

Recent developments on microalgae cultivation in Brazil to produce biofuels

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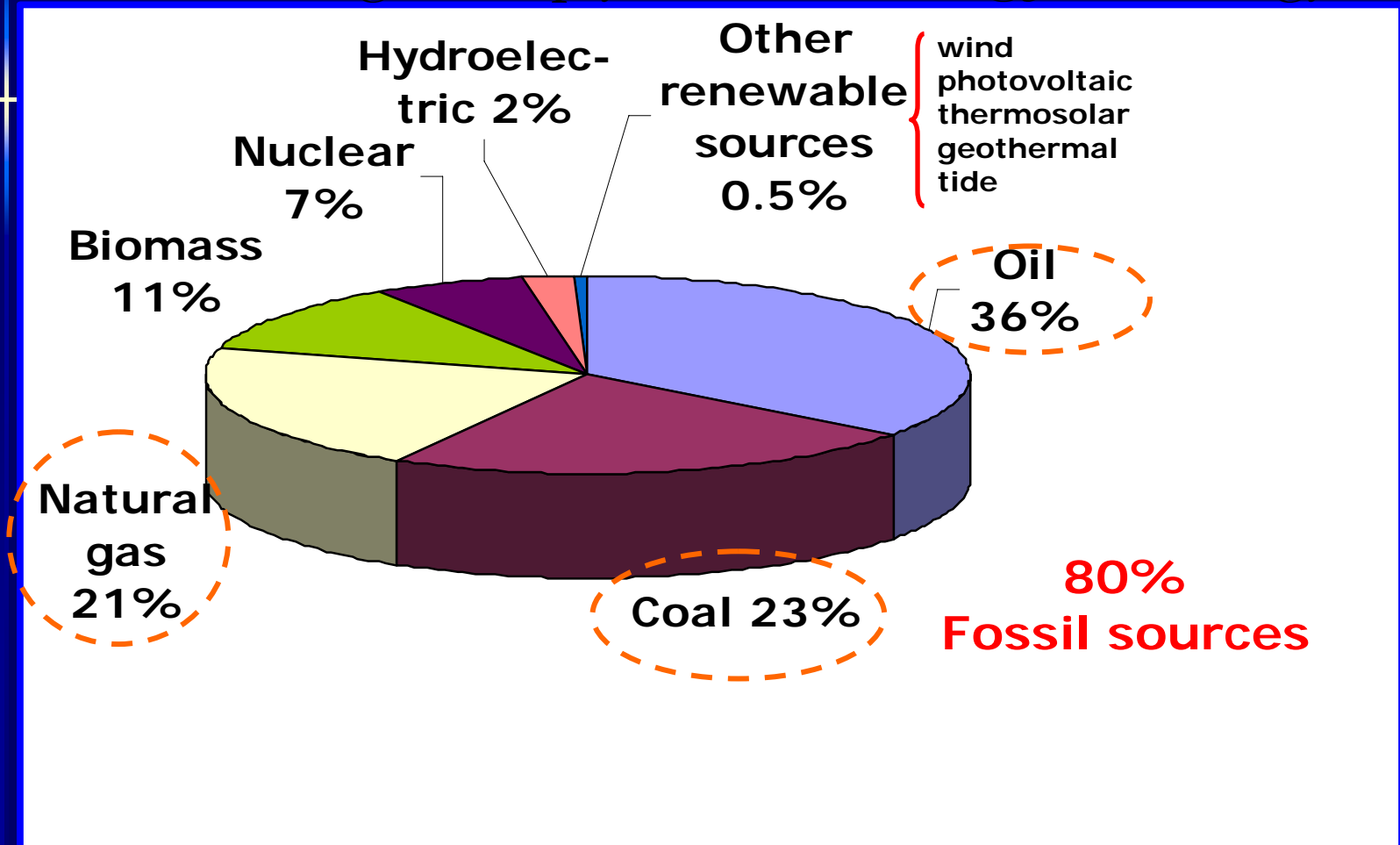
**Aquatic Biomass: Sustainable
Bioenergy from Algae?**

Berlin, Germany
October 2nd, 2009



World matrix of energy

Increasing 2.3% p.y. – a world *hungry* for energy



Source: MAPA (2006)

World supply of energy

Country	Primary energy supply (TEP)	Renewable energy (TEP)	Renewable energy (%)
Argentina	57.6	6.2	10.8
Australia	115.6	6.6	5.7
Brazil	185.1	82.7	44.7
France	265.6	18.6	7.0
Germany	351.1	9.2	2.6
United Kingdom	235.2	2.5	1.1
USA	2,281.4	99.1	4.3
World	10,038.3	1,331.9	13.3

Source: Adaptated from MAPA (2005) and EPE/MME (2006) – <http://www.epe.gov.br>

80 large hydroelectric and
47 small ones

Brazilian energy matrix is one of the “cleanest” in the world. Data from *Balanço Energético Nacional* (BEN-2007), released on May 08, 2008, indicate that sugar cane (16% of the energy matrix) overcome hydroelectric energy (14.7% of the energy matrix) as a source of energy in Brazil, below oil and its derivatives only (37.8% of the Brazilian energy matrix).

Petroleum world demand

Projections for world oil prices (barrel)

- 2009: US\$ 61.00
- 2015: US\$ 110.00
- 2030: US\$ 130.00
- World oil market by 2030: \approx US\$ 400 trillion
- A significant part of this amount will be replaced with biofuels

International Energy Outlook

2009

May 2009

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U.S. Department of Energy
Washington, DC 20585

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PARADIGM SHIFT

**RETHINK OUR ENERGY MATRIX AND
FEEDSTOCK SOURCES**



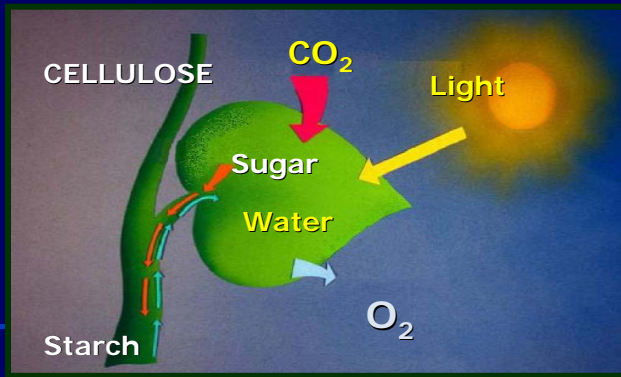
**SEARCH FOR ALTERNATIVE AND RENEWABLE
RESOURCES LESS POLLUTANT**



DIVERSIFY THE USE OF SUCH RESOURCES



**REDUCE OUR DEPENDENCY ON FOSSIL
SOURCES**



Why using biomass to replace fossil sources of energy?

Biomass

- 👉 *Organic matter* from *vegetal* or *animal sources*
- 👉 Origin direct or indirect from *photosynthesis*
- 👉 *Renewable*

Plant biomass

- 👉 Natural biomass
- 👉 Food biomass
- 👉 Residual biomass
- 👉 Biomass from *energetic* cultivation





Advantages of Brazil to use biomass

- One of the greatest biomass potential on Earth
- Large areas still available to energy agriculture
- Intense solar radiation
- Diversity of climate
- Luxuriant biodiversity
- Abundance of water
- Pioneering role in large scale biofuel production - ethanol
- High creation of jobs
- Resources from international carbon market



***Sugarcane is
a history of
great success
in Brazil***





LAND OCCUPATION AND AVAILABLE AREA "WITHOUT IMPACT"

Sugarcane plantation in center-south region of Brazil

Cultivars/land occupation		Area (million ha)
Cane	(9.5%)	6
Soya		20
Corn		13
Planted wood		6.6
Pasture		150
Available area without impact		100-150
Cultivated area		63
Brazil – total area		855

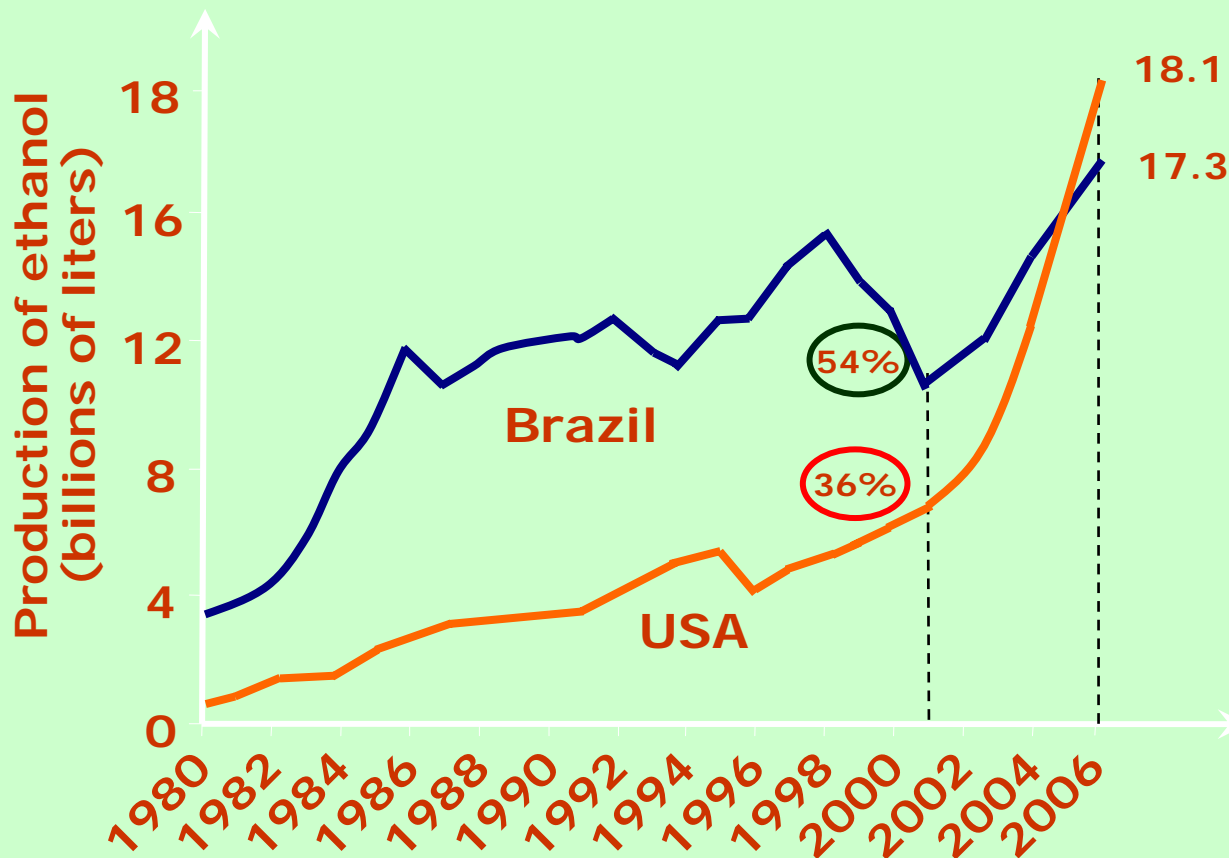


- It would be possible to substitute, today, the world demand of gasoline (4×10^9 liters daily);
- It would be avoided net CO_2 emissions of 1.8×10^9 to 2.7×10^9 ton/year.

Source: Cortez (2006)



Brazilian and American production of ethanol



Production 2007:
 (billions of litres)
 Brazil: 21.90
 USA: 24.55

Brazil: 363 distilleries +
 86 in construction

USA: 101 distilleries + 30
 new units (biorefinery)

Sources: Fairbanks (2005); MAPA (2007); Gazeta Mercantil (mar 2007); *World Ethanol & Biofuel Report* (Jan 2007) e MAPA (2008)

The use of bioethanol in Brazil

- Currently, 97% of the cars sold in Brazil are flex fuel: engines work with both gasoline and bioethanol
- Volkswagen created the 1st flex fuel engine in Brazil in 2003
- In addition, gasoline has a blend of 25% bioethanol (and bioethanol has 15% gasoline)
- The consumption of ethanol is greater than gasoline in Brazil



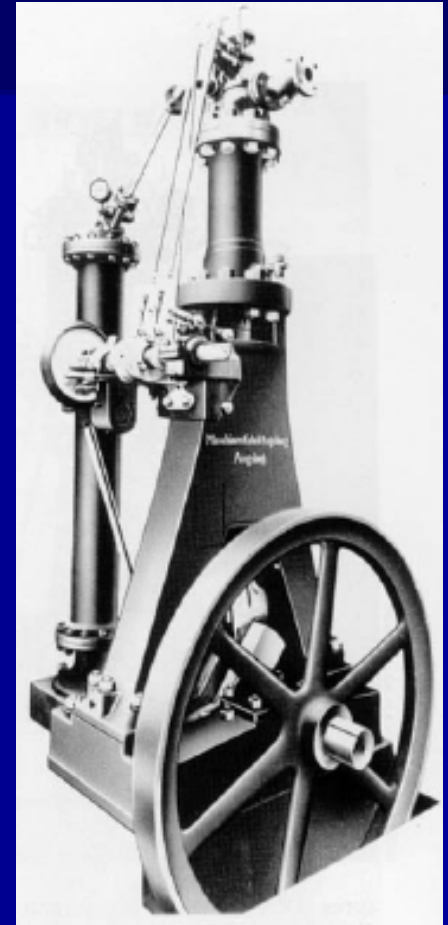
Plants as biomass sources for biodiesel



Rudolf Diesel (1858-1913)

“The Diesel engine can be fed with vegetable oils and would help considerably the agriculture of countries which use it” (1911)

“The use of vegetable oils for engine fuels may seem insignificant today. But such oils may become in course of time as important as petroleum and the coal products of the present time” (1912)



Plants as biomass sources for biodiesel

There are many sources for biodiesel production



A babassu tree (*Orbignya phalerata*) and its fruits

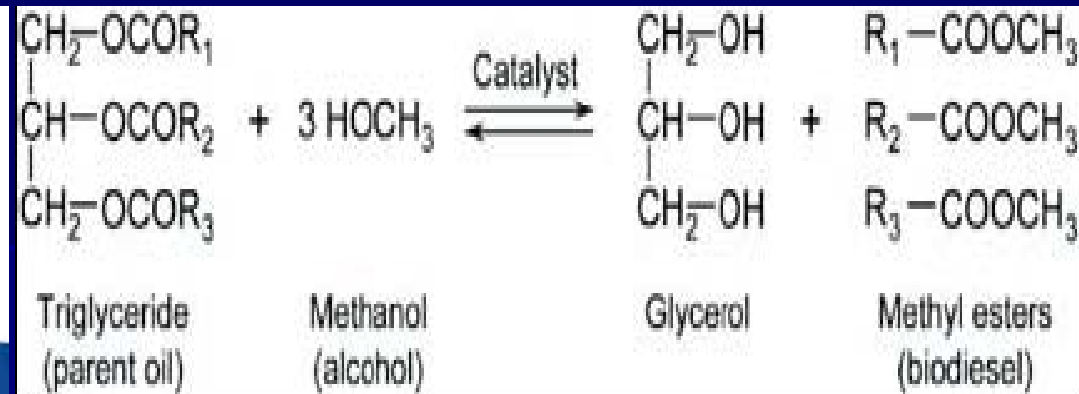


Soybeans –
78% of
Brazil's
biodiesel



Jatropha (*Jatropha curcas*)

Plants as sources for biodiesel



- Extraction – chushing and use of hexane
- Transesterification
- Catalysed by an acid, a base or by enzymes (lipases)
- Methanol or ethanol (ethanol is cheaper in Brazil, but less efficient)
- Remotion of glycerin reduces viscosity
- This technique is known since the 1950's
- Biodiesel is washed to remove the excess of alcohol and glycerin

Oily plants for biodiesel production in Brazil

Castor



Sunflower



Soyben



Palm



Cotton



Mean productivity (kg/ha)

1,500

1,500

3,000

20,000

3,000

Oil content

47%

42%

18%

20%

15%

Oil yield (kg/ha)

705

630

540

4,000

450

Production of plant oil in 2005 - Brazil (m³)

90,000

23,000

5,600,000

151,000

315,000

Productivity of oily plants to produce biodiesel

Plant	Cost of production (R\$/ha)	Productivity of grains (kg/ha)	Oil in the grains (%)	Productivity of oil (l /ha/ano)
Peanuts (<i>Arachis hypogaea</i>)	3,000.00	2.700	40 - 43	1,215
Palm oil (<i>Elaeis guineensis</i>)	2,100.00	20.000	22	4,400
Sunflower (<i>Helianthus annuus</i>)	1,100.00	2.000	38 - 48	630-900
Castor oil plant (<i>Ricinus communis</i>)	650.00	500	45 - 50	240-705
Soybean (<i>Glycine max</i>)	1,300.00	3.000	18	440-600

National Program of Production and use of Biodiesel



- National Program that stimulates the production of biodiesel, created in 2004-2005
- Brazil is able to produce 4.3 billion litres of biodiesel a year, but only 1.75 billion litres will be used in 2009
- There are 55 plant production of biodiesel countrywide
- Currently, a blend of 4% of biodiesel is added to diesel (it will be increased to 5% on January 1st)



Brasil Ecodiesel, in Floriano (Piauí State) produces 100 ton a day



Brazil is increasing the use of biodiesel

- The National Program of Production and Use of Biodiesel is stimulating the production of new plant sources for biodiesel production
- Each new source is added to the network of production and distribution of biodiesel in the country, controlled by the National Agency of Oil, Natural Gas and Biofuels

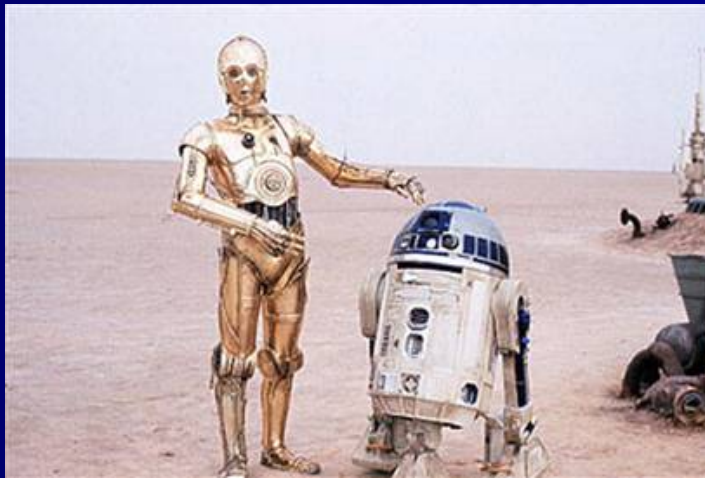


Cultivation of *Arthrospira platensis* at Fundação Universidade Federal do Rio Grande, Rio Grande - RS



- Currently, microalgae are considered a promising source for biodiesel production by the federal government

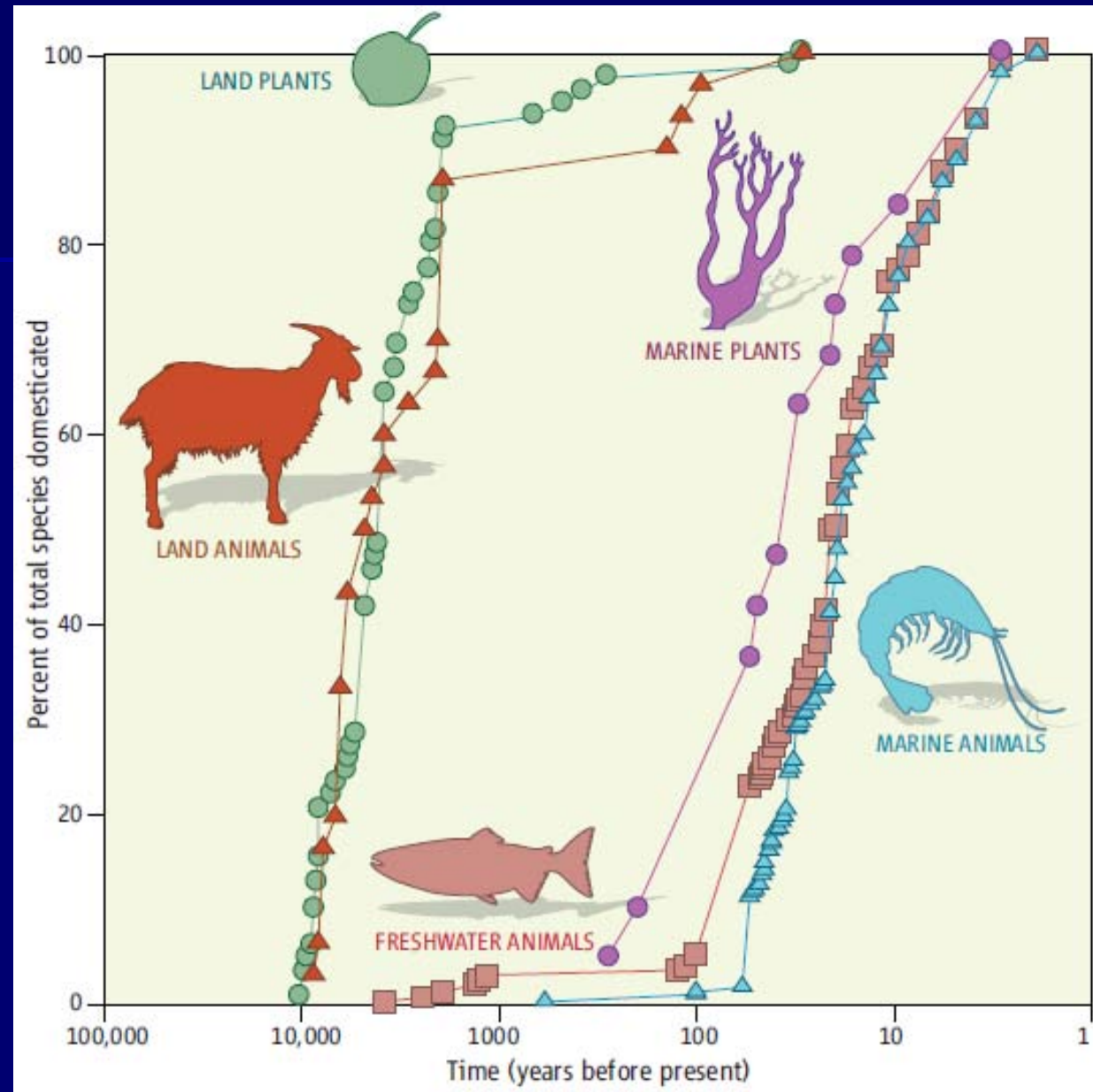
Microalgae for biofuels: science fiction?



Not at all!!!

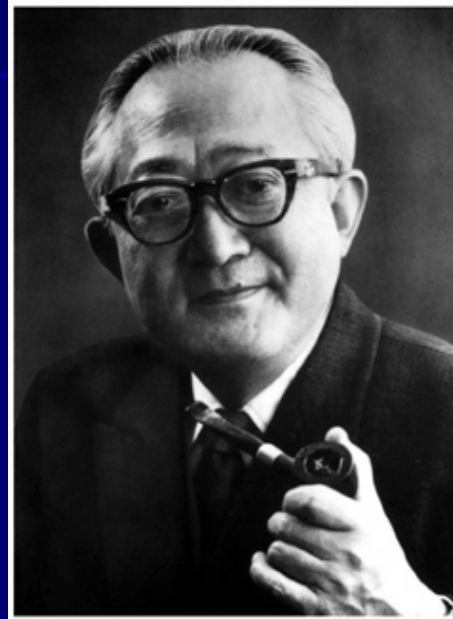
Agriculture X aquaculture

- Aquatic species, including microalgae, are under domestication
- *Ca. 97%* of the 430 aquatic species commercially used at the present were domesticated throughout 20th century
- *Ca. 90%* of land plants currently used in agriculture were domesticated 2,000 years ago (Duarte *et al.*, 2007)



Advantages of microalgae

- The huge potential of microalgae to generate biofuels is recognized since the pioneering studies of Hiroshi Tamiya (1903-1984), in Japan, in the 1950's



Tanks and ponds, open systems



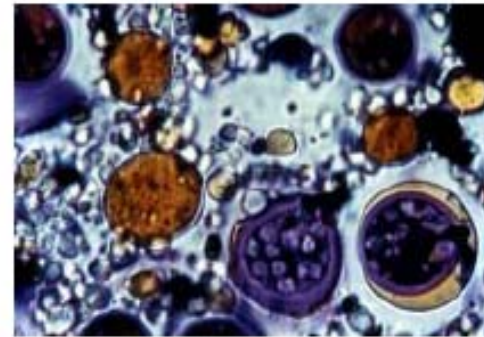
Photobioreactors, closed systems

Aquatic Species Program - NREL

- A large screening program to search for suitable algal species for biodiesel
- Run by the National Renewable Energy Laboratory (US Department of Energy) from 1978 - 1996
- The final report (1998) pointed that biodiesel from algae is technically feasible, but economically unsuitable at that time (oil barrel \approx US\$ 15.00)
- Now NREL runs many other research programs created after ASP

NREL/TP-580-24190

A Look Back at the U.S. Department of Energy's Aquatic Species Program: Biodiesel from Algae

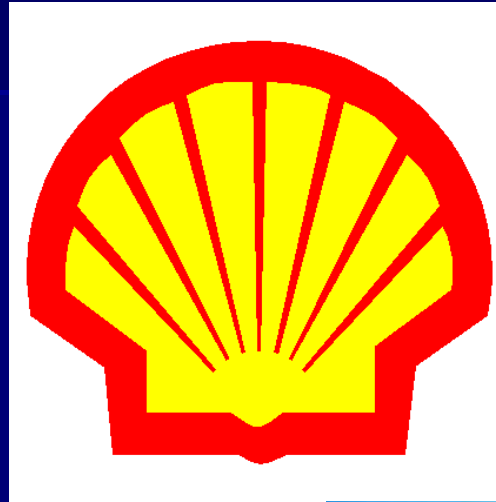


Close-Out Report



Everybody wants microalgae...

- Shell Co. created an experimental pilot-plant to produce biofuels from microalgae in Hawaii (USA) in 2007
- Cyanotech, a Hawaii-based company with tradition with *Arthrospira* and *Haematococcus* production, is also investing in microalgae biofuels



Everybody wants microalgae...

- The world's biggest publicly funded project to make transport fuels from algae will be launched today (October 23rd, 2008) by a government agency which develops low-carbon technologies
- The Carbon Trust announced a project to make **algal biofuel** a commercial reality by 2020
- The plan could see up to **£26m** spent on developing the technology and infrastructure to ensure that algal biofuels replace a significant proportion of the fossil fuels used by UK drivers
- Transport accounts for one-quarter of the UK's carbon emissions and is the fastest growing sector
- Finding carbon-neutral fuels will be crucial to the government meeting its target to reduce overall emissions by 80% by 2050



Everybody wants microalgae...

- Last July 15th, ExxonMobil announced a US\$ 600 million budget for algal biofuel research (2009-2013)
- Some US\$ 300 million go to Synthetic Genomics, a J. Craig Venter company located in San Diego
- PetroAlgae is involved with this initiative

