

Algae As An Enabling Technology For Carbon Recycling

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Algae has been cultivated and harvested by man since recorded history. Its uses as a food or for fertilizer are well documented. Over the last ten years it has re-emerged as candidate feedstock for production of biomass derived fuels. There are serious challenges to the proposition that algae will compete with the existing portfolio of energy crops. Further, the current national algae roadmap process is dramatically flawed because it does not consider the full inventory of risks which the algae value chain must confront. Algae's carbon uptake efficiency can be mechanized into a system that recycles the CO₂ from fossil fuel combustion. Today, carbon recycling is driving significant innovation and engineering progress because carbon regulations are viewed as inevitable. Within sustainability perspective it is algae's versatility to serve multiple applications that is essential to a functional value proposition.

Key Points

- The Algae Value Chain Will Support Sustainability Goals
- Algae Enables CO₂ Management Which Has Driven Its Accelerated Commercialization
- Algae Applications In BioFuels Face Challenges
- Risks Are Being Misrepresented

Algae Plays a Special Role in the Environment



Produces 50% of Earth's oxygen

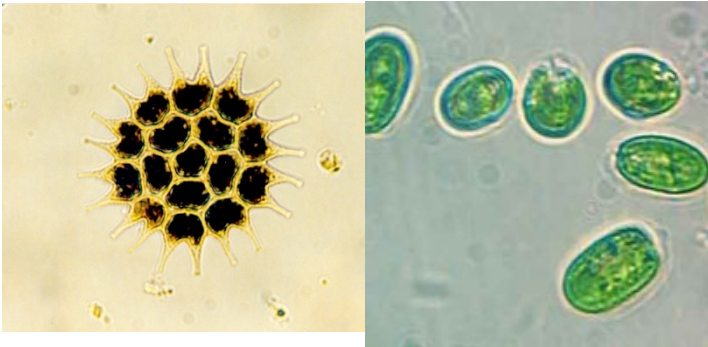
Algae and cyanobacteria very diverse

Microscopic to giant kelp

Efficient, rapid growth, can double biomass in a day

Few species have been studied for biofuel potential

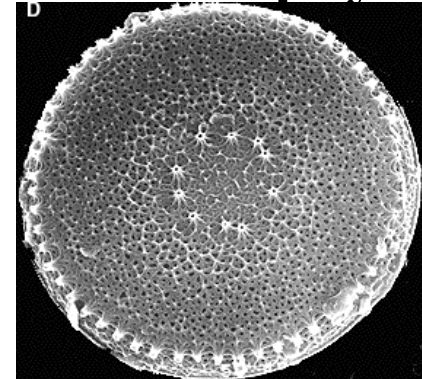
Chlorophyceae



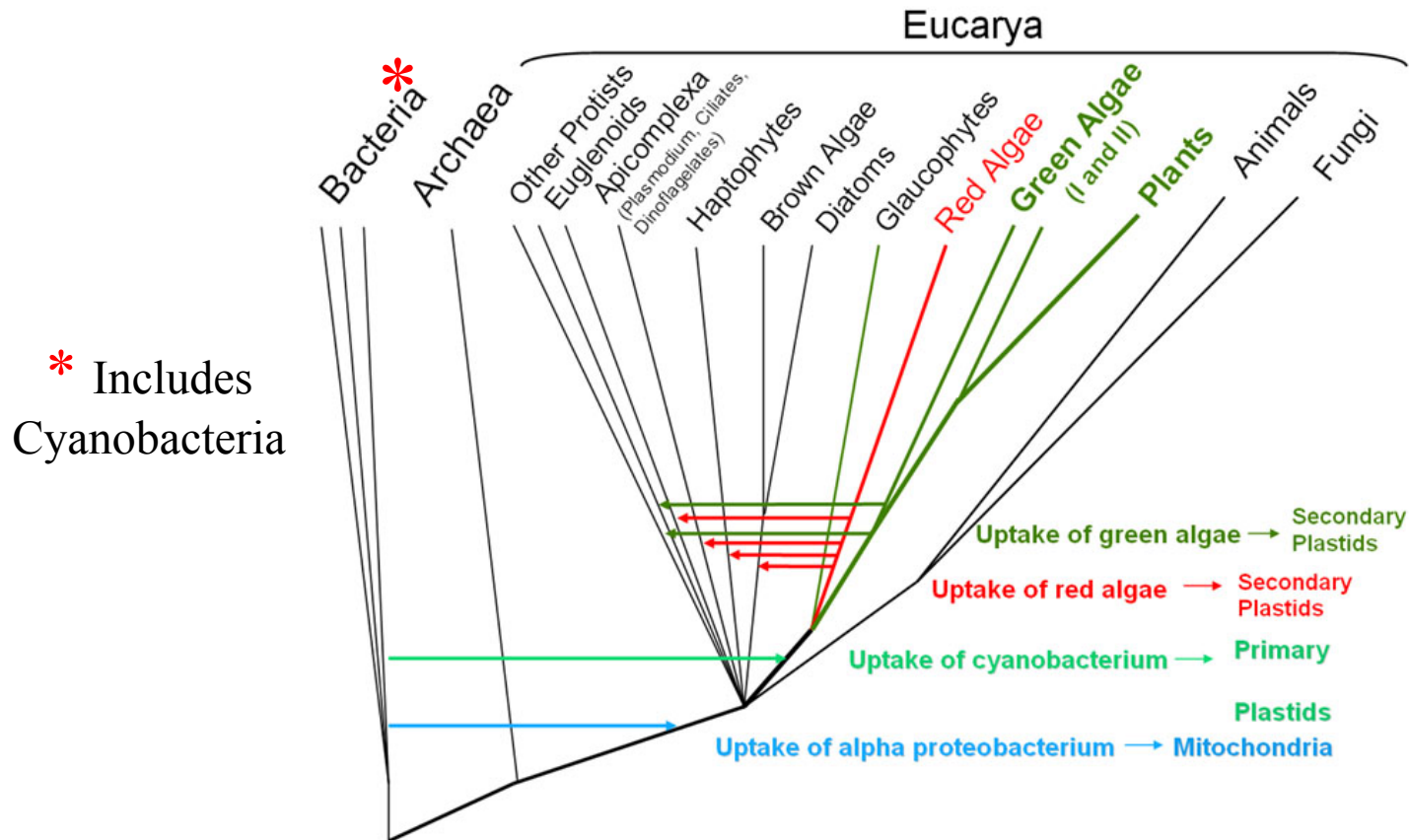
Dinophyceae



Bacillariophyceae

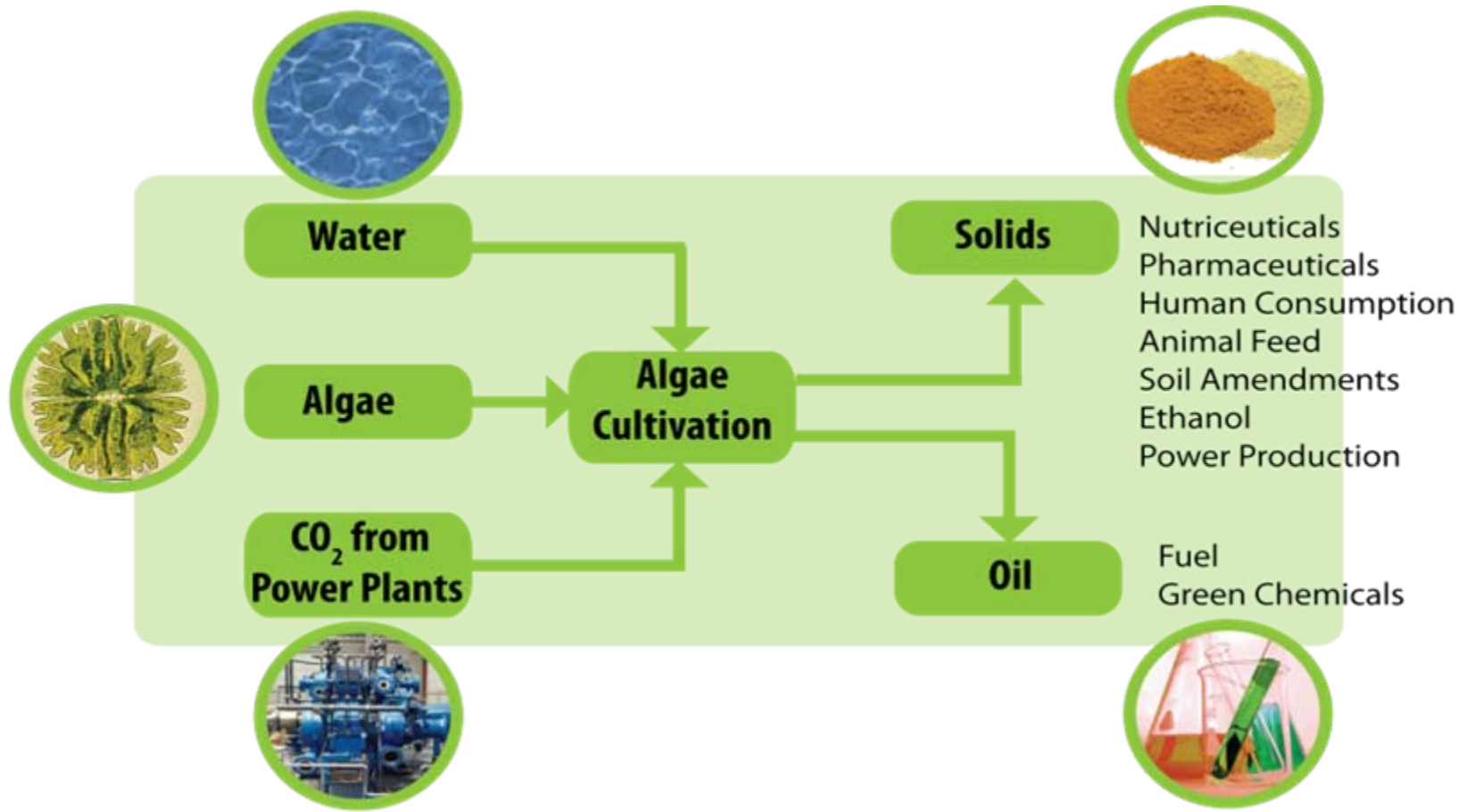


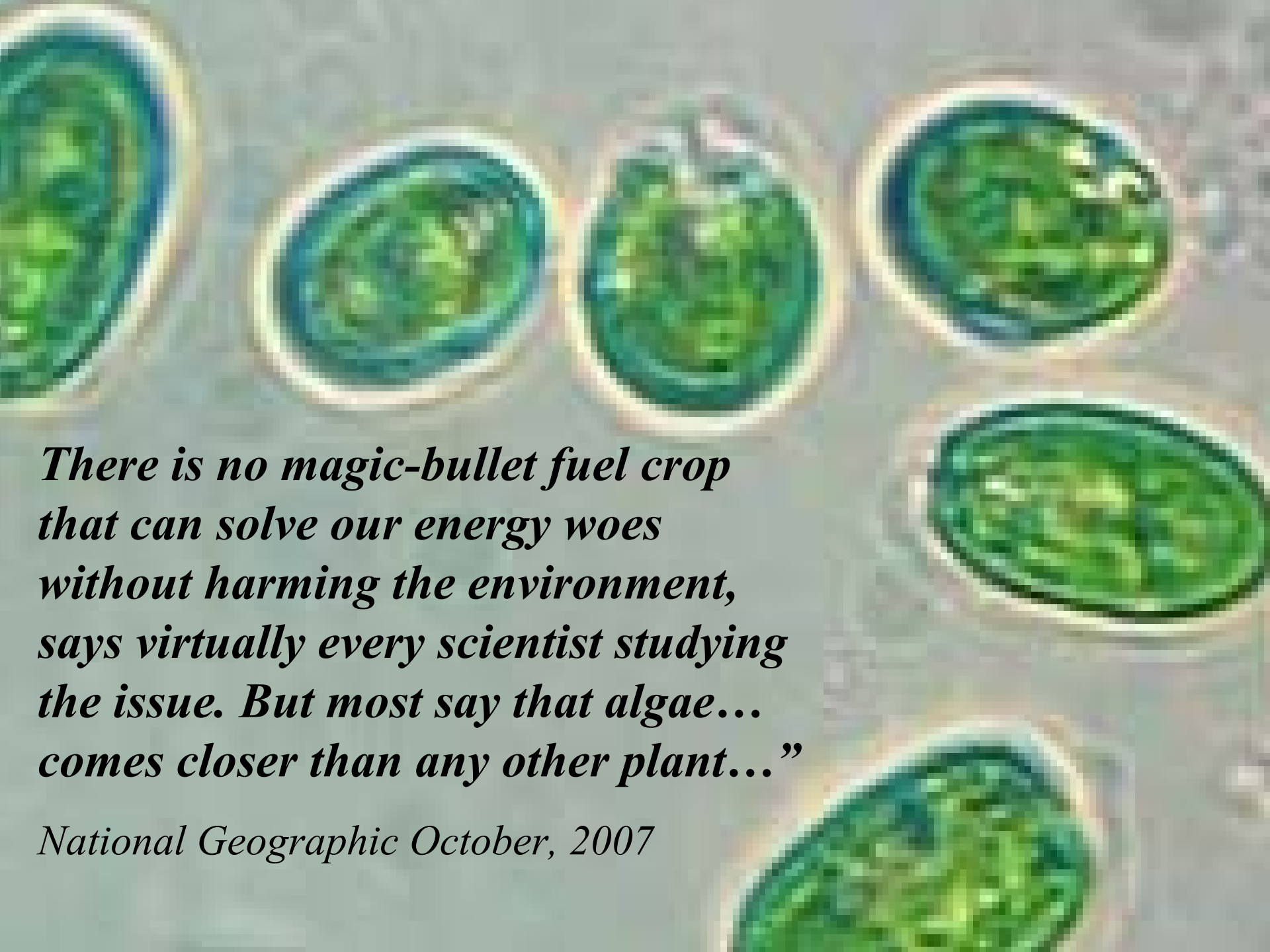
Evolutionary relationship of photosynthetic bacteria, algae, and higher plants



Chloroplasts in algae and all higher plants were originally derived by capture of a photosynthetic bacterium by a eukaryotic organism. DNA in chloroplasts is similar to bacterial DNA

Algae Can Enable Advances In Fuels, Economic Development, Carbon Management and Energy Security

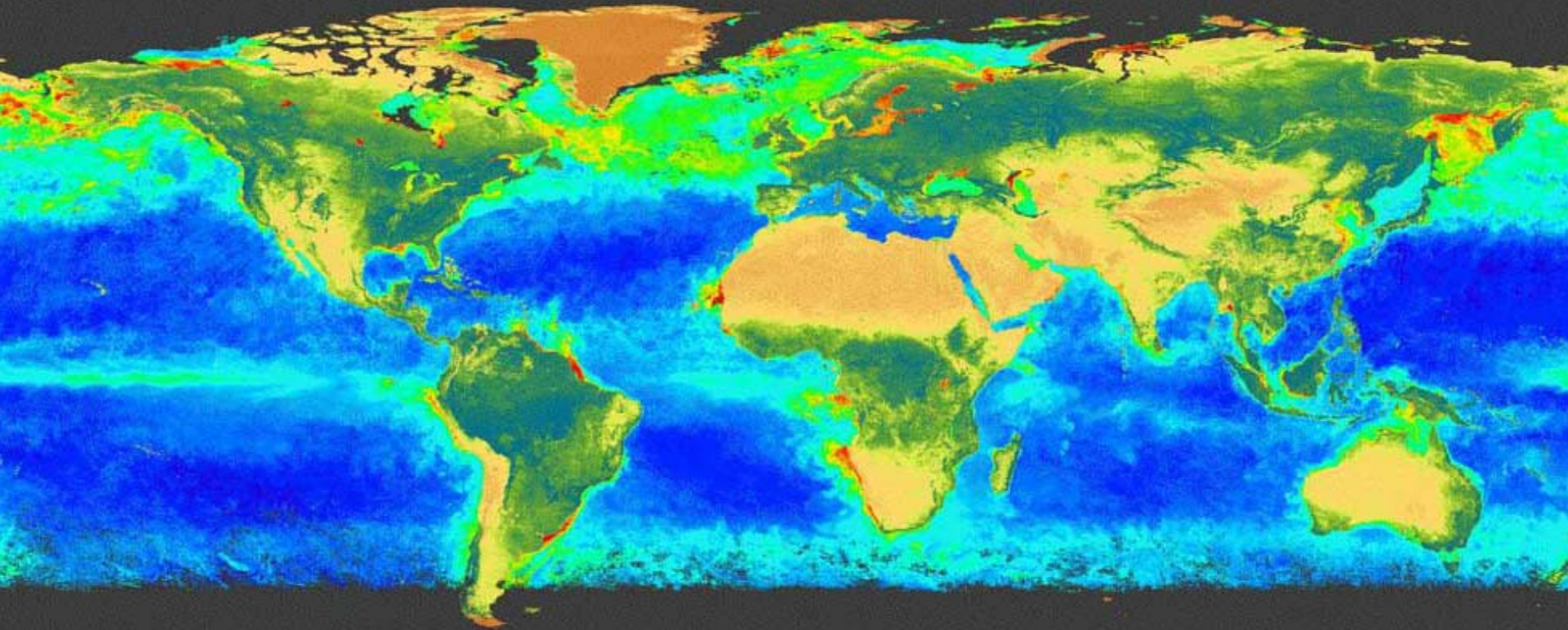


A microscopic view of several green, oval-shaped algae cells. The cells are arranged in a loose pattern, with some overlapping. Each cell has a distinct green interior and a thin, light-colored outer boundary. The background is a light, slightly textured grey.

There is no magic-bullet fuel crop that can solve our energy woes without harming the environment, says virtually every scientist studying the issue. But most say that algae... comes closer than any other plant..."

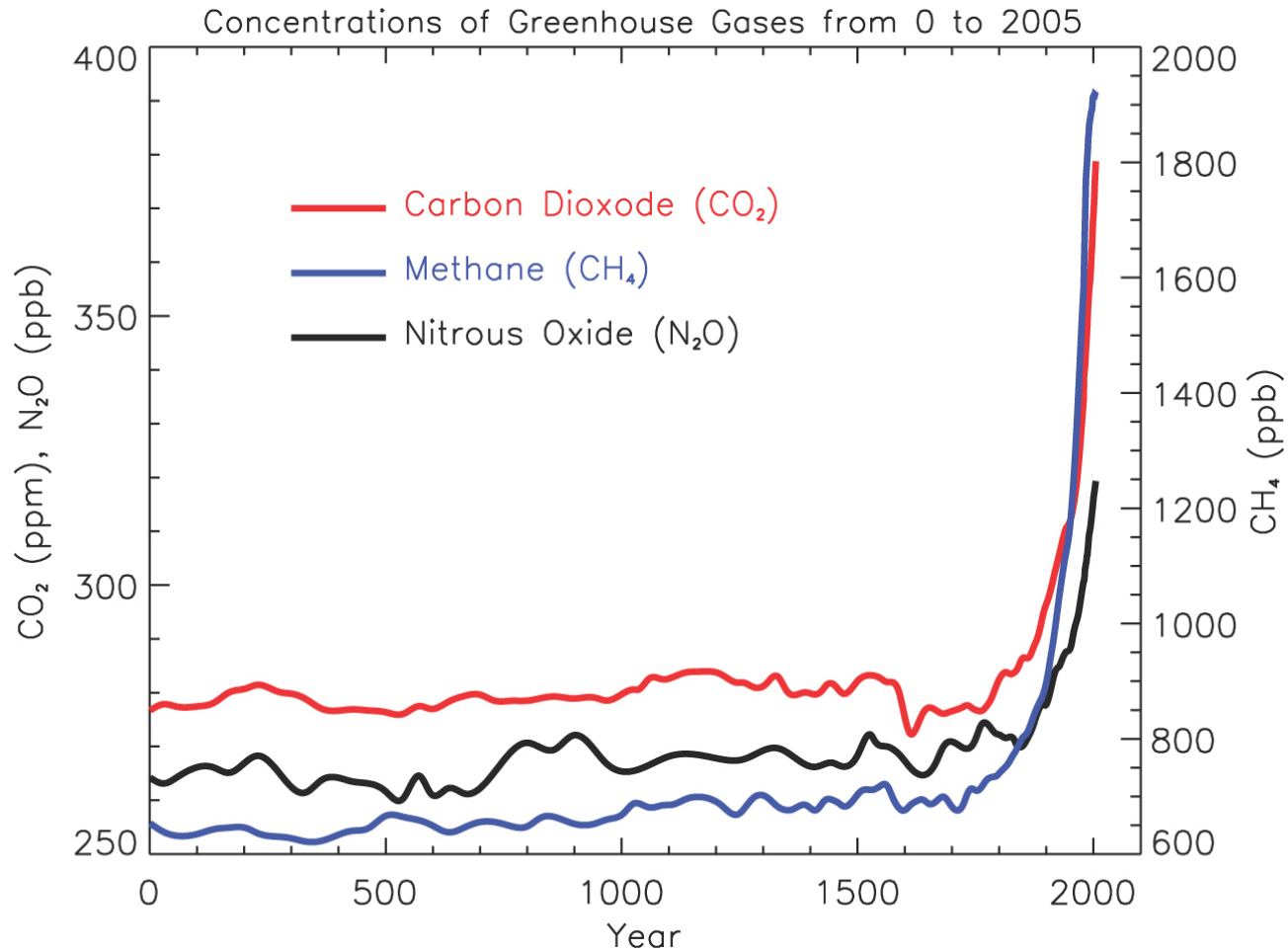
National Geographic October, 2007

Global Biosphere from NASA SeaWiFS



**Algae produce 50% of O₂ but are less than
1% of total plant biomass on Earth**
**Efficient: they do not waste energy creating
huge mass of cellulose!**

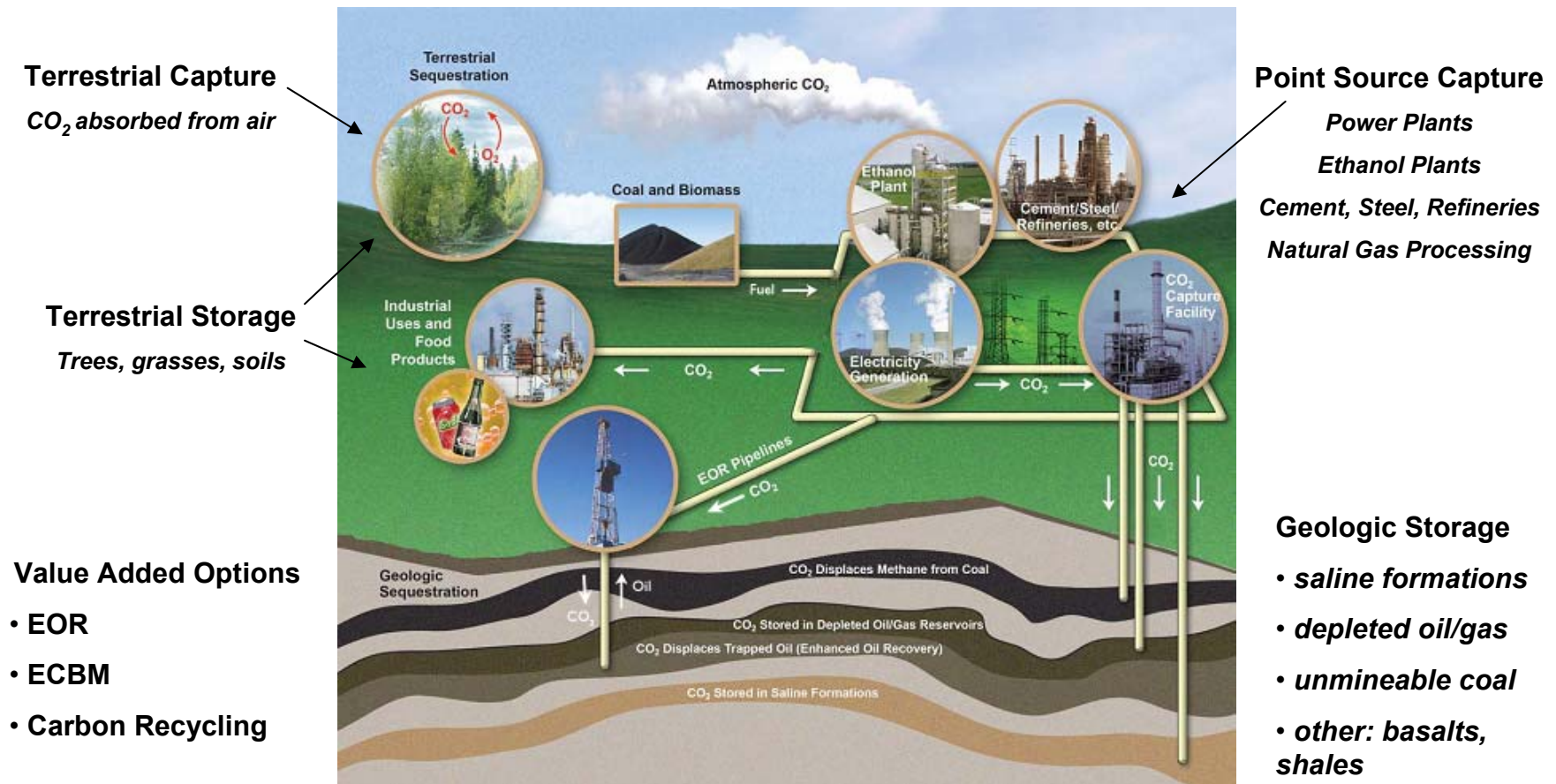
Atmospheric GHG concentrations



Intergovernmental Panel on Climate Change Working Group I. 2007. Climate Change 2007: The Physical Science Basis. Cambridge University Press. Frequently Asked Questions 2.1. Figure 1. Page 135.

What is Carbon Sequestration?

Capture and storage of CO₂ and other Greenhouse Gases that would otherwise be emitted to the atmosphere



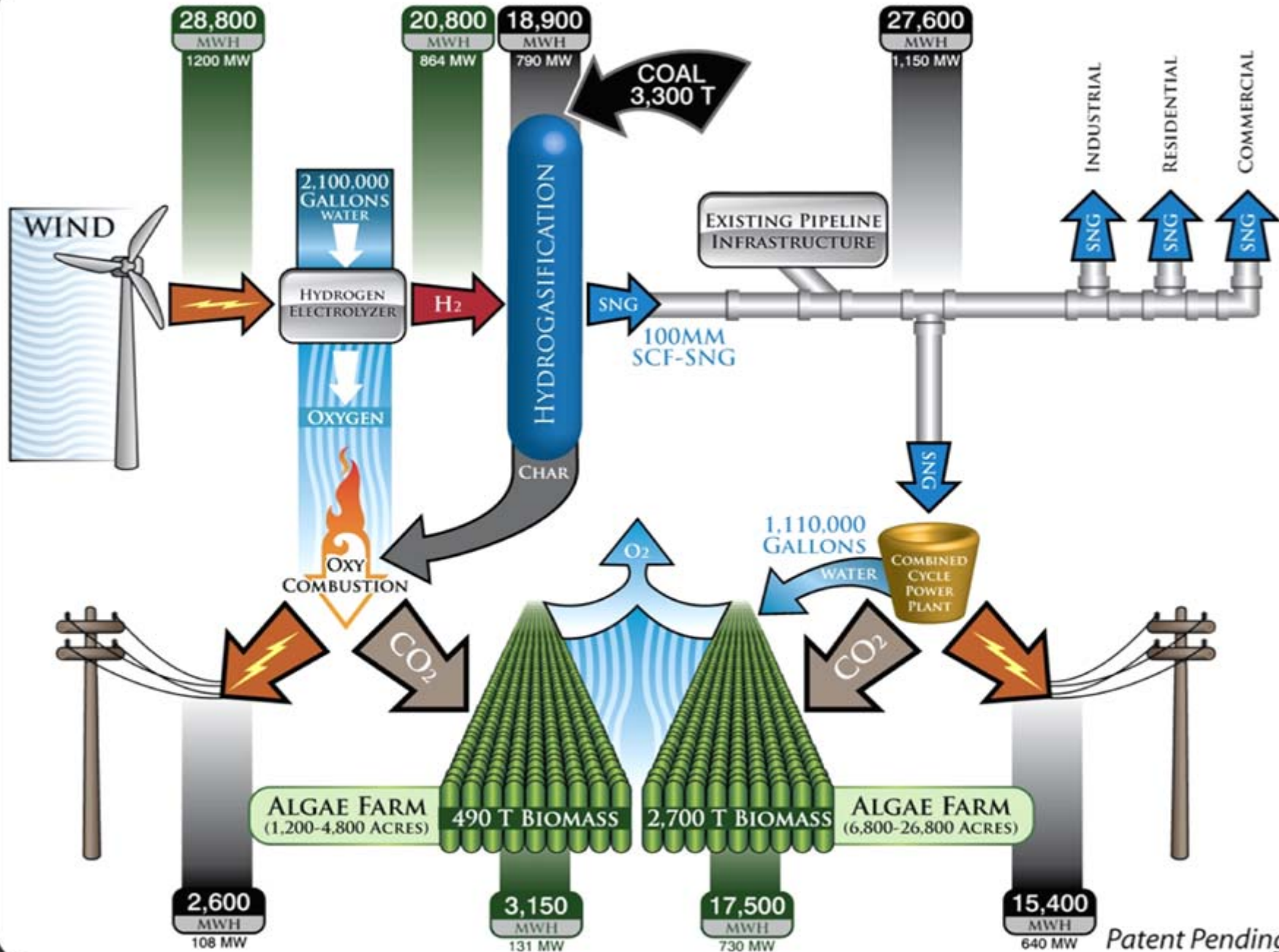
How Much CO₂ Are We Talking About?

- 1 million metric tons of CO₂:
 - Every year would fill a volume of 32 million cubic feet
 - *Close to the volume of the Empire State Building*
- U.S. emits roughly 6 billion tons (gigatons) of CO₂ per year
 - Under an EIA reference case scenario cumulative CO₂ emissions 2004-2100 are expected to be 1 trillion tons
 - *Enough to fill Lake Erie with liquid CO₂ almost twice*



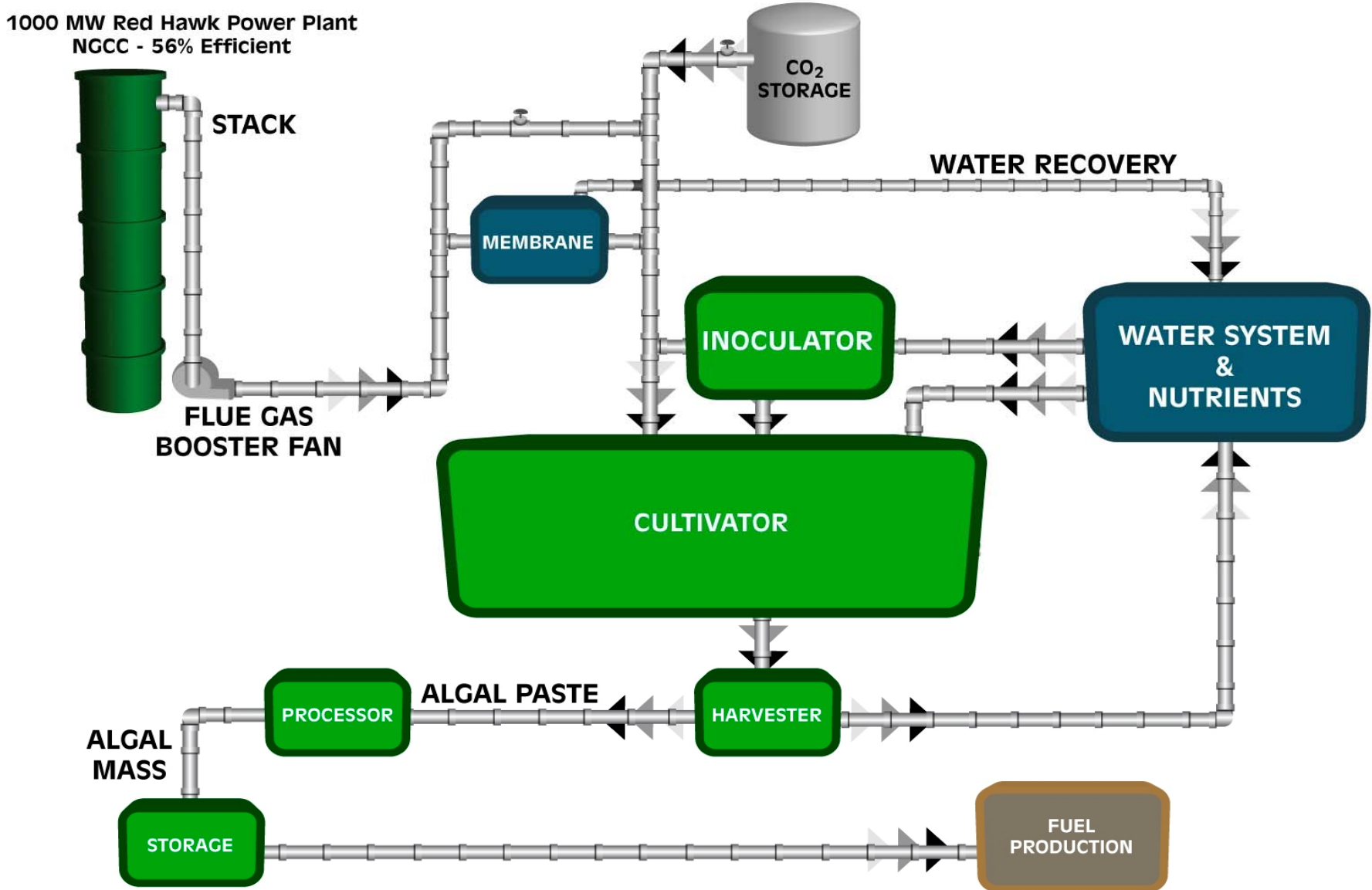
Fossil Fuel Combustion CO2 Emission Management

- Operationally Non-Impacting To Power Production
 - Scalable To Handle Significant Mass Flow
 - Developed By Utility Led Team
 - Life Cycle Risks/Costs Engineered
 - Resource Stewardship
 - CO2 Liability Triggers National Action
- = Arizona Public Service / National Energy Technology Laboratory (NETL) Project



Arizona Public Service – Algae Engineering Leader

CO₂ Recycling Process



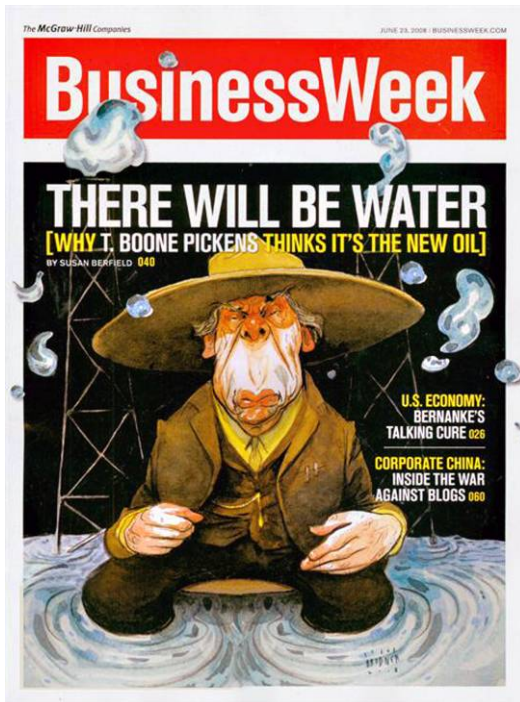
Challenges

- Financing For Scale Up
- Subsidies For Feedstocks
- Fuel Processing & Qualification
- Cellulosic Momentum
- Intellectual Property Traps

Water

“Whiskey is for drinking, water is for fighting.”

– *Mark Twain*



The economics of water utilization are likely to change significantly in the near future.

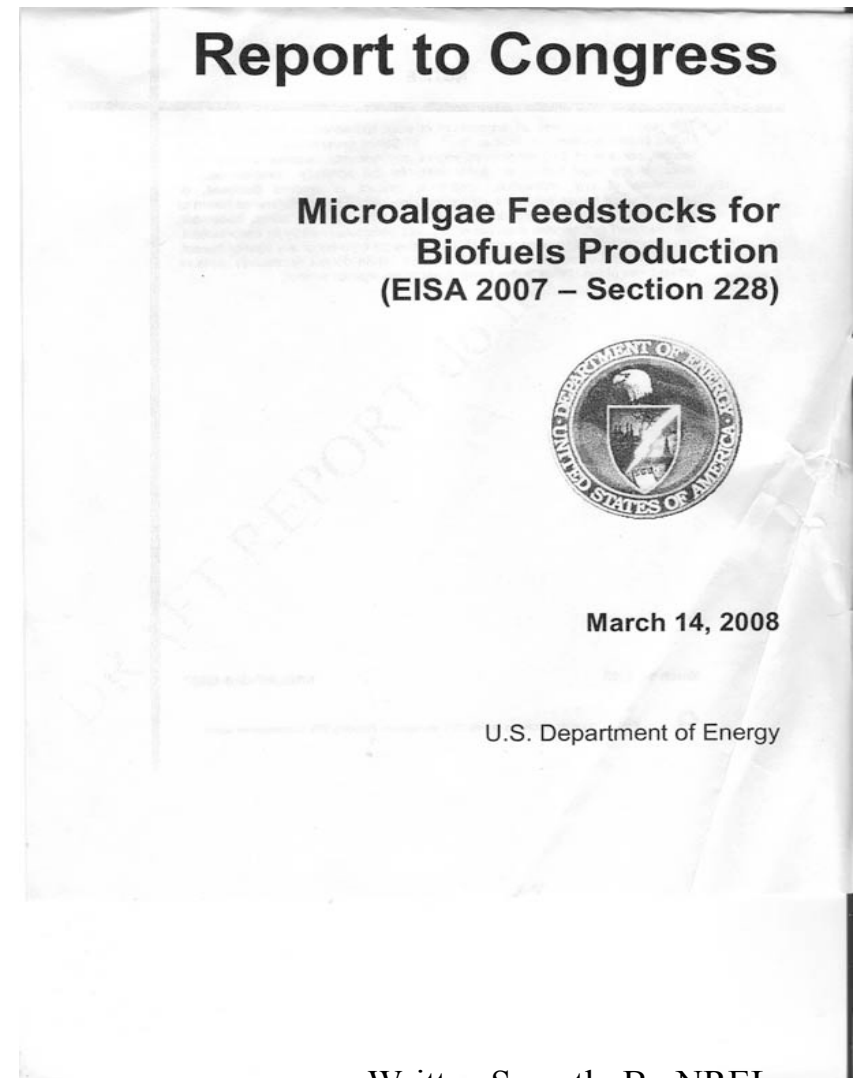
Risks

- Congress Is Misinformed
- National Algae Roadmap Controlled By National Renewable Energy Lab (MRI)
- Genetically Modified Algae (Transgenic)
- Sustainability Goals Sidelined
- Credibility Depleted

“ A greater understanding of the underlying principles is necessary before commercial scale-up Is feasible”

“ A significant amount of research and a number of breakthroughs are needed to make algal biofuels a commercial reality”

- Scale-up Unproven
- Economic Feasibility Unknown
- NREL’s BioProcessing Pilot Plant has a critical role to play



Written Secretly By NREL

- FOIA Release
- 2007 – 2012
- \$50M Value
- Scope: Entire Value Chain
- Intellectual Property Goals
- Several Other CRADAs

1. Reestablish NREL's Primacy In National Algal R&D
2. Provide Chevron A Strong Position In Algae To Jet Fuel
3. NREL Apply Its Access
4. MRI Monetizes IP



National Renewable Energy Laboratory

National Renewable Energy Laboratory

Cooperative Research and Development Agreement

STEVENSON-WYDLER (15 USC 3710)
 COOPERATIVE RESEARCH AND DEVELOPMENT AGREEMENT
 (hereinafter "CRADA") No. CRD-07-208

between

Midwest Research Institute, Operator of
 The National Renewable Energy Laboratory
 under its U.S. Department of Energy Contract No. DE-AC36-99GO10337,
 1617 Cole Blvd., Golden, CO 80401 (hereinafter "Contractor")

and

Chevron Technology Ventures, a division of Chevron U.S.A., Inc.
 3901 Briarpark Drive
 Houston, TX 77042
 (hereinafter referred to as the "Participant")

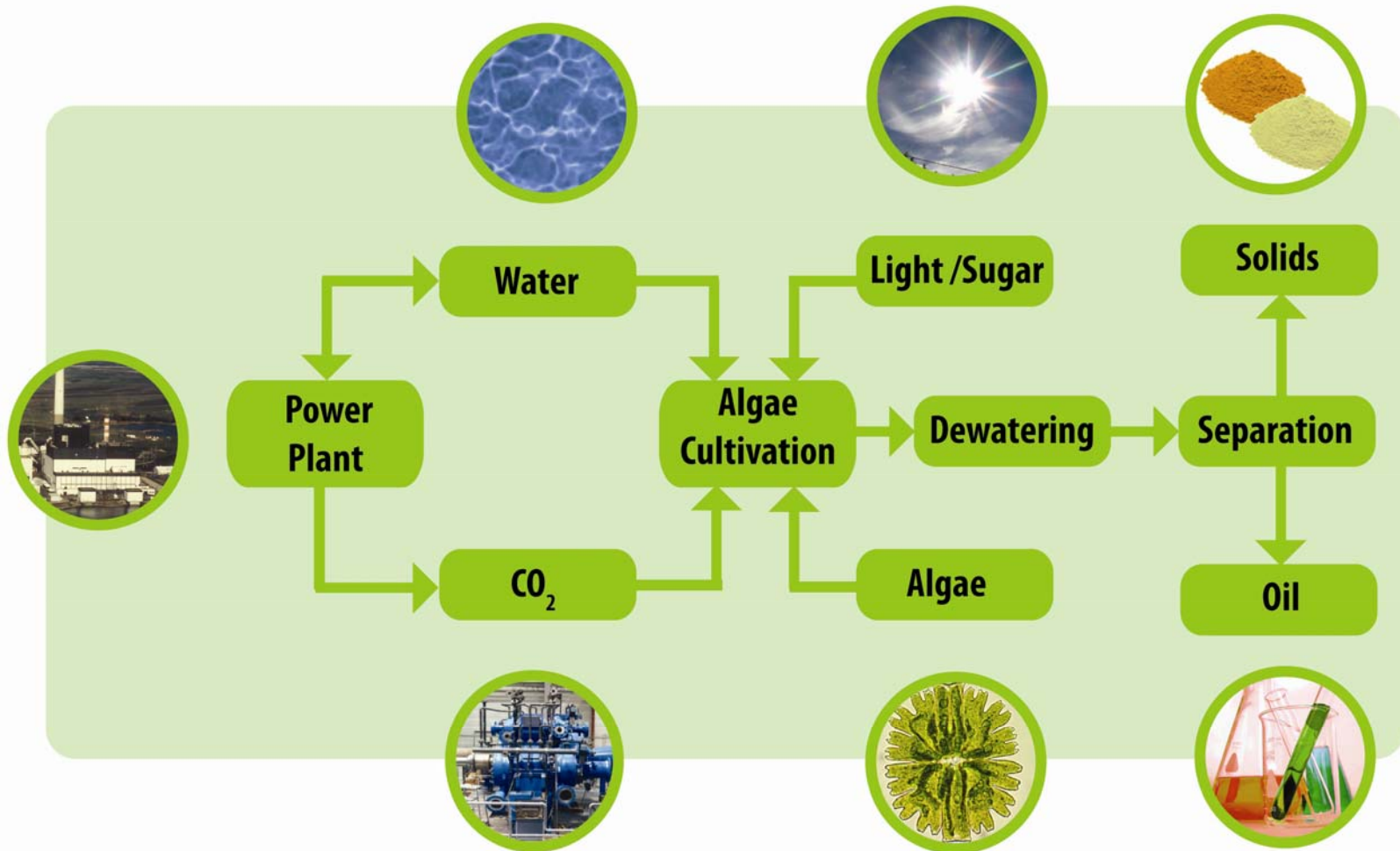
The Participant and the National Renewable Energy Laboratory are hereinafter jointly referred to as the "Parties" and individually as a "Party".

Natural Choices vs. GMO

- Nature Offers A Broad Array Of Algae To Characterize & Use
- The Genetic Modification Of Algae Creates Risks To:
 - Ecosystem
 - Public Health
 - Public Acceptance
 - Regulatory Acceptance



Algae Value Chain Presents Many Opportunities



Construction of Shenhua DCL Commercial Plant

2002



2003



2004




2008



2006





Presentation Material Credits:
Dr. B.G. Mitchell, Scripps
DOE-NETL & DOE-NREL
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Mr. D. Haberman, IF, LLC

**Spirulina algae, photo courtesy
Amha Belay, Earthrise**

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Thank You !



Measuring The Desert For Algae Cultivation