches</td>
<td>C</td>
<td>Ongoing work at ANL &amp; NREL</td>
</tr>
<tr>
<td>Topic 3: Top-down/bottom-up</td>
<td>C</td>
<td>Related work on top-down/bottom-up comparison at NREL &amp; PNNL (energy systems more broadly)</td>
</tr>
<tr>
<td>Topic 4: Case studies</td>
<td>O</td>
<td></td>
</tr>
<tr>
<td>Topic 5: Guide on tools</td>
<td>C</td>
<td>Provision of data on U.S. tools in conjunction with U.S. national labs (relates to previous Intertask on LCA tool comparison)</td>
</tr>
<tr>
<td>Topic 6: Specific studies on</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6a: CC effects of land-use</td>
<td>O</td>
<td></td>
</tr>
<tr>
<td>6b: Optimize land carbon</td>
<td>O/C</td>
<td>(new work starting at LLNL, ORNL, NREL; potential future input)</td>
</tr>
<tr>
<td>6c: Circular economy LCA</td>
<td>C</td>
<td>Ongoing work at multiple national labs including NREL &amp; ANL</td>
</tr>
<tr>
<td>6d: Quantify risk &amp; uncertainty</td>
<td>O</td>
<td></td>
</tr>
</tbody>
</table>

* Roles: O=observer; C=contributor; L=leader
## Interest Task 45 WP2

<table>
<thead>
<tr>
<th>Work Package 2</th>
<th>Role*</th>
<th>Relevant projects/programs in country or own organization</th>
</tr>
</thead>
<tbody>
<tr>
<td>Topic 1: Measure sustainability</td>
<td>C</td>
<td>ORNL (sustainability criteria and indicators)</td>
</tr>
<tr>
<td>Topic 2: Model LUC</td>
<td>O</td>
<td>PNNL (GCAM), Purdue (GTAP)</td>
</tr>
<tr>
<td>Topic 3: Spatio-temporal tools for environmental impacts</td>
<td>O/C</td>
<td>ANL (ecosystem services), INL (landscape design), ORNL (Antares project), PNNL (forest landscapes)</td>
</tr>
<tr>
<td>Topic 4: Spatio-temporal tools for socio-economic impacts</td>
<td>O/C</td>
<td>(contribution pending final scope and applicable DOE project)</td>
</tr>
<tr>
<td>Topic 5: Monitor sustainability indicators</td>
<td>O/C</td>
<td>ORNL (sustainability criteria and indicators)</td>
</tr>
<tr>
<td>Topic 6: Uncertainty</td>
<td>O</td>
<td></td>
</tr>
<tr>
<td>Topic 7: sustainable land use planning</td>
<td>O/C</td>
<td>ANL (ecosystem services), INL (landscape design), ORNL (Antares)</td>
</tr>
<tr>
<td>Topic 9: Trade offs, stakeholder perspectives</td>
<td>O</td>
<td></td>
</tr>
</tbody>
</table>

* Roles: O=observer; C=contributor; L=leader
### Interest Task 45 WP3

<table>
<thead>
<tr>
<th>Work Package 3</th>
<th>Role*</th>
<th>Relevant projects/programs in country or own organization</th>
</tr>
</thead>
<tbody>
<tr>
<td>All topic areas</td>
<td>O</td>
<td></td>
</tr>
</tbody>
</table>

* Roles: O=observer; C=contributor; L=leader
<table>
<thead>
<tr>
<th>Inter-Task project &amp; joint Task activities*</th>
<th>Role**</th>
<th>Relevant projects/programs in country or own organization</th>
</tr>
</thead>
<tbody>
<tr>
<td>WB2/SDG</td>
<td>O</td>
<td>Interest and related work starting at LLNL, NREL, ORNL. Potential future contribution given synergy between intertask scope and U.S. DOE BETO project work.</td>
</tr>
<tr>
<td>ResGas</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>BECCS/U</td>
<td>O</td>
<td>Interest and related work starting at LLNL, NREL, ORNL. Potential future contribution given synergy between intertask scope and project work.</td>
</tr>
<tr>
<td>ASA</td>
<td>C</td>
<td>Related work at NREL; will engage other national labs depending on specific action items</td>
</tr>
</tbody>
</table>

* WB2/SDG; ResGas; BECCS/U; ASA
** Roles: O=observer; C=contributor; L=leader
Patrick Lamers, PhD
Systems-Level Analysis Lead
Bioenergy Technologies, NREL-SI
National Renewable Energy Laboratory | MS 300
15013 Denver W Pkwy | Golden, CO 80401 | 303-384-7625
patrick.lamers@nrel.gov
Office of Energy Efficiency and Renewable Energy (EERE)

Sustainable Transportation

Renewable Electricity Generation

Energy Saving Homes, Buildings, & Manufacturing
Office of Energy Efficiency and Renewable Energy (EERE)

- Office of Transportation
  - Vehicle Technologies Office (VTO)
  - Bioenergy Technologies Office (BETO)
  - Fuel Cell Technologies Office (FCTO)

- Office of Renewable Power
  - Solar Energy Technologies Office (SETO)
  - Geothermal Technologies Office (GTO)
  - Wind Energy Technologies Office (WETO)
  - Water Power Technologies Office (WPTO)

- Office of Energy Efficiency
  - Building Technologies Office (BTO)
  - Federal Energy Mgmt. Program (FEMP)
  - Advanced Manufacturing Office (AMO)
  - Weatherization & Intergovernmental Programs Office (WIPO)
  - Sustainability Performance Office (SPO)

- Operations & Strategic Innovation Office (OSIO)
BETO’s Mission & Vision

**Vision**
A thriving and sustainable bioeconomy fueled by innovative technologies

**Mission**
Developing transformative and revolutionary sustainable bioenergy technologies for a prosperous nation

**Strategic Goals**
Develop industrially relevant technologies to enable domestically produced biofuels and coproducts without subsidies
Intra- and Interagency Partnerships & Relationships

**DOE Office of Science**
- BERCs
- EFRCS
- Joint Solicitation

**DOE ARPA-E**
- Algae
- Information Sharing

**USDA - Agriculture**
- Agriculture resources
- Conversion technologies

**Dept. of Defense**
- R&D
- Biofuel Offtakes

**DOE Vehicles Tech. Progm.**
- Engine/Fuel testing
- Future Vehicle Dev.

**Dept. of Transportation**
- Distribution and end-use

**EPA**
- RFS
- Fuel Approval

**Private Sector**
- Industry build-out
- Financing

**DOE Bioenergy Technologies Office**

**Private Sector**

**Basic**

**Applied**

**Demonstration**

**Deployment**
U.S. Primary Energy Consumption: Past and Projected

U.S. fuel consumption (2017)

2017 U.S. fuel consumption (transportation sector by fuel type)

- Motor gasoline
- Aviation gasoline
- Jet fuel
- Diesel fuel (distillate)
- Residual fuel oil
- Lubricants

2017 U.S. transportation fuel consumption (billion gallons per year)

<table>
<thead>
<tr>
<th>Fuel*</th>
<th>Amount†</th>
<th>typical use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Motor Gasoline</td>
<td>137.6</td>
<td>cars</td>
</tr>
<tr>
<td>Distillate Fuel Oil</td>
<td>45.8</td>
<td>Trucks/rail/bus</td>
</tr>
<tr>
<td>Jet Fuel</td>
<td>25.8</td>
<td>jets</td>
</tr>
<tr>
<td>Residual Fuel Oil</td>
<td>4.6</td>
<td>ships</td>
</tr>
<tr>
<td>Lubricants</td>
<td>0.9</td>
<td>all</td>
</tr>
<tr>
<td>Aviation Gasoline</td>
<td>0.2</td>
<td>non-jet</td>
</tr>
<tr>
<td>Propane (other C3)</td>
<td>0.1</td>
<td>buses</td>
</tr>
</tbody>
</table>

LNG not reported, † billion gallons/year

https://www.eia.gov/totalenergy/data/monthly/index.php#petroleum
Global Production of Biofuels - Future

United States Energy Trends

**Energy Productivity** (Indexed to 2000)
- GDP: +36%
- Energy Consumption: -2%

**Transportation Oil Efficiency** (VMT/Barrel Oil Equivalent)
- +13%

**Renewable Electricity**
- % Total Generation: +82%
- % New Capacity: 51%

**Personal Energy Expenditures** (% Total Expenses, nominal)
- -17%

**NOx & SO2 Emissions** (Million Short Tons)
- -66%

**Energy CO2 Emissions** (Billion Metric Tons)
- Total: -12%
- Power Sector Only: -24%
Mature industry in Brazil since 1970’s from sugarcane to ethanol used in light duty vehicles to displace gasoline.

US corn based ethanol since 1980’s initially used as oxygenate replacement due to ban of methy-tertiary-butyl ether. Current consumption about 14 billion gallons/year (10% of gasoline demand in light duty vehicles).

US bio-diesel production from soybean and waste oils. Current consumption about 1 billion gallons/year (2% of diesel demand in heavy duty vehicles).

New process technologies that convert biomass and waste-based feedstocks into fuels are beginning to be commercialized.

Source: Renewable Fuels Association: http://ethanolrfa.org/pages/statistics
Bioenergy Related National Policy Efforts

- **U.S. EPA administers the Renewable Fuel Standards (RFS) which requires certain quantities of renewable fuels to be blended into motor gasoline and diesel fuel.**
  - The RFS was created under the Energy Policy Act (EPAct) of 2005
    - Required 7.5 billion gallons of renewable-fuel to be blended into gasoline by 2012
  - Under the Energy Independence and Security Act (EISA) of 2007 it was expanded to RFS2 and changed in several times
    - RFS2 increased the volume of renewable fuel required to be blended into transportation fuel from 9 billion gallons in 2008 to 36 billion gallons by 2022
  - EPA approved volumes have fallen short of the trajectory in recent years and are not on track to meet the originally proposed goal

**Bioenergy Related National Policy Efforts**

**U.S. EPA recent proposal for bio-intermediates**
- Allow renewable fuel produced from biointermediates to generate RINs for existing approved pathways, supporting the growth of advanced
- Only the renewable fuel producer would be permitted to generate RINs biofuels
- Biointermediate producers would be subject to requirements similar to those for renewable fuel producers

**U.S. EPA recent proposal to allow year round E15**

**U.S CARB is considering developing a proposal to:**
- Allow alternative jet fuel (AJF) to generate LCFS credits as an opt-in fuel
- Allow credit generation for AJF loaded to all planes in California, whether destinations are in state or out of state
- Allow credit generation for military use of AJF

- **U.S. CARB granted (February 2016) approval for refinery co-processing:**
  - This approval relate to the application of Ensyn’s Renewable Fuel Oil as a renewable feedstock for refineries in California for the production of renewable gasoline and diesel (refinery co-processing).
Renewable Identification Numbers (RINs) Generated in 2017

<table>
<thead>
<tr>
<th>RINS¹</th>
<th>million gallons</th>
<th>percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>D6 Renewable fuel</td>
<td>14,860</td>
<td>78%</td>
</tr>
<tr>
<td>ethanol</td>
<td>14,860</td>
<td></td>
</tr>
<tr>
<td>renewable diesel</td>
<td>245</td>
<td></td>
</tr>
<tr>
<td>D4 Biomass-based diesel</td>
<td>3,070</td>
<td>20%</td>
</tr>
<tr>
<td>biodiesel</td>
<td>3,070</td>
<td></td>
</tr>
<tr>
<td>renewable diesel</td>
<td>770</td>
<td></td>
</tr>
<tr>
<td>renewable jet</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>D5 Advanced Biofuels</td>
<td>99</td>
<td>0.7%</td>
</tr>
<tr>
<td>ethanol</td>
<td>99</td>
<td></td>
</tr>
<tr>
<td>naphtha</td>
<td>32</td>
<td></td>
</tr>
<tr>
<td>other</td>
<td>13</td>
<td></td>
</tr>
<tr>
<td>D3/D7 Cellulosic</td>
<td>10</td>
<td>1.3%</td>
</tr>
<tr>
<td>ethanol</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>natural gas²</td>
<td>217</td>
<td></td>
</tr>
<tr>
<td>heating oil</td>
<td>2</td>
<td></td>
</tr>
</tbody>
</table>

¹ 93% of the RINs were generated in the U.S.
² renewable compressed natural gas and liquefied natural gas

Renewable fuel (D6)
- Example source: corn starch
  - GHG reduction ≥ 20%

Advanced biofuel (D5)
- Example source: sugarcane
  - GHG reduction ≥ 50%

Cellulosic (D3/D7)
- Example source: corn stover, wood chips, biogas
  - GHG reduction ≥ 60%

Biomass-based diesel (D4)
- Example source: soybean or canola oil, waste oil, animal fats
  - GHG reduction ≥ 50%

*corn starch is capped at 15 billion gallons

Note the competition for lipids in jet fuel vs diesel markets, 3M gallons vs 4B gallons.