U.S. DEPARTMENT OF
ENERGY
Office of
ENERGY EFFICIENCY &
RENEWABLE ENERGY

Bioenergy Technologies Office: Technology Update and Investment Strategy

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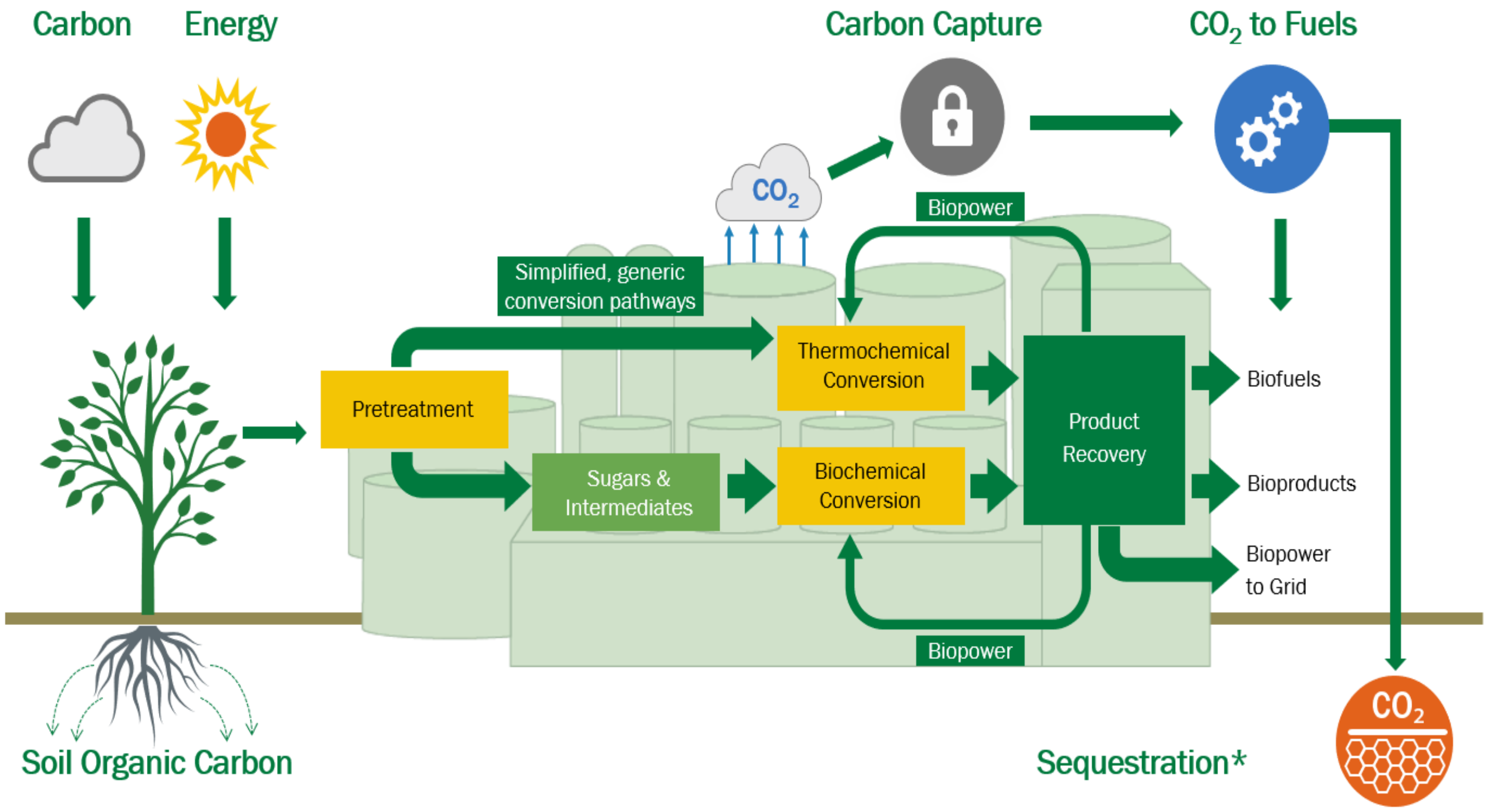
Biomass: Nature's Carbon Removal Technology (for 3.4 Billion Years)

- **Biomass** includes food waste, municipal solid waste, agricultural and forest wastes, animal wastes, and energy crops.

- **Bioenergy** is the conversion of biomass to energy that can replace fossil fuels.



* Office of Fossil Energy R&D on technologies of relevance to bioenergy industry.

Bioeconomy: An economy based on products, services, and processes derived from biological resources (e.g., plants and microorganisms).

The bioeconomy encompasses multiple sectors, including agriculture, textiles, chemicals, and energy.

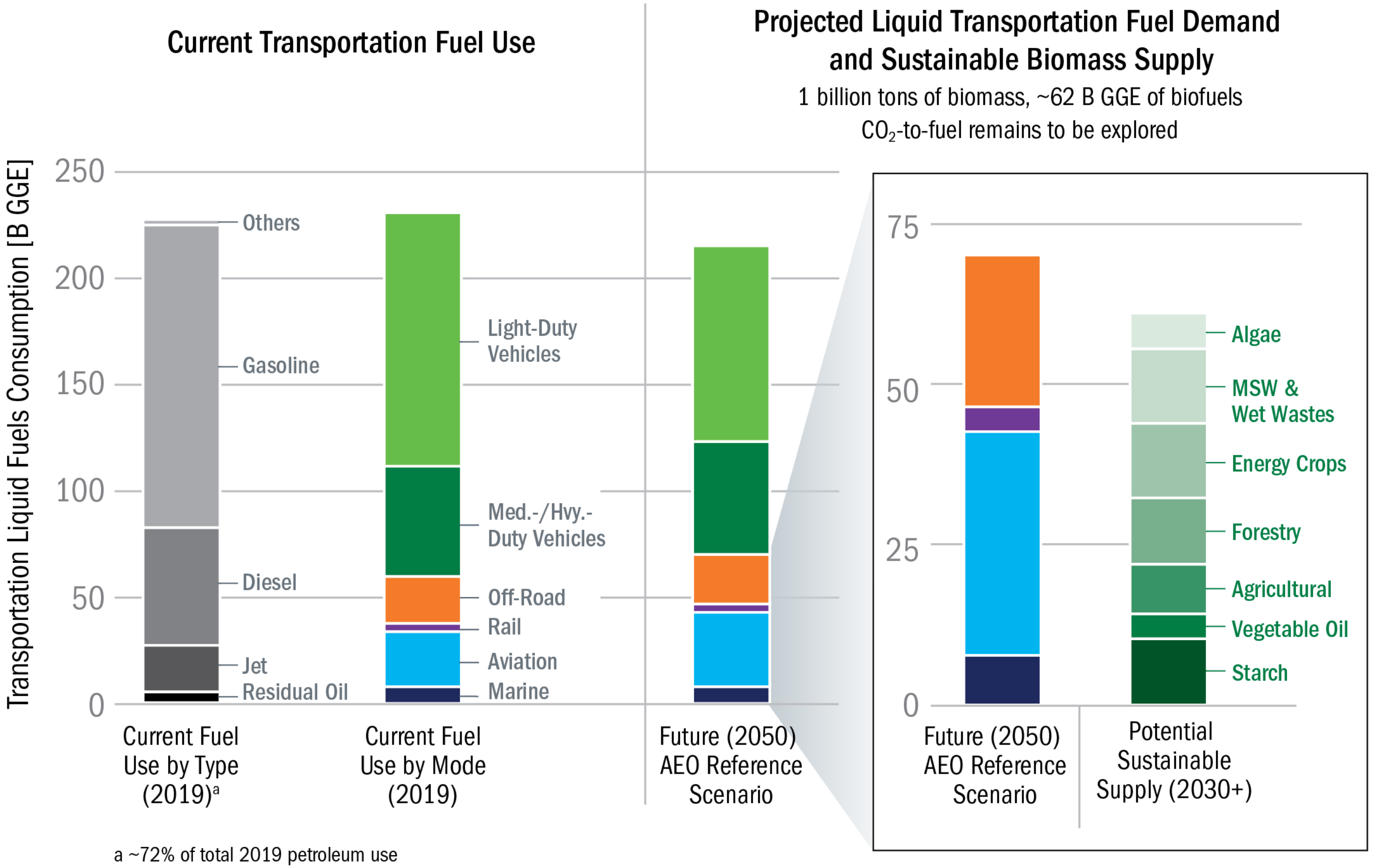
Bioenergy is a key component of the U.S. bioeconomy.

The Role of Biomass in Sustainable Transportation

- Transportation accounts for 34% of U.S. greenhouse gas (GHG) emissions.
- Biofuels are part of a sustainable transportation fuel strategy to decarbonize all modes.
- U.S. biomass can meet the needs of "hard to electrify" modes, such as aviation, marine and rail.

Focus areas for biofuels:

- **Ethanol for passenger cars**
- **"Drop-in" fuels that can use existing infrastructure such as renewable diesel/sustainable aviation fuels**



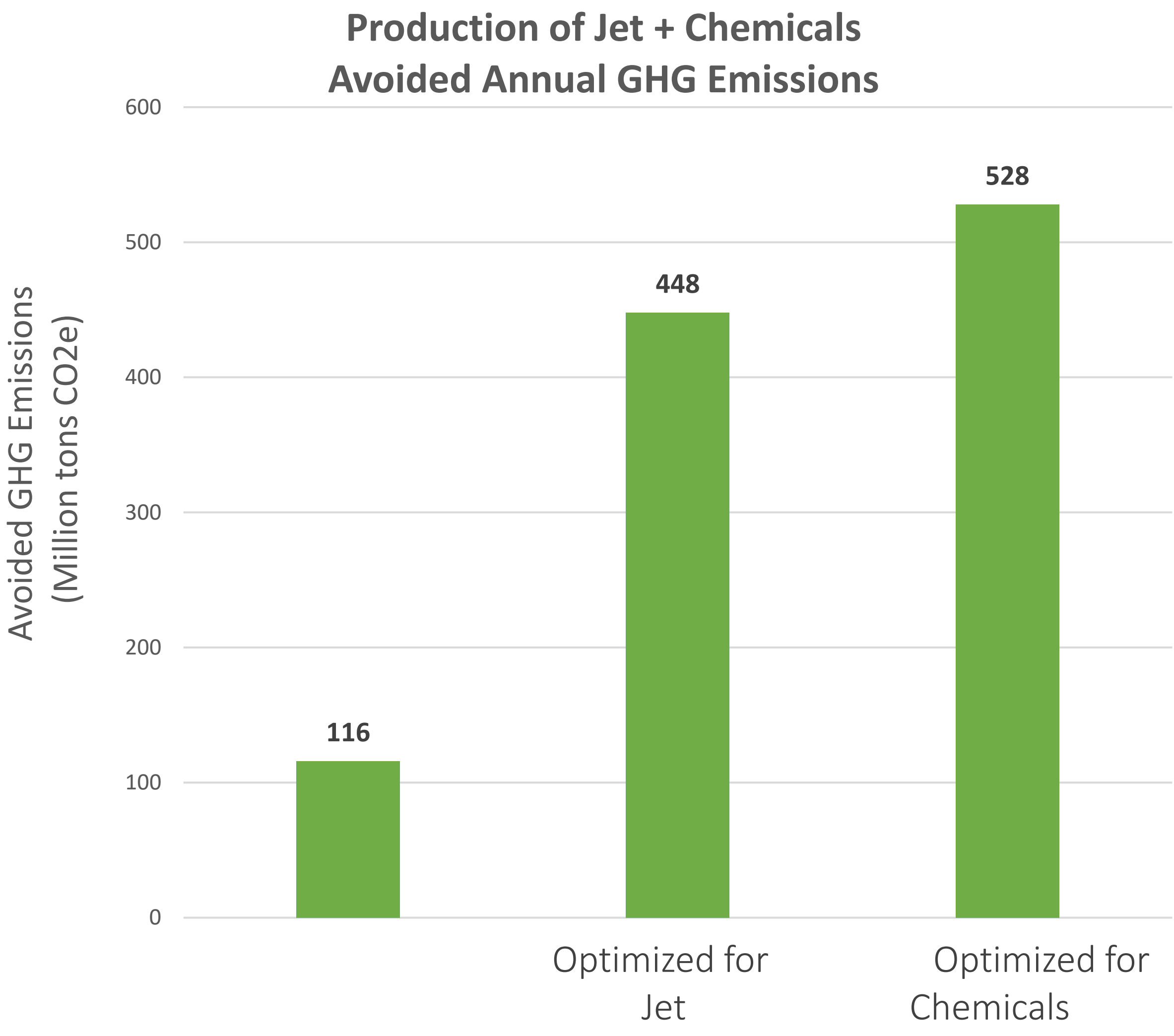
a ~72% of total 2019 petroleum use

AEO = annual energy outlook | GGE = gasoline gallon equivalent | MSW = municipal solid waste

Industry: Biochemicals/Materials

- Chemical production accounts for 5.5% of U.S. GHG emissions.
- Biomass is the only renewable resource that can replace petroleum to make carbon-based chemicals.
- Biomass-derived chemicals could significantly reduce GHG emissions.

Focus areas
- **Drop-in replacements for petro-chemicals**
- **Performance enhanced biochemicals**
- **Recyclable on demand**

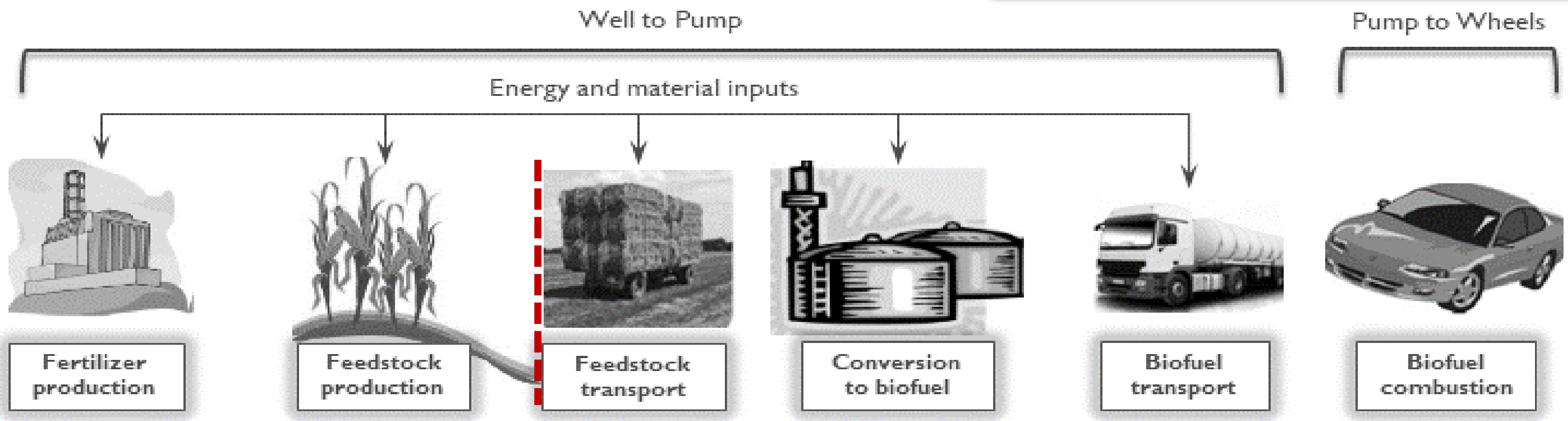


Climate-Smart Agriculture is a Key Enabler

- Agriculture activities serve as sources and sinks for GHGs.
- Decarbonizing transportation/chemicals and decarbonizing agriculture are intrinsically linked.
- By developing tools and strategies to quantify and improve soil carbon sequestration and ecosystem services, we can produce biofuels with a lower carbon intensity.

Focus areas in agriculture:

- **Maximize soil CO_2 sequestration by developing healthy, productive soils and regenerating distressed soil.**
- **Develop climate-smart ag practices.**
- **Produce clean energy on-site from animal waste.**
- **Develop wastewater treatment strategies that produce bioenergy feedstocks.**



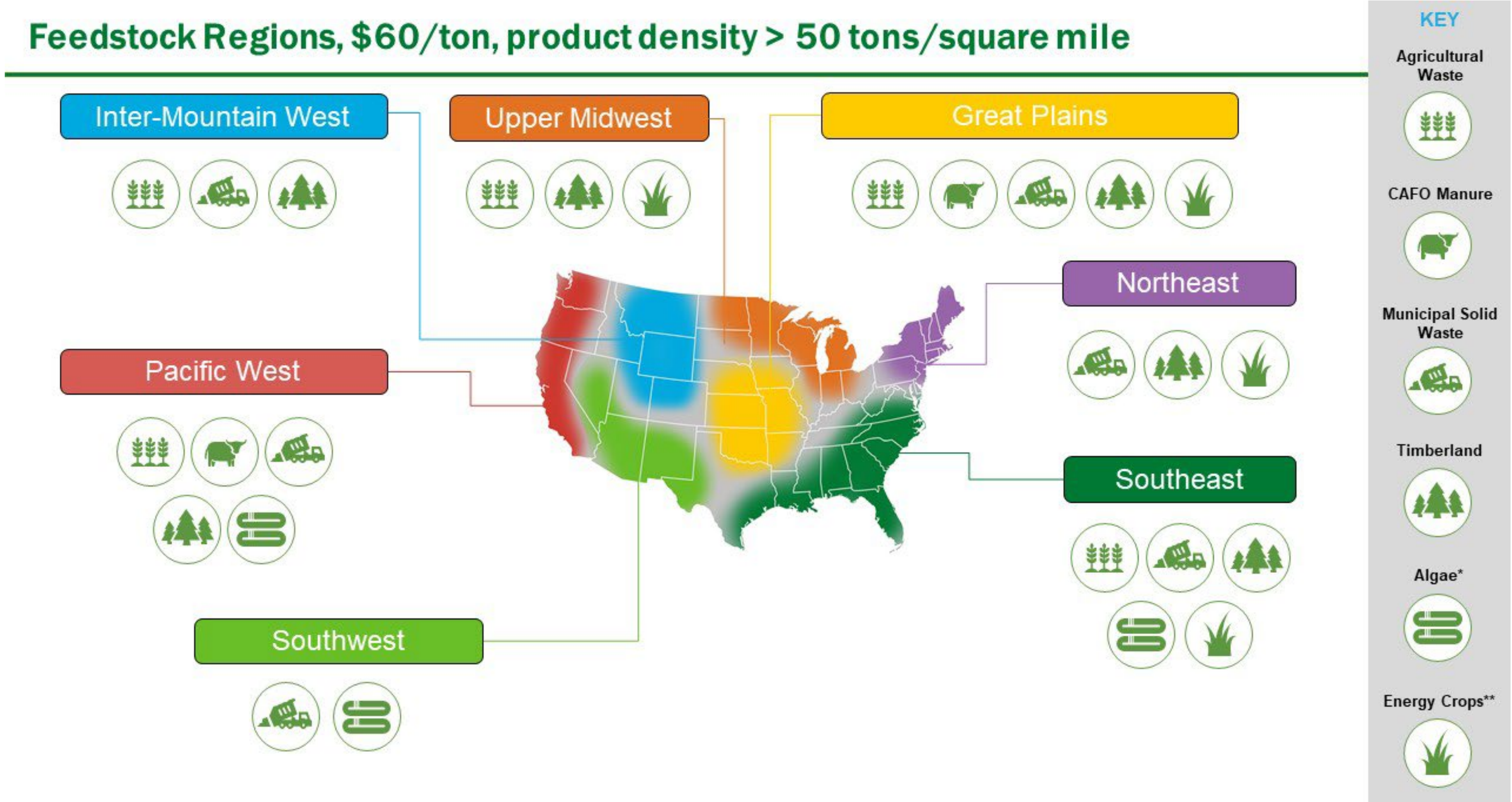
Emissions Contribution

Fertilizer production	Feedstock production	Feedstock transport	Conversion to biofuel	Biofuel transport	Biofuel combustion
16-20%	26-31%	2%	44%	2%	1%

Argonne Final Report to ARPA-E (2019): *Developing a Framework for Lifecycle Analysis of Biofuels on the Farm Level*

Biomass is Widely Available

- The U.S. has the potential to produce 1 billion tons of sustainable biomass annually.
- About 645 million tons of biomass is needed to make 35 billion gallons of SAF annually.
- No single resource type is sufficient on its own to meet demand.
- A diversified feedstock supply will:
    - Deliver economic and environmental benefits across the U.S.
    - Increase resilience across the supply chain.



*Saline, current productivities, minimally lined saline ponds, co-location with CO_2 from coal, natural gas, and ethanol plants at prices from $755-$2,889 per dry ton ($2014)
**Energy crops derived from 2040 dataset, all other biomass from 2017 dataset

Benefits of a Bioeconomy

Across the United States, a bioeconomy will:

- Create jobs in agriculture, waste management, transportation, manufacturing, construction
- Invest in communities and help manage waste disposal, creating new revenue streams
- Reduce methane emissions associated with waste disposal
- Produce clean water and reduce fertilizer use in agriculture
- Achieve lasting carbon reductions across the U.S. economy

Photo courtesy of FDC Enterprises

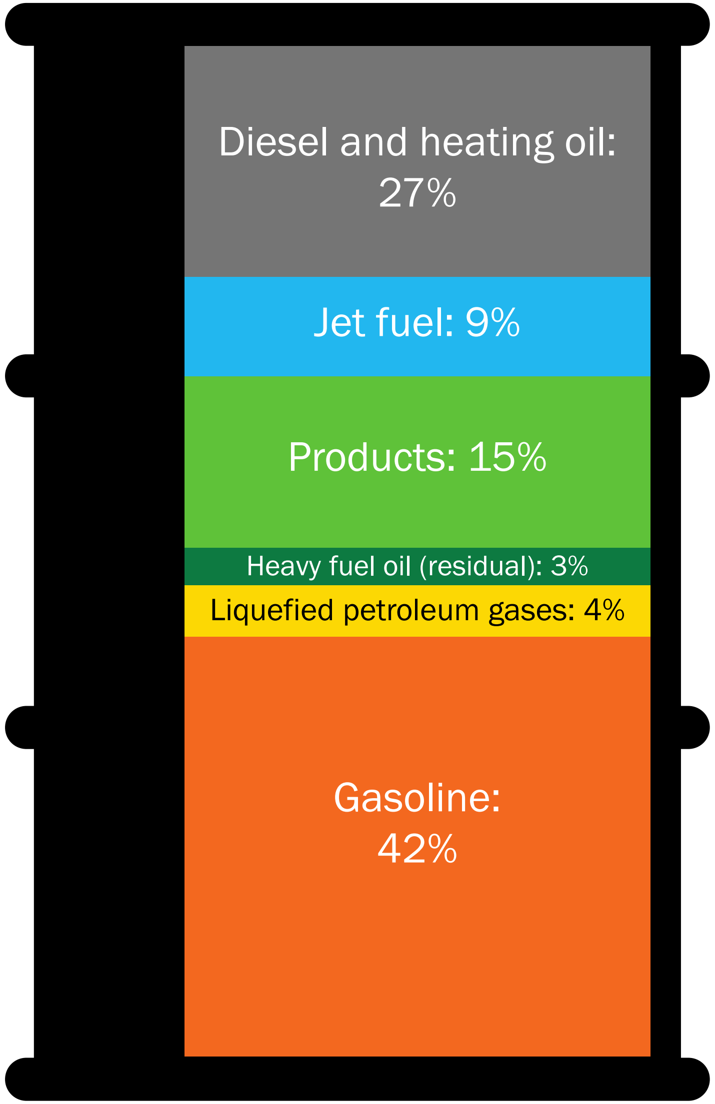
Key Takeaways

- Biomass can play a significant role in decarbonizing several sectors of the economy.
- Biomass can create good jobs, economic opportunities, and environmental benefits for all states and regions in the U.S.
- Near-term deployment is driven by strong market pull.
- Continued investments in technology R&D and scale-up demonstration are needed to ensure access to all feedstocks in all regions and meet decarbonization goals
    - Including goal of meeting **100% of domestic demand** for aviation fuel with SAF.
- Strong sustained policies are necessary to accelerate investments.

Goal of the Workshop

- What is the role of bioenergy in soil carbon storage?
- What new practices and approaches are needed to store carbon in soils?
- Focus on technical opportunities to:
  - Optimize and stabilize carbon storage in soils
  - Assess the impact of agronomic and forestry practices on soil carbon levels and GHG emissions
  - Determine costs, benefits, and tradeoffs to carbon storage as it relates to bioenergy systems.

Our Economy is Built on Carbon



Photos by iStock

BETO Critical Program Areas

Production and Harvesting

Feedstock Technologies

Lower cost, improve quality, and increase types of renewable carbon feedstock intermediates available for conversion.

Advanced Algal Systems

Increase algae productivity through algal strain improvement and efficient cultivation.

Conversion and Refining

Conversion Technologies

Reduce costs of deconstructing feedstock into intermediate products (such as sugars, intermediate chemicals, bio-oils, or gaseous mixtures)

Upgrade intermediates into liquid biofuels, bioproducts, and biopower

Distribution and End Use

Systems Development and Integration

Systems research to combine tech components, unit operations, or subsystems developed by R&D programs into integrated processes.

Integrated processes tested (pre-pilot to demo scale) to identify further R&D needs or verify readiness for scale-up and commercialization.

Crosscutting

Data, Modeling, and Analysis

Track technology progress and identify opportunities and challenges related to economic/environmental impact of advanced bioenergy systems.

Future Directions of the Feedstock Technologies Program

Strategic Goal: *Develop science-based strategies and technologies to **cost-effectively** transform renewable carbon sources into **high-quality**, **sustainable**, **conversion-ready**, and **energy-dense** feedstocks for biofuels, bioproducts, and biopower.*

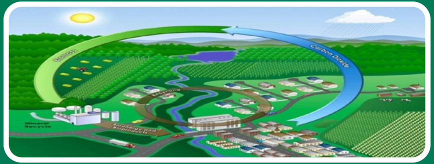
– Focus on Renewable Carbon Sources
  - FT expands its breadth of biomass materials beyond agricultural and forestry residues and energy crops into waste solids (e.g., MSW) and gases (e.g., CO2) for producing conversion-ready feedstocks
  - FOA on feedstock preprocessing and quality improvement for Sustainable Aviation Fuels (FOA link here)

– Climate-Smart Practices For Low Carbon Intensity Feedstocks
  - Produce and supply low carbon intensity feedstocks from agriculture and forestry crops and residues for sustainable aviation fuels production
  - Decarbonizing agriculture and healthy forestry management

FT's Investment in Soil Carbon

Regional Feedstock Partnership (SunGrant Initiative)

Several projects ($14M) that demonstrated the production of herbaceous and woody feedstocks across a wide geography over 5-7 consecutive growing seasons. Emphasis on sustainable practices for each of the feedstocks, including soil carbon in relation to residue removal.



Landscape Design for Sustainable Bioenergy Systems FOA

One project awarded ($9M), establish multi-disciplinary landscape design process, improve sustainability metrics, and assess logistics systems to deliver feedstocks to conversion facilities for bioenergy

Affordable and Sustainable Energy Crops (ASEC) FOA

Three projects awarded ($15M), using new varieties/cultivars of energy crops leading to increased availability, cost-effectiveness, and environmental sustainability of energy crop production systems

Bio-Restore: Biomass to Restore Natural Resources FOA

Three projects ($9M), will develop and employ new methods to quantify the environmental and economic benefits associated with growing energy crops on marginal and/or unproductive land with a focus on restoring water quality and soil health.

FT's Investment in Soil Carbon

- **FY22 Projects**
  - 3 Cover Crop Projects
    - Cover crop valorization for biofuels and products (INL)
    - Maximizing the value of late year cover crops in the Pacific Northwest (PNNL)
    - National availability and costs of cover crops managed as biofuel feedstocks (ORNL)
  - 2 Carbon Banking/Sink Projects
    - Global impacts of enhancing domestic ecosystem carbon sinks (PNNL/NREL)
    - Benefits and Land Use Effects of US Energy Crop-based Carbon Banking (ORNL)

Photo of clover root system; courtesy of Daniel Santosa (PNNL)

Soil Carbon Status

- Worldwide, there are around 2,500 gigatons of carbon in soil, with 1,550 gigatons as organic carbon and 950 gigatons as inorganic carbon.

  Lal (2004); Ontl & Schulte (2012)

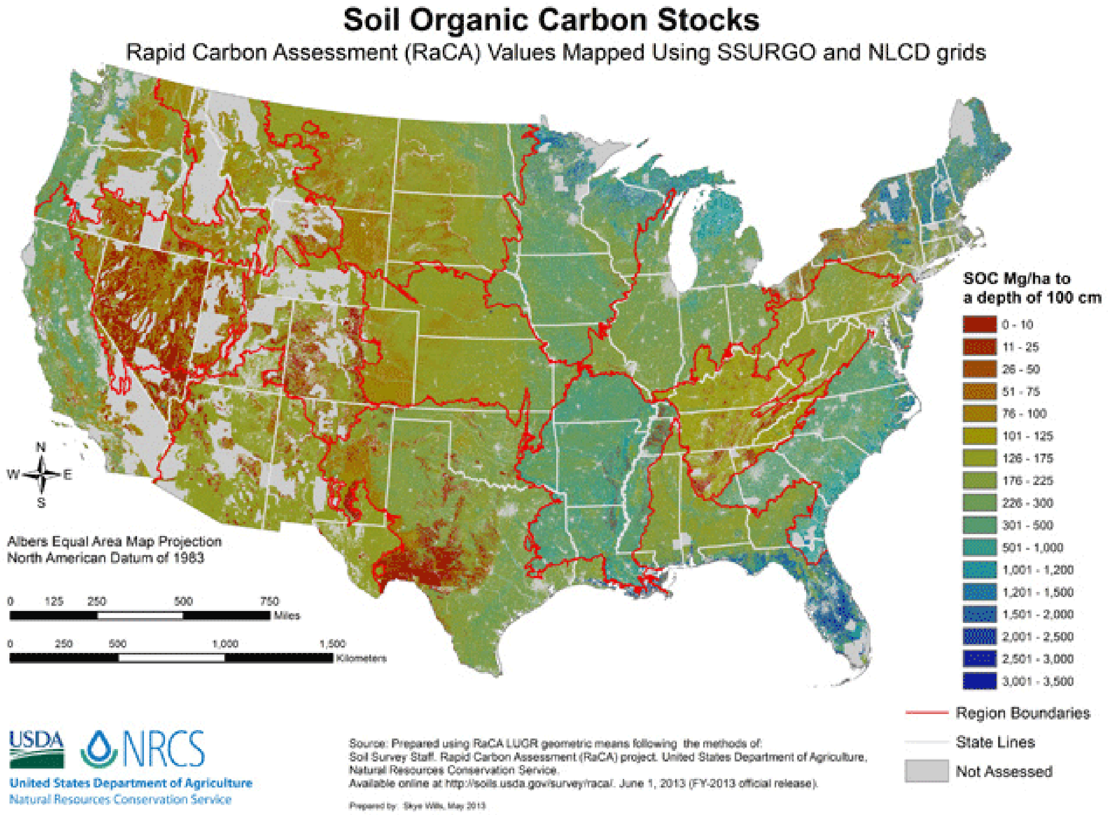
- For terrestrial ecosystems, approximately 40 percent to 50 percent of total organic carbon is stored in forest soils.

  IPCC (2007)

- Atmospheric CO_2 concentrations have risen nearly 50 percent since 1850, from 280 parts per million to 419 parts per million.

  NOAA (2021)

- The actual value of total organic carbon content in soils represents the difference between inputs (e.g., plant and animal residues) and losses (e.g., microbial degradation of organic matter, wind and water erosion, offtake in plant and animal production, wildfire combustion of peatland soils) of soil organic carbon.



Opportunities on Soil Carbon Storage in Bioenergy

- **Explore soil carbon storage by a wide range of feedstocks over business as usual**
  - Ag residues, forestry, energy crops, cover crops, oil seed crops
  - Assess feedstock influence on soil carbon storage (enhancement of existing levels and longevity).
- **Identify major factors in soil carbon storage across sites for different feedstocks**
  - Management practices, soil properties, climate
  - Leverage previous field trials to extend timeline for determining significant soil carbon accumulation.
- **Investigate tradeoffs between storage and carbon intensity of feedstocks for bioenergy applications**
  - Impact of harvest rate, height, tillage, inputs, and yield

Agenda – Monday, March 28th, 2022

Time (ET)	Agenda Item	
9:30 a.m.	Workshop Opening	
	Stakeholder Questions and Introduction to XLeap	
10:00 a.m.	Highlights from Previous Federal Programs on Soil Carbon and Current Agency Perspectives/Directions	
11:00 a.m.	Presentation Question and Answer Session, Mediated via XLeap	
11:15 a.m.	Virtual Lunch Break: Open Networking Session via XLeap	
12:00 p.m.	Keynote Talk: Negative Emission Farming and Soil Carbon Sequestration Rattan Lal, Director Rattan Lal Center for Carbon Management and Sequestration, Ohio State University	
	Presentation Question and Answer Session, Mediated via XLeap	
1:00 p.m.	Mechanisms of Soil Carbon Storage	Mgmt Strategies to Optimize Soil Carbon Storage
1:45 p.m.	Stakeholder Input Breakout Sessions, Mediated via XLeap	
2:50 p.m.	Break	
3:00 p.m.	3x5 Stakeholder Lightning Talks	
3:55 p.m.	Adjourn	

Agenda – Tuesday, March 29th, 2022

Time (ET)	Agenda Item	
9:30 a.m.	Virtual Coffee Hour: Open Networking Session in XLeap	
10:30 a.m.	Welcome and Second Day Opening Asmeret Asefaw Berhe, University of California Merced	
10:55 a.m.	Agricultural Management Practices to Optimize Soil Carbon Storage	Forest Management Practices to Optimize Soil Carbon Storage
11:43 a.m.	Stakeholder Input Breakout Sessions, Mediated via XLeap	
1:00 p.m.	Virtual Lunch Break: Open Networking Session in XLeap	
2:00 p.m.	Research and Development Needed to Support Soil Policy for Carbon Storage in Bioenergy	Tools for Decision Making in Bioenergy and Soil Carbon Storage
2:40 p.m.	Presentation Question and Answer Session, Mediated via XLeap	
3:10 p.m.	Final Stakeholder Input Breakout Sessions, Mediated via XLeap	
3:50 p.m.	Adjourn	

The Feedstocks Technologies Team

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Thank You!

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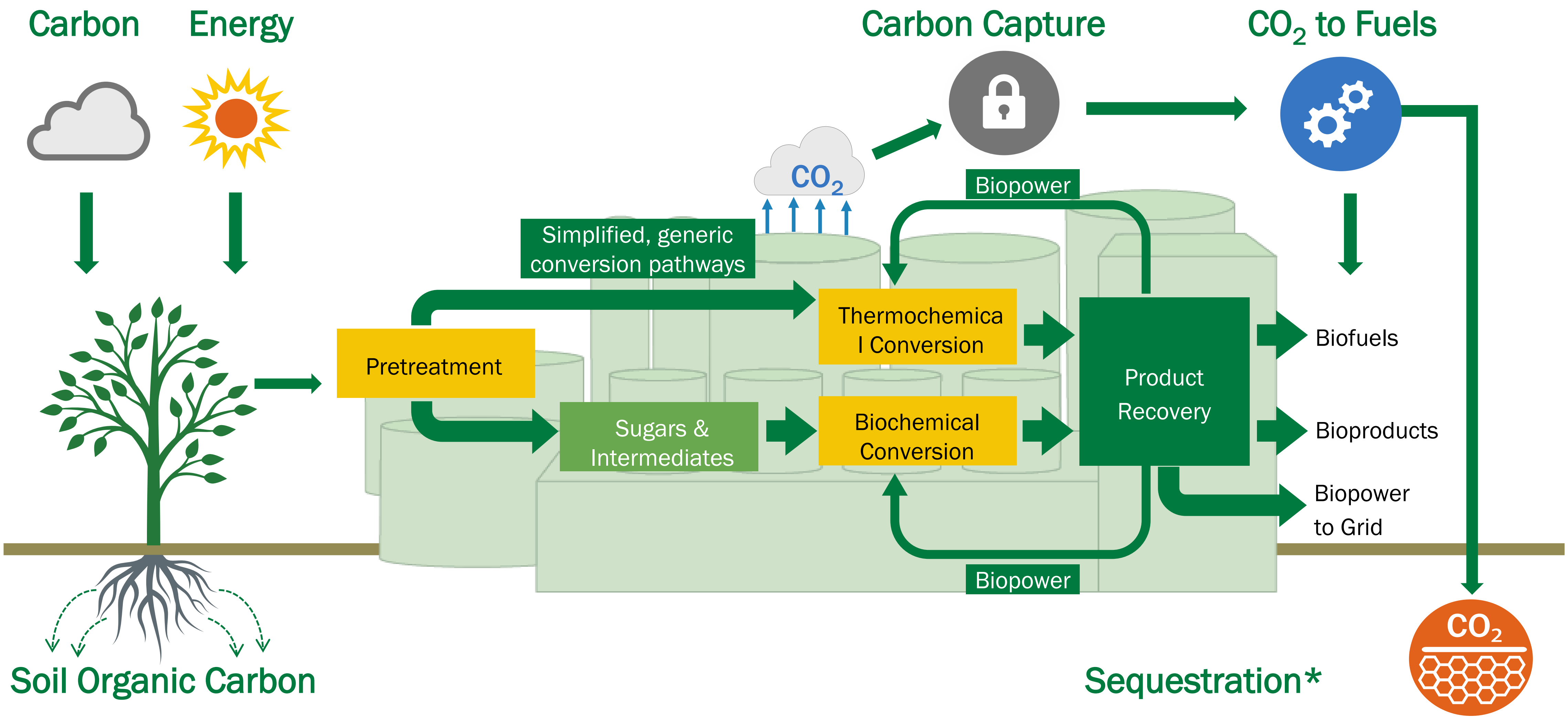
Feedstock | Algae | Conversion | Systems | Data

Backup Slides

What we need to know about Soil Carbon Storage?

- What are the most important practices or mechanisms governing carbon storage in soils per feedstock type?
- What are the trade-offs between crop yield and carbon storage for agricultural and silvicultural feedstocks?
- What are the tradeoffs in the use of soil amendments to enhance soil carbon levels and storage?
- What are the tradeoffs between sequestration and carbon intensity of feedstocks for bioenergy applications
- What approaches in bioenergy applications provide the greatest recalcitrancy to achieve long-term soil carbon storage, such as 1,000+ years?
- What R&D is needed to optimize soil carbon recalcitrancy/durability in bioenergy applications?
- What other approach or mechanisms not covered should be discussed?

Biomass – Nature's Carbon Removal Technology (since 3.4 Billion years ago)



* *Office of Fossil Energy R&D on technologies of relevance to bioenergy industry.*

BETO Vision, Mission, and Strategic Goals

A thriving and sustainable bioeconomy fueled by innovative technologies

Developing transformative and revolutionary sustainable bioenergy and coproduct technologies for a prosperous nation

Develop industrially relevant technologies to enable domestically produced biofuels, biopower, and coproducts