National Lab Day

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NREL Biomass Program

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NREL at a Glance

- **2,000** Employees, plus more than 400 early-career researchers and visiting scientists
- **World-class** facilities, renowned technology experts
- **Partnerships** with industry, academia, and government
- **Campus** operates as a living laboratory
- **National economic impact**
- **$872M annually**
# Scope of Mission

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NREL’s Research Spans Biochemical and Thermochemical Conversion of biomass to Fuels, Chemicals and Products

Lignocellulosic Structure of Biomass

Biochemical Conversion

Thermochemical Conversion

Algae Growth & Conversion

Fuels
Chemicals
Products

Analysis and Sustainability
Can High Energy Jet Fuel be Produced from Biomass?

Figure used by permission from Prof. J Heyne, University of Dayton
Can High Octane Gasoline be Made from Biomass?

- **C1 OXY**'s
  - O
  - DME

- **C2 OXY**'s
  - OH
  - Ethanol

- **C4-C7 high-octane gasoline** (low aromatics)
- **C4 olefins** (butadiene, butenes)
- **C3-6 olefins**

**Fuels**

**Renewable Feedstock**

**Gasification**

**Fermentation or Hydrolysis**

**Solid Acid Catalysis**

**Diesel and Jet Fuels**

- **Biomass Derived**
- **Intermediates**
- **Chemicals or Fuel Precursors**
Can Anaerobic Digester Systems Produce Higher Value Products than Natural Gas?
Biomethanation to Upgrade Biogas to Pipeline Grade Methane

**Anthropogenic sources of CO₂**

**End Uses:** Heat, fuel, power production, chemical feedstock

**Biogas Sources**
- Wastewater
- Fermentation
- Landfill
- Energy Crops
- Manure

**Biogas Supply**
- CO₂ (25 – 50%)
- CH₄ (50 – 75%)

**Renewable Energy**

**Electrolysis**
- O₂
- e⁻
- H₂

**Water**

**Nutrient Supply**

**NG Storage Network**
- RNG

**Biomethanation**
- CO₂ + 4H₂ → CH₄ + H₂O

**Industrial or medical applications**
Conversion of Biogas to Muconic Acid

- Project aims to develop a biological process for producing muconic acid from biogas (a precursor to adipic acid and Nylon 6,6)
- Adipic acid is a top 50 bulk chemical (>2M mt/yr) traditionally derived from benzene and cyclohexane\(^1\). Market price is around $1,600/mt\(^2\)
- The project includes biogas screening on the methanotrophic organism, metabolic engineering, and novel reactor design to improve gas-liquid mass transfer

R&D focus of this project

Other BETO-funded R&D

WBS 2.3.2.201, Mike Guarnieri
Can Plastics be Upcycled to Higher Value Applications?

- Plastics recycling today is almost universally down-cycling.
- Chemical recycling of PET today is mostly bottle-to-bottle: economics are challenging.
- Bio-based solutions (enzymes, microbes, chemical catalysts) towards upcycling can offer a new strategy to advance beyond the State of Technology.
- Can ultimately enable new bio-based products from waste plastics.

Nylon Precursors

<table>
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<tr>
<th>Polymer</th>
<th>$T_g$ (°C)</th>
<th>$T_m$ (°C)</th>
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</thead>
<tbody>
<tr>
<td>BKA-Nylon</td>
<td>130</td>
<td>-</td>
</tr>
<tr>
<td>Adipic-Nylon</td>
<td>60</td>
<td>260</td>
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</tbody>
</table>
Electrons to Molecules, Adding Value to CO$_2$ and Utilizing Low Cost, Excess Electrons
We have made a lot of progress in utilizing biomass to make fuels, energy and products. There are many opportunities in:

- Developing performance advantaged fuels and chemicals from bio resources
- Using energy from low cost electricity to upgrade CO2, waste gases and biomass
Discussion