USE OF MICROALGAE FOR WASTEWATER TREATMENT AND PRODUCTION OF RENEWABLE BIOFUELS

Kent BioEnergy Corporation
WESTCAS 2010 – San Diego, CA, June 18, 2010
Dr. James C. Levin, Director of Molecular Studies
CONTROLLED EUTROPHICATION PROCESS (CEP) FOR TREATING AQUACULTURE DRAIN WATER
KENT BIOENERGY HAS RECEIVED NEARLY $7.0 MILLION IN GOVERNMENT & PRIVATE SUPPORT FOR ALGAE RESEARCH

<table>
<thead>
<tr>
<th>Agency</th>
<th>Research Topic</th>
<th>Award</th>
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<tbody>
<tr>
<td>US Dept of Commerce ATP</td>
<td>Techniques for Recycling of Aquaculture Effluents</td>
<td>$2,000,000</td>
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<tr>
<td>US Dept of Agriculture</td>
<td>Treatment and Reuse of Aquaculture Effluents</td>
<td>$350,000</td>
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<td>State of California (SSA)</td>
<td>Reducing Eutrophic Conditions in the Salton Sea</td>
<td>$1,000,000</td>
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<td>EPA</td>
<td>Management of CAFO Discharges</td>
<td>$50,000</td>
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<td>US Dept of Energy</td>
<td>Utilizing Microalgae for Carbon Sequestration and Greenhouse Gas Abatement</td>
<td>$750,000</td>
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<td>National Science Foundation</td>
<td>Microalgae Production, Harvest and Oil Extraction</td>
<td>$150,000</td>
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<tr>
<td>Corporate Client</td>
<td>Treatment of Landfill Effluents</td>
<td>$2,600,000</td>
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**TIMELINE OF DEVELOPMENT OF KENT BIOENERGY ALGAE TECHNOLOGY**

- **1970**: Algae Culture R&D (KST)
- **1972**: Algae Monoculture R&D (KST)
- **1976**: Herbivore Algal Mgmt (Brune)
- **1980**: PAS Tech (Clemson)
- **1982**: Pond Algae Culture R&D (KST)
- **1984**: Algae Aquaculture R&D (Brune)
- **1986**: KST ATP Award ($2M)
- **1990**: Clemson PAS Patent
- **1992**: Clemson CEP Patent
- **1994**: Pondway Algal System (KST)
- **1996**: DOE GHG Award (Joint)
- **1998**: KST ATP Award ($2M)
- **2000**: SETTLING TECHNOLOGIES (KST)
- **2002**: KST Licenses Clemson Patents
- **2004**: Kent BioEnergy Spinoff
- **2006**: KST ATP Award ($2M)
- **2008**: SETTLING TECHNOLOGIES (KST)
KENT BIOENERGY 160 ACRE MICROALGAE RESEARCH FACILITY LOCATED IN THE COACHELLA VALLEY
ALGAL HARVESTING AND DEWATERING SYSTEMS
CONTROL OF EXCESS NUTIRENTS ENTERING THE SALTON SEA
(Efforts to sustain fish and bird populations)

THE PROBLEM:

Terminal lake

- Salinity
- Eutrophication

High tributary flow rate (600,000 gpm)
Low nutrient concentrations (N & P)
Phosphorus is the limiting nutrient
- Use of CEP to reduce eutrophication
KBE LARGE-SCALE MICROALGAE CONTROLLED EUTROPHICATION PROCESS (CEP)
SALTON SEA BIOLOGICAL REMEDIATION PROGRAM
2002 – 2009
FOUR STAGE PROCESS OF CEP

The Problem: Excess Nutrients

High levels of nutrients enter the Salton Sea through the New River, the Alamo River, and the Whitewater River. The nutrients cause large plankton blooms, which under certain conditions can die and decay, causing widespread problems for the fish and bird populations.

The Solution: Controlled Eutrophication

- **Step One:** Settling of clay particles and turbidity reduction
- **Step Two:** Conversion of nutrients to algal biomass in high rate algal zone
- **Step Three:** Removal of 85% of algae by bioflocculation and enhanced settling
- **Final Polishing:** Removal of any remaining nutrients and algae using chemical flocculants (if needed)

Reducing the inflow of nutrients to the Sea, especially phosphorus, should result in more stable populations of plankton, which will greatly enhance the Salton Sea ecosystem. By-products from the CEP treatment process will include valuable fish and fertilizer concentrates.
KENT BIOENERGY FIELD DATA ALLOWS US TO OPTIMIZE CEP OPERATING PARAMETERS FOR MAXIMAL PRODUCTIVITY, NUTRIENT UPTAKE, AND CARBON CAPTURE
SELENIUM REDUCTION OF SALTON SEA AG DRAINAGE

Results of Whitewater River CEP Treatment

CEP
40% Se reduction with 4 – 6 Day Retention

WETLANDS
54% (Imperial) and 69% (Brawley) Se reduction with 9 – 18 Day Retention

From R. Gersberg, 2006-2007 studies
SPECIES CONSERVATION HABITAT (SHC) SITES AT THE MOUTH OF THE ALAMO & NEW RIVERS IN THE IMPERIAL VALLEY

Courtesy DWR

LAND AVAILABILITY FOR SCH CONSTRUCTION IN 2010 DRAFT

Red portion of footprint designates exposed playa between -228 to -232. Blue portion of footprint designates unexposed playa between -232 to -234.
EARLY START HABITAT – USGS
ALAMO RIVER
IN THE IMPERIAL VALLEY

Courtesy of USGS
CONSTRUCTED WETLANDS – TMR
WHITEWATER RIVER
IN THE COACHELLA VALLEY

Courtesy TMR
ALGAE INPUTS (Requirements) AND OUTPUTS (Products)

- **CO₂**
  - Atmospheric
  - Power plants
  - Industry

- **O₂**

- **Light**

- **Electricity**

- **Nitrogen & Phosphorus**
  - Ag drainage
  - CAFO waste
  - Industrial waste
  - Municipal waste

- **Microalgae**

- **Protein**

- **Oil**

- **Environmental Remediation**

- **Water (brackish, fresh, saline, waste, etc.)**

- **Solar Powered Chemical Factories**
ALGAL LIPIDS

Membrane lipids (Polar)  Storage lipids (Neutral)

Dr. Qiang Hu, Arizona State University
MICROALGAE ARE MICROSCOPIC AQUATIC PLANTS THAT USE SUNLIGHT AND CO₂ TO CREATE BIOSMASS

ALGAE CAN PRODUCE MUCH MORE BIOFUEL PER ACRE THAN LAND CROPS

<table>
<thead>
<tr>
<th></th>
<th>Ethanol</th>
<th>Biodiesel</th>
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<tbody>
<tr>
<td>Soybean</td>
<td>48</td>
<td>635</td>
</tr>
<tr>
<td>Sunflower</td>
<td>82</td>
<td>662</td>
</tr>
<tr>
<td>Peanut</td>
<td>90</td>
<td>714</td>
</tr>
<tr>
<td>Rapeseed</td>
<td>102</td>
<td>Microalga</td>
</tr>
<tr>
<td>Coconut</td>
<td>230</td>
<td></td>
</tr>
<tr>
<td>Wheat</td>
<td>277</td>
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</tr>
<tr>
<td>Corn</td>
<td>354</td>
<td></td>
</tr>
<tr>
<td>Cassava</td>
<td>410</td>
<td></td>
</tr>
<tr>
<td>Oil Palm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sugarcane</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sugar beet</td>
<td></td>
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</tbody>
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- **High Biomass Yields**: Require only Sunlight, CO₂ & Nutrients for Growth
- **Potentially Very High Lipid Yields**: CO₂ Neutral and Eligible for Carbon Credits
- **Can Utilize Low Quality Fresh or Saline Water**: Potential for Recycling Valuable Nutrients
- **Can Utilize Low Quality Non-Arable Land**: Potential for Valuable Co-Products
A VARIETY OF PROCESS OPTIONS HAVE BEEN PROPOSED FOR THE PRODUCTION OF ALGAE-BASED BIOFUELS

**Kent BioEnergy Process**

**Step 1**
- **Strain Selection**
  - Allow Wild Species to Dominate
  - Select Strains Optimal for Local Conditions
  - Manipulate Environment to Minimize Competitors
  - Use Biological Controls to Minimize Competitors
  - Use Genetically Modified Algae Strains (GMO)

**Step 2**
- **Algae Culture**
  - Managed Natural Water Bodies and Static Ponds
  - High Rate Open Ponds
  - Hybrid System (High Rate Ponds + PBRs)
  - Photo-bioreactors (PBRs)
  - Light Diffusion and Fiberoptics Technology

**Step 3**
- **Algae Harvest**
  - Mechanical Centrifuge or Filtration
  - Biologically Enhanced Settling
  - Biological Harvest & Conversion
  - Chemical Flocculation
  - Electrical Floatation (DAF)

**Step 4**
- **Oil Extraction**
  - Roller Press Crushing
  - Soxhlet Hexane Extraction
  - Cold Hexane Extraction
  - Supercritical Fluid Extraction (CO₂)
  - High Pressure Pulsing / Sonication / Electroporation

**Cost**
KENT BIOENERGY PROCESS FOR ENERGY AND CO-PRODUCT GENERATION IN CEP MICROALGAE SYSTEMS
KBE TECHNOLOGY HAS MARKET APPLICATIONS IN POLLUTION CONTROL AND BIOMASS PRODUCTION

<table>
<thead>
<tr>
<th>Pollution Control</th>
<th>Co-Products</th>
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</thead>
<tbody>
<tr>
<td>Agricultural Runoff</td>
<td>Biofuels</td>
</tr>
<tr>
<td>Dairy Waste</td>
<td>Feed Additives</td>
</tr>
<tr>
<td>Industrial Effluent</td>
<td>Fertilizers</td>
</tr>
<tr>
<td>Digester Effluent</td>
<td>Electricity</td>
</tr>
<tr>
<td>Greenhouse Gases</td>
<td>Chemicals &amp; Biopolymers</td>
</tr>
</tbody>
</table>
CRITERIA FOR LOCATION OF FULL-SCALE COMMERCIAL SITES

Temperature

Cloud Cover

Rainfall

Optimal U.S. Locations

- existing KBE site
ALGAE CULTURE ACTIVITIES IN THE IMPERIAL AND COACHELLA VALLEYS

Earthrise

Carbon Capture

Kent BioEnergy

SunEco Energy
CONCLUSIONS

• ALGAE CULTURE DOES NOT COMPETE WITH FOOD PRODUCTION
• NON-ARABLE LAND LOCATED IN ARID CLIMATES
• EXPOSED PLAYAS AND REDUCE FINE DUST IRRITANTS
• NON-POTABLE WATER (WASTEWATER, BRACKISH, SALINE)
• USE OF WASTE NUTRIENTS (ORGANIC) – AGRICULTURAL & MUNICIPAL
• REMOVES POLLUTANTS AND RESTORES VALUABLE HABITAT
• RECYCLES CARBON DIOXIDE & MITIGATES GHG EMISSIONS

• PRODUCES MANY VALUABLE PRODUCTS, INCLUDING BIOFUELS
• PROVIDES NEEDED JOBS IN THE VALLEY
• STIMULATES LOCAL COMMERCE

• IS ELEGABLE FOR GOVERNMENT GRANTS
  a) Water reclamation
  b) Habitat restoration
  c) Renewable energy
ALGAE BIOMASS REQUIRE MUCH LESS AGRICULTURAL LAND THAN TERRESTRIAL CROPS

Replacing all diesel usage in the US with renewable algae-based biodiesel would require about 8 million acres of production, about the size of the US sorghum farming industry.

Total US area: 2.3 billion acres
Total farm area: 0.9 billion acres