Algae Technology

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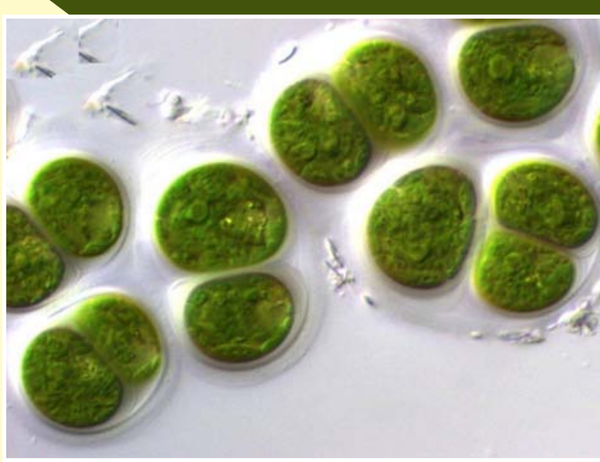
Microalgae



- Carbon management – what's so different?
- Management strategy: recycle (vs. sequestration)
- Carbon recycle via algae
  - Why algae to fuel?
  - Carbon balance
  - Potential
  - Challenges

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Carbon management: what's so different about it?

- Magnitude: % vs. ppm
  - 25 billion tons, of which about 35% comes from power production
- CO_2: chemical 'dead end', toxic
- Acts globally
  - Off-site management
  - Global (and viable) approach

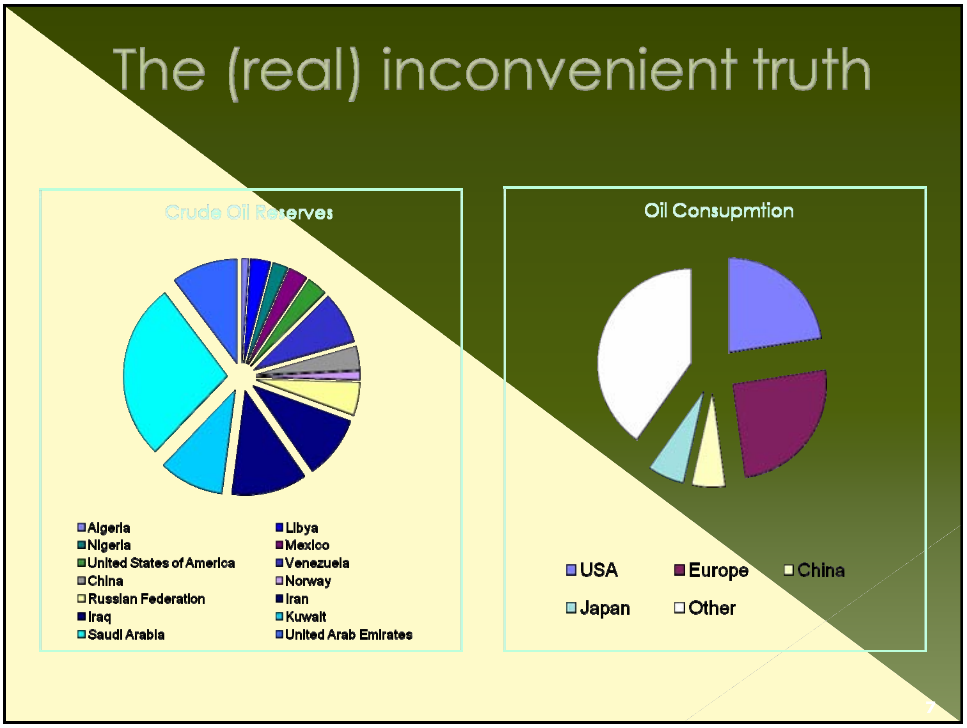
Carbon recycle

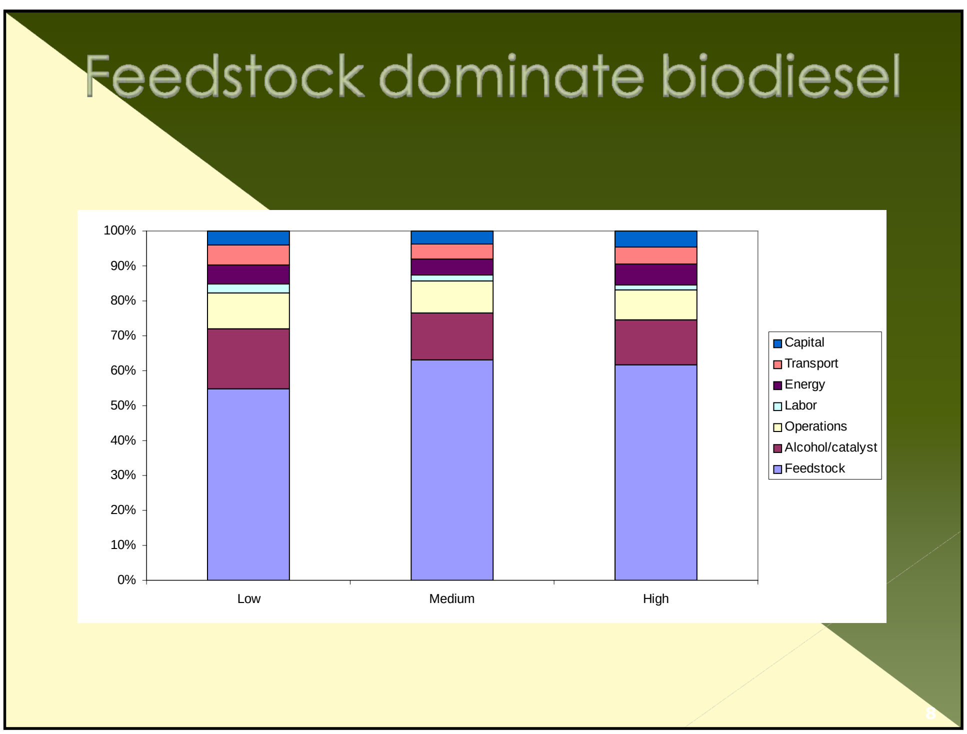
- The fuel/feed connection
- Net carbon balance
- Cost ($/ton)
- Liability
- Impact

Petroleum and algae

- Where did petroleum come from?
  - Ancient layers of organic material…
- What organic material? Dinosaurs?
  - No, mostly algae….

So we ARE driving algae-fuel every day!


The (real) inconvenient truth
Crude Oil Reserves
Algeria
Libya
Nigeria
Mexico
United States of America
Venezuela
China
Norway
Russian Federation
Iran
Iraq
Kuwait
Saudi Arabia
United Arab Emirates
Oil Consupmtion
USA
Europe
China
Japan
Other


Feedstock dominate biodiesel
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Low
Medium
High
Capital
Transport
Energy
Labor
Operations
Alcohol/catalyst
Feedstock

Barriers

- Overall costs
  - With key components: Feedstock and energy
- Fertile land and water ARE limiting factors for large-scale production

As a result, biofuels are projected to be a 'niche' energy market.

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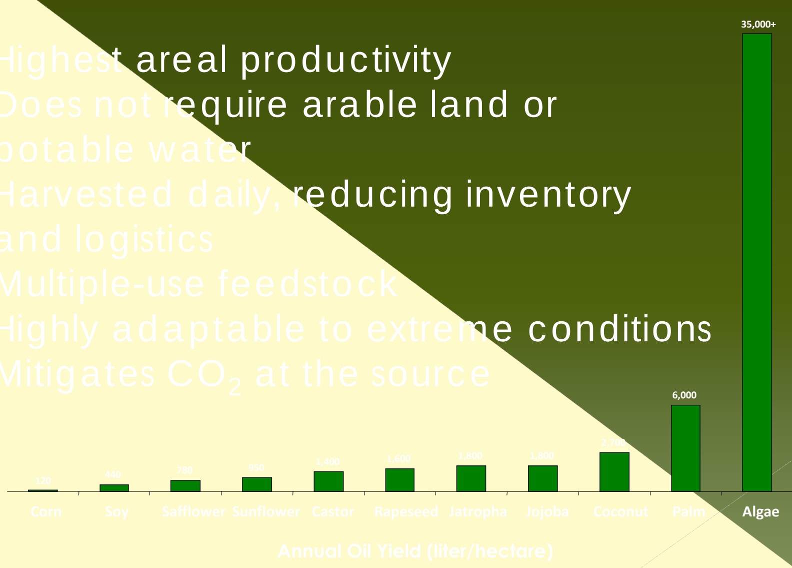
Why microalgae?

- Highest areal productivity
- Does not require arable land or potable water
- Harvested daily, reducing inventory and logistics
- Multiple-use feedstock
- Highly adaptable to extreme conditions
- Mitigates CO_2 at the source



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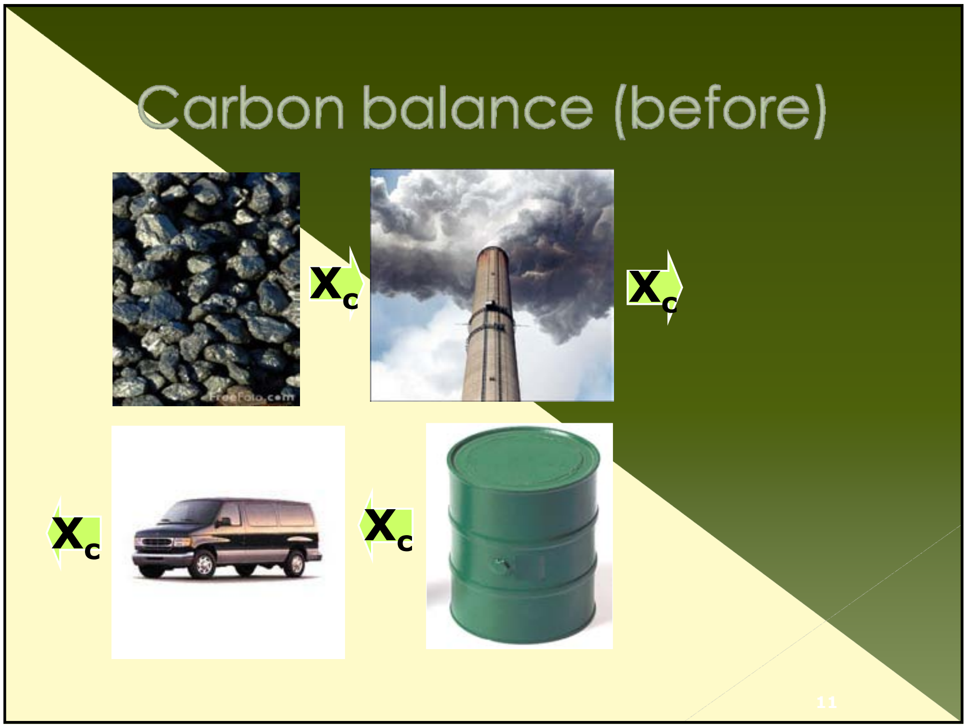
Carbon balance (before)
Xc
Xc
Xc
Xc


Carbon balance (after)
Xc
Xc
Xc
Xc
Xc

Net CO_2 mitigation

- Gas handling
  - From the source to the algae farm
- Algae farming
  - Growing and harvesting the algal culture
- Dewatering and washing
  - Separating algae from external water and salts
- Oil extraction
  - From a wet algal slurry

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Net CO_2 mitigation

Calculation Methodology

Biological CO_2 Uptake = Biomass Productivity x Carbon Content x 4

Parasitic CO_2 = Σ (Energy Usage, Nutrients & Chemicals, Construction & Materials, and Labor)

Net CO_2 Mitigation = (Biological CO2 Uptake) – (Parasitic CO_2)

Cost

- 1 ton of algae = 2 tons of CO_2
- 1 ton of algae (fuel and feed) = $1,000
- Value of CO_2 credit = $50/ton algae*

CO_2 revenues are insignificant for the business

› * Assuming credit value $25/ton CO_2

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Business Model: Just sit there and be beautiful

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Microalgae: Impact

If algae is used to mitigate 20% of US power generation CO_2 emission:

- $5x10^8$ tons per year of CO_2 emissions would be recycled
- $2.8x10^6$ bbl/d biodiesel would be produced
- **20%** of the US imported fuels would be produced **domestically** and **profitably**
- Requires $18x10^6$ hectares of non-arable land
  - Size less than 50% of domestic corn fields

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Is it a Proven Technology?

- Tested at a 1,000MW plant owned by Arizona Public Service (APS)
- Performance to be analyzed by the US National Energy Technology Lab
- External class I cost estimates

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From the lab to the roof

- Performance proven at MIT's 20 MW power plant
- Successful operation in real world conditions
- Performance independently validated
  - 86% of NO_x removed (24 hr average)
  - Up to 82% of CO_2 removed (daytime average)

2004: MIT, Cambridge, MA
35MW (Oil & Gas)

Field Rollout

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2005-2007: APS Redhawk, AZ

1,060MW (Gas)

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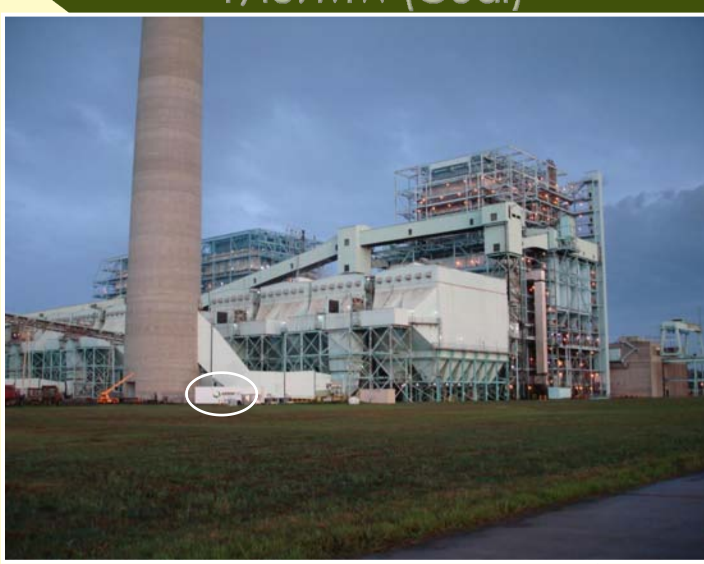
2006: NRG Dunkirk, NY
600MW (Coal)

2007: NRG Big Cajun II, LA
1,489MW (Coal)



2007: NRG Big Cajun II, LA

1,489MW (Coal)

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2007: Sunflower Electric, KZ

360MW (Coal)

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2007: Ashkelon, Israel

2,000MW (coal)

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2007: Hazelwood Station, Australia

1,600MW (Coal)

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Example: Mejilones, Chile

Area potential: over 300 km2; production potential: 420M liter biodiesel per year, and 200M liter ethanol per year

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Challenges

- Scalability
- Viability
- Algal strain selection

So, what do we offer?

- A viable CO_2 mitigation approach

“Coal is—and will remain—the premier domestic fuel source for power generation purposes in the United States for the foreseeable future. It is incumbent on us not only to build new coal plants using technology which limits or eliminates greenhouse gas emissions but to find the best way to retrofit the country’s existing fleet of coal plants for post-combustion carbon capture.”

David Crane, NRG President and CEO

Thank You !

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