Low carbon intensity ethanol production from sugar beets in California with integrated anaerobic digestion

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Steve Zicari, PhD Student
Agricultural and Biological Engineering Department
Major Professor - Dr. Ruihong Zhang
Low Carbon Fuel Drivers in CA

• **AB 32** –
  – GHG reduction to 1990 levels by 2020
  – CA LCFS – 10% reduction in fuel CI by 2020
    • CA LCFS credit value?

• **CA Executive Order S-06-06**
  – Produce >20% of state’s biofuels and biopower by 2020

• **EISA 2007 – Energy Security and Independence Act**
  – RFS2 – 16B GPY Advanced/Cellulosic fuel mandates
    • RIN value?
# UCD – Mendota Bioenergy Collaboration

<table>
<thead>
<tr>
<th>Team Member</th>
<th>Qualifications &amp; Related Business Technical Expertise</th>
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<tbody>
<tr>
<td><strong>MBLLC</strong></td>
<td>Organized January 2 2010 to develop Advanced Bioenergy Center-Mendota and 1 MGY pilot plant at Red Rock Ranch, Five Points, CA. William C. Pucheu, General Manager.</td>
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<tr>
<td><strong>UC Davis</strong></td>
<td>World-renowned biomass production and biofuel research and innovation programs. Operates pilot biogas energy plant for use in this project. Considerable expertise on biofuels development analysis. Dr. Ruihong Zhang, Dr. Stephen Kaffka, Dr. Alissa Kendall, Steve Zicari P.E.</td>
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<td><strong>Easy Energy Systems</strong></td>
<td>Easy Energy Systems is the manufacturer of the Modular Ethanol Production System (MEPS), a fully self-contained, fully automated ethanol production system that is pre-built in the EES factory for shipment and installation at the customer’s site. The MEPS utilizes various feedstocks to efficiently produce fuel grade ethanol in 1 MGY (Million Gallons per Year), 2 MGY, or 5 MGY quantities. Mark Gaalswyck, CEO</td>
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<td><strong>Bioenergy Institute</strong></td>
<td>Known for innovative technologies and policy development at water/energy interface. Major supporter of renewable energy as an economic and community development driver. Manages 1,200-acre University Farm as teaching laboratory for agricultural feedstock practices and technologies advancement. Dr. David Zoldoske, Dr. Mechel Paggi</td>
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<td><strong>Red Rock Ranch, Inc.</strong></td>
<td>Since 1980 has farmed 5,000 acres of fruit and vegetable crops, including almonds, grapes, and alfalfa, as well as energy beet feedstock. John E. Diener, CEO</td>
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<td><strong>Biodico</strong></td>
<td>Builds, owns, and operates biodiesel production facilities based upon patented/proprietary technology developed over past 17 years. Has developed biodiesel production facilities and conducted feedstock and production feasibility studies for clients worldwide. Received US EPA Project of the year award for developing first biogas operated, renewable biofuels production facility. Russ Teall, CEO</td>
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Why Sugar Beets for Biofuels in CA?

Benchmarking Sugar Beet Ethanol*

- Beet yields highest in the world and long history of beet production in California
- May rapidly supply “Advanced” biofuel markets
- Agronomic benefits to growers

Significant improvement in sustainability of standard practices possible through introduction of integrated process design and biogas production
First Generation Ethanol – CARB Pathways with Biogas

**Western Plains Energy, LLC: 2A-2B Pathways, Direct Emissions, Ethanol, Dry Mill, Wet DGS**

- **Feedstock:** Sorghum ~ 2 gCO$_2$/MJ
- **Biogas:** ~10 gCO$_2$/MJ

**D/W DGS:** Wet ~ 10 gCO$_2$/MJ with natural gas

**CHP or LFG:** ~ 2-3 gCO$_2$/MJ

**Biogas:** ~10-15 gCO$_2$/MJ not as much distinction between DDGS & WDGS

**POET Ethanol, LLC: 2A-2B Pathways, Direct Emissions, Corn Ethanol**

- **Fuel Source/Configuration:**
  - Nat Gas
  - CHP
  - LFG
  - Biogas

- **g CO$_2$/MJ:**
  - 30% Biogas Use: 10%, 30%, 80%, 100%
  - % Biogas Use: 10%, 30%, 80%, 100%
Researching Integrated Beet Biorefining at UCD

NOVEL PROCESS PLATFORM: DEDICATED DIRECT CONVERSION OF BEETS TO ETHANOL

Integrated Processing Products:
- Pulp
- Leaves
- Roots
- Water
- Animal Feed
- Fertilizer
- Enzymes

Enzymatic Hydrolysis
- Fermentation
- Distillation/Dehydration
- Protein Separation
- Anaerobic Digestion of Stillage
- Effluent Treatment

Sugar Beet
- Harvesting
- Washing/Grinding

WATER
- FERTILIZER
- ENERGY
Typical Sugar/Fermentation Scheme:

Beets → Wash → Slice → Heated Extraction → Purification → Evaporation → Crystallization → Refined Sugar

Water → Heated Extraction

Pulp (pressed, wet or dried) (To feed, or...)

Molasses

Thick Syrup → Ethanol

Fermentation (C6+C5?) → To Distillation (Stillage to AD or Feed)

Refined Sugar → British Sugar, UK
**Simplified Processing Scheme:**

- **Beets** → **Wash** → **Grind** → **Heat/Cool** → **Liquefaction** → **Fermentation** → **Ethanol**

- **Commercial Cellulase + Pectinase**

- Water
  - Harsh Chemicals

- To Distillation
  - (Stillage to AD or Feed)

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“Standard” downstream design? (rapid deployment potential)

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**Process Development Research**
Lab Research: Fermentation

• Various pretreatment and reactor configurations tested.

• Conventional and modified organisms tested
  – Industrial *S. cerevisiae* (yeasts) perform well
  – Rapid fermentation times (12-48 hrs)
  – Yields ~0.4+g Ethanol/g TS typical
    • 24-30 gal EtOH/wet-ton beet
  – Microbial contamination important to manage
Lab Research: Enzyme Liquefaction

- Major impact of liquefaction = viscosity reduction and solubilization of sucrose
  - Additional structural carbohydrate release minor (~10%).

- Several commercial enzyme products screened primarily for effect on viscosity reduction.
  - Synergistic effect of pectinases and cellulases.

- Low severity thermal pretreatment (70-120 °C) has strong influence on liquefaction rate. Rates < 8 hours desirable for industrial processing.
  - Offsets enzyme loading costs, heat recovery important.
Lab Research: Anaerobic Digestion

- Batch AD of stillage and supplemental feedstocks
  - stable at >4 gVS/L/d, 1.37 L CH₄/L/day, >75% VS reduction

- Continuous AD of stillage testing in progress
  - ASBR and fixed film configurations
    - stable at >4 gVS/L/d, 1.37 L CH₄/L/day, >75% VS reduction

(Data and figure attribution: Batch, Jiajia Li; Continuous, Caitlin Asato)
UC Davis Beet-Ethanol Pilot Testing

Fall-Winter 2012/2013
Co-location at the UCD Biogas Energy Project Facility

Comprehensive Process Demonstration
Local Beet Production
Biofuel and Co-product Generation

- 40 tons processed over 8-weeks
Processing, Fermentation

- Significant process improvement and troubleshooting of unexpected issues at pilot scale
Distillation and Anaerobic Digestion

- High efficiency fermentation and biogas yields demonstrated at pilot scale.
- 5-ton batches validating lab results
Life Cycle Assessment Modelling

Agricultural System

Field Preparation, Planting & Harvest Activities

Conversion Facility

Power

Life Cycle Carbon Intensity Results

g CO₂e/MJ

Soil N₂O + Agrochemical Inputs + Diesel = 11.3
BEET PRODUCTION

Soil N₂O + Agrochemical Inputs + Diesel = 3.3
ENZYMES & YEAST

Soil N₂O + Agrochemical Inputs + Diesel = 4.0
TRANSPORT

Soil N₂O + Agrochemical Inputs + Diesel = 5.4
FACILITY HEAT + POWER

Renewable Energy Inputs = -17.5

CO-PRODUCT CREDIT = 22

Gasoline: 99

LCA evaluation and figures courtesy of Dr. Alissa Kendal and Anthy Alexiades for projected 40MM GPY Ethanol facility, 2014
Successful R&D Collaboration with Commercial Partners

Lab and Pilot Testing - 2011-2013

$1.5 MM CEC Grant
Agronomic, process, and life-cycle assessment research
Lab-scale fermentations
40-ton pilot trial (~5 tons/day)

Demonstration Facility – 2014-2015

$5 MM CEC Grant
~120 ton/day facility
50,000 Gal Ethanol/yr
12-month harvest demo.
Anaerobic Digestion @ UC
Co-product identification

Commercial Facility??

10-20 MM Gal Ethanol/yr?
600,000 tons beets/yr?
(~1000 tons/day)?
12-month harvest?
Integrated Gasifier and Anaerobic Digestion?

For Immediate Release: February 28, 2013
Media Contact: Allison apRoberts - 916-654-4989

Energy Commission Awards Nearly $5 Million for Biorefinery Development in Fresno County
Project Will Convert Sugar Beets into Biofuel Ethanol, Create Jobs, and Promote Clean Energy Innovation in California
Five Points, CA: Red Rock Ranch
Mendota Bioenergy, LLC
1 MGY Energy Beet to Ethanol Demonstration Plant
Red Rock Ranch, Five Points, CA
On Line 3rd Quarter, 2014

http://easyenergysystems.com
MBLLC - Commercial Plant
Harvest Planning

**Highlights**

- Year round harvest Phase 1# - 15 MGY - 1,000 tons/day (40 trucks/day)
- Advanced 300 T/hr. harvester, paperless logistics & sampling technology
- Avg 30-40 mi draw radius; linkage to dairies

KWS sugar beet seeds

ROPA harvester

Harvest region (concentric rings are 40, 60, 80, 100 miles)
Summary

• Sugar beets show potential as a feedstock for near-term low carbon biofuel production in CA.
  — Enabled by high yields and integrated processing to liquid and biogas fuels

• UC Davis will be conducting data collection, modelling, and validation of demo-plant ethanol and AD operations over the next 12 months.

• It is expected that further process improvements to maximize product valuation and efficiency will be identified with ongoing research.
Thank you!