Kent BioEnergy Corporation

Energy, Water Treatment, and Co-Products from Microalgae

Commercial Applications of Microalgae:

Considerations for Scale-up by Algae R&D Companies

U.S. Dept. of Energy Biomass 2011

Washington D.C.
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Director of Systems Eng.

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THE CHALLENGE

COMMERCIALIZATION OF MICROALGAE

- Kent BioEnergy Background
- Feedstock Production
- Applications of Microalgae
  - Nutrient recovery
- KBE Strategy

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Kent BioEnergy is Active in Aquatic Research and Development in Several Fields

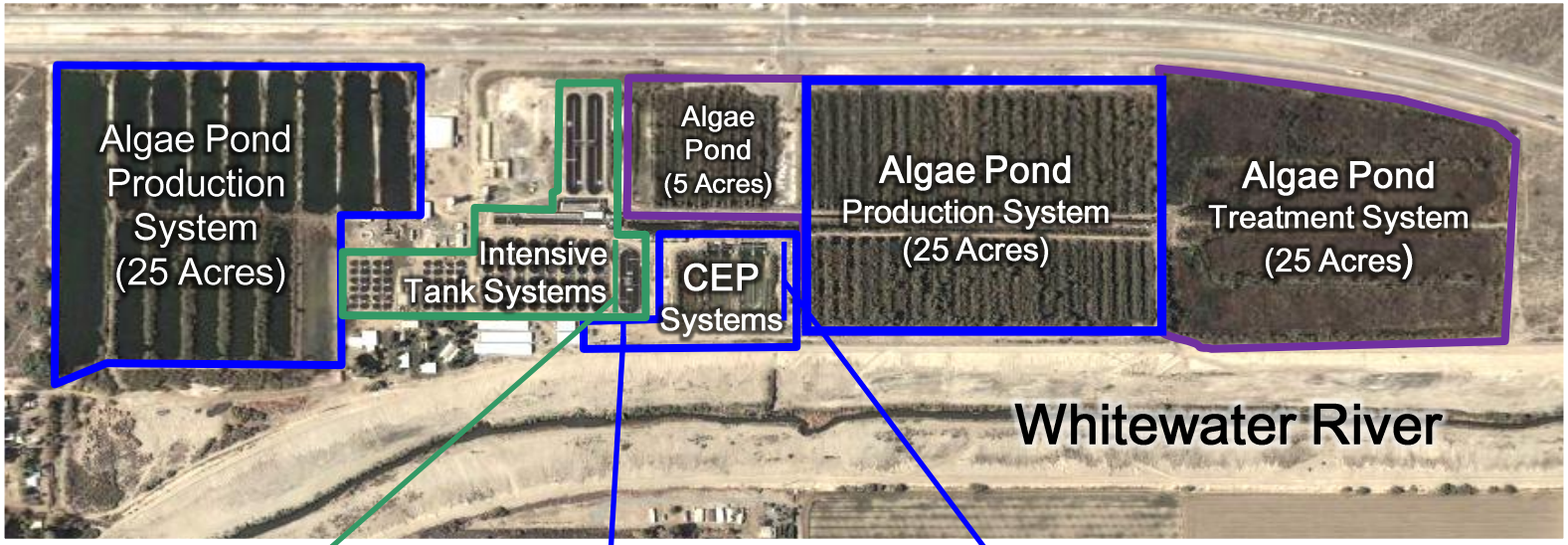
Aquaculture System Design

Water Treatment Research

Molecular Biology Research

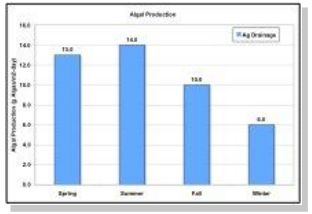
Algae-Biofuel Research

KENT BIOENERGY'S 160 ACRE R&D FACILITY

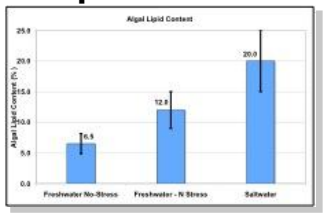


Years of Research in Large-scale Algae Production Systems Have Allowed KBE to Optimize Pond Operating Parameters for Maximal Productivity, Nutrient Uptake, and Carbon Capture

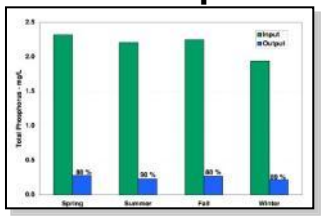
Seasonal Productivity



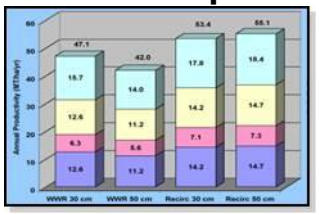
Lipid Content



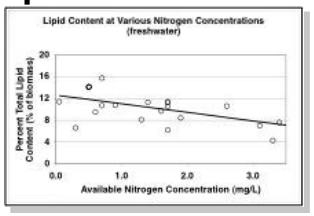
Nutrient Uptake



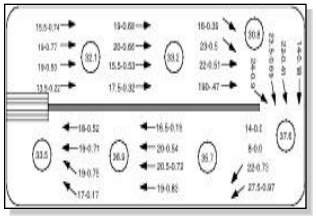
Water Depth



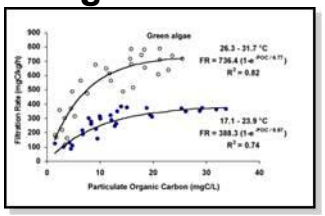
Lipid Maximization



Flow Patterns



Algal Harvest



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Feedstock Production

- Biology
  - Strain Optimization
- Cultivation
  - System Optimization
- Harvesting and Dewatering
  - Mechanical
  - Chemical
  - Biological

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HARVESTING AND DEWATERING

Algae Harvest Method	Relative Cost	Algal Species	Previous Studies
Foam fractionation	Very High	*Scenedesmus, Chlorella*	Smith 1988
Ozone flocculation	Very High?		Sukenik et al. 1987
Centrifugation	Very high	*Scenedesmus, Chlorella*	Brunner and Hemfort 1990
Electrofloatation	High?		Shelef et al. 1984
Inorganic Chemical Flocculation	High	*Oxidation ponds*	Golueke and Oswald 1965
Polyelectrolyte Flocculation	High	*Dunaliella*	Barclay et al. 1987
Filtration	High	*Spirulina, Coelastrum*	Shelef et al. 1984
Microstrainers	High	*Spirulina*	Kormarik and Cravens 1979
Tube Settling	High?	*Micractinium*	Nurdogan and Oswald 1996
Discrete Sedimentation	Medium?	*Coelastrum*	Mohn 1980
Phototactic Autoconcentration	Unknown	*Euglena, Dunaliella*	Nakajima and Takahashi 1991
Autoflocculation	Low?	*Micractinium*	Moellmer 1970
Bioflocculation	Low?	*Micractinium*	Beneman et al. 1980
Tilapia-Enhanced Sedimentation	Very Low?	*Scenedesmus, Chlorella*	Schwartz et al. 2004

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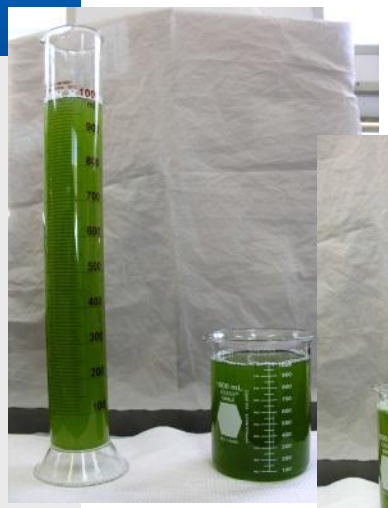
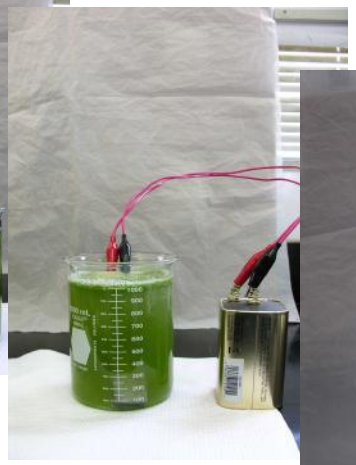
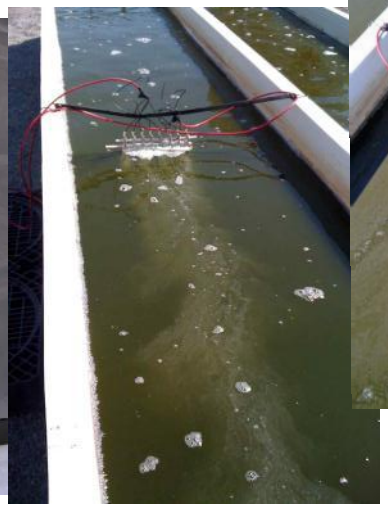
CENTRIFUGATION AND ELECTRO-FLOATATION

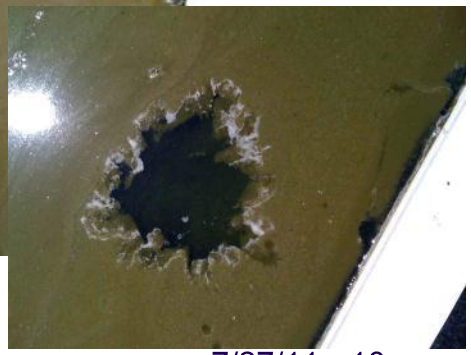
CENTRIFUGATION

Electro-FLOATATION

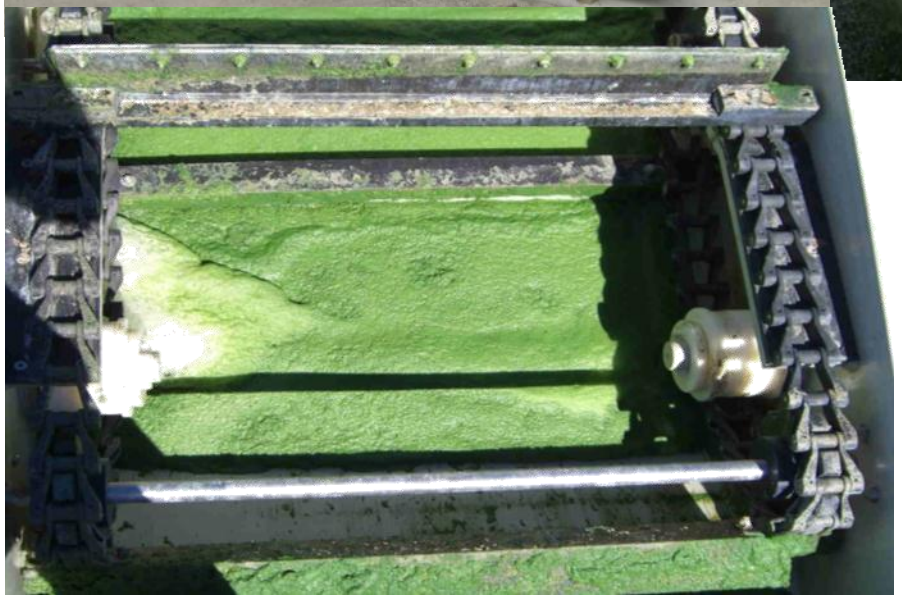






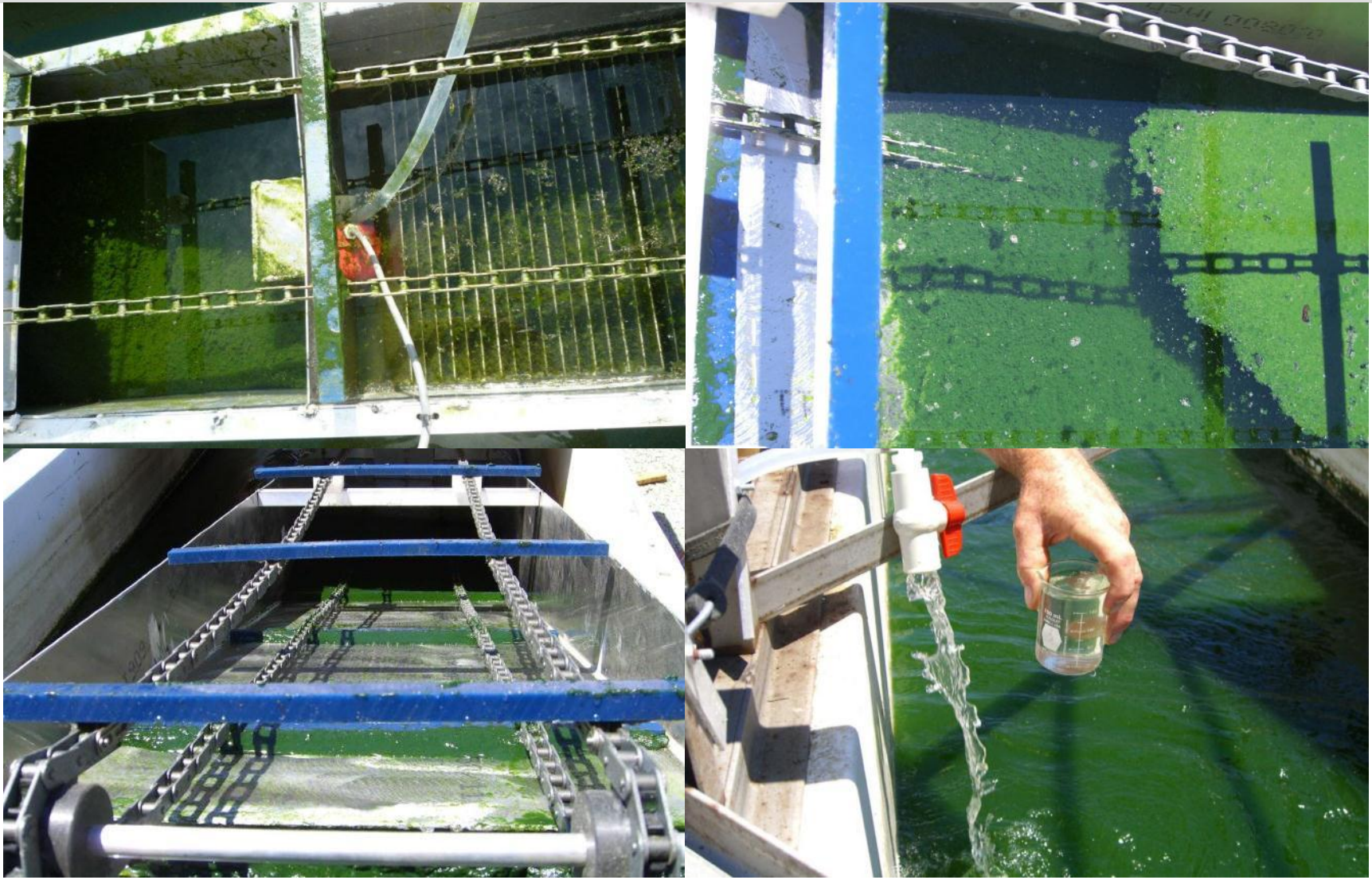


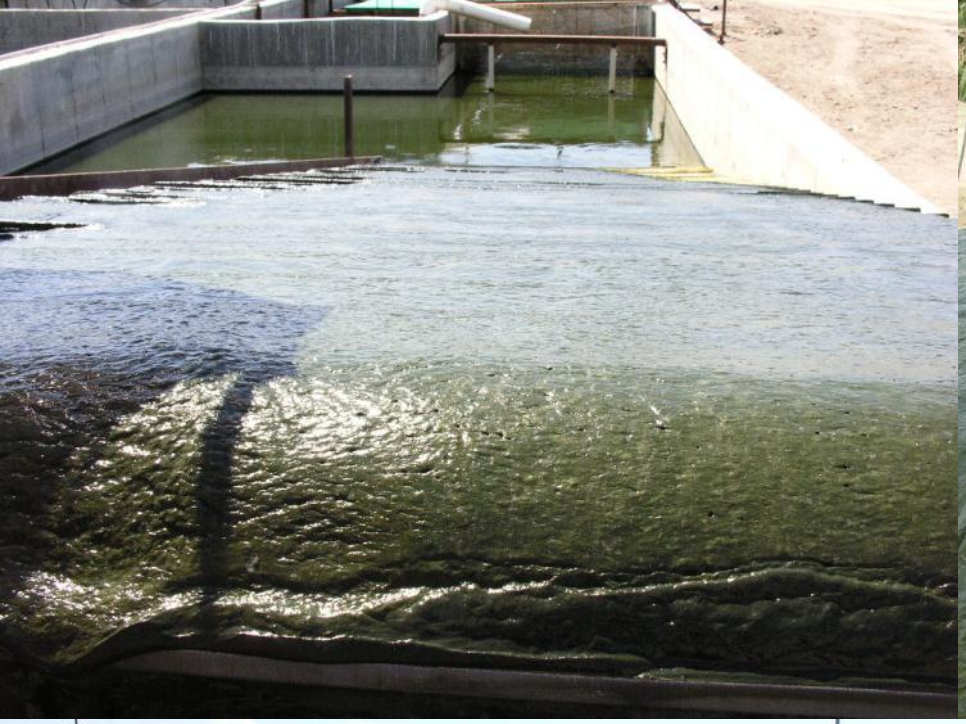
DISSOLVED AIR FLOATATION



KBE's Harvesting Technology – 2nd Gen

KBE's Harvesting Technology – 2nd Gen





HARVESTING AND DEWATERING

	Costs
• **Mechanical & Chemical Technologies**	
– Centrifugation (10 - 15% -30% solids)	$0.30 – 0.80 / Lb
– DAF (7.5 - 10% - 20% solids)	$0.40 – 0.70 / Lb
– Electro-floatation (2 - 4% - 8% solids)	$0.10 – 0.30 / Lb
• **Biological Technologies**	
• Bioflocculation (7 – 10% - 15% solids)	< $0.01 / Lb

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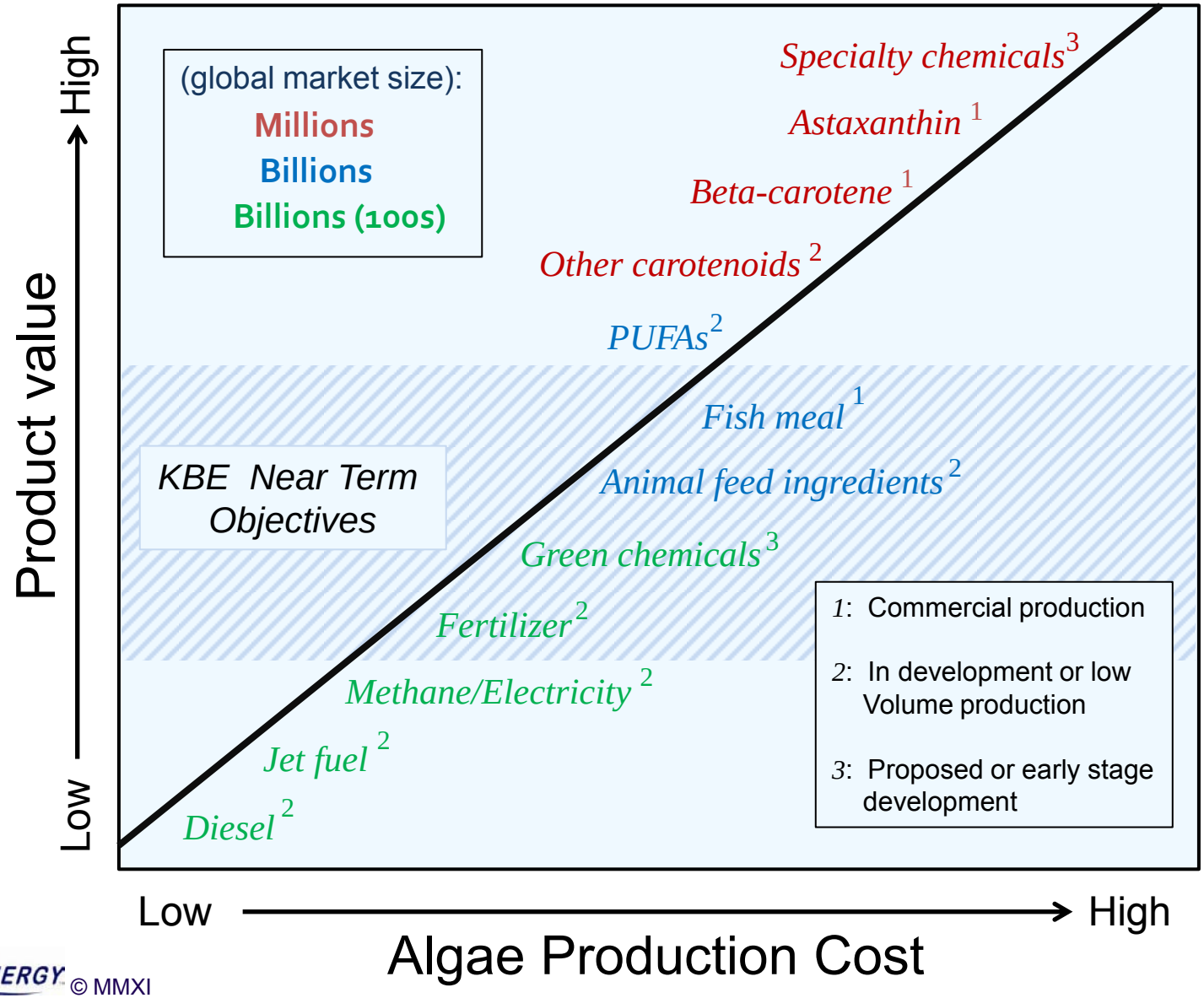
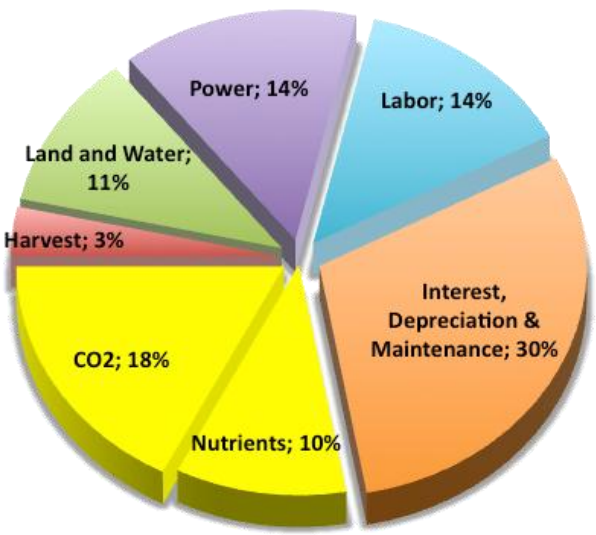
MARKET VALUE VS. PRODUCTION COSTS



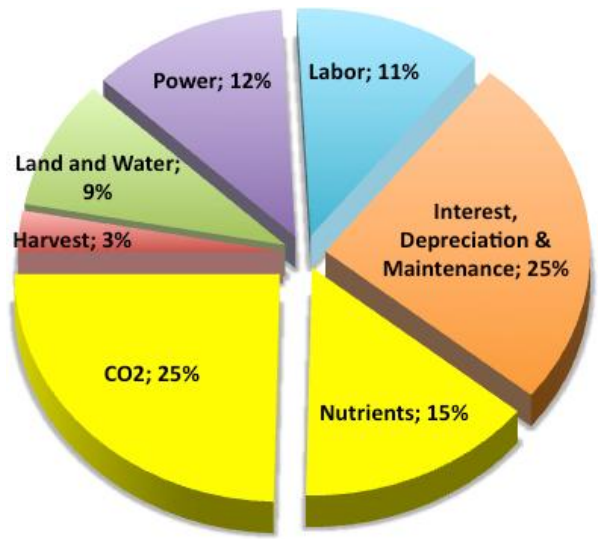
Nutrient Costs Significantly Impact the Cost of Producing Algae Biomass

Algal Productivity

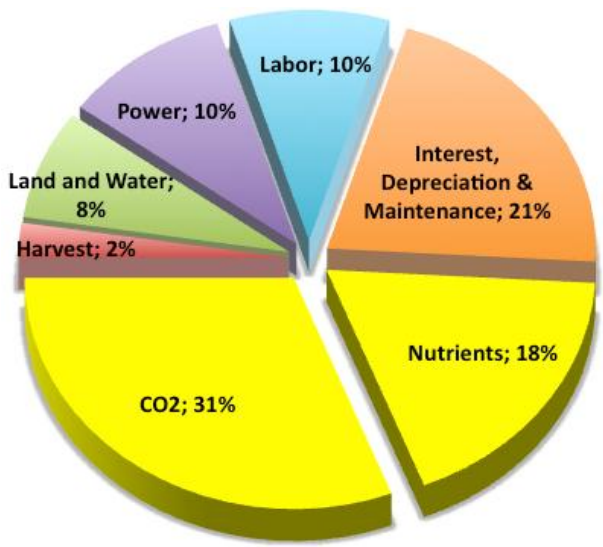
12 g Algae / M^2 / Day
20 Tons / Ac / Yr



20 g Algae / M^2 / Day
32 Tons / Ac / Yr



30 g Algae / M^2 / Day
50 Tons / Ac / Yr



Production Costs With Purchased Nutrients ($ / Lb dry algae)

$0.47	$0.33	$0.27

Diverse Applications of KBE Algae Technology

Pollution Control		Biomass Production	
Landfill Leachate		Biodiesel Fuel	
Greenhouse Gases		Feed Additives	
Aquaculture Effluent		Fertilizers	
Agricultural Runoff		Electricity	
CAFO Waste		Chemicals and Biopolymers	

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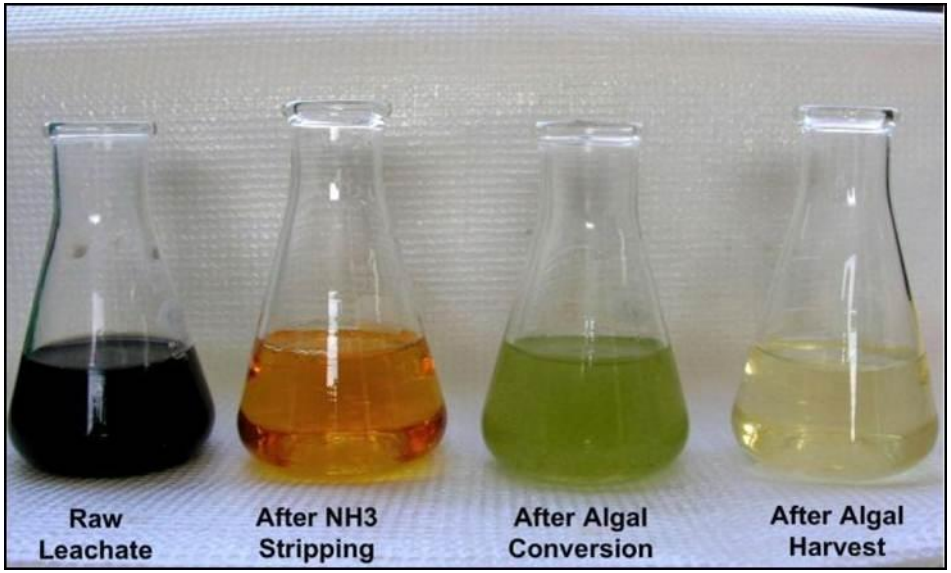
Application of CEP for Water Pollution Control (2002-2011)

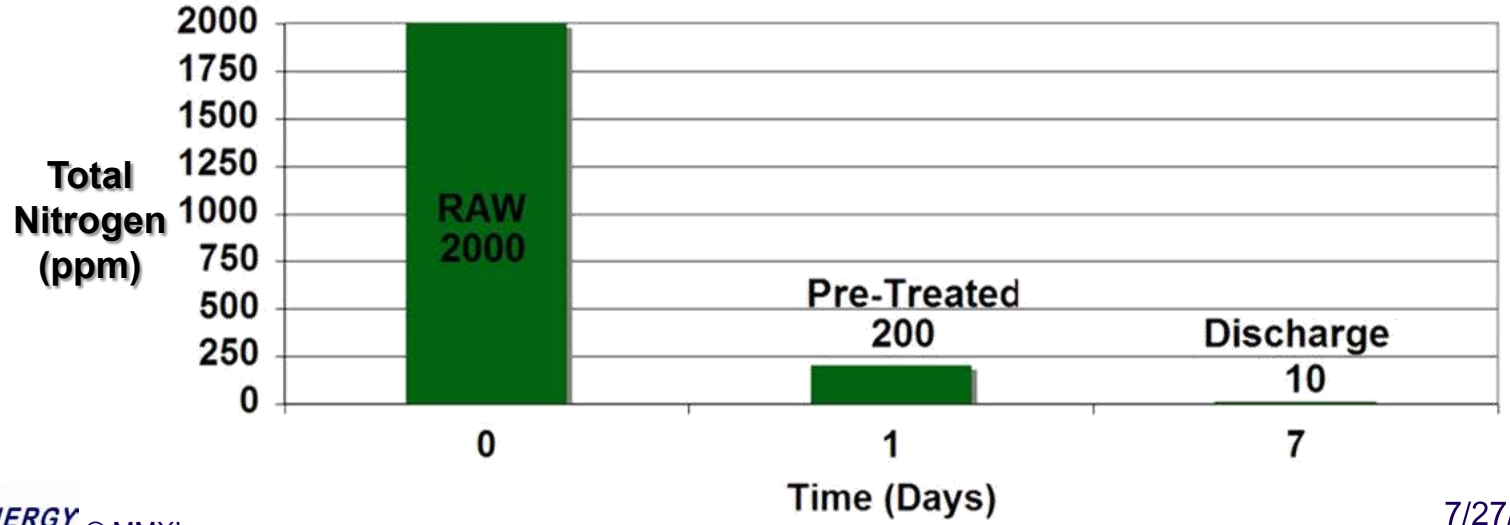
Salton Sea Remediation

Algae Removes Nutrients (N & P)

Clean Water to Salton Sea

SUCCESSFUL TREATMENT OF LANDFILL LEACHATE





Processing Of Municipal Organic Waste for Energy and Algal Biomass Production

Raw Municipal Organic Waste (MOW)

Collection

Processing Station

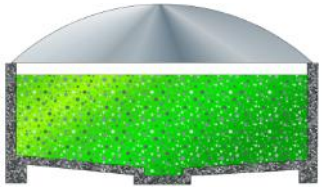
Processed MOW Slurry

Tanker Transport to KBE

KBE Algae Facility (802 Acres)

Anaerobic Digestion Tanks

Biogas and Nutrient Collection



Power Generation

Algae Production

Algae Harvest

Co-Product Extraction

KBE Algae-based MOW treatment is "Supergreen" = low / no GHG emissions

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COST REDUCTION WITH RECYCLED NUTRIENTS

Algal Productivity

12 g Algae / M^2 / Day 20 Tons / Ac / Yr	20 g Algae / M^2 / Day 32 Tons / Ac / Yr	30 g Algae / M^2 / Day 50 Tons / Ac / Yr

Production Costs With Purchased Nutrients ($ / Lb dry algae)

$0.47	$0.33	$0.27

Production Costs With Recycled Nutrients ($ / Lb dry algae)

Nutrient source: Eutrophic Water Supply *

$0.44	**$0.28**	**$0.20**

*** Wastewater treatment type application for agriculture drainwater or municipal treatment plant**

100% of Nutrient requirements
WWT revenue of $0.5/ Lb N, $0.35/ Lb P

Nutrient source: Anaerobic Digestion of food waste **

$0.38	**$0.20**	**$0.10**

**** In combination with Anaerobic Digestion of food waste**

100% of Nutrient requirements
100% of Carbon requirements
Electricity production based on AD of food waste at 1 ton per acre per day at 20 g algae/m2/day

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Three-Phase Technology Implementation Plan

	Near Term	Mid Term	Long Term
WASTE TREATMENT	Landfill Leachate (US)	Industrial Effluents (atrazine, selenium)	Industrial Effluents (requiring GMO)
	MOW Digester Effluent (US)	MOW Digester Effluent (overseas)	CO_2 Mitigation (power plants)
	Agricultural Effluents	Food Processing Waste	
	CAFO Waste (dairies, feed lots)	River & Lake Pollution (US, overseas)	
BIOMASS PRODUCTION	Animal Feeds (aquaculture, cattle supplements)	Feed Additives (e.g. astaxanthin)	Pharmaceutical Products (biotherapeutics, excipients)
	Fertilizer (e.g. ammonium sulfate)	Nutraceuticals (e.g. beta-carotene, Omega-3 fatty acids)	Renewable Chemicals (plastics, fabrics, colorants)
	Electricity	Renewable Chemicals (biodegradable plastics)	Industrial Enzymes (mutases, plastic degrading enzymes)
	Fermentation Feedstocks (sugars, starches)	Fishmeal Substitute (*Artemia*)	Biofuels

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KBE Business Development Approach

- **Focus on green, sustainable objectives**
  - Create bioenergy, pollution control, and high value products
  - Work with strategic partners having complementary resources
  - Develop proprietary technologies as barriers to competition
- **Focus on worldwide market opportunities**
  - Energy, pollution, and waste management are global issues
  - Global resources will be necessary for large-scale biofuel production
- **Focus on near-term revenues with long-term potential**
  - Succeed in existing markets now and biofuels in the future

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Commercial Applications of Microalgae

Approaches to Challenging Opportunities

www.kentbioenergy.com