DIVERSIFIED ENERGY

Simgae™

Low Cost, Broad Application Algal Biomass Production System

September 2008

Simgae™ is a derivation of Simple Algae

Who is Diversified Energy®?

- **Alternative and renewable energy technology, project development, and services company**
- **Working in three energy areas**
  - Gasification (HydroMax®)
  - Biofuels (Centia™, Simgae™, glycerol burner)
  - Green chemicals
- **Focus on commercialization of promising technologies**
- **Headquartered in Gilbert, Arizona**
- **Core team in place and key partnerships established to support development**
- **Strong state and federal gov't relationships**
- **Technologies being funded by DOE, DOD, state of CA and comm. partners**

"Develop and mature alternative energy technologies, systems, and projects to economically address United States and World energy demand"

Portfolio of Technologies being Developed

Molten Metals Gasifier (HydroMax®)

Iron-tin bath for industrial-scale syngas production

- Supports a wide range of feedstocks and various moisture contents
- Produces a clean syngas (low tars and oils, sulfur removed)
- Scales down economically ($5-$7/MMBtu)
- DOE, DOD, and state of CA grants

"Renewable Petroleum" System (Centia™)

Converts various triglycerides to petroleum-equiv. fuels

- Can handle wide range of feedstock triglycerides
- Produces petroleum fungible biogasoline, biojet and 2nd generation diesel fuels
- High energy/mass conversion efficiencies
- No (or little) external hydrogen use
- Can produce aromatics directly
- State of NC grant

Crude Glycerol Combustion Burner

Efficiently and safely burns low-value crude glycerol

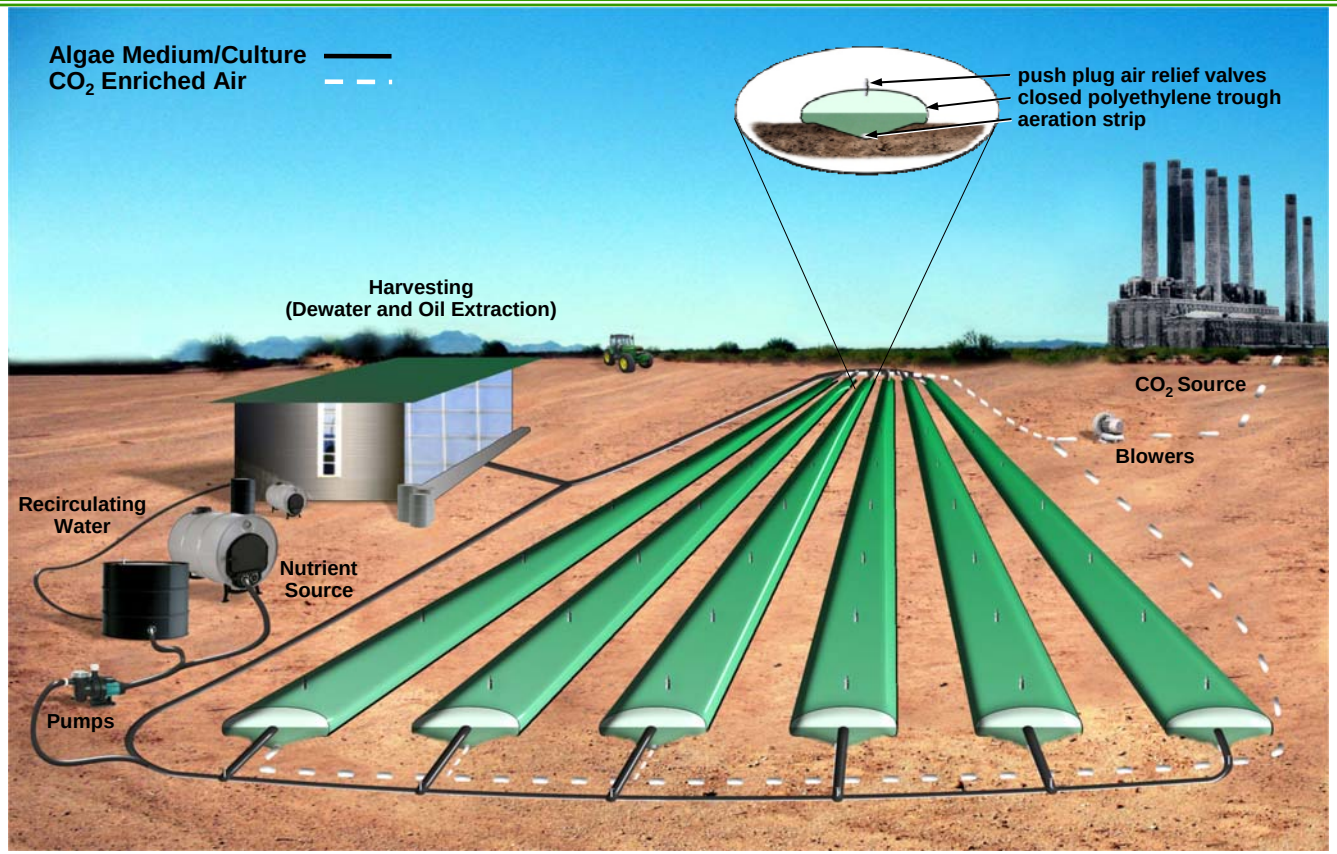
- Have burned various types of glycerol
- Produces *very* low emissions of aldehydes
- Output used for heat, electricity, etc. needs
- Offers cost effective means for biodiesel industry to capture value from their waste glycerol (10% of biodiesel production)
- 90k Btu/hr prototype system is running

Algal Biomass Production System (Simgae™)

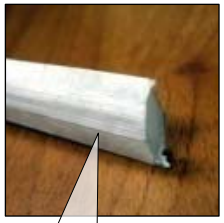
Farming-based approach for low-cost, scalable algae

Today's Subject

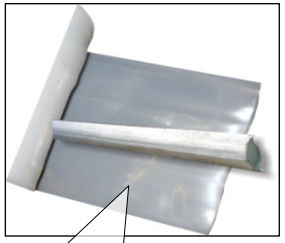
The Simgae™ Approach



Tape on a roll



Tyvek® aeration approach



Tape and Tyvek®

- **Focus on *cost* and *simplicity* by reuse of irrigation and farming practices**
- **Proprietary tape and aeration approach – key pieces**
- **The *land* provides for support, thermal management, and tape lifetime**
- **Broad location flexibility**
- **Leveraging 3rd party technologies for dewatering and oils separation**

Leveraging Common Agriculture Hardware and Practices

Plastic Agriculture Mulch

- common use in agriculture industry
  - creates a miniature greenhouse
    - helps with thermal control
  - colors, UV, opaqueness variants

Extrusion Machinery

- common machinery
- high-volume capacity
- dyes designed for tape design
- 2500’ rolls, 80 lbs/roll

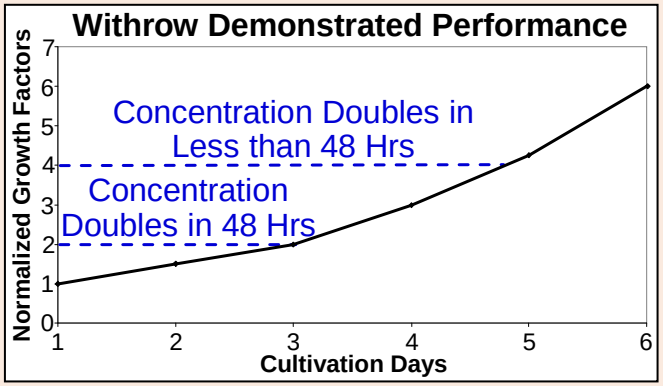
Trough Prep and Installation Machinery

- trough prep and tape installation
- common agriculture/irrigation machinery

Results from 1st Generation Demonstrations

System Development Center

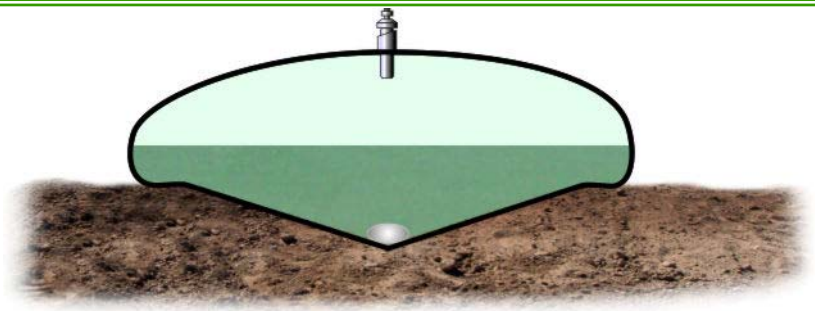
Results/Lessons Learned:
1) Algal biomass tripled in 48-hour periods
2) Tape-to-fitting interfaces
3) Successful demonstration of Tyvek® aeration tubes
4) Continuous mixing via aeration to increase light exposure
5) Thermal management techniques
6) CO_2 and nutrient feed optimization



Withrow Dairy (Casa Grande, AZ)

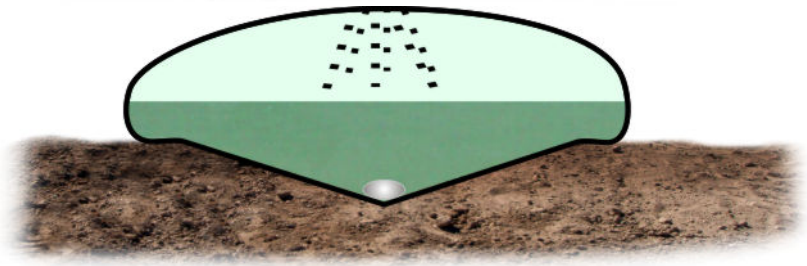
Results/Lessons Learned:
1) 48-hour doubling periods observed
2) Land laser leveling enhances operations
3) Fitting design and integration
4) System installation techniques
5) Aeration approaches
6) Blower requirements for CO_2 aeration
7) Utilization of IC-engine exhaust gases for thermal control and as a CO_2 source
8) Utilization of lagoon water for nutrients
9) Thermal management approaches
10) Metered N-P-K/micronutrient distribution
11) All-weather, 24/7 operations

2nd Generation Designs Under Consideration



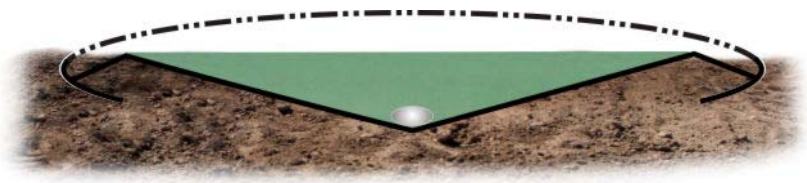
Design 1 – Closed Trough

- Push plug air relief
- Continuous aeration strip



Design 2 – Closed Trough

- Perforation-based air relief
- Continuous aeration strip



√ ***Design 3 – Covered Trough***

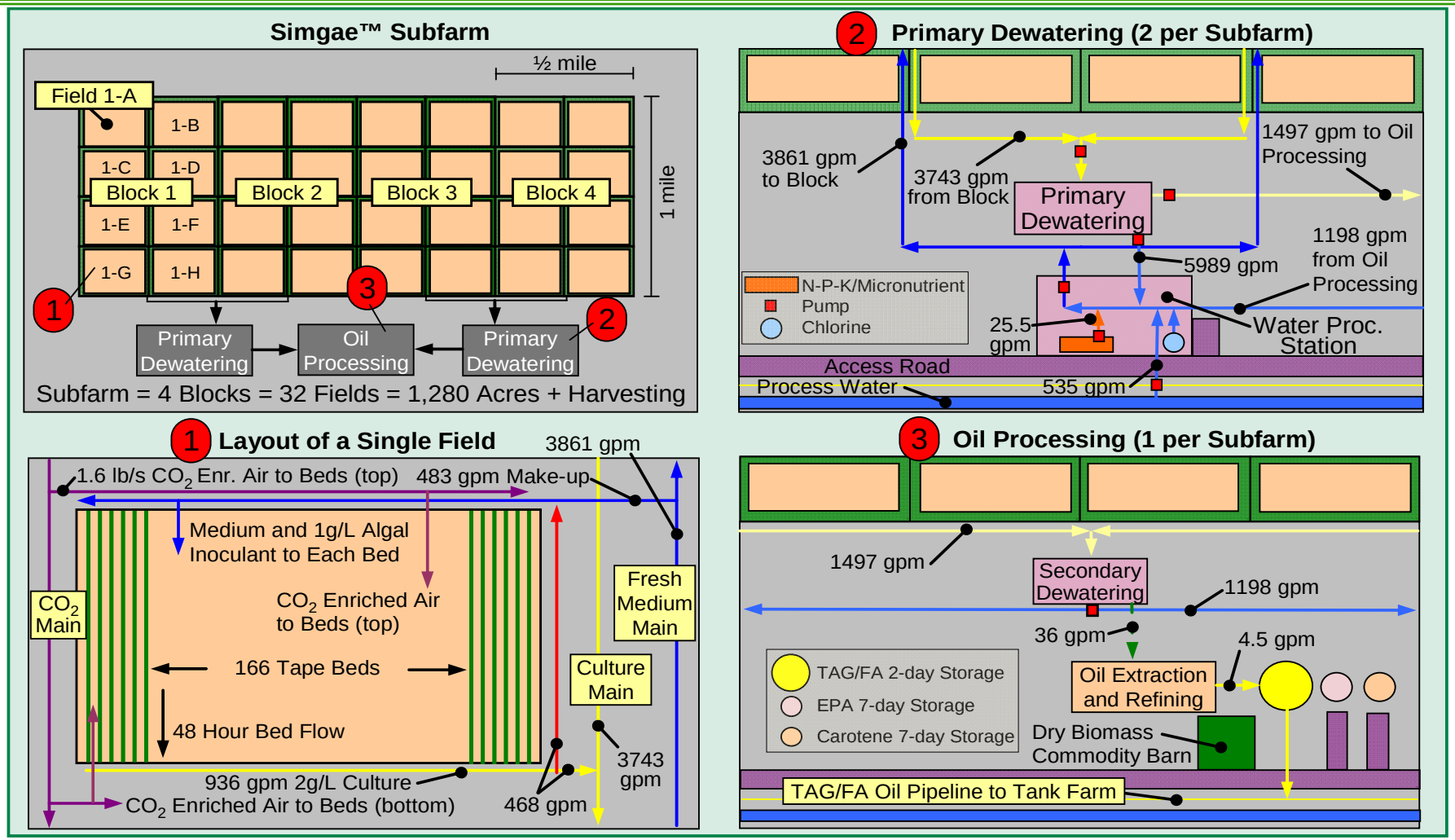
- Agricultural mulch covering
- Continuous aeration strip

** sideview*

Design Alternate – Periodic In-line CO_2

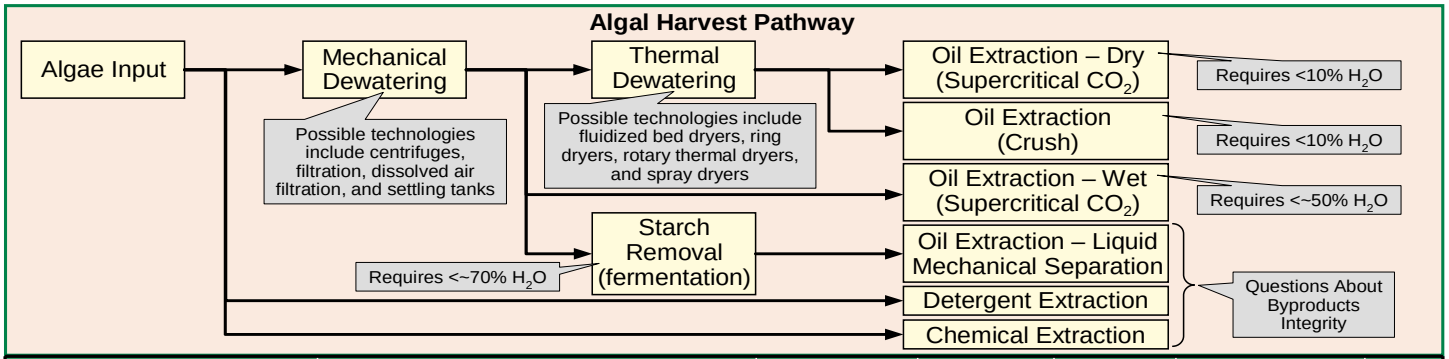
- Periodic CO_2 injection every x feet
- Applicable to covered or closed trough

Subfarm™ (1280 acre) Commercial Module



Detailed Commercial-Scale Design has been Assessed

Harvesting Methodologies and Initial Rankings



Red = Not Selected

Vendor	Technology	Technical Competence (35%)	Personnel Assigned (35%)	Financial Stability (10%)	Reputation, Response, etc. (20%)	Total Score
sensitive	Dewatering and Drying	5.00	4.00	5.00	5.00	4.65
	Dewatering and Drying	4.75	5.00	4.00	4.50	4.71
	Drying	5.00	3.00	5.00	4.00	4.10
	Drying	4.75	3.00	3.00	5.00	4.01
	Drying	5.00	3.00	5.00	3.00	3.90
	Super Critical CO_2 Oil Extraction	3.90	4.10	2.25	3.00	3.63
	Super Critical CO_2 Oil Extraction	5.00	3.00	4.00	3.50	3.90
	EM Cellular Disruption/Oil Extraction	4.00	5.00	2.00	3.00	3.95
	End-to-End Using Fermentation	4.00	5.00	4.00	4.00	4.35
	End-to-End Using Detergent Extraction	5.00	5.00	4.50	5.00	4.95
	Homogenization	3.00	5.00	2.00	3.00	3.60

- **Simgae™ system focuses on algal growth approach**
- **Strategy is to leverage advances by others in dewatering and oils extraction to build end-to-end architectures**
- **Detailed assessments of 3rd party organizations are underway, some testing has been completed**

Subfarm™ Assumptions and Expected Performance

Assumption Description	Value	Justification
Algal Lipid Content, *Nannochloropsis* sp. (% dry mass)	20%	Ref #2; Ref #8; ORNL-team experience
TAG/FA Content (% dry mass)	13%	Ref #8; Ref #1; ORNL-team experience
Carotenoids Content (% dry mass)	<0.5%	Ref #4; Ref #8
EPA Content (% dry mass)	>2%	Ref #1; Ref #6; supported by Ref #4 and Ref #5
Cycle Time (doubling time from 1 g/L to 2 g/L)	2 days	DEC Field #1 exp. w/*Chlorella* sp.; Ref #1; Ref #10 pg 186
Oil Extraction Efficiency	>90%	vendor feedback; current hexane extraction range of 90-97%
Subfarm Availability	80%	2.4 month/year cumulative planned/unplanned maintenance

Performance Parameter	Baseline	Goal I Performance	Goal II Performance
Bed Algal Biomass Production (lbs/bed/cycle)	136	169 (1.25X baseline)	186 (1.37X baseline)
Acre Algal Biomass Production (tons/acre/year)	51	64	70
Subfarm Algal Production (tons/year)	52,598	65,748	72,059
TAG/FA Production (gallons/year)	1,641,058	2,051,322	2,248,249
EPA Production (tons/year)	947	1,184	1,297
Carotenoids Production (tons/year)	237	296	324
Algal Biomass (Solids) Production (tons/year)	45,261	56,576	62,007

- < $20k / acre capital costs
- < $8k / acre / year in operations and maintenance costs (assuming co-located CO_2)

Reasonable, Substantiated, and Thorough Performance Expectations

Development and Commercialization Plan

2008 | 2009 | 2010

funding event

1st Generation Demos

- Unoptimized
- At Withrow Dairy and DEC
- 50' and 1250' beds
- Several tape designs
- Fertility = lagoons and drip
- CO_2 = external tank
- 2 algae strain varieties
- Oil samples generated
- Initial yield assessment
- Costs better understood
- Modeling refined
- Self funded

Pre-Commercial Design and Installation

Pre-Commercial Demonstration

- End-to-end, including harvesting demos by selected 3rd parties
- In AZ, ~ 10 – 40 acres in size
- Finalize tape design
- Use preferred algal strain
- Optimize/explore ~ 30 parameters
- Conduct long operational runs
- Explore thermal control approaches
- Detailed yield, cost, and performance assessments
- Biomass and oils given to 3rd parties

Ma'alaea (Maui) Candidate Pilot-Plant

Pilot Plant #1

- 100+ acre sizes, leading to Subfarms™
- Various locations – CO_2, fertility, and climate

R&D Center

Parameters for Optimization during Pre-Commercial Demonstration

1.0 Fertility Water	b. Aeration Materials Selection	i. Biofouling and Mitigation Approaches
a. Components	c. Aeration Extrusion Approach	**6.0 Environmental Effects on Hardware**
b. Concentration	d. Air Relief Architecture	a. Temperature
c. Advanced Growth Stimulants	e. Manifold Design	b. Ultra-Violet Radiation
2.0 CO_2	**5.0 Tape**	c. Material Degradation from Ozone
a. CO_2 / Air Mixture Ratio	a. Tape Shape / Design	d. Rain, dust, frost, etc.
b. CO_2 Uptake Efficiency	b. Tape Dimensions	**7.0 Installation Techniques**
c. Sources of CO_2	c. UV Inhibitors and Colors	a. Field and Trough Preparation
i. Sequestered CO_2	d. Wall Thickness	b. Tape and Mulch Laying / Removal
ii. Flue Gas	e. Lifetime	**8.0 System Architecture**
3.0 Algae	f. Temperature Control	a. Final System Design
a. Algae Strain(s) Selection	i. Mulch	b. Harvesting Interface / Integration
b. Initial Algae Concentration	ii. Paints	c. Water Management System
c. Temperature Growth Range	iii. Drip Irrigation	d. Lifetime / Availability
d. Oil vs. Starch vs. Protein Production	iv. Burying Incoming Medium	
e. Grow Cycle Time	v. Flue Gas Heat Utilization	
4.0 Aeration and Air Relief System	g. Culture Flow Rates	
a. Aeration Flow Rates / Pumping	h. Agitation and Fluid Dynamics	

- **Build upon lab and site demonstrations to optimize 35 parameters within eight different categories**
- **Partners may include: ORNL, LANL, ASU, Mortenson Construction, dewatering and oils extraction vendors**