U.S. DEPARTMENT OF ENERGY

Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

IEA Bioenergy

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



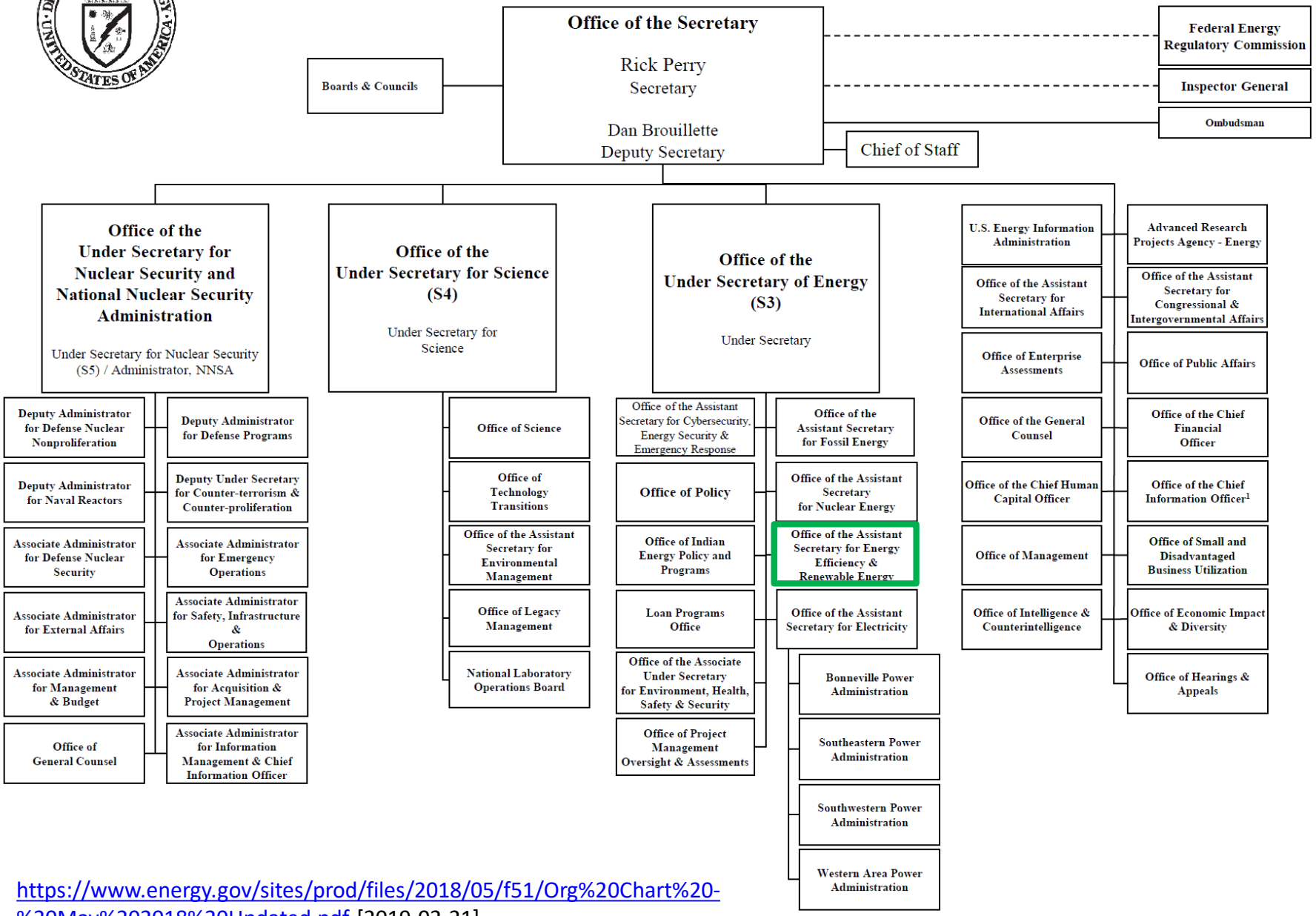


Patrick Lamers

IEA Bioenergy Task 45 Kick-off Meeting
Stockholm, Sweden | February 27, 2019

NREL/PR-6A20-73369

DEPARTMENT OF ENERGY



https://www.energy.gov/sites/prod/files/2018/05/f51/Org%20Chart%20-%20May%202018%20Updated.pdf [2019-02-21]

May 2018

Office of Energy Efficiency and Renewable Energy (EERE)

Sustainable TRANSPORTATION

Office of Transportation

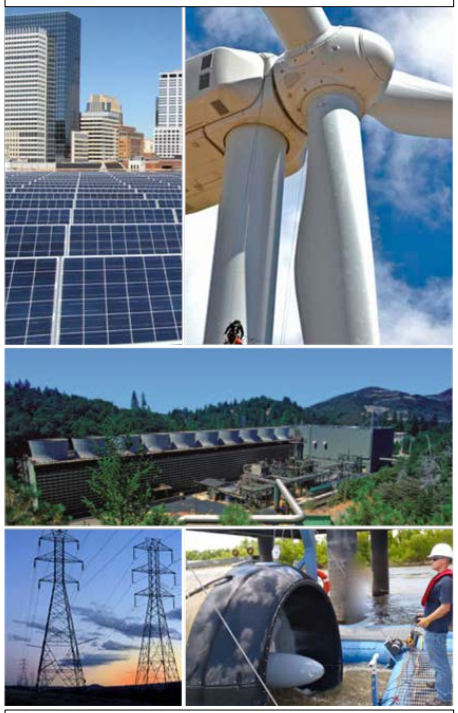
Vehicle Technologies Office

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

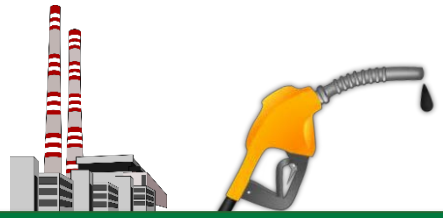
Intergovernmental, etc.

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.

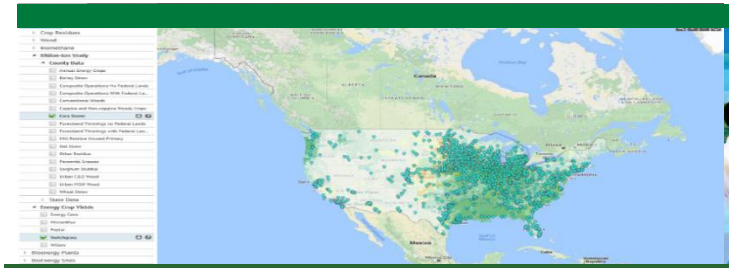
Strategic Analysis & Crosscutting Sustainability

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**.

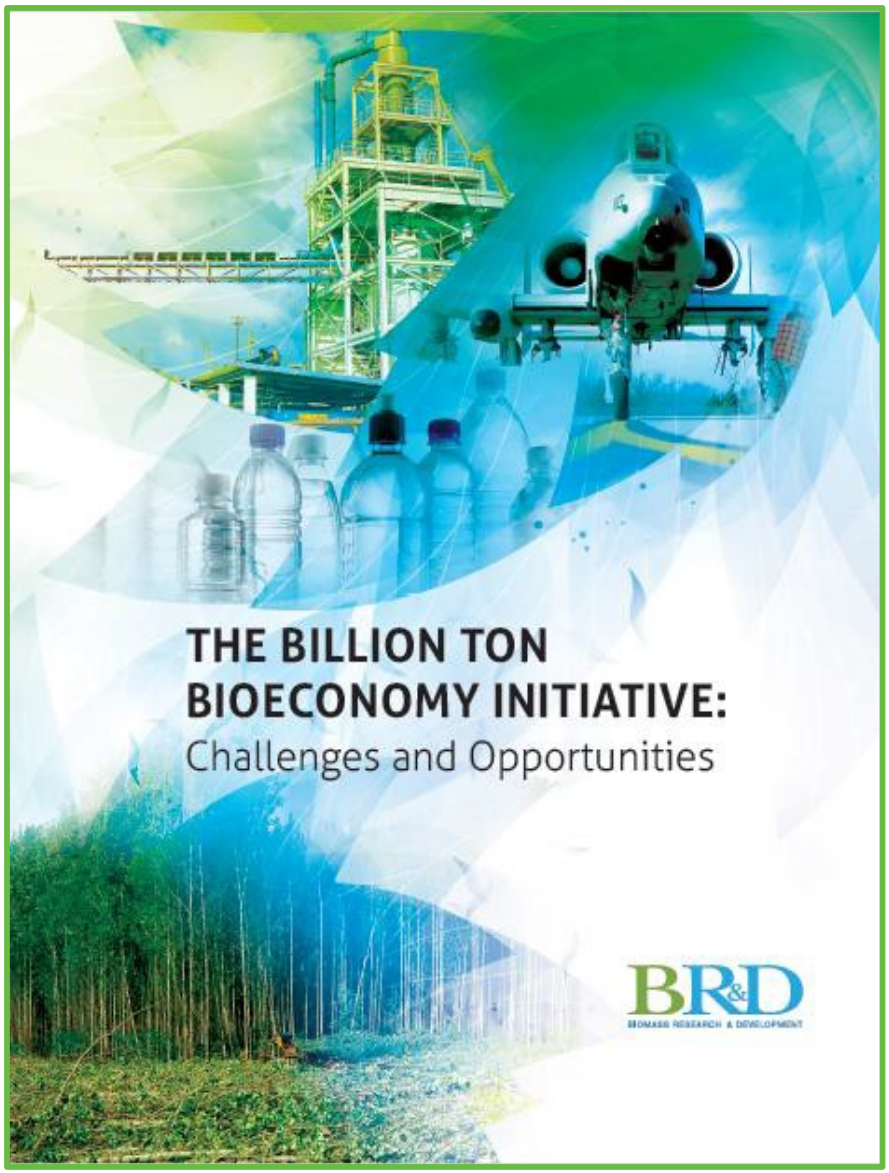
- The BR&D Board facilitates coordination among federal government agencies that affect the research, development, and deployment of biofuels and bioproducts.

Membership

Senate-confirmed sub-cabinet officials from 8 executive branch agencies

Co-chair *Co-chair*

Biomass Research & Development Board



"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

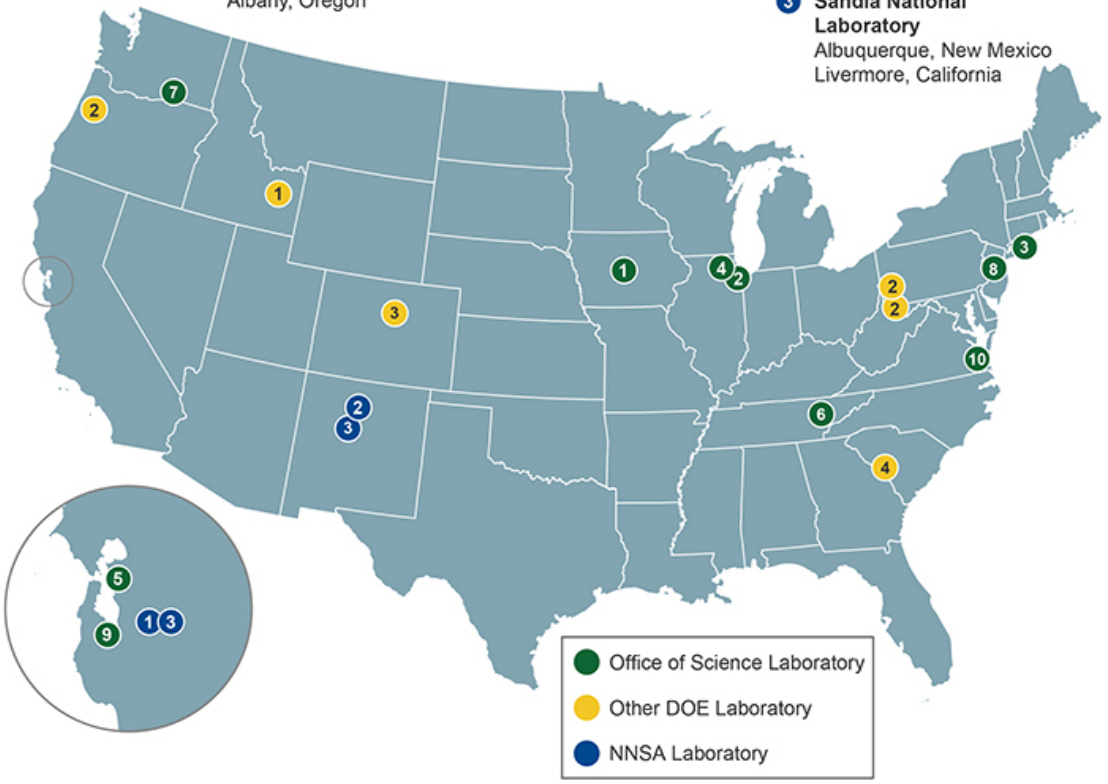
1. **Ames Laboratory**
   Ames, Iowa
2. **Argonne National Laboratory**
   Argonne, Illinois
3. **Brookhaven National Laboratory**
   Upton, New York
4. **Fermi National Accelerator Laboratory**
   Batavia, Illinois
5. **Lawrence Berkeley National Laboratory**
   Berkeley, California
6. **Oak Ridge National 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

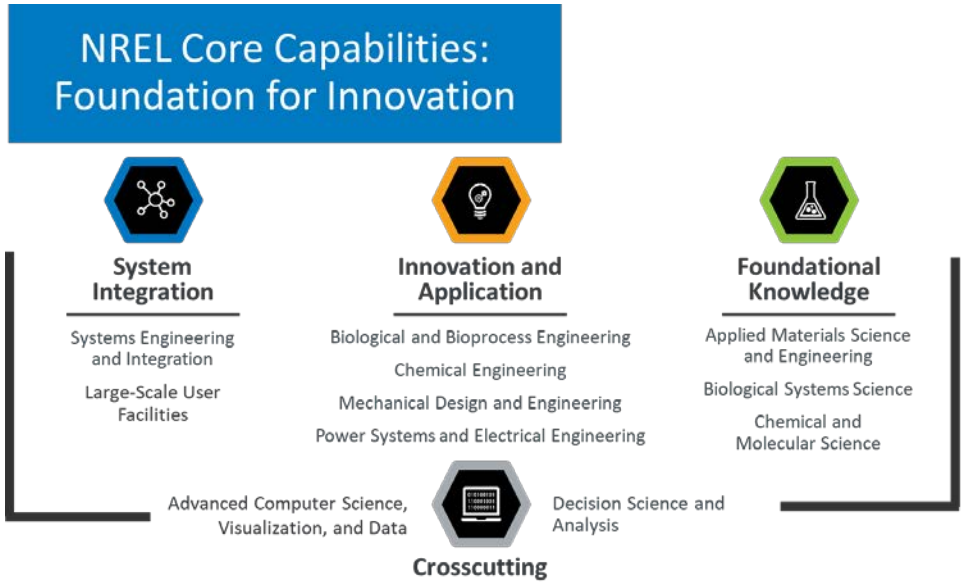
- **Close operating partnership with BETO**

- Independent, **arms-length relationships with national labs** (incl. NREL)

NREL

NREL


NREL at a Glance
1,850
Employees, plus more than 600 early-career researchers and visiting scientists
World-class facilities, renowned technology experts
nearly 820
Partnerships with industry, academia, and government
Campus operates as a living laboratory
$1.1B annually
National economic impact


NREL Core Capabilities: Foundation for Innovation
System Integration
Systems Engineering and Integration
Large-Scale User Facilities
Innovation and Application
Biological and Bioprocess Engineering
Chemical Engineering
Mechanical Design and Engineering
Power Systems and Electrical Engineering
Foundational Knowledge
Applied Materials Science and Engineering
Biological Systems Science
Chemical and Molecular Science
Advanced Computer Science, Visualization, and Data
Decision Science and Analysis
Crosscutting


Ski Day 2019


NREL's Science Drives Innovation
Renewable Power
Solar
Wind
Water
Geothermal
Sustainable Transportation
Bioenergy
Vehicle Technologies
Hydrogen
Energy Efficiency
Buildings
Advanced Manufacturing
Government Energy Management
Energy Systems Integration
High-Performance Computing
Data and Visualizations

IEA Bioenergy Task 45

Country: United States

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

* Roles: TL=Task Leader; WPL=WP Leader; NTL=National Team Leader; A=Associate

IEA Bioenergy

Interest Task 45 WP1

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

* Roles: O=observer; C=contributor; L=leader

IEA Bioenergy

Interest Task 45 WP2

Work Package 2	Role*	Relevant projects/programs in country or own organization
Topic 1: Measure sustainability	C	ORNL (sustainability criteria and indicators)
Topic 2: Model LUC	O	PNNL (GCAM), Purdue (GTAP)
Topic 3: Spatio-temporal tools for environmental impacts	O/C	ANL (ecosystem services), INL (landscape design), ORNL (Antares project), PNNL (forest landscapes)
Topic 4: Spatio-temporal tools for socio-economic impacts	O/C	(contribution pending final scope and applicable DOE project)
Topic 5: Monitor sustainability indicators	O/C	ORNL (sustainability criteria and indicators)
Topic 6: Uncertainty	O	
Topic 7: sustainable land use planning	O/C	ANL (ecosystem services), INL (landscape design), ORNL (Antares)
Topic 8: bioeconomy net effects	C	NREL (LCA based Bioeconomy Environmentally-extended Input-Output Model: BEIOM; Jobs and Economic Development Impact model: JEDI)
Topic 9: Trade offs, stakeholder perspectives	O	

* Roles: O=observer; C=contributor; L=leader

Interest Task 45 WP3

Work Package 3	Role*	Relevant projects/programs in country or own organization
All topic areas	O	

* Roles: O=observer; C=contributor; L=leader

Interest inter-Task activities

Inter-Task project & joint Task activities*	Role**	Relevant projects/programs in country or own organization
WB2/SDG	O	Interest and related work starting at LLNL, NREL, ORNL. Potential future contribution given synergy between intertask scope and U.S. DOE BETO project work.
ResGas	-	
BECCS/U	O	Interest and related work starting at LLNL, NREL, ORNL. Potential future contribution given synergy between intertask scope and project work.
ASA	C	Related work at NREL; will engage other national labs depending on specific action items

* 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

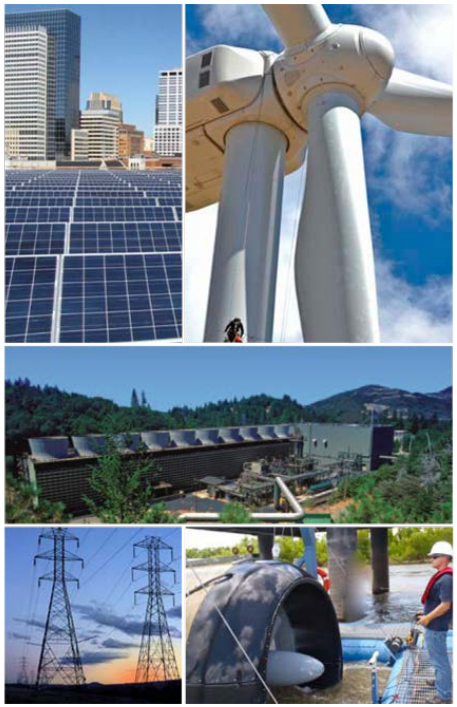
patrick.lamers@nrel.gov

Backup slides

Office of Energy Efficiency and Renewable Energy (EERE)

Sustainable
TRANSPORTATION

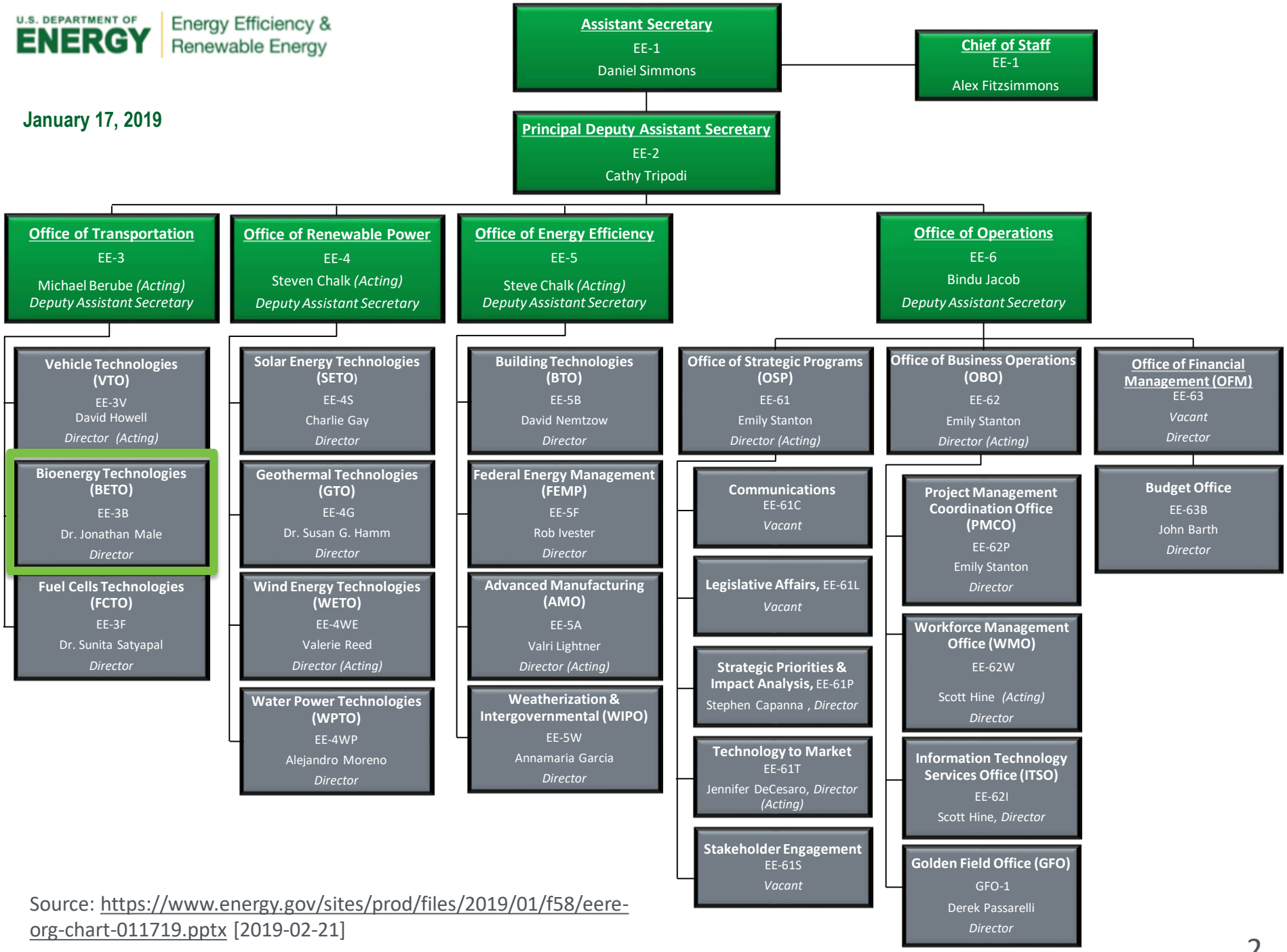
Renewable
ELECTRICITY GENERATION



Energy Saving
HOMES, BUILDINGS, & MANUFACTURING

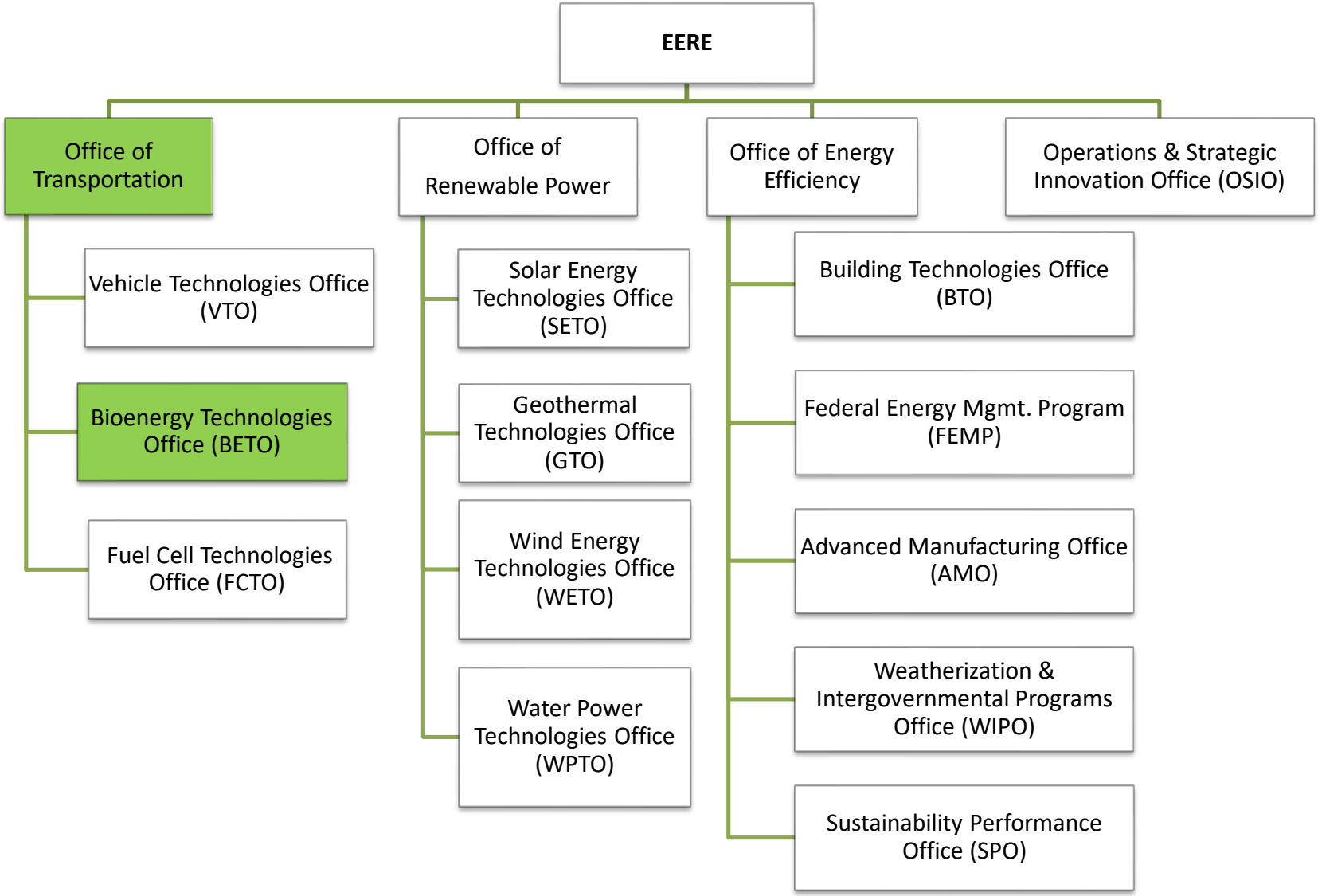
U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

January 17, 2019



Source: https://www.energy.gov/sites/prod/files/2019/01/f58/eere-org-chart-011719.pptx [2019-02-21]

Office of Energy Efficiency and Renewable Energy (EERE)



BETO's Mission & Vision

Vision

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

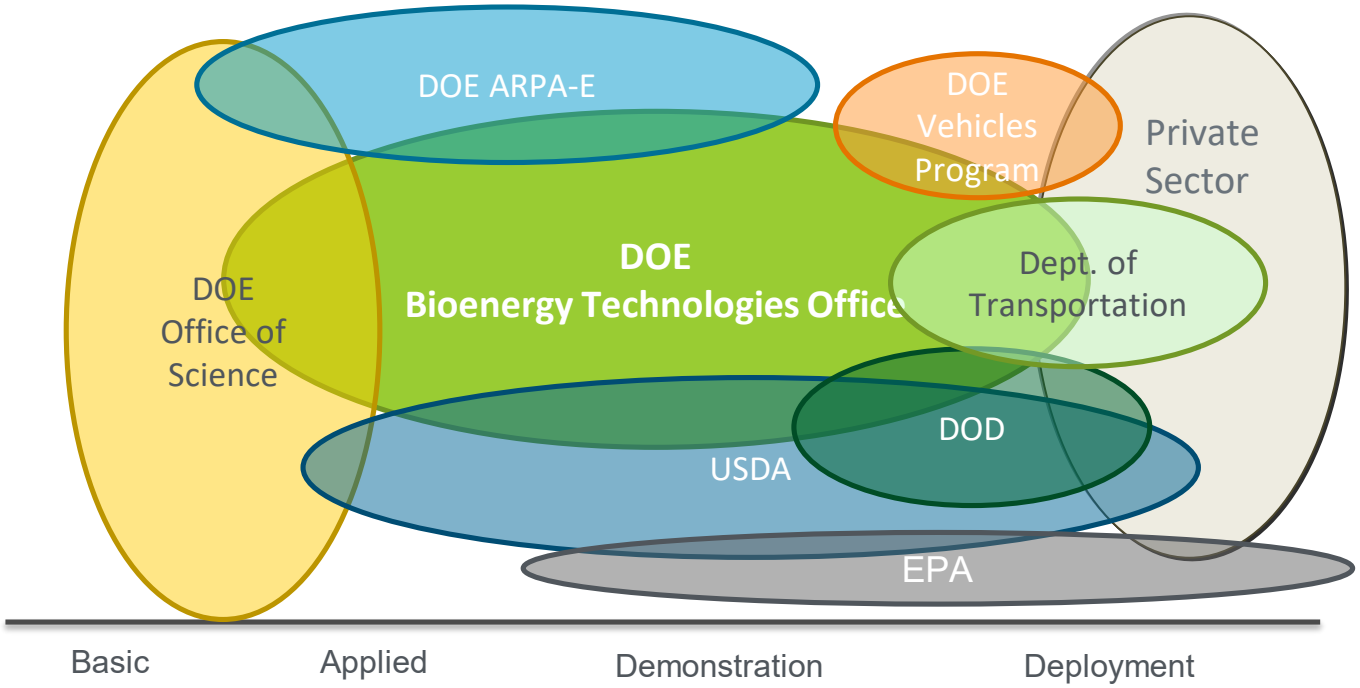
Mission

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

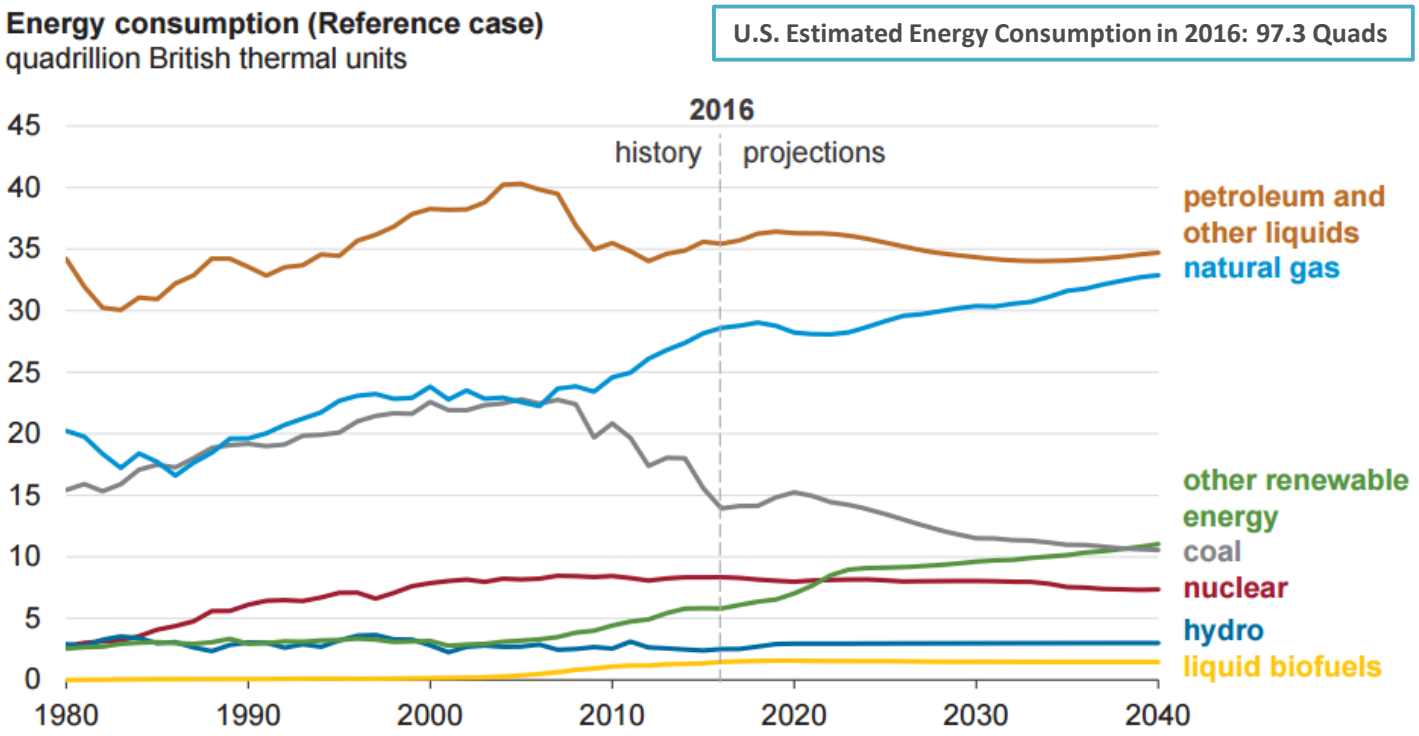
Intra- and Interagency Partnerships & Relationships



DOE Office of Science	DOE ARPA-E	USDA - Agriculture	Dept. of Defense	DOE Vehicles Tech. Progm.	Dept. of Transportation	EPA	Private Sector
• BERCs • EFRCS • Joint Solicitation	• Algae • Information Sharing	• Agriculture resources • Conversion technologies	• R&D • Biofuel Offtakes	• Engine/Fuels testing • Future Vehicle Dev.	• Distribution and end-use	• RFS • Fuel Approval	• Industry build-out • Financing

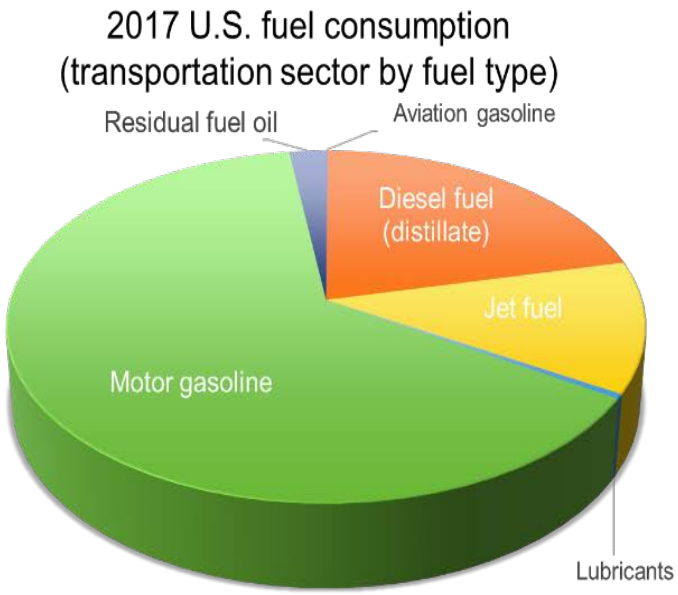
Backup slides

U.S. Primary Energy Consumption: Past and Projected



Source: Energy Information Administration, "Annual Energy Outlook 2017", Reference Case.

U.S. fuel consumption (2017)



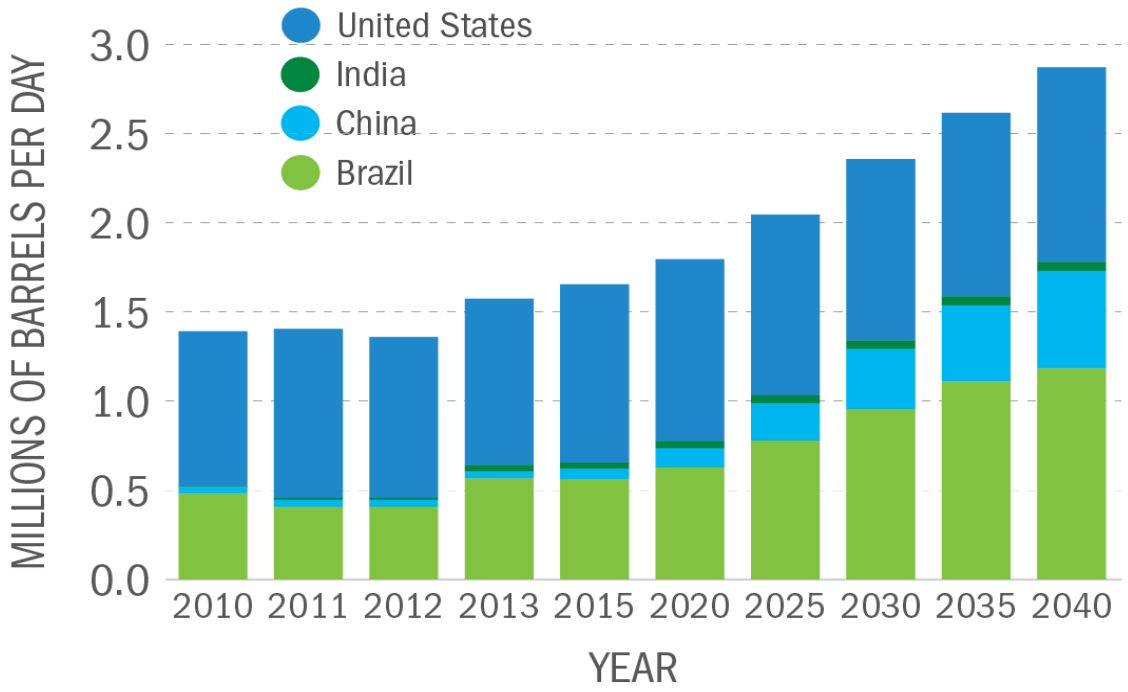
2017 U.S. transportation fuel consumption
(billion gallons per year)

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

https://www.eia.gov/totalenergy/data/monthly/index.php#petroleum

* LNG not reported, † billion gallons/year

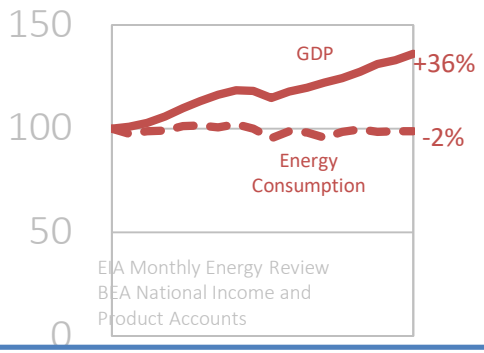
Global Production of Biofuels - Future



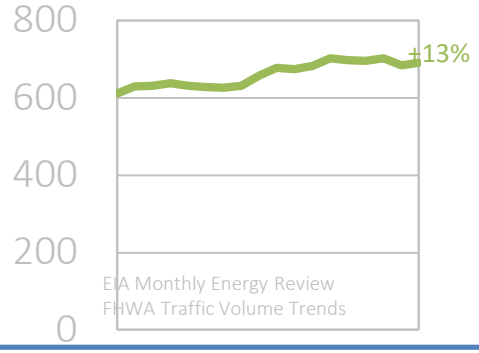
U.S. Energy Information Administration (EIA), *International Energy Outlook 2016* (Washington, DC: EIA, 2016), DOE/EIA-0484, https://www.eia.gov/outlooks/ieo/pdf/0484(2016).pdf.

United States Energy Trends

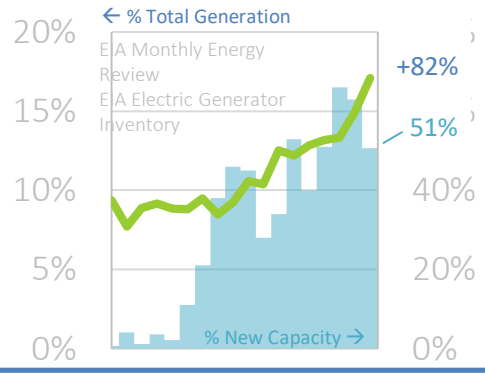
Energy Productivity
(Indexed to 2000)



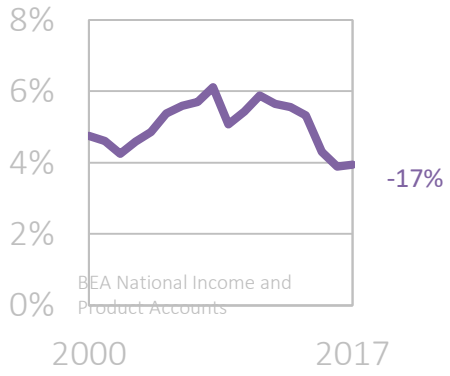
Transportation Oil Efficiency
(VMT/Barrel Oil Equivalent)



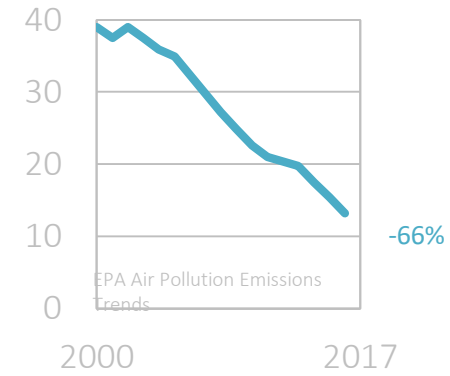
Renewable Electricity



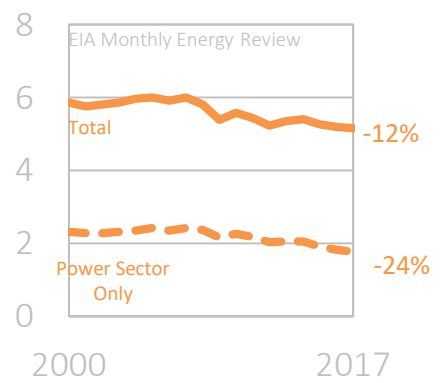
Personal Energy Expenditures
(% Total Expenses, nominal)



NO_X & SO_2 Emissions
(Million Short Tons)



Energy CO_2 Emissions
(Billion Metric Tons)



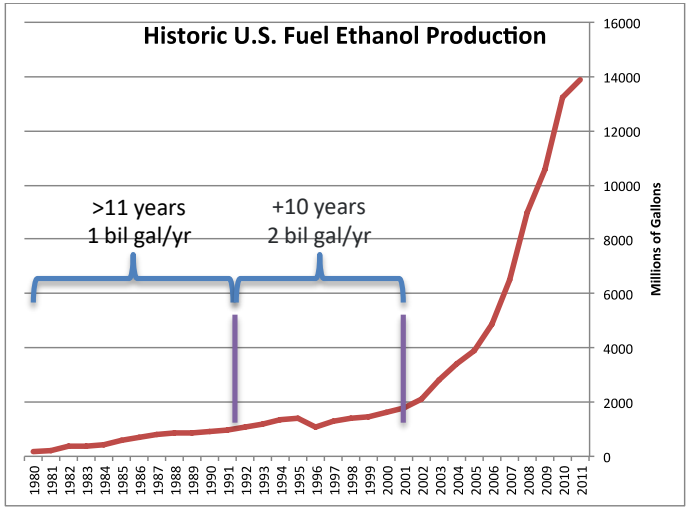
US Alternative Fuels History

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).

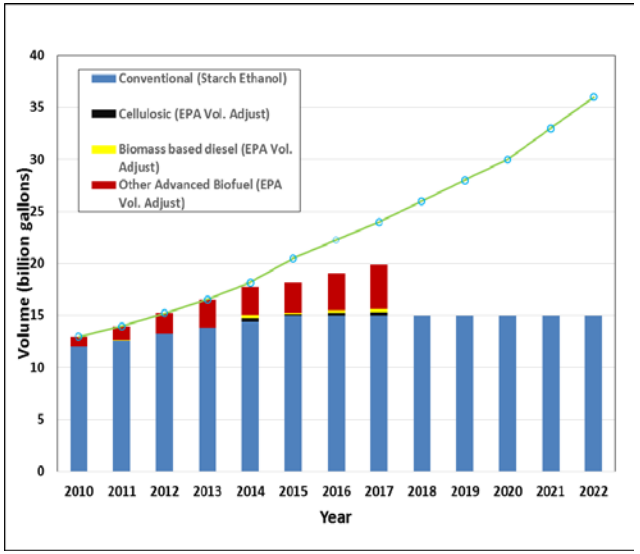
New process technologies that convert biomass and waste-based feedstocks into fuels are beginning to be commercialized.



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

Source: https://www.epa.gov/renewable-fuel-standard-program/renewable-fuel-annual-standards

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:

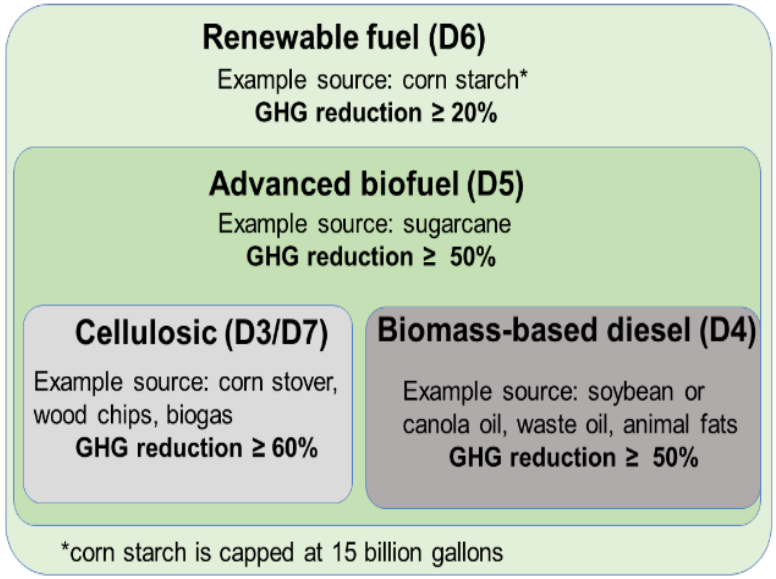
- Allow alternative jet fuel (AJF) to generate LCFS credits as an opt-in fuel
- Allow credit generation for AJF loaded to all planes in California, whether destinations are in state or out of state
- Allow credit generation for military use of AJF

- ***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

RINS[1]	million gallons	percent
D6 Renewable fuel		78%
ethanol	14,860	
renewable diesel	245	
D4 Biomass-based diesel		20%
biodiesel	3,070	
renewable diesel	770	
renewable jet	3	
D5 Advanced Biofuels		0.7%
ethanol	99	
naphtha	32	
other	13	
D3/D7 Cellulosic		1.3%
ethanol	10	
natural gas[2]	217	
heating oil	2	

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



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