Emerging Markets Online

GLOBAL ENERGY AND BIOFUELS INTELLIGENCE

Biofuels and Algae Markets, Systems, Players and Commercialization Outlook

Rice Global E&C Forum November 20, 2009

Emerging Markets Online

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Biodiesel 2020: A Global Market Survey (2008)
Algae 2020: Biofuels Commercialization Outlook (2009)

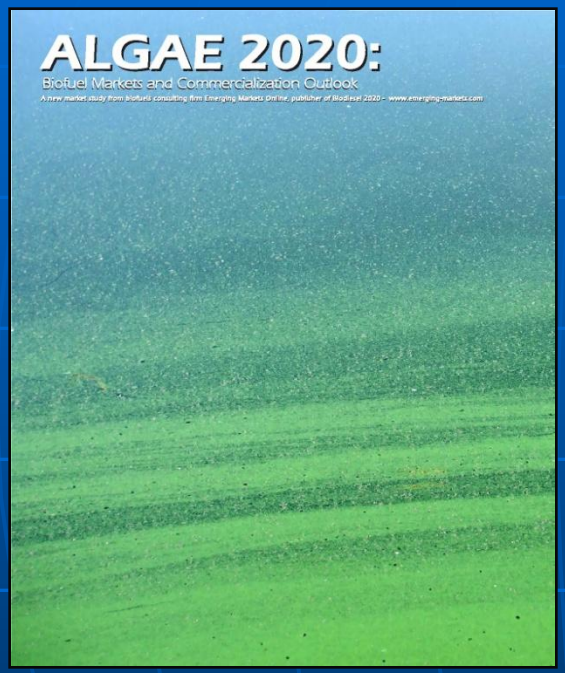
Columnist, Biofuels International

***H*Q - Houston, TX**

BIODIESEL 2020: A GLOBAL MARKET SURVEY

- 685 page study, February 2008
- ***Country Studies***
  US, Brazil, EU, China, India
- ***Feedstock Markets and Trends***
  Soy, Rapeseed, Palm, Jatropha, Castor, Yellow Grease, Fats
- ***2nd Generation Projects and Trends***
  Algae, Renewable Diesel, BioCrude, Biomass to Liquids, Green Diesel
- ***Outlook and Opportunities***

ALGAE 2020: Biofuel Markets, Co-Products, Green Chemicals BioPlastics, Livestock Feed and Commercialization Outlook



June, 2009

- ***Algae Market Potential and Applications***
  - Biodiesel & Biocrude
  - Drop In Fuels – Renewable Diesel, Gasoline
  - Aviation Fuels
  - Livestock Feed and Aquaculture Feed Markets
  - Nutraceutical and Pharmaceutical Markets
  - Green Plastics, Chemicals, Polymers Markets
- ***Algae Production Methods Overview***
  - Production Systems Overview: Open Ponds vs Closed Photo Bioreactor Systems (PBRs), Growing Algae in The Dark
  - Inputs for Algae Systems CO2 and NO2
  - Extraction Methods
  - Biorefining Technologies – 1st Gen & 2nd Gen
- ***Algae Project Profiles and Case Studies***
- ***Outlook for Commercialization: 2010-2015***

1. GLOBAL BIOFUELS MARKETS

image courtesy of sapphireenergy.com

USA Biofuels Targets

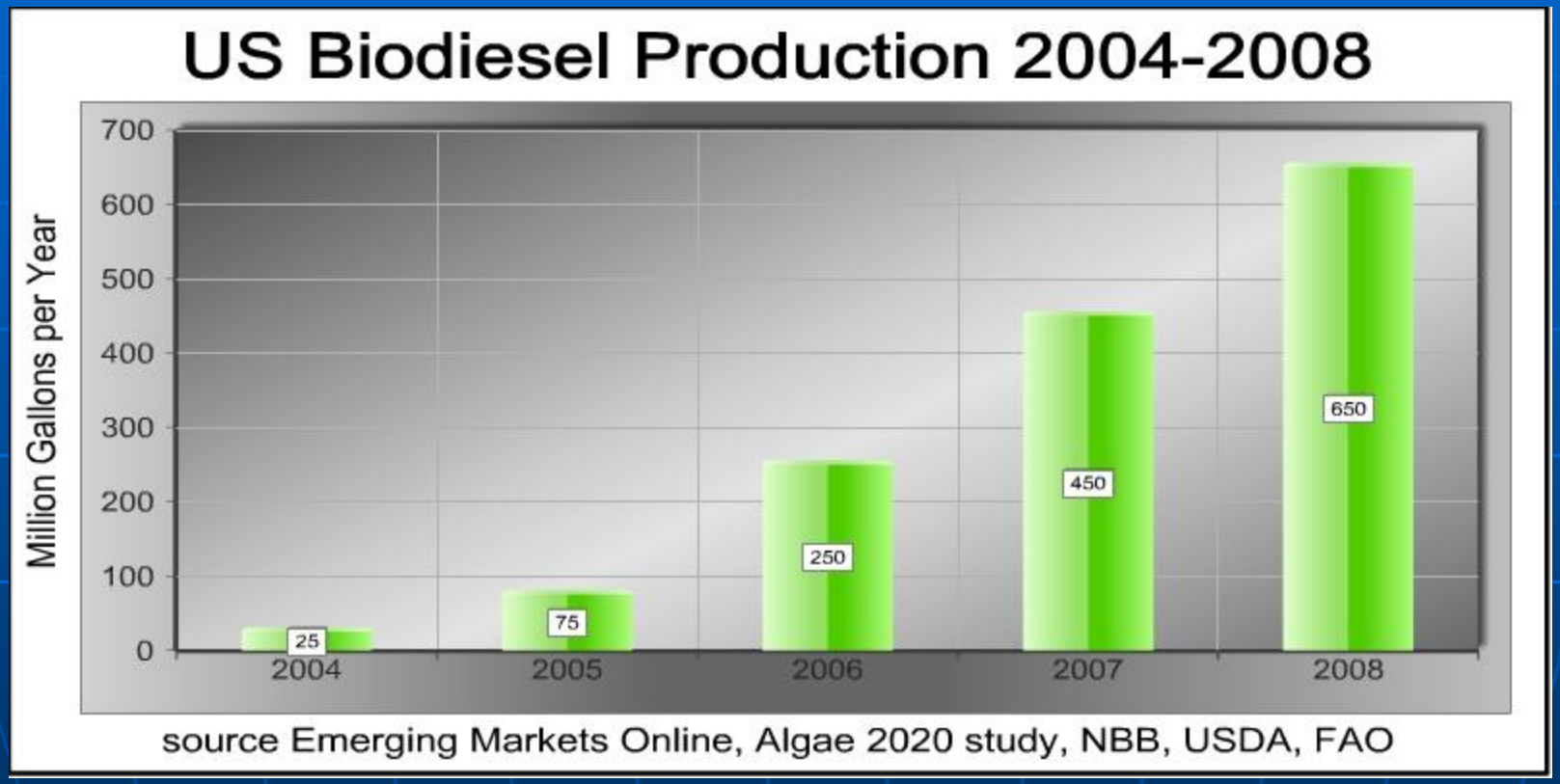
- Federal RFS – 36 billion gallons by 2022
- *21 Billion Gallons from Advanced Biofuels*

US Algae Market Potential

- US Military is #1 Consumer of Diesel Fuel in The World
- Industrial Diesel markets represent 25% of petrol consumption
- More than 95% of passenger cars use gasoline, 3% on diesel
- ***PROBLEM:*** *The US can not produce enough corn and soybeans to meet targets, even with cellulosic corn*
- ***OPPORTUNITY:*** *Algae can serve as a feedstock for First Generation Biodiesel and Ethanol Plants, Aviation Fuels Markets and Biocrude for Biogasoline*

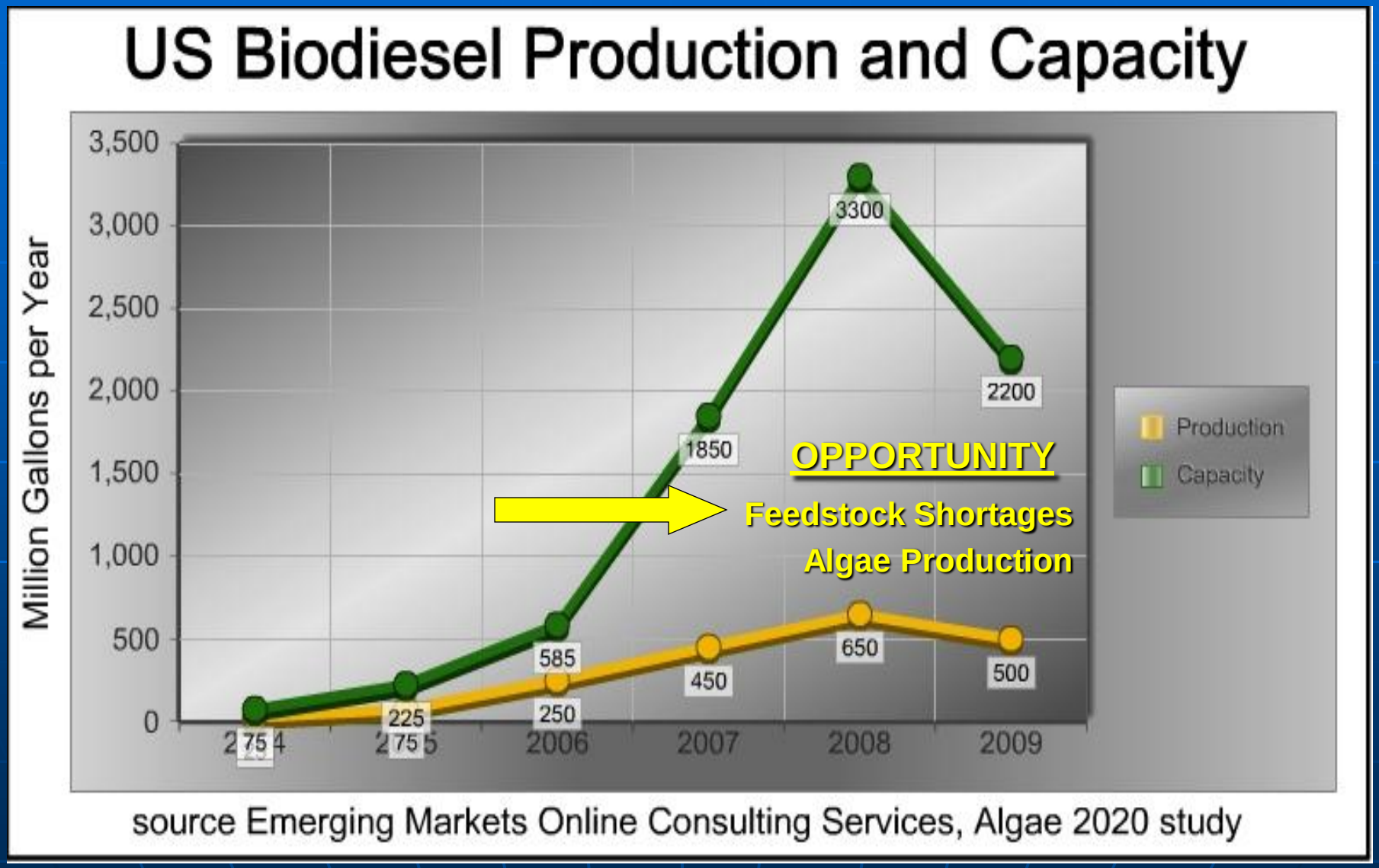
SOURCE - ALGAE 2020 AND BIODIESEL 2020 STUDIES

USA BIODIESEL MARKET OVERVIEW



SOURCE - ALGAE 2020 STUDY

USA BIODIESEL MARKET OVERVIEW



SOURCE - ALGAE 2020 STUDY

EU BIOFUEL MARKET GROWTH TRENDS

EU Biofuels Targets

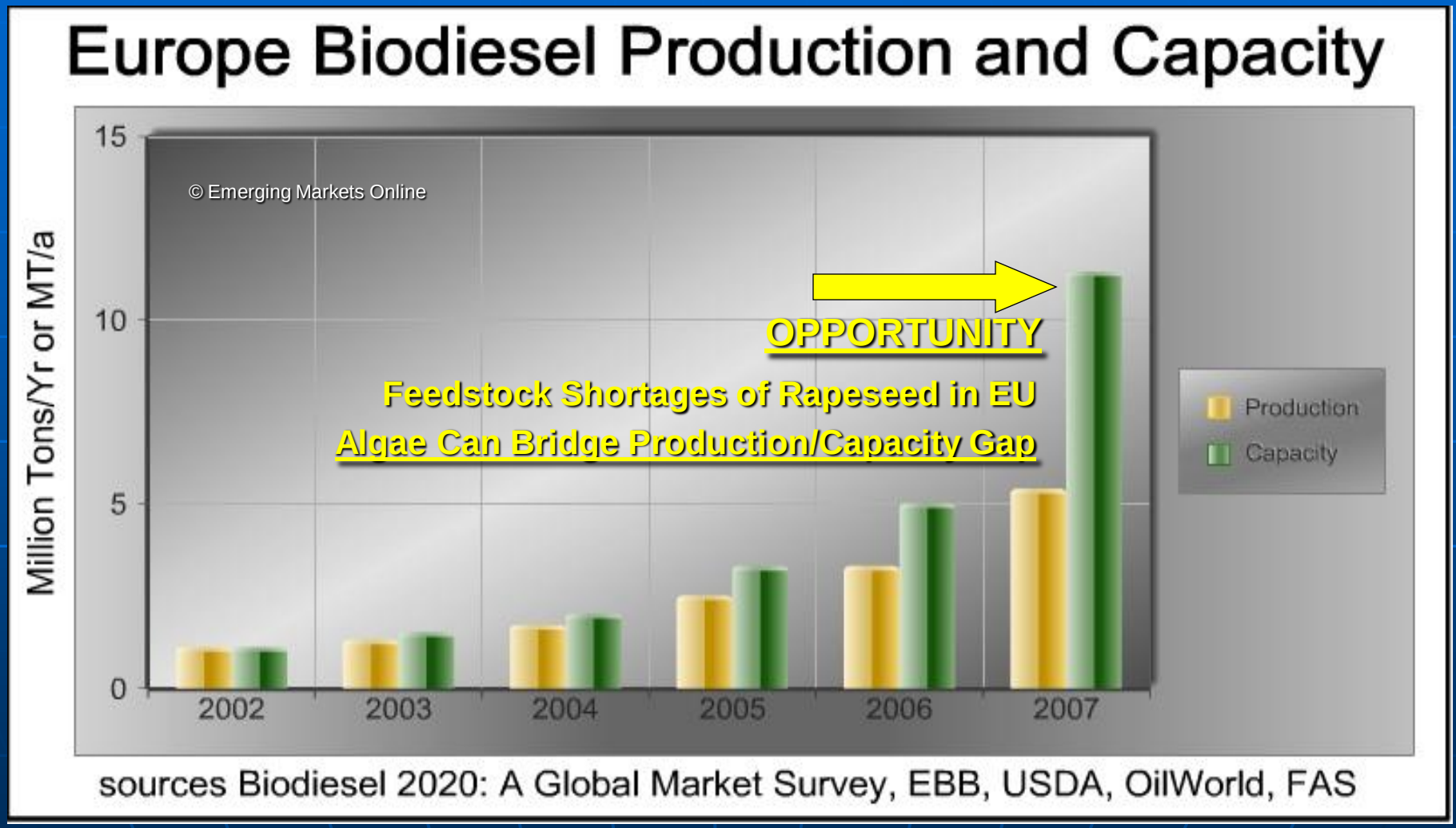
- *Target 2 - 5.75% by 2010*
- **Proposals: 10% by 2020 (EU Revision)**
- **Feedstock *sustainability* concerns #1 for 2009**

EU Algae Market Potential

- **More than 50% of cars run on diesel**
- ***PROBLEM:* Europe can not produce enough rapeseed, sunflower to meet targets**
- ***OPPORTUNITY:* Algae can serve as a feedstock for First Generation Biodiesel and Ethanol Plants, Aviation Fuels Markets and Biocrude for Renewable Diesel and Gasoline**

SOURCE - Algae 2020 and Biodiesel 2020 studies

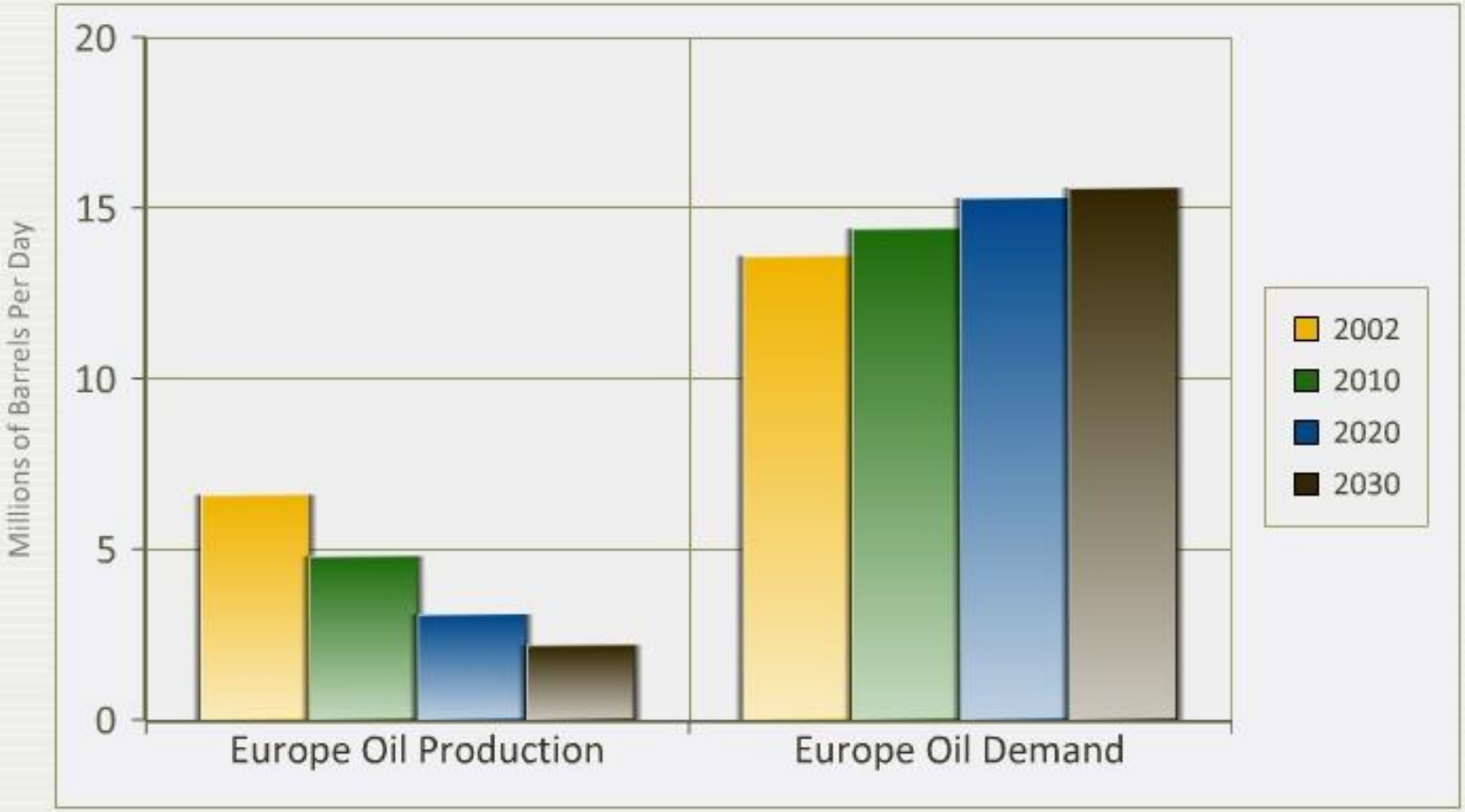
EUROPE BIODIESEL MARKET GROWTH TRENDS



Europe Oil Production and Demand Forecast to 2030

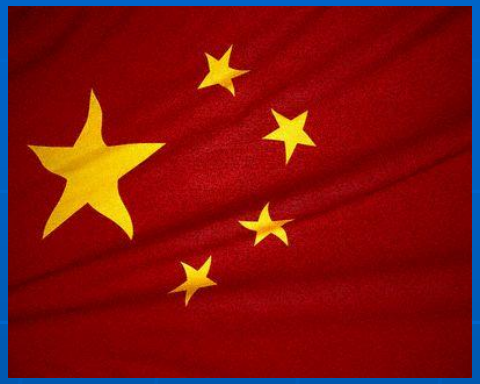
Target Markets for Algae Biocrude, Drop In Fuels & Biodiesel

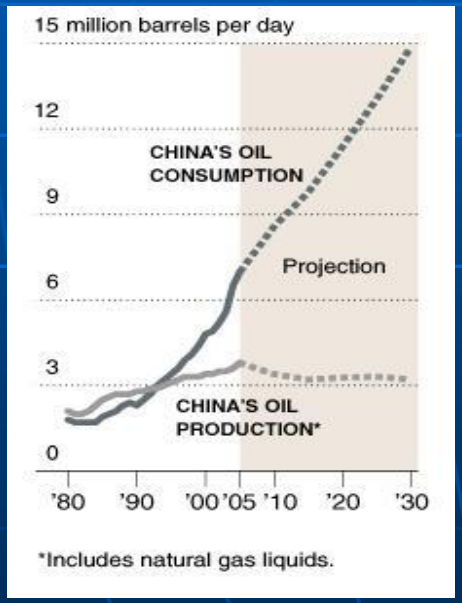
Europe's decreasing production, and increasing consumption presents opportunities for algae crude oil for biodiesel and drop in fuels - renewable diesel, renewable gasoline, and aviation fuel



Source: Algae 2020 Study, Emerging Markets Online Consulting Services, IAE, EIA forecasts

CHINA'S BIOFUELS MARKET OVERVIEW





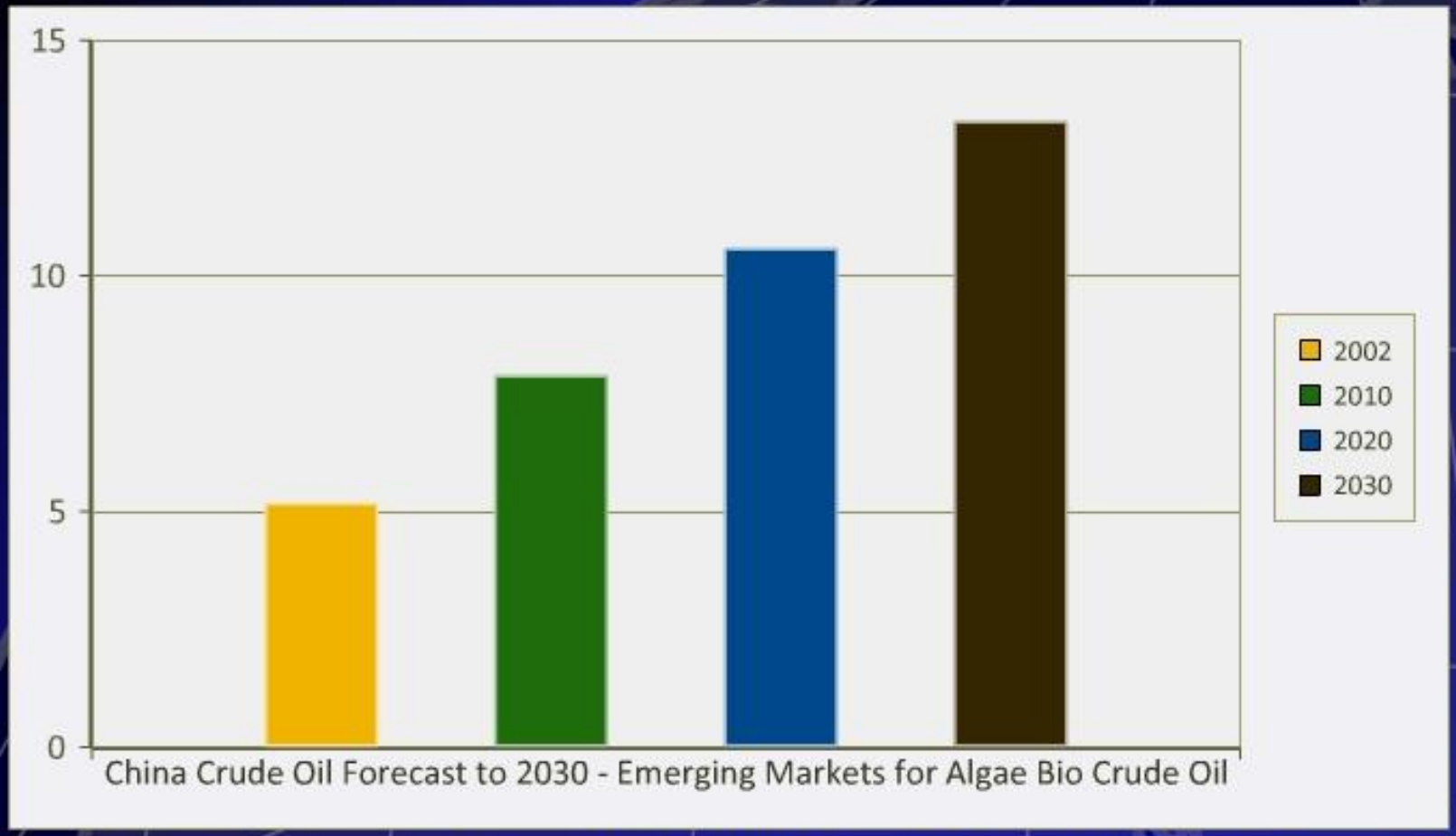
- ***China's Biofuels Targets***
  - **2010 - to increase biofuels production to nearly 4 million MT by 2010**
  - **2020 - *target to replace 15 percent of China's transportation energy needs* by producing 12 million+ tons of biofuels**
- ***China's Biofuel Markets***
  - **Traditional use of waste vegetable oil**
  - **Plans for bigger plants using non-food sources such as jatropha, recycled waste and sewage feedstock**
  - **China is Installing Two 500 MW Coal-Fired Power Plants Every Week for The Next 10 Years, According to Estimates from MIT & China's MOST**
  - **Opportunity – Algae For Carbon Capture & Production of Clean Biofuels, Biocrude & Drop-in Fuels**
  - ***China – 1.3 Billion Sources of Renewable Energy!***

SOURCE - BIODIESEL 2020: A GLOBAL MARKET SURVEY

China Crude Oil Demand to 2030

Target Markets - Algae Biocrude Oil for Drop In Fuels - Renewable Diesel, Gasoline, Aviation

Producers of algae crude oil or "green crude" are receiving increased investments for use in biodiesel refineries, as well as for use in petroleum refineries to produce drop in fuels - renewable diesel, renewable gasoline, and clean aviation fuels



Source: Algae 2020 study, Emerging Markets Online Consulting Services, IAE, EIA forecasts

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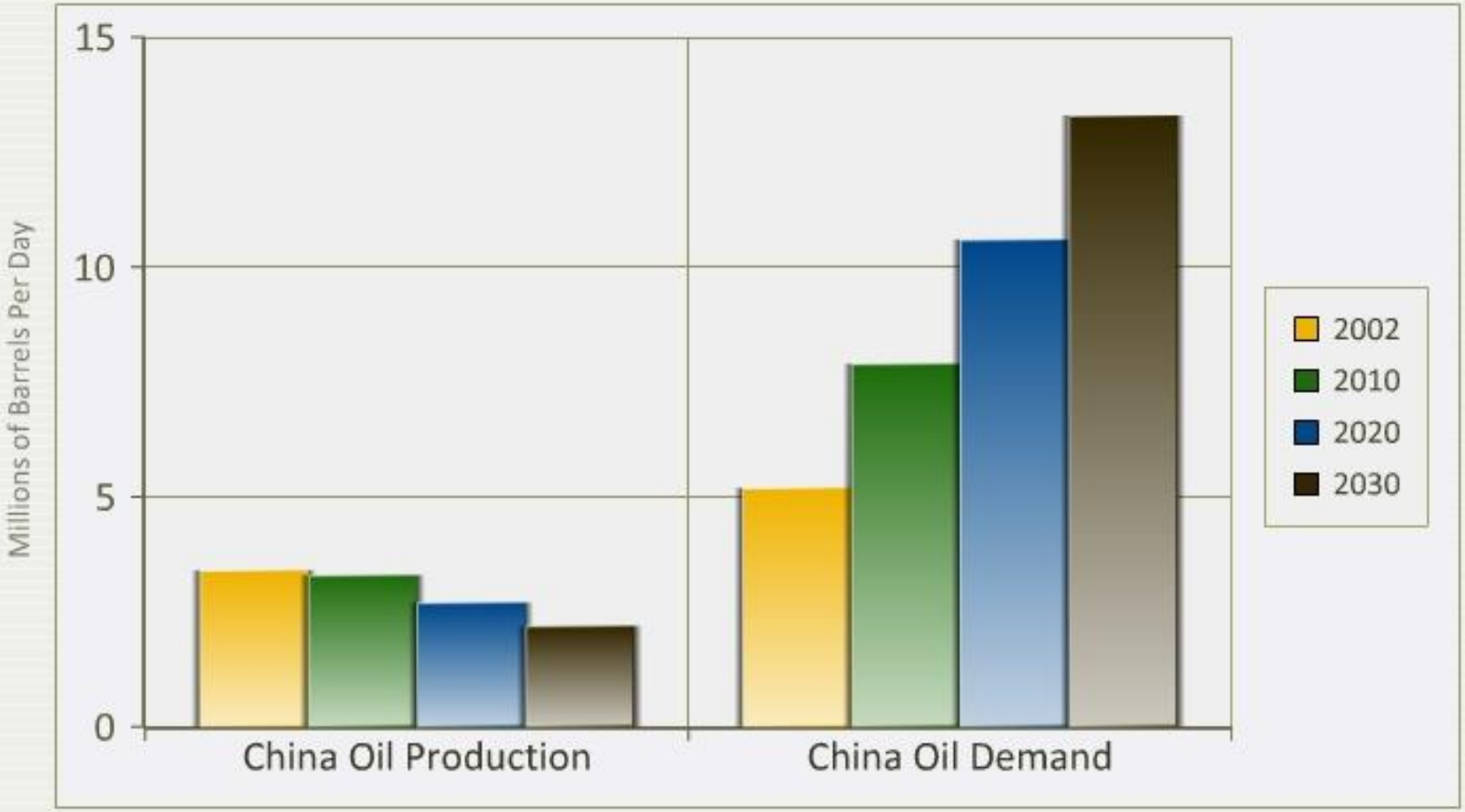

Source: Algae 2020 Study, Emerging Markets Online Consulting Services, IAE, EIA forecasts

INDIA'S BIODIESEL MARKET OVERVIEW

India's Biodiesel Targets:

- National Biodiesel Program started 2006
- Two Phases – jatropha plantation program
- *Target – 20% of diesel fuel by 2012*
- Growth for rural, city and regional areas
- Socio-economic plans for growth in marginal areas to benefit rural farmers

India's Biodiesel Markets:

- Key focus: Jatropha plantation, production
- **Opportunity for Algae to Serve a Huge Growing Market and 20% Government Target**

SOURCE - BIODIESEL 2020: A GLOBAL MARKET SURVEY

India Crude Oil Demand to 2030

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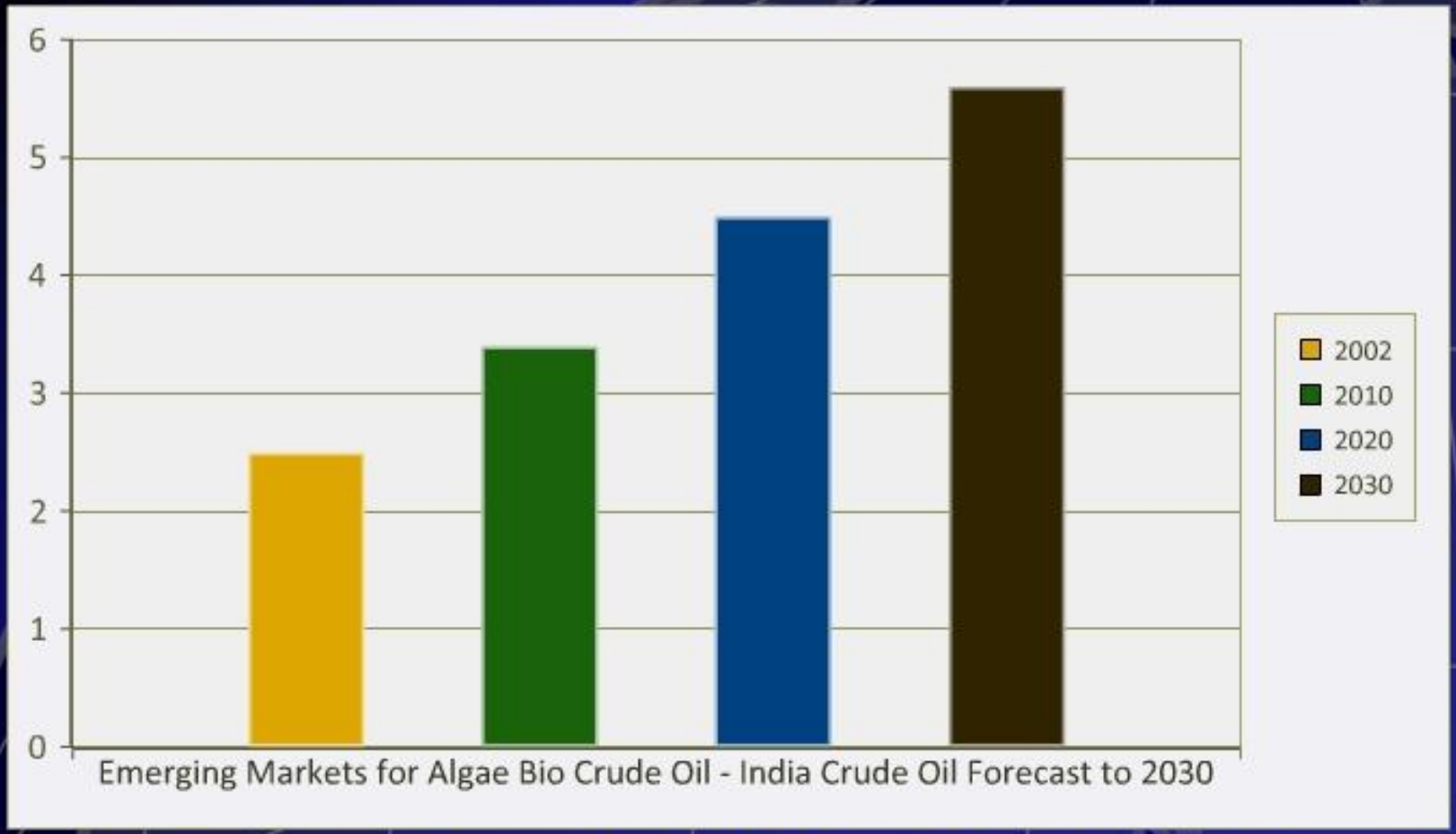

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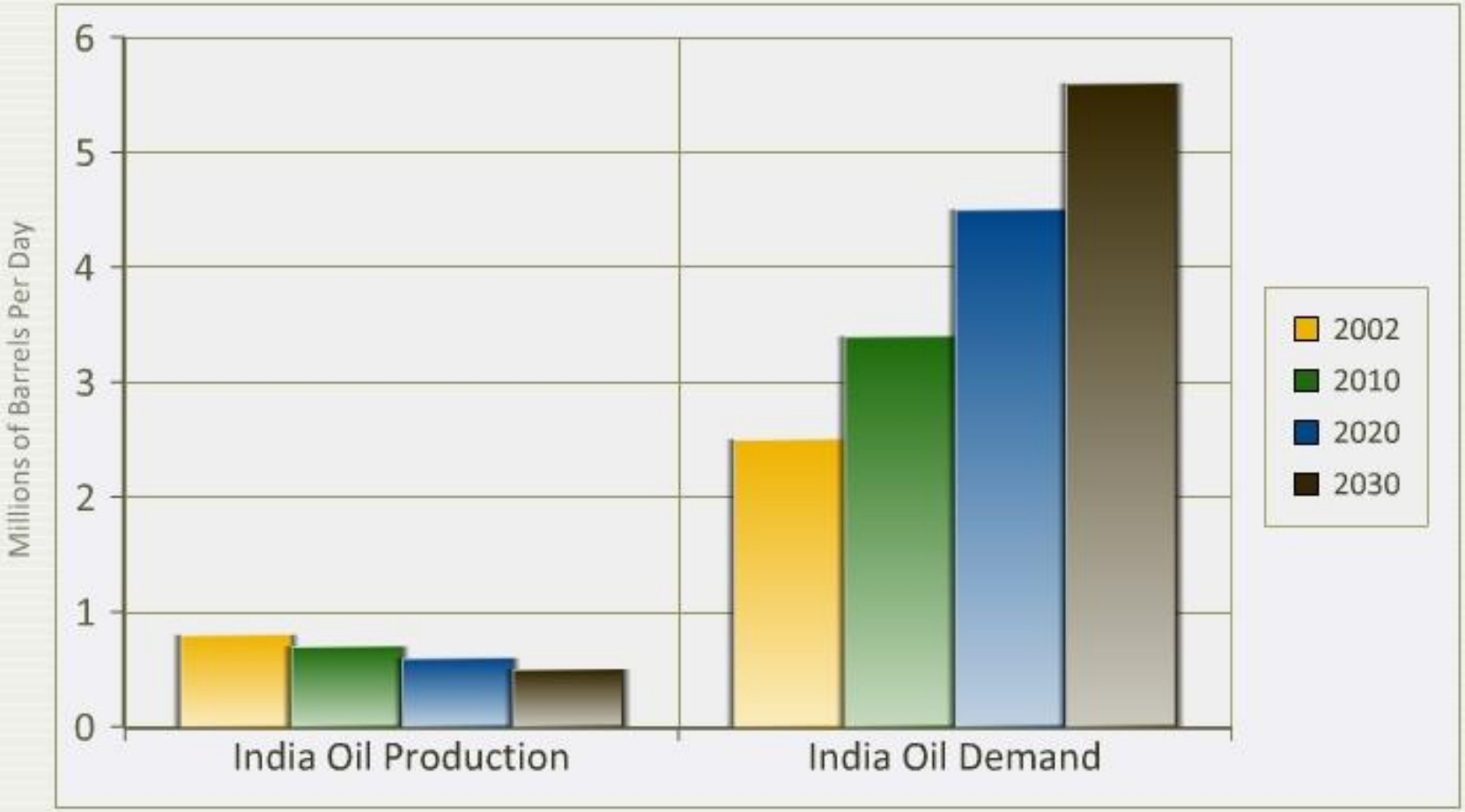
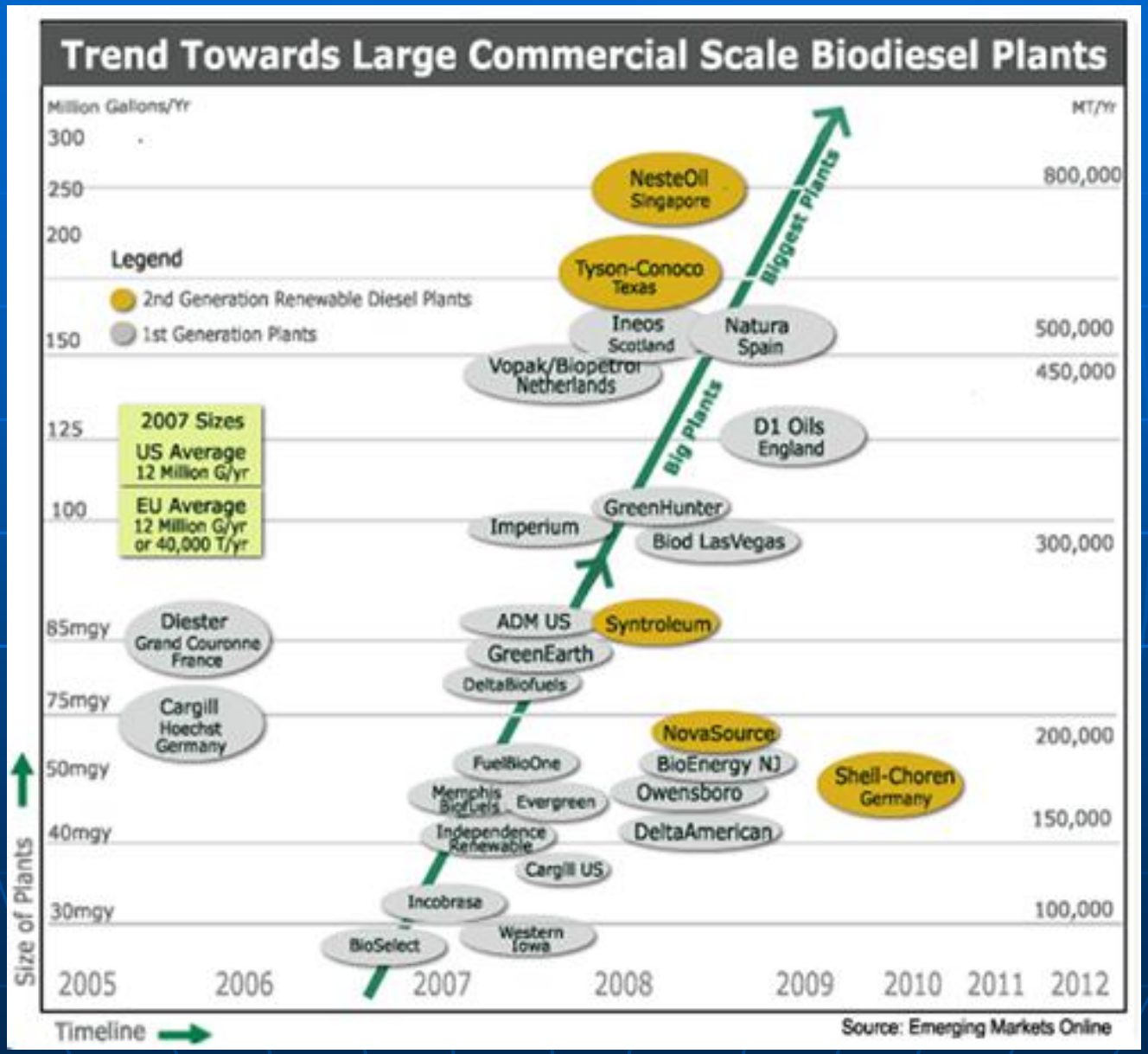


Source: Algae 2020 Study, Emerging Markets Online Consulting Services, IAE, EIA forecasts

Scale of Biofuels Systems is Critical To Meeting the US 21 Billion Gallon RFS2

2008 + Trend Towards Large-Scale Projects Using Lower Cost Feedstocks

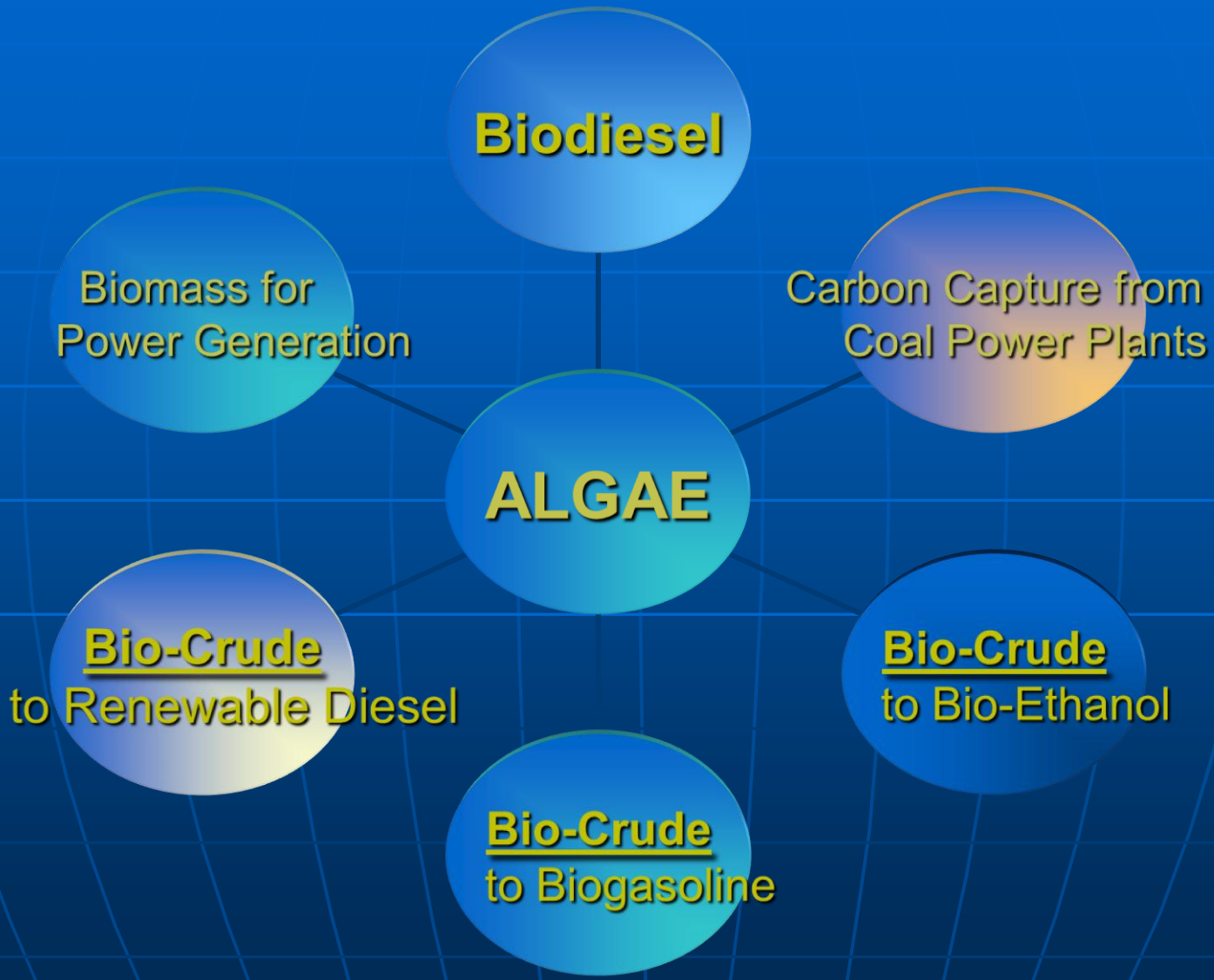


ALGAE - BASED BIODIESEL

Comparison of Algae vs. other Feedstocks for Biodiesel Production Per Acre

Feedstock	Gallons Per Acre
Soy	40-50 US gallons/acre
Canola/Rapeseed	120-150 US gallons/acre
Jatropha	175-250 US gallons/acre
Palm	650 US gallons/acre
Algae	5-10,000 US gallons/acre

Applications for Algae to Biofuels – Multiple Uses



Source: Algae 2020 and Biodiesel 2020 studies, Emerging Markets Online

2. ALGAE PRODUCTION METHODS

Algae Growth Systems – Common Method 1 of 2
Ponds and Raceway Systems – *98% of All Algae Production is in Ponds*

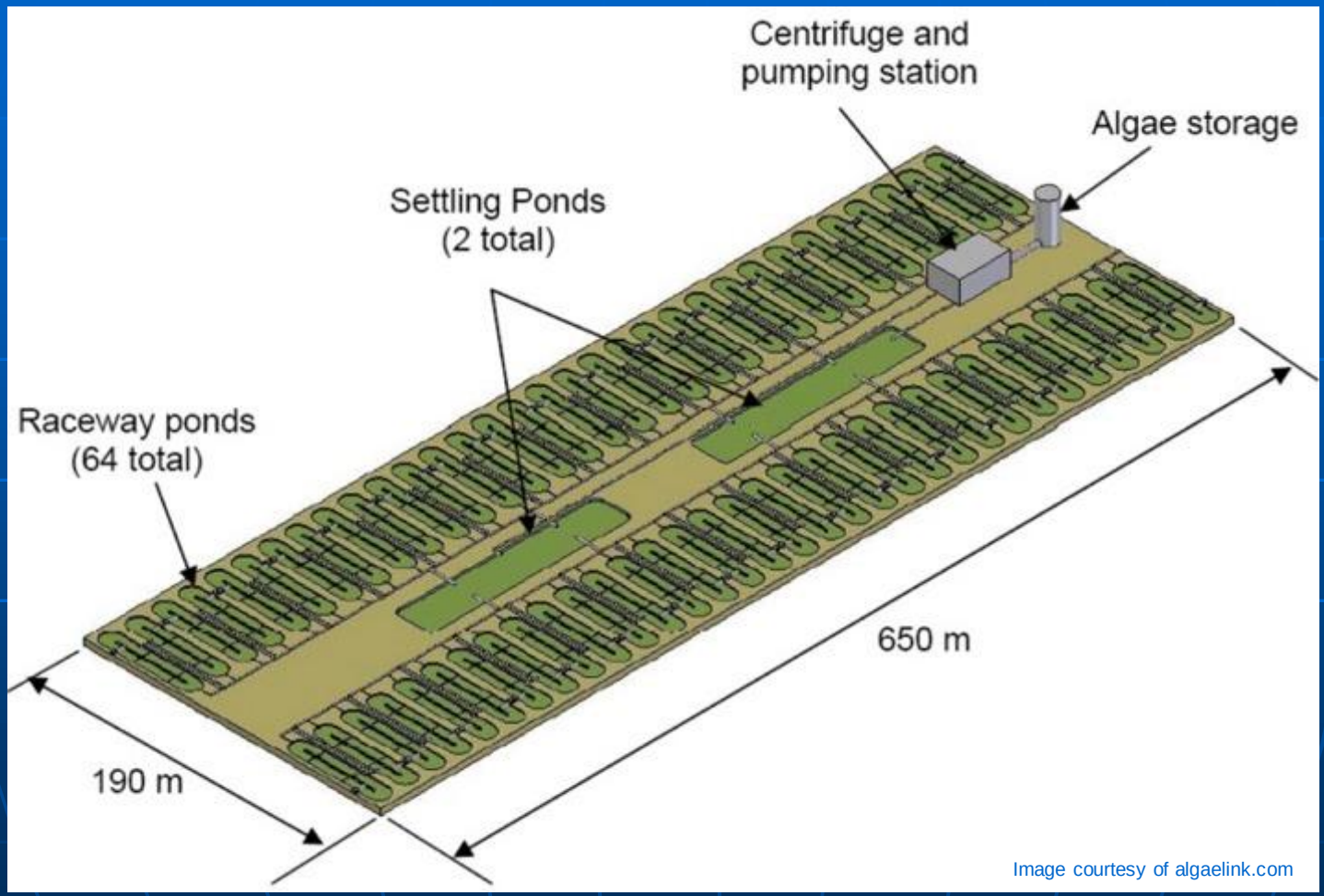


Diagram – Algae Farm Using 64 Open Pond "Raceways" to Grow Algae

Source: citation from analysis in Algae 2020 and Biodiesel 2020 studies, Emerging Markets Online

Algae Growth Systems – Common Method 2 of 2
Photo Bio Reactor Systems:

Long Term Possibilities - Short Term Problems *(Green Fuels, Algaelink, Vertigro)*

Good for Innocculum, Testing and High-Value Specialty and Pharmaceutical Markets

Not Yet Ready for Commercial Fuels in The Next 2-3 Years

Note: Failure is Success if You Learn From it

A Photo-Bioreactor in Translucent Tube from GreenFuels

Global Green Solutions/Vertigro Vertical Photo Bioreactor System

Source citations mentioned in Algae 2020 and Biodiesel 2020 studies Emerging Markets Online

Images courtesy of greenfuelonline.com and valcent.net

Solazyme – 3rd Method – Microbial Fermentation – High Yield Algae

Growing Algae in The Dark Converting Starches to Lipids/Oils for Biocrude, Drop In Fuels

Growing algae in the dark

Solazyme's Biodiesel Mercedes

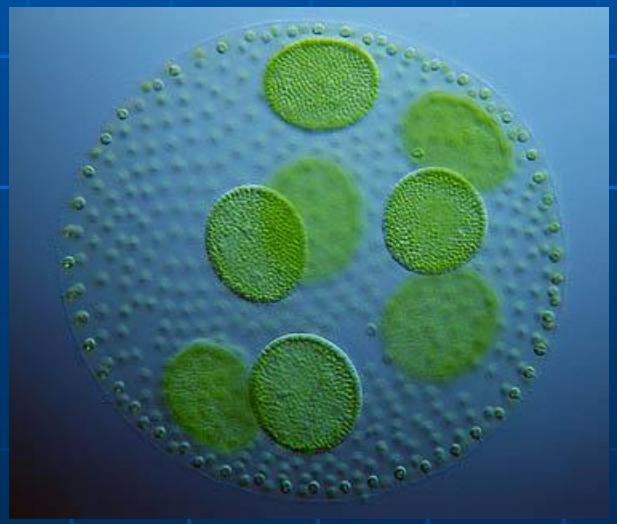
- **Solazyme <u>Grows Algae in The Dark</u> Converting Sugar and Starches to Lipids/Oils**
- **Solazyme *<u>has already raised $70 million</u>* in capital, including Chevron as a key investor**
- **Solazyme's fuel has met ASTM Standard D 1655 *For Aviation/Jet Fuel***

Source citations mentioned in Algae study, Emerging Markets Online

images courtesy of solazyme.com

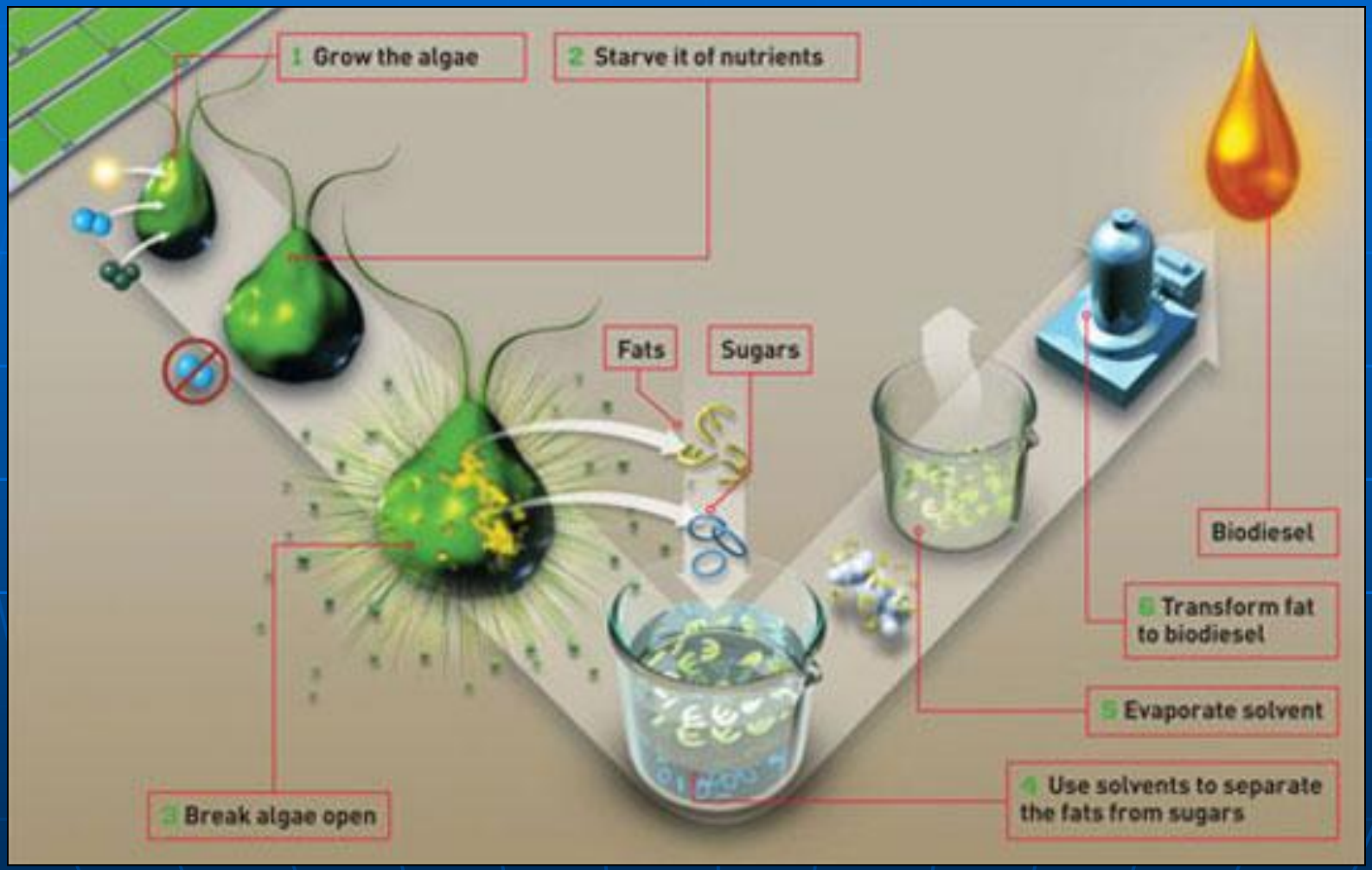
Applied Algae Production Systems

Algae to Biodiesel, Ethanol, Biocrude and Jet Fuel



Applied Systems – Algae for First Generation Biodiesel or Ethanol

Process Diagram: Algae Production for Oils to Biodiesel and Sugars to Ethanol



Algae fats/lipids can be converted to *biodiesel*, sugars converted to *ethanol*

Source: cited in Algae 2020 and Biodiesel 2020 studies, Emerging Markets Online

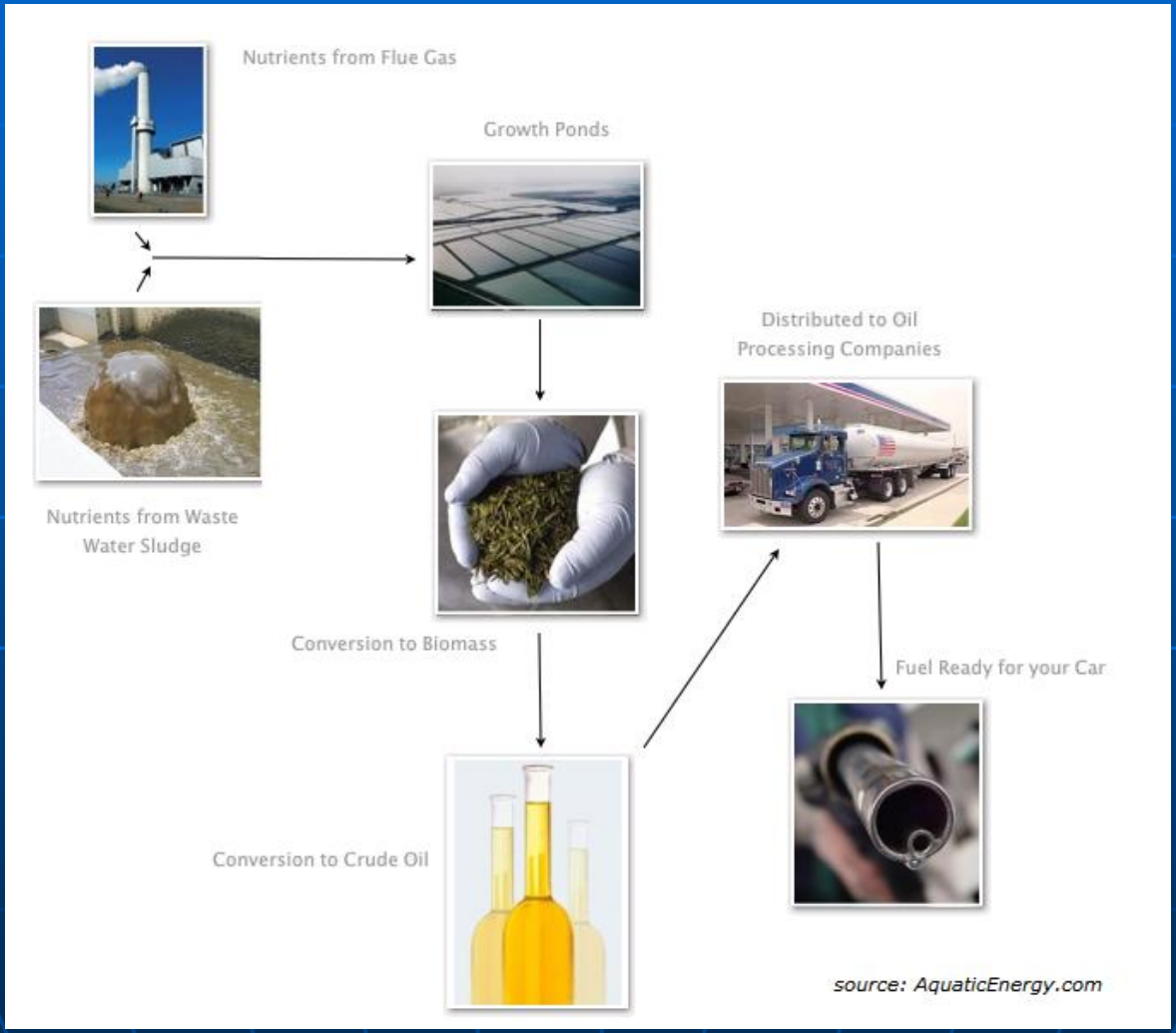
ALGAL BIOMASS PRODUCTION SYSTEMS

System Inputs	Production	Harvesting	Extraction	System Outputs
Algal Species	Ponds & PBRs	Sedimentation	Expeller Press	Biodiesel and Biocrude
Sunlight	Fermentation Systems	Centrifuges	Hexane Solvent	Renewable Diesel, Gasoline
Water Source	Equipment	Filtration	Supercritical CO2	Animal and Fish Feed
CO2 Source	Energy & Labor	Microstraining	Enzymatic Hydrolysis	Livestock Feed Protein Additives
Nutrients npk	System Monitors	Foam Fractionation	Microwave	Organic Fertilizer
Suitable Land	Biometric Analysis	Bio Flocculation	Cavitation	Pharmaceutical Products
Finance	CAPEX Estimates	Electro Flocculation	Ultrasonic Cavitation	Green Plastics, Chemicals
	OPEX Estimates	Shrimp & Fish	Cellular Decompression	Omega 3, 6 and DHA oils
	Target Markets & Strategies			Clean Power Generation

Source: Algae 2020, Emerging Markets Online Consulting Services

Applied Systems – Algae to 2nd Gen Bio-Crude for Petroleum, Aviation Fuels

Process Diagram: Algae Conversion to Biomass, Then Bio-Crude Oil



Source: cited in Algae 2020 study, Emerging Markets Online

3. ALGAE PROJECTS AND CASE STUDIES

SAPPHIRE ENERGY

"Green Crude" and *Renewable Gasoline* for Petrol Refineries, Aviation Fuel

Pond-Based Fuels For Biocrude and Renewable Gasoline

image courtesy of sapphireenergy.com

Sapphire produces "Green Crude" for petrol refineries and aviation fuel and *recently raised $100 Million* from Bill Gates & Rockefeller Foundation

Source citations mentioned in the Algae 2020 study, Emerging Markets Online

ALGAE TO ENERGY - Bio-Crude Oil for *Drop-In Fuels* *and* Animal Feed

Pond-Based Systems for Producing ***Biocrude Oil for Drop-In Fuels*** and ***Animal Feed***

ALGAE to ENERGY™

www.algae-to-energy.com

Algae-to-Energy's production system – four key components:

1) Deep Water Ponds – able to produce higher volumes per acre vs raceway ponds

2) Extraction Systems – at lower costs licensed from Missing Link Technology (MLT)

3) Harvesting Systems – lower cost systems, innovative methods licensed from MLT

4) Products – Biocrude, Drop-In Fuels, Animal Feed, Bio-Polymers and Plastics

Source citations mentioned in Algae 2020 Study, Emerging Markets Online

images courtesy of originoil.com

PETROALGAE - Turning Algae into Green Diesel and Animal Feed

Pond-Based Systems for Producing Renewable Diesel and Animal Feed Proteins

PetroAlgae

PetroAlgae system uses multi-culture system with algae, cyanobacteria & micro-crops

1. Production - PA grows crops in segmented micro-crop growing areas
2. Extraction - PA extracts proteins from the biomass for animal feed
3. Green Diesel – the remaining biomass can be refined into Green-Diesel fuel

Source citations mentioned in Algae 2020 Study, Emerging Markets Online

images courtesy of originoil.com

ALGENOL – Turning Algae into Ethanol

Algenol's Algae to Ethanol Process Diagram

Algenol's Algae Ethanol Project in Mexico project uses seawater and Powergen CO2, and produces clean energy and drinking water

Source citations mentioned in Algae 2020 study, Emerging Markets Online

image courtesy of algenbiofuels.com

ALGAE INVESTMENTS TRENDS

The Key Trends are:

(a) Investment in Companies with *"Proof of Concept"*
With Pilot or Demonstration Phase Projects Ready to *Scale Up*

(b) Investment in Companies Producing *Drop-in Fuels:*
Biocrude for Renewable Diesel, Renewable Gasoline, Aviationf

(c) Investment in Synthetic Biology Projects for Higher Value Markets: Pharma/Nutraceuticals and Specialty *Green Chemicals*

July 2009 :
Exxon and Synthetic Genomics $600 Million

ALGAE FINANCE, INVESTMENT AND GRANTS - SELECTED PROJECTS

Organization	Investment	Project Scope/R&D
Sapphire Energy	$100 million in R&D from Bill Gates' Cascade Investments and Rockefeller Foundation	Algae for biocrude demonstration project in Las Cruces, California, and the production of renewable gasoline
Solazyme	$75 million in R&D finance so far from private investors, Chevron	Algae for biocrude, jet fuel and biodiesel in San Francisco, California
GreenFuels	$92 Million in project finance	Green fuels plans to produce 25,000 tons of algae for Aurantia SA in Spain
UK Carbon Trust	$40 million challenge for algae commercialisation by 2020	In October 2008, UK Carbon trust announced a fund to award up to $40 million in grants for algae projects
Aurora Biofuels	Raised a second round of funding of $20 million from Oak Investment Partners, Gabriel Venture Partners and Noventi	Aurora Biofuels is an algae-to-biodiesel startup with roots at University of California at Berkeley.
Algaelink	Undisclosed amount from KLM airlines, new Chinese ventures	New investments in the Netherlands based algae production manufacturer.
Petrosun	$40 million in funding from China	Formation of Petrosun China, a 50/50 joint venture with Shanghai Jun Ya Yan Technology Development
NREL	$25 million from 1970s to 1990s	Renewed investment in 2008 from Chevron,the US DOE, and several other firms.

source: Algae 2020 - Advanced Biofuels Markets and Commercialization Outlook from Emerging markets Online

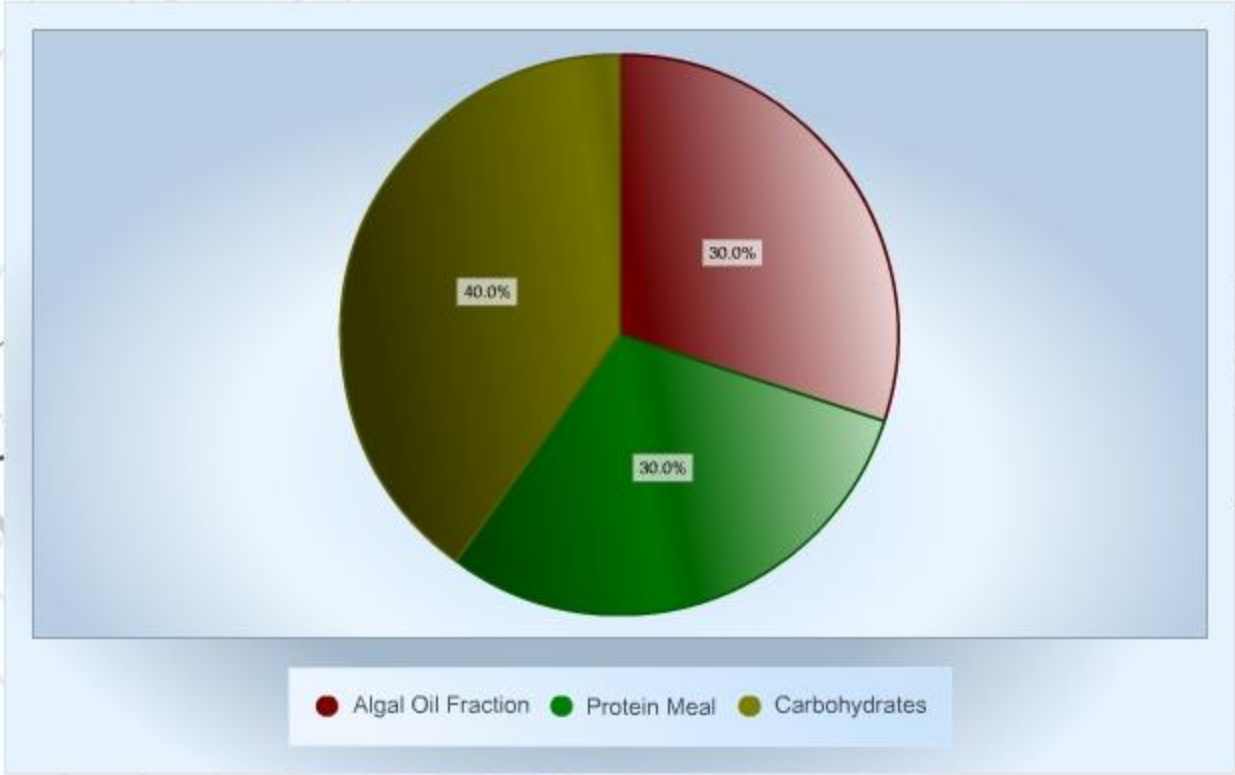
Source citations mentioned in Algae 2020 study, Emerging Markets Online

Algae Market Strategies:

Co-Products Besides Fuel are Critical to Success

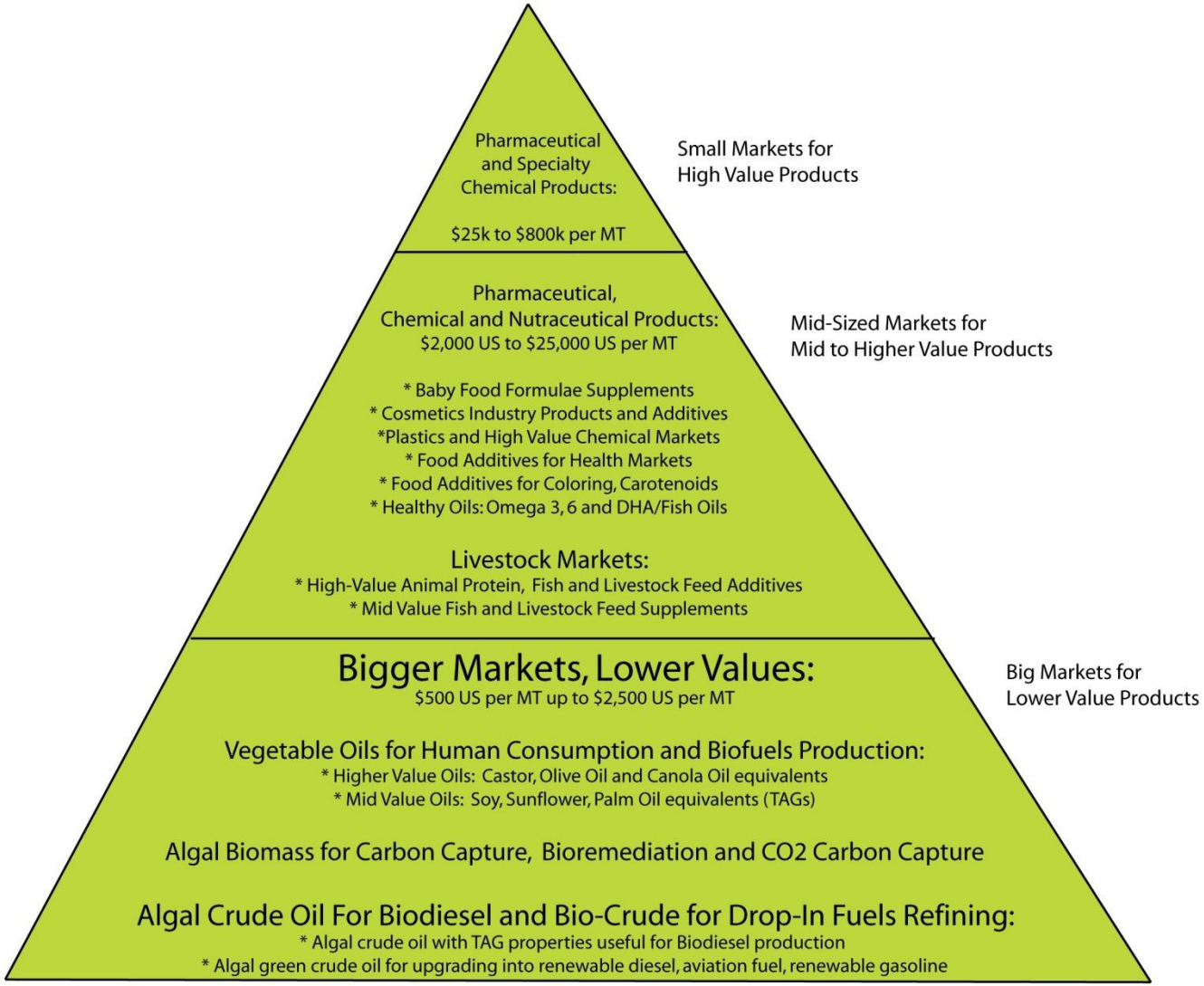
Algal Product and Market Strategies

Algal fractions, products and target markets Algae 2020



Algae products are and will be used to manufacture: fuel, feed, food, fertilizer, plastics and green chemicals. Algae meal will be a protein supplement for aquatic and livestock/poultry feeds.

Algae 2020 Market Value Model



source: Emerging Markets Online Consulting Services; Algae 2020 study

ALGAE COMMERCIALIZATION OUTLOOK

Algae 2020 Market Commercialization Outlook

Sources: Algae 2020 study, Emerging Markets Online Consulting Services

Algae 2020 Study from Emerging Markets Online Consulting Services http://www.emerging-markets.com

Timeline for Commercialization of Algal Biofuels and Products

Phase 1: 2010 For High Value Markets - Phase 2: Fuel Markets Begin in 2011-2012

2009 – Algae R&D Projects Mature, Start of Sales Into Higher-Value Non-Fuel Markets

2010 – Algae Pilot Projects & Demonstration Projects Increase in Scale & Production

2011 – Early Algae Fuel Production Projects Arrive For Defense, Government, CO2

2011– Early-Stage C02 Capture Projects Arrive *(Expensive at first, then cheaper)*

2012-2015: *Scale Up:* Commercial Projects, Production, Markets *(Costs decrease)*

2010-2015: *Phase 1: Small Markets*: Higher-Value Commodity Products: Pharma/Nutraceuticals, Animal Feed Supplements, High Value Oils, Green Polymers: Bio-Degradable Chemicals, Materials, Additives

2012-2020: *Increased Production, Competition Lowers Costs, Market Share Up*

2012-2020: *Phase 2: Big Markets:* Algae Grows as a Commodity for Fuels: Biodiesel, Biocrude, *Drop in Fuels, Ethanol, Aviation Fuels, Animal Feed, Large-Scale Green Chemical Markets, Plastics, Polymers Emerge*

Source ALGAE 2020 STUDY, Emerging Markets Online

Back to the Future? Algae Raceway Ponds from NREL / DOE - 1987

Microalgae Biodiesel Production in Raceway Ponds and Harvesting Ponds – Artist's Conception

Source: NREL-DOE, cited in Algae 2020 study

Algae Farms - A Look at Future Models - PBRs

Solix - 2012 to 2020 Scale Up

Source: Solix Biofuels

For more information

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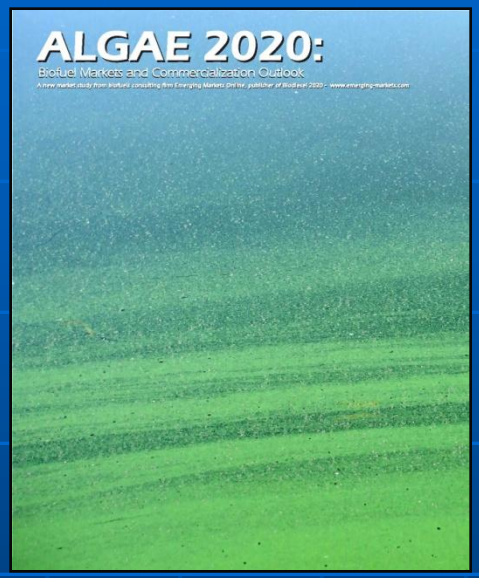

Contact: Will Thurmond

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- ***American Biofuels Council – Chairman of Research***
- ***former Chairman of R&D, National Algae Association***
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