

# ALGAE BIOMASS

*for energy and food*



**XL RENEWABLES**  
Phoenix, Arizona

2009 Spring Ag Forum  
February 27, 2009



# Current Pilot

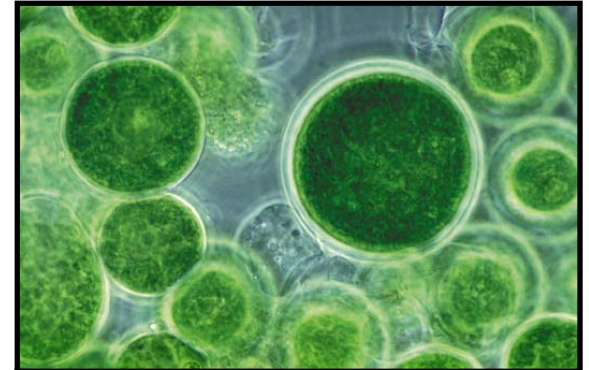




# What is ALGAE Biomass?

## Microalgae

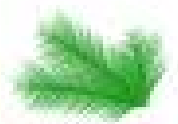
- **Microscopic aquatic plants**
- **Use photosynthesis to convert sunlight, water and carbon dioxide (CO<sub>2</sub>) into biomass and oxygen (O<sub>2</sub>)**
- **Require added CO<sub>2</sub> for fast growth**



red  
alga



brown  
alga



green  
alga



## Algae = CORN or SOYBEANS

as a Food and Industrial Feedstock

Varieties are highly variable:

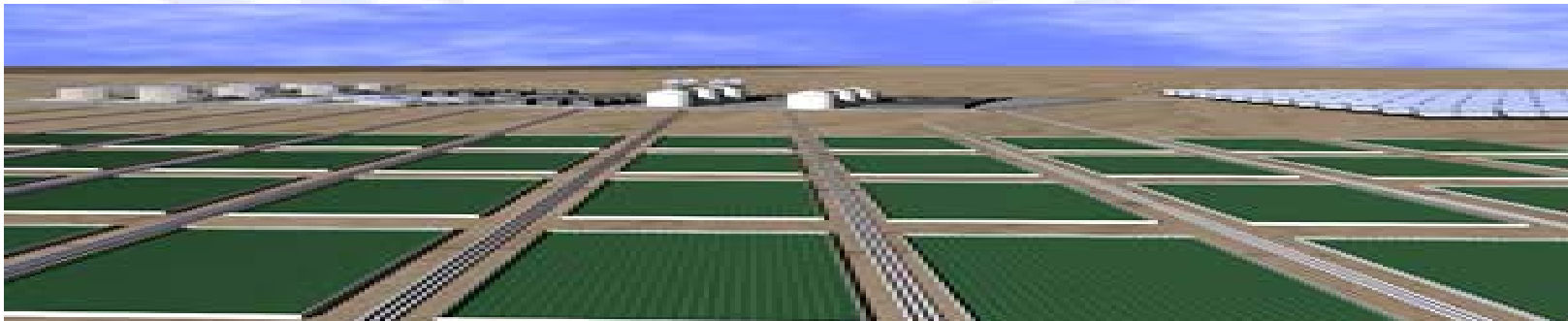
	<u>Variety Variation</u>
– Oils	10% - 50%
– Proteins	25% - 55%
– Carbohydrates	10% - 50%





## An Algae Farm:

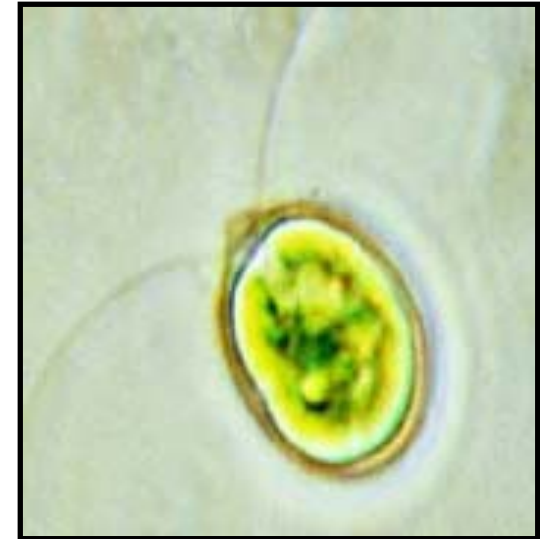
1. Grows algae biomass in water with added CO<sub>2</sub>
2. Harvests the algae solids from the water
3. Markets whole algae, algae oils and algae meals





# Why ALGAE?

- **Greater productivity per acre than terrestrial field crops**
  - 30 – 50 tons biomass per acre (Raceways)
  - 50-100 tons biomass per acre (Troughs)
- **A Non-Food Resource**
  - Not currently used as a primary food source
- **Theoretically uses non-productive land**
  - Ideal for marginal farmland
  - Utilizes saline, brackish or wastewater
- **Converts CO<sub>2</sub> to Oxygen**
  - Potential CO<sub>2</sub> Mitigation for CO<sub>2</sub> Emitters

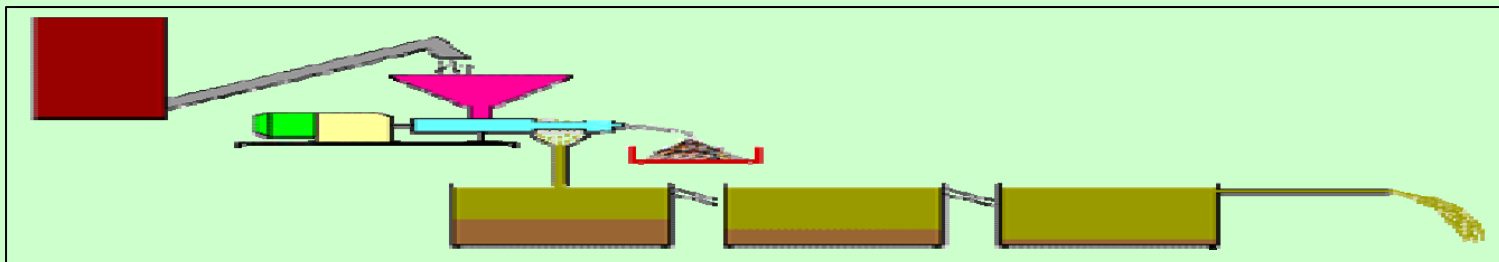




# Why ALGAE?

## High Oil Yield (SVO) Potential

Oil yields	gallons/ac-yr
Soybeans	50
Sunflower	100
Canola	160
<b>Microalgae</b>	<b>4,000-10,000</b>





# What is the holdup?

## COST

We are just learning how to grow algae biomass economically.

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<b>Oil yields</b>	<b>gallons/ac-yr</b>	<b>Cost/gal</b>
Soybeans	50	<\$2.00
Sunflower	100	<\$2.00
Canola	160	<\$2.00
<b>Microalgae</b>	<b>4,000-10,000</b>	<b>&gt;\$2.00</b>





# Algae Biomass Supply

**Assumptions: 1 Billion Barrel Equivalent (1/30<sup>th</sup> of world demand)**

- 50% Oil Yield from Algae Biomass
- 5,000 gallons per acre of Algae Oil
- 37.6 tons/acre Annual Yield of Algae Biomass
- Equivalent to 120 Barrels/Acre



**8.4 Million Acres Required**

**158 Million Metric Tons of Algae Meal**

**Similar to current Soybean Meal Production**





# Industry Investment





- **Algal Biomass Organization (ABO)**

- [www.algalbiomass.org](http://www.algalbiomass.org)
- Began with Algae Biomass Summit, San Francisco, 2007
- Co-Sponsored by XL Renewables; Byrne & Co; and Wilson, Suncini, Goodrich & Rosati
- Major Players: Boeing, KLM/Air France, etc.

## **Mission Statement**

The Algal Biomass Organization promotes the development of viable commercial markets for renewable and sustainable commodities derived from algae.





# Interesting Times

**Demand for  
Carbon Neutral  
Energy Supply**

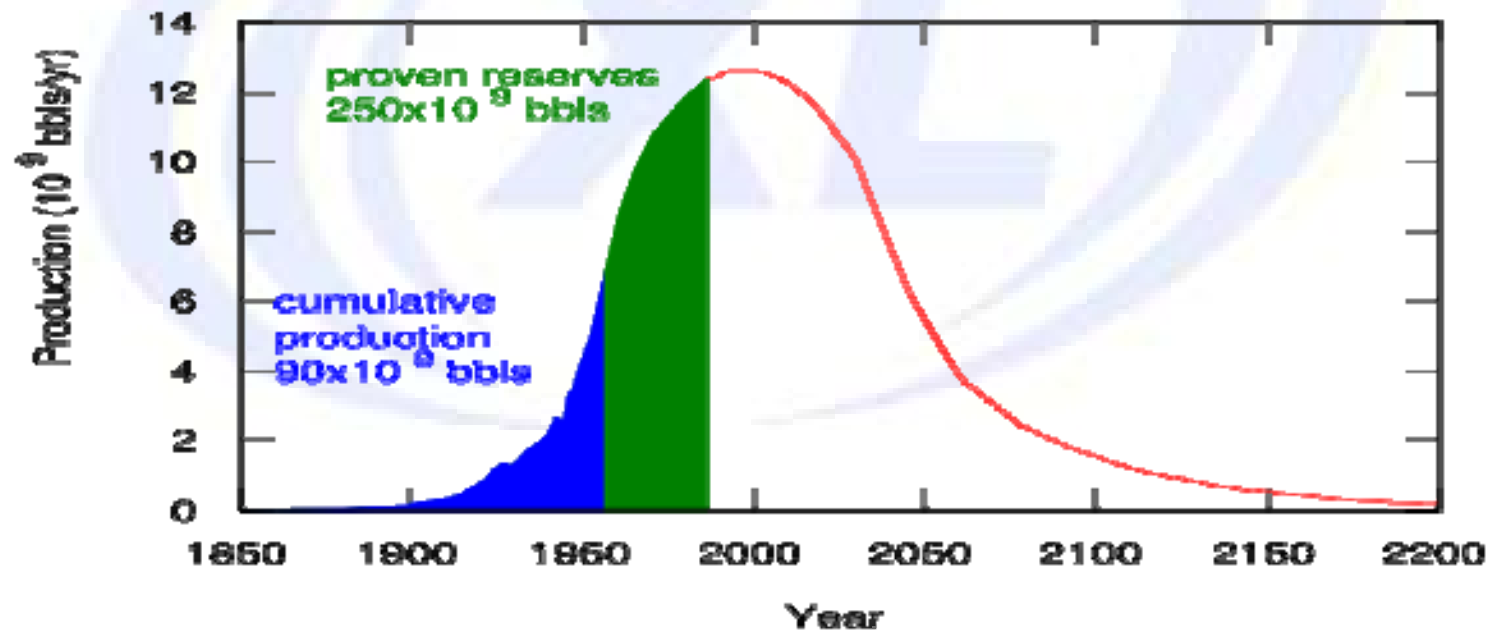
**Increased  
Energy  
Costs  
over  
the  
Long  
Term**

Photo from  
John R. Benemann  
Benemann & Associates





## Decline of the OIL AGE





# Emergence of Renewable Energy



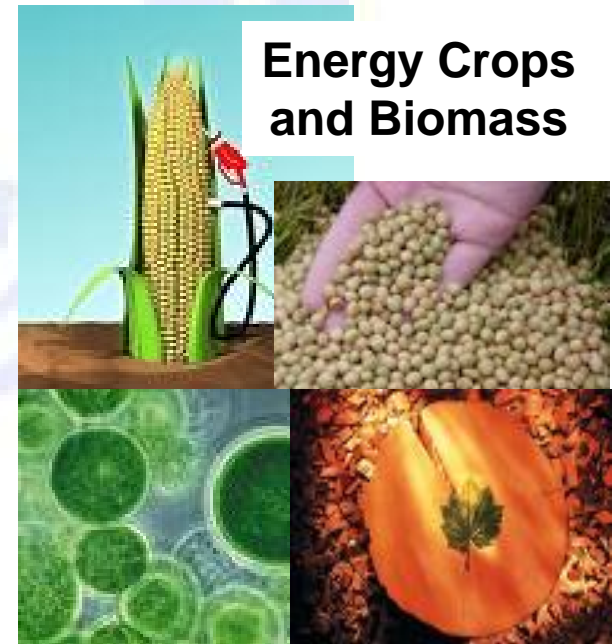
**Solar**



**Wind**



**GeoThermal**



**Energy Crops and Biomass**



**Convert Waste Streams**

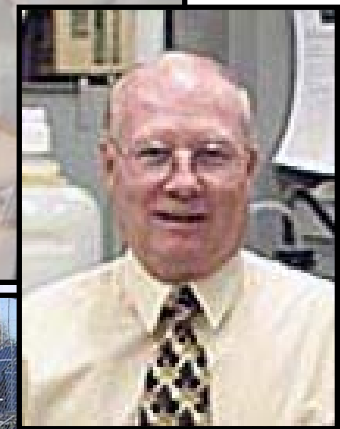
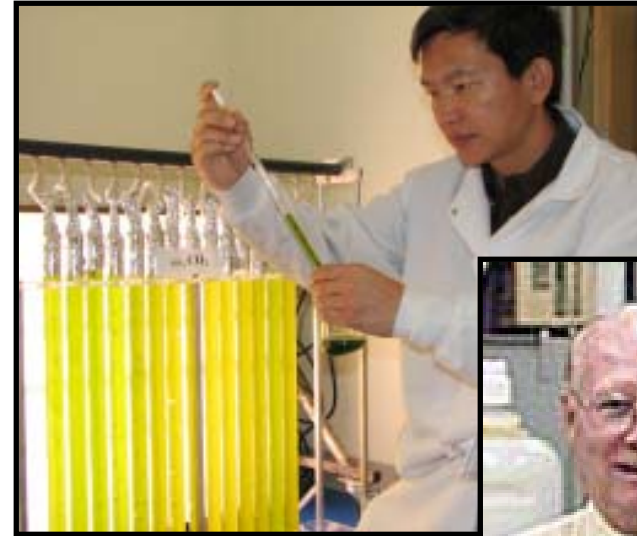


# Research and Development

**Milton Sumerfeld, Ph.D**

**Qiang Hu, Ph.D**

Global collaborators on the scale-up of commercial algae production at every stage of growth, development, harvest and processing.





# Research and Development

- XLR established an Algae Development Center in 2007 in Casa Grande, AZ
- Center has provided a platform for:
  - Production system development
  - Algae variety development
  - System optimization
  - Operating protocols
- Baseline production goals –  
**25 to 50 tons/acre/year**
- **Next Step: Commercial Installation**







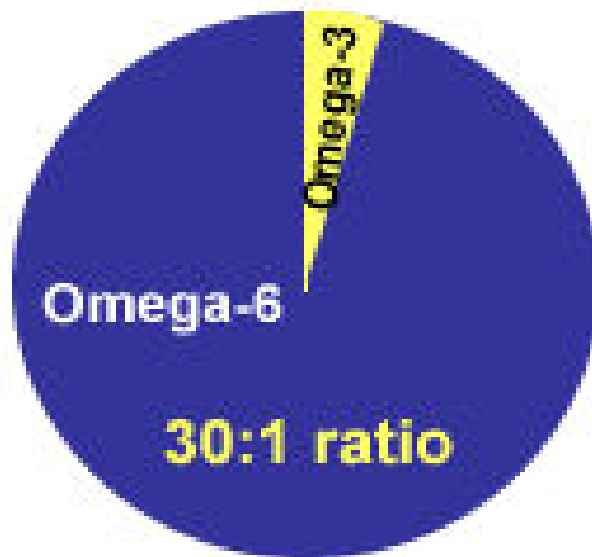
# Omega 3's and Proteins

## Market Drivers besides Oil:

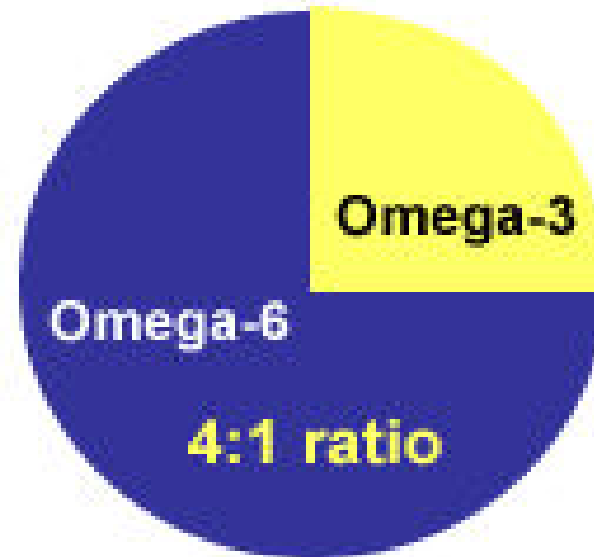
- Bringing Omega 3 & Omega 6 Fatty Acids into balance may be the most significant opportunity in Animal and Human Nutrition of our time.
- An additional Protein supply is critical to meeting the demand for animal proteins preferred by a growing world population.



# Positive Health Affects



Typical American Diet  
(unhealthy intake of corn,  
safflower & soybean oils)



Balanced Diet  
(rich in Omega-3's)

Omega 6 = inflammatory, Omega 3 = anti-inflammatory



# President promotes Omega 3's



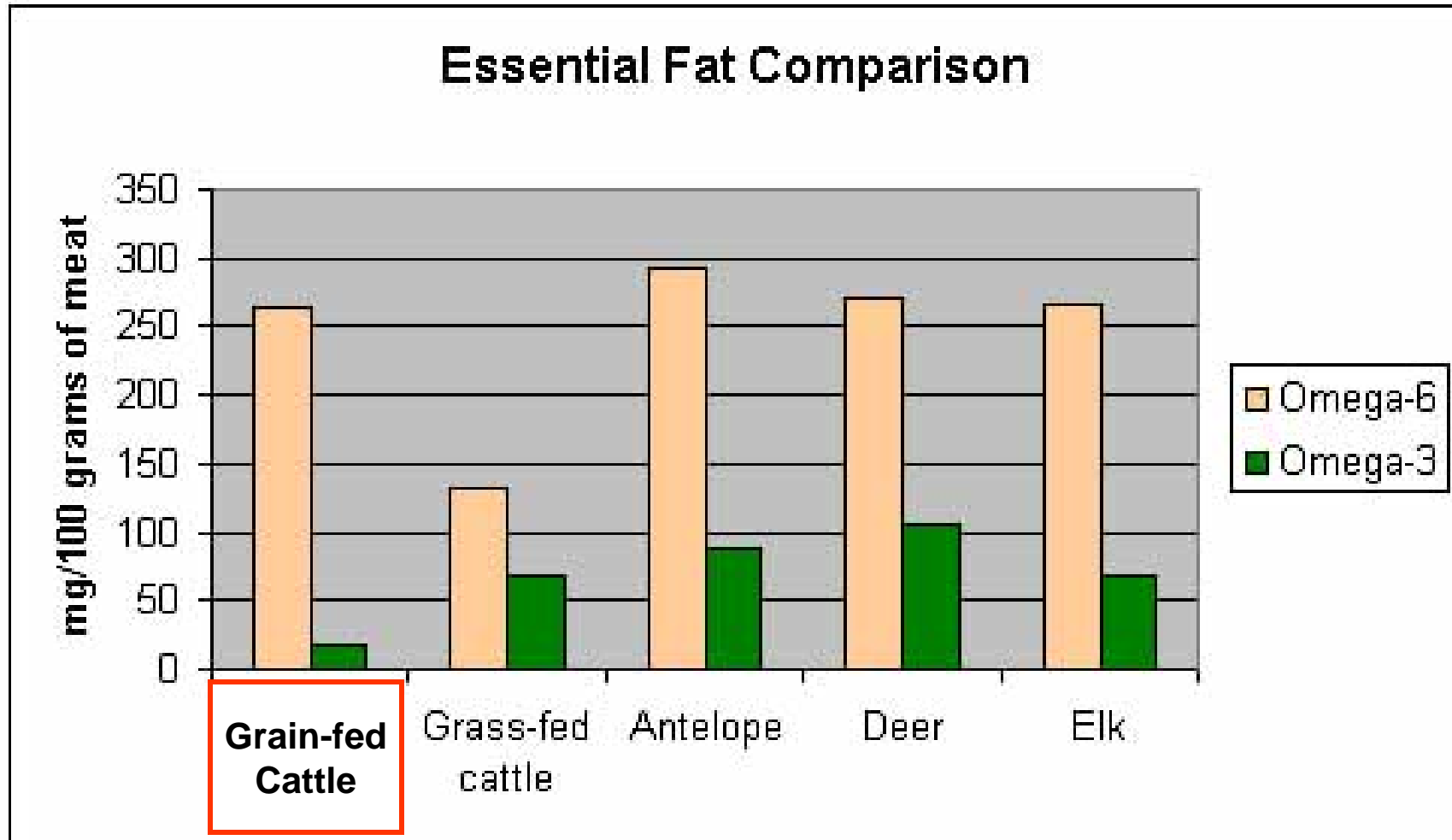
*EXECUTIVE OFFICE OF  
THE PRESIDENT  
OFFICE OF MANAGEMENT  
AND BUDGET  
WASHINGTON, D.C. 20503  
FOR IMMEDIATE RELEASE  
2002-13*

**OMEGA-3's are beneficial to health and  
TRANS-FATS are detrimental to health.**

**White House “Prompts” USDA and  
HHS: Increase Omega 3 Fatty Acids**

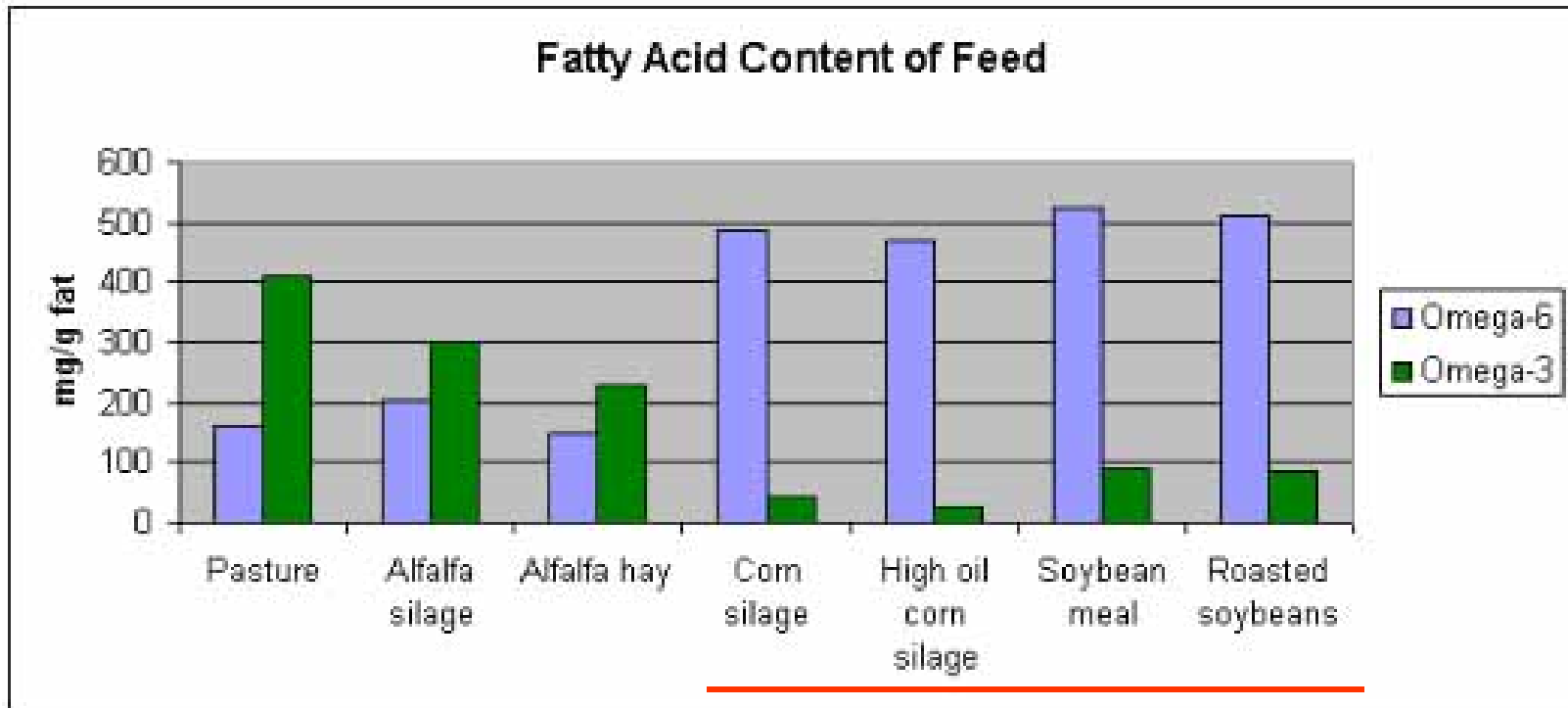


# BEEF as an example



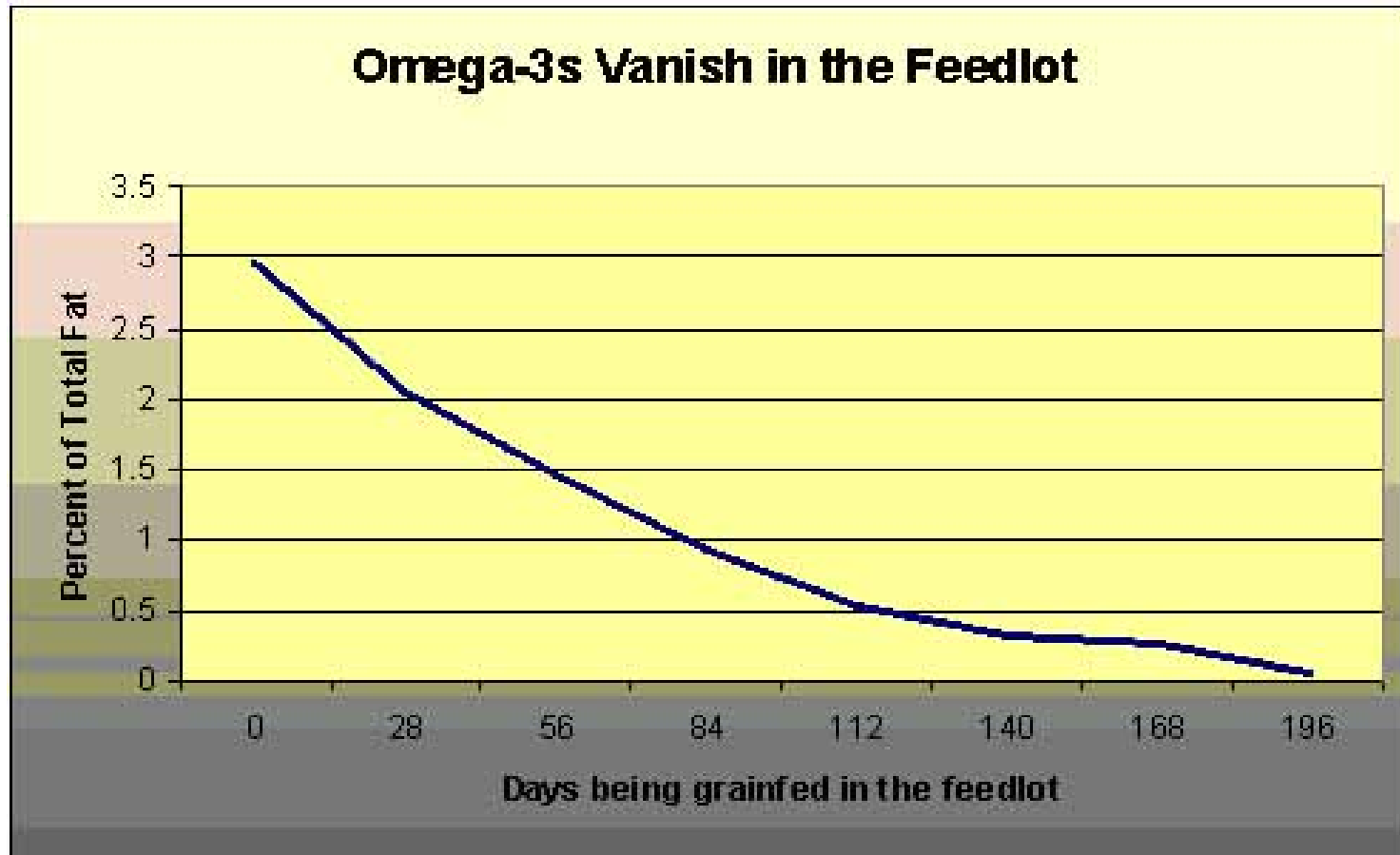


# Feed Supply is the Cause





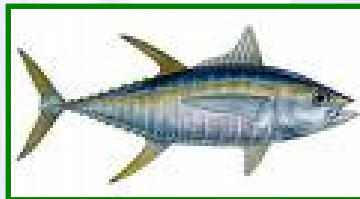
# Feedlot Beef is out of Balance



*Data from: J Animal Sci (1993) 71(8):2079-88.*



# Farm Raised Fish and Shrimp



**Also suffers from  
Omega 3 imbalance  
Issues**

**Consumer Concerns**

**Market Resistance**



# Meat, Eggs and Milk

Imbalance can be corrected with a modified diet and supplements.

**Pork**



**Poultry**



**Dairy**







# Dairy Cows show Benefits

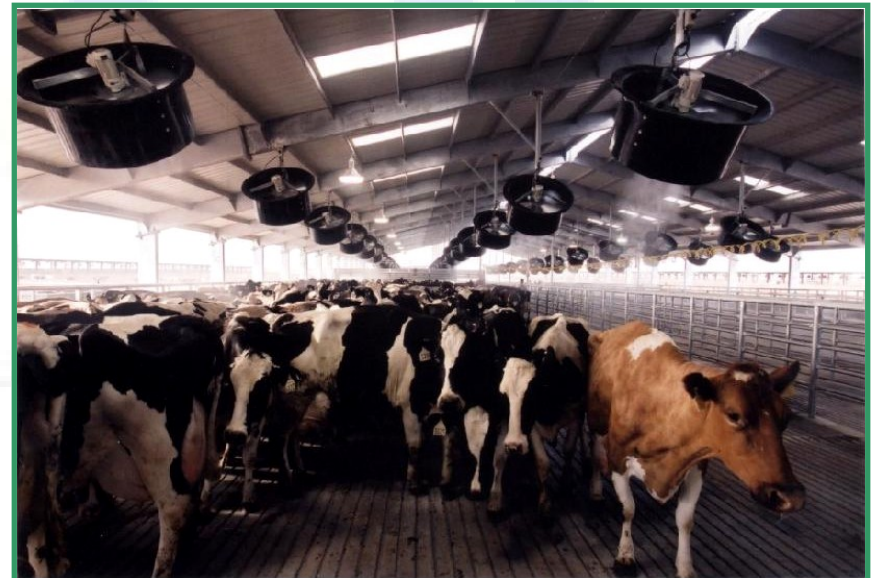
**Increased Omega 3 levels in Milk**

**Reduced Feed Consumption**

**Improved Herd Health**

**Improved Reproduction**

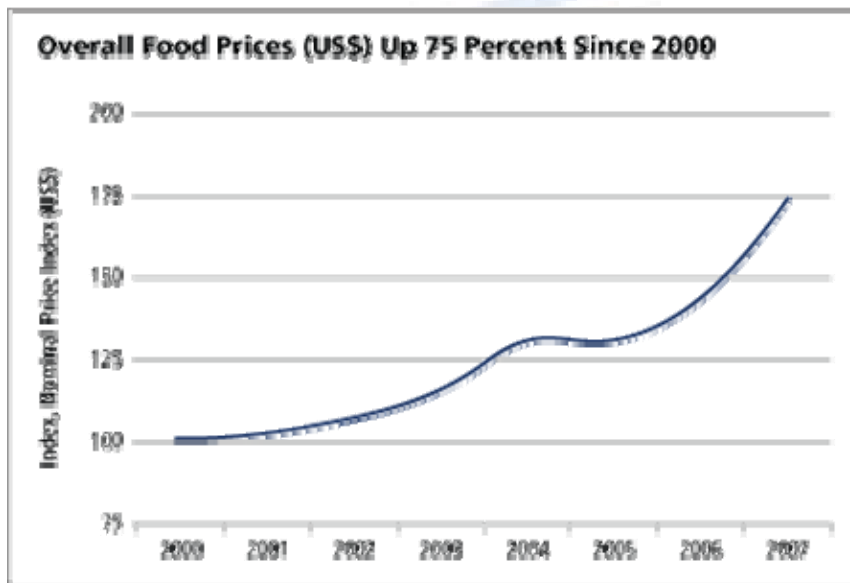
**Longer Productive Life**





# World Protein Supplies

**“We must double the current food supply in 30 years.”**



Source: World Bank, DDCS2

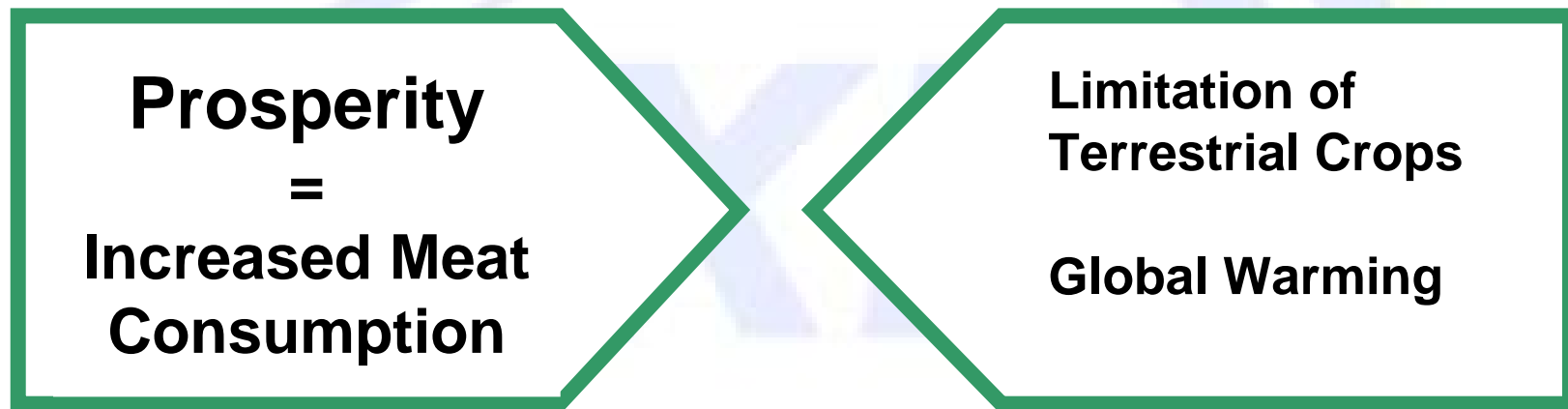


**Robert Zoellick, President, World Bank**



# Dealing with Limitations

## Food Supply Dilemma



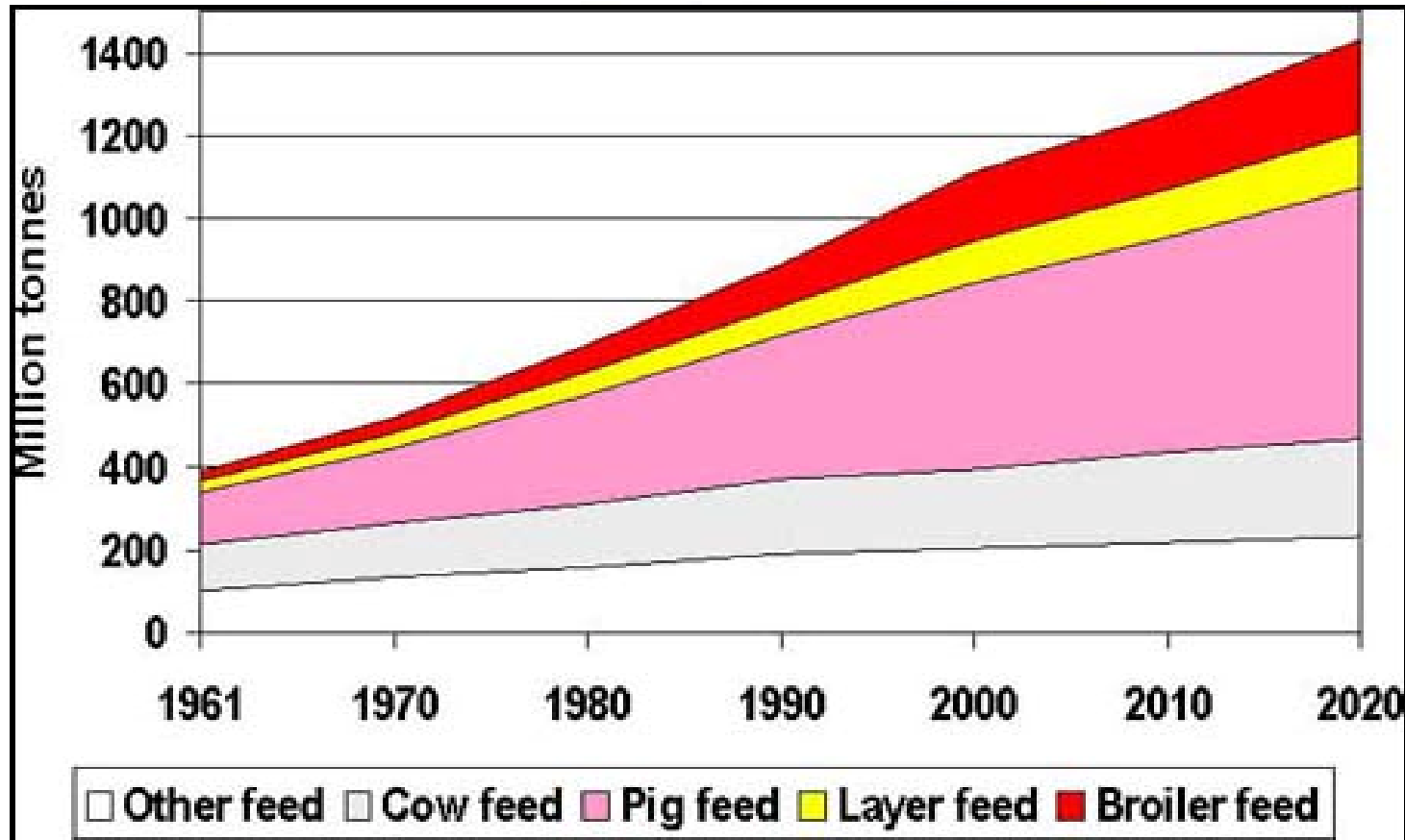
“Humanity is approaching a crises point with respect to the interlocking issues of population, food, natural resources and sustainability.”

- *Population Summit*



# Can we supply the demand?

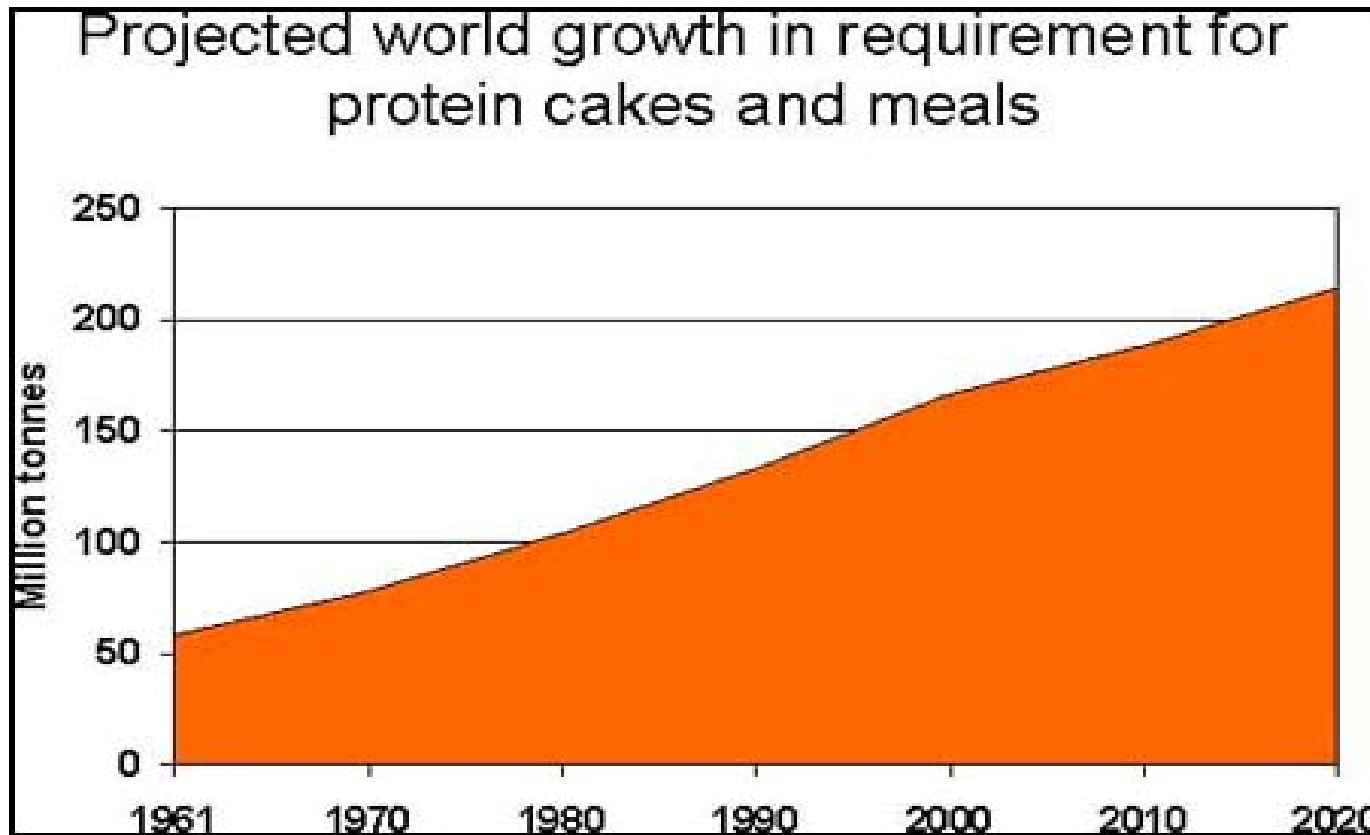
Projected world growth in demand for animal feed



Source: FAOSTAT



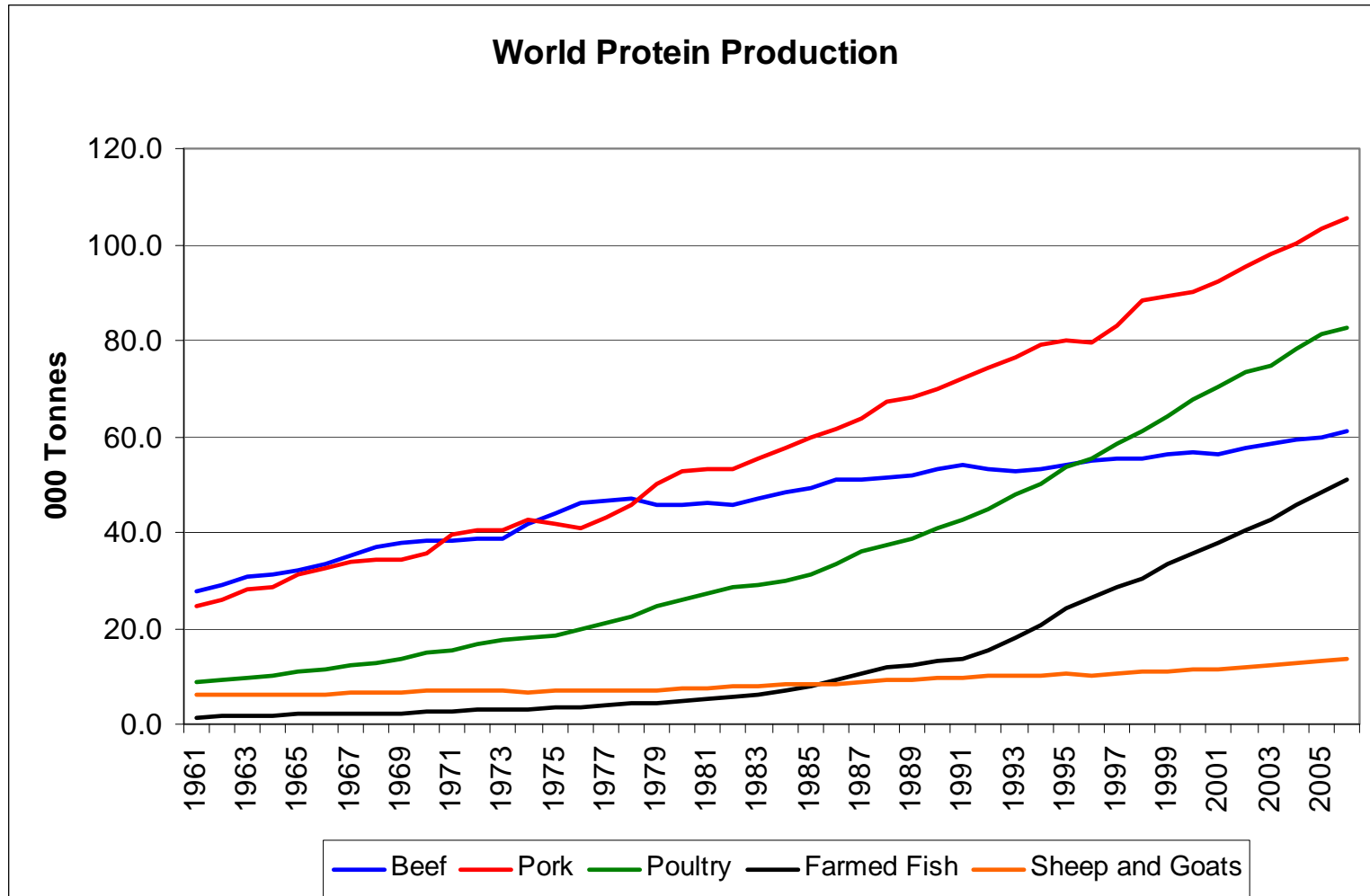
# Demand for Oilseeds



Source: FAOSTAT



# Soaring Demand for Meat



Compiled by Earth Policy Institute from FAOSTAT



# Is Algae Biomass Suitable for Feeds?

# YES!

**Many Algae Varieties are  
ideal for Animal Feed Markets**

**Supplemental Feeding brings  
Omega 6 & 3's into balance**

**High Protein Source**





# ALGAE derived Fatty Acids

## Omega 3 Fatty Acids for Human Consumption



**No “off-flavors” of fish oil**

**No cholesterol content**

**Vegetarian source of essential fatty acids**

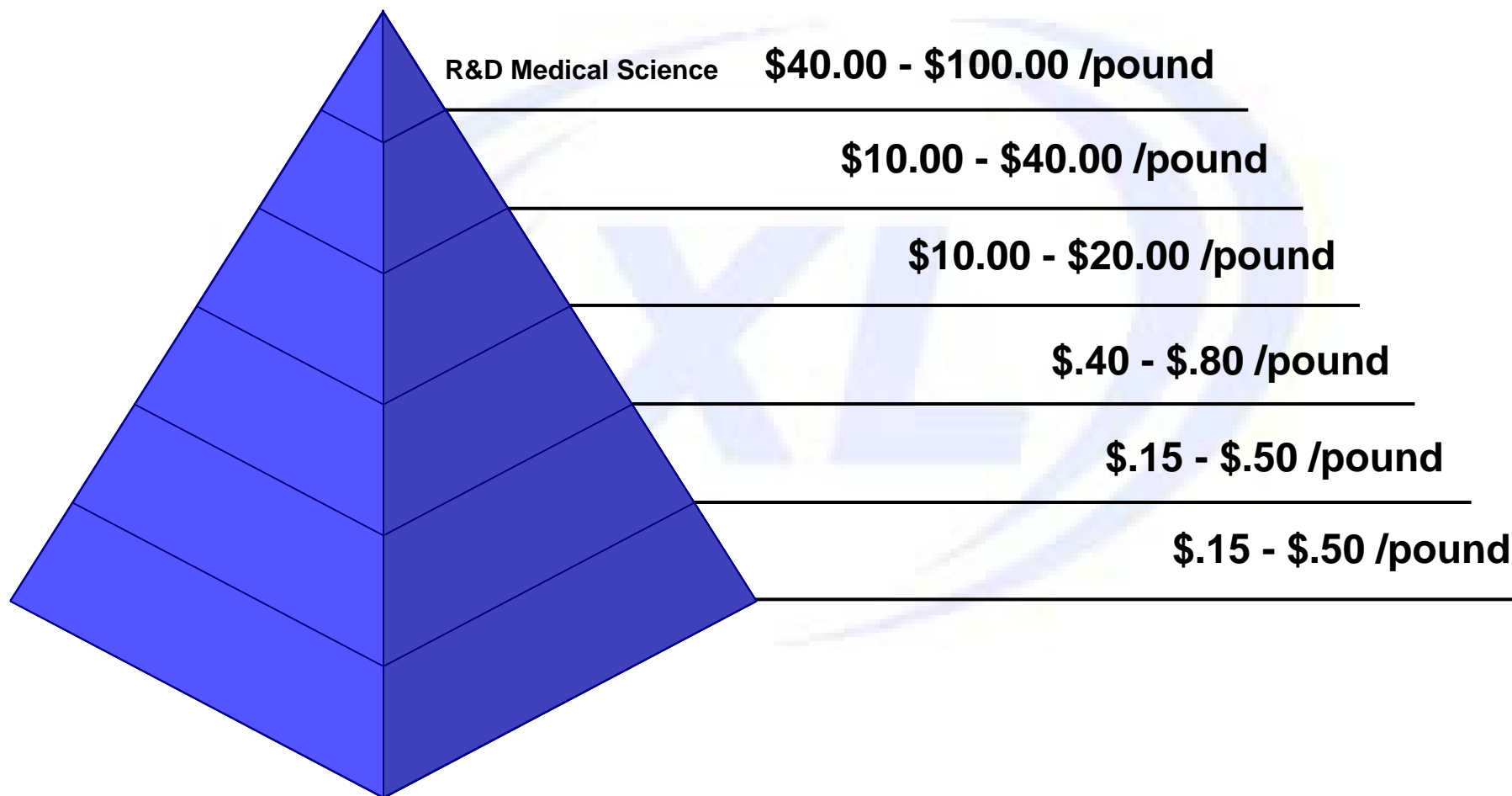
**Algae Biomass is “pure” and “all-natural”**







# Potential Product Markets





# Future of Algae Biomass

Algae Biomass can potentially be a major source of proteins, oils and carbohydrates along with other crops like Corn and Soybeans



Renewable Energy is the primary driver of this opportunity, but the world will benefit with a new food supply.



Production of Omega 3 Fatty Acids provides a demand for hundreds of thousands of acres of production.





# Production Criteria

- Economical Supply of CO<sub>2</sub> Gases
- Nutrient Source – N-P-K and Micro Nutrients
- Flat Land with Brackish or Wastewater Water Supply





# Location of Production Facilities

## Primary Requirements:

1. CO<sup>2</sup> (Carbon Dioxide)
2. Fertility
3. Energy
4. Sunlight
5. Temperature





# Ideal Locations

- **CAFO's**  
(Confined Animal Feeding Operation)
- **CO2 Pipelines/Wells**
- **Power Plants**
- **Other CO2 Emitters**
  - Ethanol Plants
  - Breweries
  - Cement Plants
  - Etc.



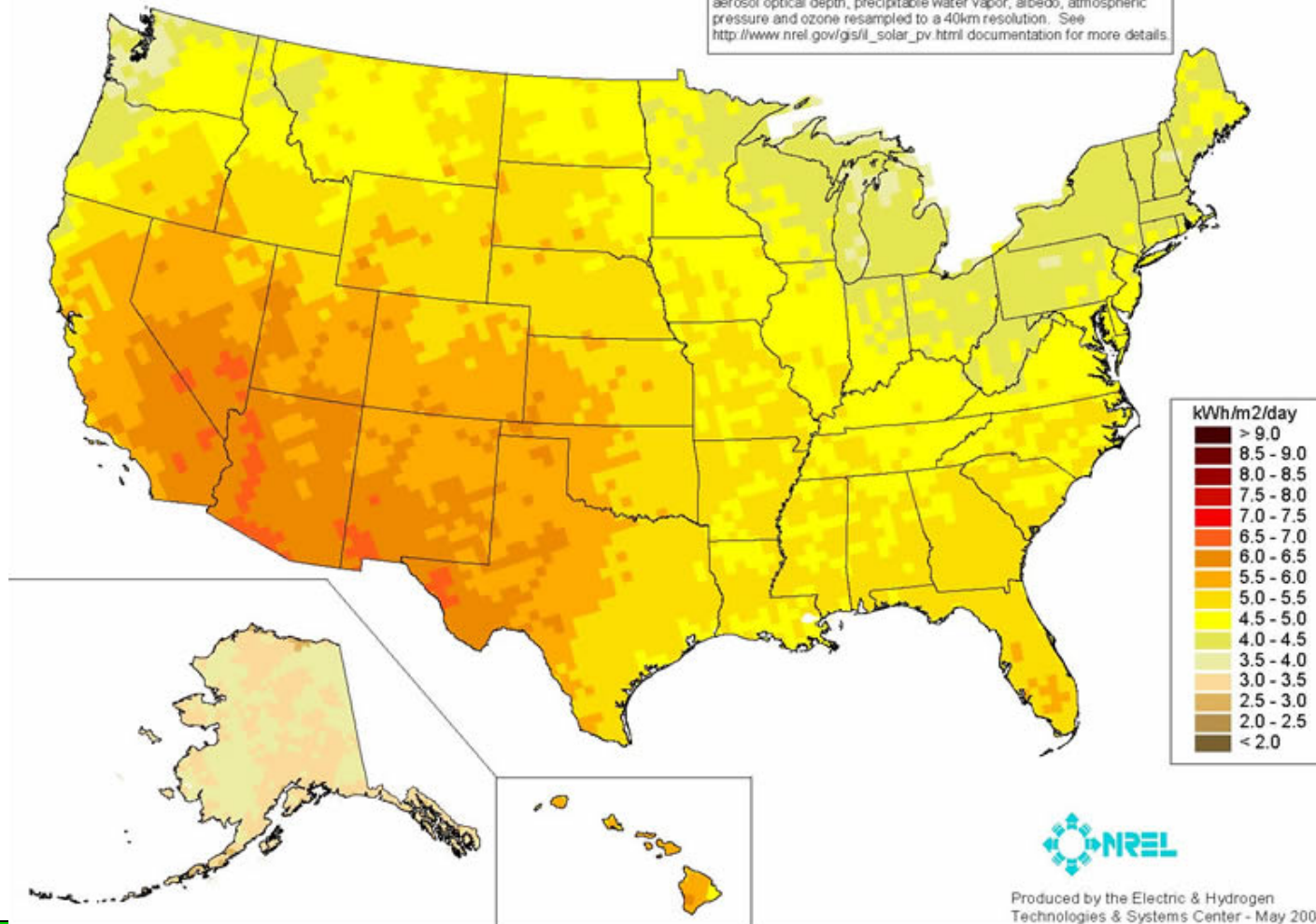


# Arizona is Ideal Location

PV Solar Radiation  
(Flat Plate, Facing South, Latitude Tilt)

Annual

Model estimates of monthly average daily total radiation using inputs derived from satellite and/or surface observations of cloud cover, aerosol optical depth, precipitable water vapor, albedo, atmospheric pressure and ozone resampled to a 40km resolution. See [http://www.nrel.gov/gsi/solar\\_pv.html](http://www.nrel.gov/gsi/solar_pv.html) documentation for more details.

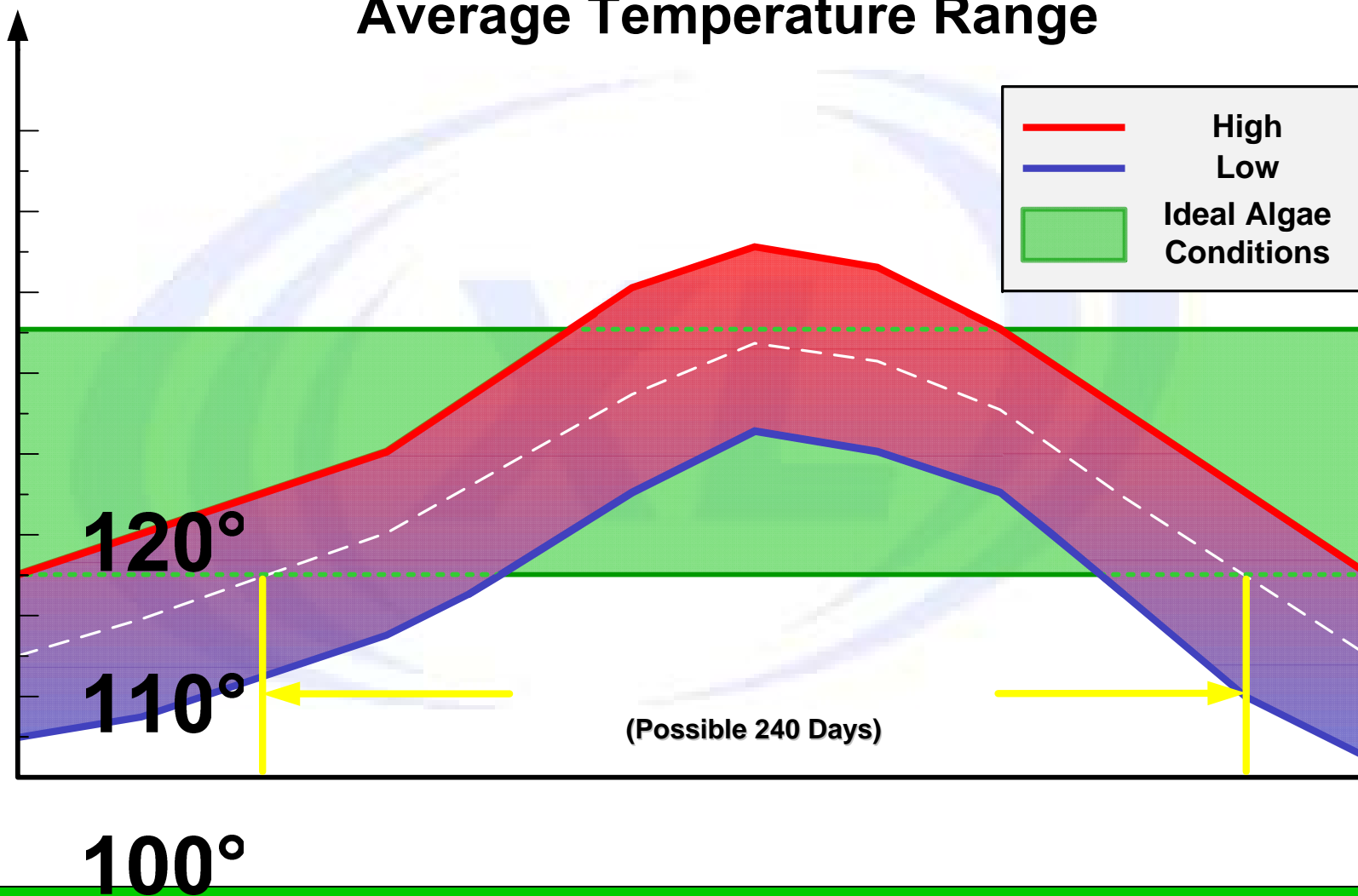


Produced by the Electric & Hydrogen  
Technologies & Systems Center - May 2004



# Algae in Arizona

## Average Temperature Range

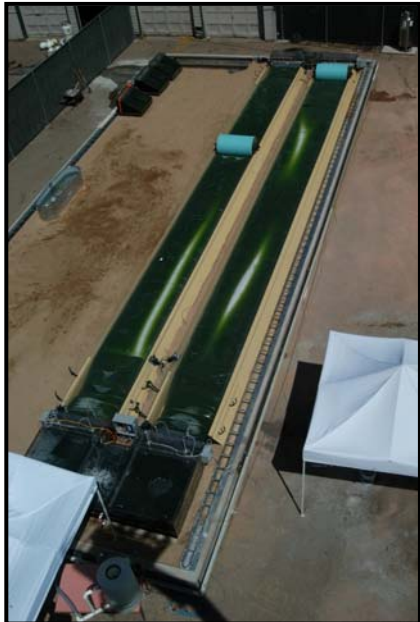


Ph

neit 90°



# Production Methods



Solix



Solazyme



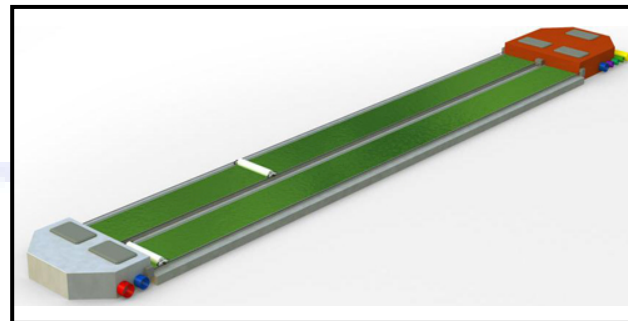
Valcent



Greenfuel Technologies



AlgaeLink



A2BE Carbon Capture



Green Star Products





# Production Methods



Systems inspired by wastewater and aquaculture industries



# Israeli Production



**Produces Red Algae for Nutraceutical Market at \$1,200 per pound**

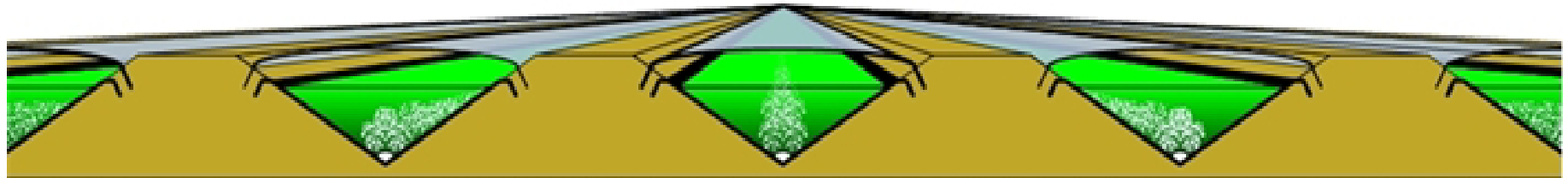


# Super Trough Concept





# XL Super Trough System

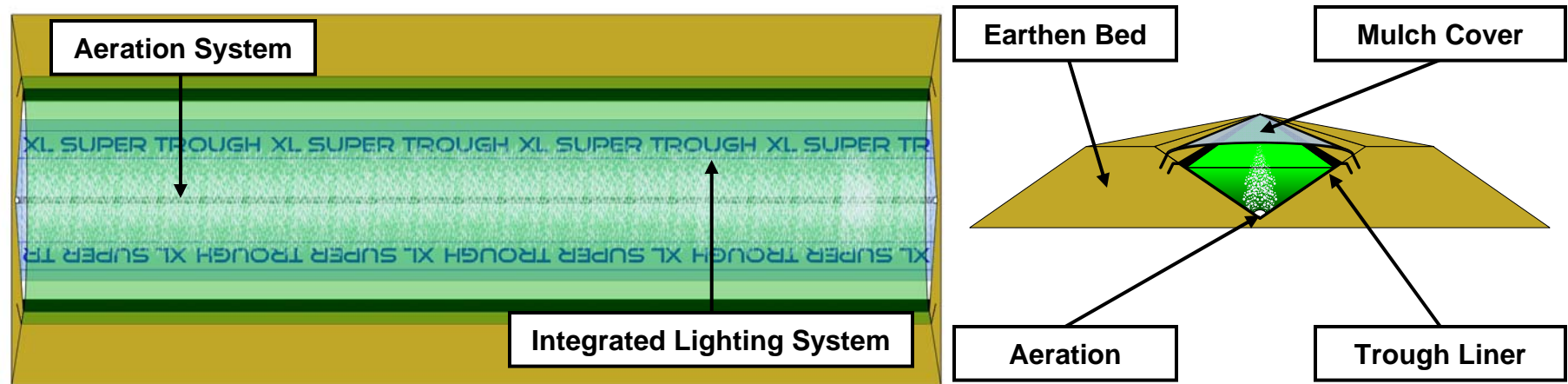


- Low Cost and Simple
- Mechanized installation and maintenance
- Utilize proven agricultural components
- Highly scalable
- Optimized Production





# XL Super Trough System



- Design includes integrated lighting to extend growth period
- Continuous aeration allows for long distance runs with optimum yields
- Mulch cover extends growing season by insulating temperature and refining solar radiation



## Production and Harvest

# 40 Acres of Algae Production



**Field Flow:**  
3,400 gpm

**Harvest Flow:**  
2,000 gpm

**Concentrate  
Flow: 200 gpm**



## Troughs and Weir Tank





# Capital Cost

## Commercial Algae Farm (production & processing)

	<u>per Acre</u>	<u>TOTAL</u>
<b>40 acres</b> - 1 Field - 2,000 – 3,000 tons	\$50,000	\$ 2,000,000
<b>160 acres</b> - 4 Fields - 8,000 – 12,000 tons	\$40,000	\$ 6,400,000
<b>640 acres</b> - 16 Fields - 32,000 – 48,000 tons	\$35,000	\$22,400,000

(Assumes \$25,000 for production system plus processing for oils and meals)





# Operating Revenues

## Key Market Assumptions:

### **Value for Biofuels: \$400 /ton for Oil**

- \$0.20 /lb (\$400 / 2,000lbs)
- \$1.50 /gallon (\$0.20 X 7.52lbs per gallon)

### **Value for Proteins: \$400 /ton for Ton**

- \$0.20 /lb (Superior to Soy Protein)

### **Value for Omega 3's: \$800+ /ton**

- \$800 /ton for whole algae pellets (7.5% EPA/DHA Concentration)
- \$4,000 /ton for oil (30% EPA/DHA Concentration)



# Operating Revenues

	<u>Biofuels</u>	<u>Omega's</u>
Gross Revenue:		
Algae Biomass	\$400 /ton	\$800 /ton
Yield	<u>50 tons</u>	<u>50 tons</u>
<b>TOTAL Gross Revenue</b>	<b>\$20,000 /ac</b>	<b>\$40,000 ac</b>
Expense:		
Marketing (10%)	\$ 2,000	\$ 4,000
Production/Processing (\$400 /ton)	\$20,000	\$20,000
Management (\$50 /ton)	<u>\$ 2,500</u>	<u>\$ 2,500</u>
<b>NET CASH FLOW</b>	<b>-\$ 4,500</b>	<b>\$13,500</b>
less Debt Service	<u>\$ 6,000</u>	<u>\$ 6,000</u>
(\$40,000, 10 yr, 8%)		
<b>Net Cash After Debt</b>	<b>-\$10,500</b>	<b>\$ 7,500</b>



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# Thank You!

