Potential for Ethanol Production in Hawaii

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• Reduce Hawaii’s dependence on oil
• Protect the environment
• Reduce the negative impacts related to using imported fuels
• Enhance renewable energy use and energy efficiency
• Improve the security and reliability of Hawaii’s energy system
Selected Legislation Recently Enacted in Support of Hawaii Energy Strategy

• Act 95 (2004): Requires 20% of Hawaii’s electricity to be generated from renewable resources by 2020
• Act 199 (1994): Requires that 85% of gasoline for use in motor vehicles contain 10% EtOH by volume
• Act 240 (2006): Mandates statewide alternative motor fuels standard to reach 20% by 2020
Pathways for Bioenergy Systems

Crops
- Sugarcane
- Sweet Sorghum
- Cassava
- Corn
- Guinea Grass
- Banagrass
- Eucalyptus
- Leucaena
- Jatropha
- Kukui
- MicroAlgae
- Soybean
- Peanut
- Sunflower
- Oil Palm

Intermediate Products
- Sugars
- Starch
- Fiber
- Oil
- Waste Cooking Oil

Conversion Technologies
- Hydrolysis
- Fermentation
- Hydrolysis
- Gasification
- Pyrolysis
- Combustion
- Transesterification

Bioenergy Products
- Ethanol
- Other Fuels, Chemicals, & Biomaterials
- Electricity & Heat
- Biodiesel

Legend:
Blue – Commercial in Hawaii
Green – Commercial elsewhere
Pink – Grown commercially in Hawaii
Orange – Under Development
Objectives of Current Study

• Inventory agricultural lands and determine suitability for energy crop production
• Estimate production of targeted energy crops based on modeled yields (ton/acre) and scenarios of land and water availability
• Estimate ethanol potential (gal/yr) based on energy crop production and selected ethanol conversion technologies
Availability of Agricultural Lands

- Geographic information systems (GIS) based approach using layers available from SOH

- Categories of land considered
  - Land zoned for agriculture (1,928,034 acres)
    - Land owned by the State of Hawaii (SOH) (430,000 acres)
    - Land owned by large land owners (LLO)
    - Agricultural land of importance to the State of Hawaii (ALISH) (977,043 acres)
Crops Selected for Ethanol Feedstocks

• **Sugarcane (sugar and fiber)**
  – Water requirements: >78” per year
  – Sugarcane soils less than 20% slope

• **Banagrass (fiber)**
  – Water requirements: >78” per year
  – Sugarcane soils less than 20% slope

• **Eucalyptus (fiber)**
  – Water requirements: >40” per year
  – Sugarcane, pineapple, or woodland soils less than 20% slope

• **Leuceana (fiber)**
  – Water requirements: >20” per year
  – Sugarcane, pineapple, or woodland soils less than 20% slope
Ethanol Conversion Technologies

• Sugarcane
  – Sugar fermentation by yeast with yield of 141 gallon per ton fermentable sugars
  – 0.9 tons of fiber per ton of fermentable sugars are required to service the energy demand of the process leaving 0.6 ton fiber per ton of fermentable sugars for additional ethanol production
  – No attempt to integrate ethanol production from fermentable sugars with that from fiber production

• Fiber
  – Hydrolysis of cellulose and hemicellulose to simple five and six carbon sugars with subsequent conversion yielding 70 gallon per ton of fiber
  – Lignin fraction of fiber used to service energy requirements and yields surplus electricity, 2.3 kW hr per gallon of ethanol
Potential Ethanol Production

Annual SOH motor gasoline as EtOH equivalent

20% of SOH annual motor gasoline by volume

91

- Zoned Ag
- SOH
- LLO
- ALISH

Sugarcane
Trees
Sugar first priority, trees second priority
Banagrass

million gallon per year

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Potential Ethanol Production by Large Landowners by Island

Blue lines indicate 20% of 2005 motor gasoline sales by volume for each county.

- **Sugar**
- **Wood**
- **Sugar First then Wood**
- **Banagrass**
- **2005 Gasoline Sales as EtOH Equivalent**

### Graph Details:
- **Y-axis:** Million gallons
- **X-axis:** Oahu, Maui, Lanai, Molokai, Hawaii, Kauai

### Data Points:
- **Oahu:**
  - Sugar: 450 million gallons
  - Wood: 0 million gallons
  - Sugar First then Wood: 450 million gallons
  - Banagrass: 0 million gallons
  - 2005 Gasoline Sales: 450 million gallons
- **Maui:**
  - Sugar: 150 million gallons
  - Wood: 0 million gallons
  - Sugar First then Wood: 150 million gallons
  - Banagrass: 0 million gallons
  - 2005 Gasoline Sales: 150 million gallons
- **Lanai:**
  - Sugar: 50 million gallons
  - Wood: 0 million gallons
  - Sugar First then Wood: 50 million gallons
  - Banagrass: 0 million gallons
  - 2005 Gasoline Sales: 50 million gallons
- **Molokai:**
  - Sugar: 100 million gallons
  - Wood: 0 million gallons
  - Sugar First then Wood: 100 million gallons
  - Banagrass: 0 million gallons
  - 2005 Gasoline Sales: 100 million gallons
- **Hawaii:**
  - Sugar: 300 million gallons
  - Wood: 0 million gallons
  - Sugar First then Wood: 300 million gallons
  - Banagrass: 0 million gallons
  - 2005 Gasoline Sales: 300 million gallons
- **Kauai:**
  - Sugar: 50 million gallons
  - Wood: 0 million gallons
  - Sugar First then Wood: 50 million gallons
  - Banagrass: 0 million gallons
  - 2005 Gasoline Sales: 50 million gallons

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## Summary

<table>
<thead>
<tr>
<th></th>
<th>Zoned Ag</th>
<th>Zoned Ag, State Owned</th>
<th>Zoned Ag, Large Land Owners</th>
<th>Zoned Ag, ALISH</th>
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</thead>
<tbody>
<tr>
<td><strong>1) Sugar cane</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Acres</td>
<td>360,324</td>
<td>50,828</td>
<td>252,145</td>
<td>329,520</td>
</tr>
<tr>
<td>Ethanol (mil gal/yr)</td>
<td>429</td>
<td>61</td>
<td>312</td>
<td>393</td>
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<tr>
<td><strong>2) Trees</strong></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Acres</td>
<td>698,632</td>
<td>160,360</td>
<td>491,040</td>
<td>571,060</td>
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<tr>
<td>Ethanol (mil gal/yr)</td>
<td>489</td>
<td>112</td>
<td>344</td>
<td>400</td>
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<tr>
<td><strong>3) Sugar cane first priority, trees second priority</strong></td>
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<td></td>
</tr>
<tr>
<td>Sugar Acres</td>
<td>360,324</td>
<td>50,828</td>
<td>252,145</td>
<td>329,520</td>
</tr>
<tr>
<td>Wood Acres</td>
<td>394,136</td>
<td>115,488</td>
<td>288,105</td>
<td>294,564</td>
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<td>Ethanol (mil gal/yr)</td>
<td>705</td>
<td>142</td>
<td>513</td>
<td>599</td>
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<td><strong>4) Banagrass</strong></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Acres</td>
<td>360,324</td>
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<td>252,145</td>
<td>329,520</td>
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<tr>
<td>Ethanol (mil gal/yr)</td>
<td>525</td>
<td>74</td>
<td>374</td>
<td>480</td>
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</table>

**Note:** All assume the availability of land, water, and cellulose to ethanol technology
Full report, *Potential for Ethanol Production in Hawaii*, available at: