Algal biofuels and co-products

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FAO on algae-based biofuels

- Aquatic Biofuels Working Group (ABWG)
  Informally established in Fall 2008

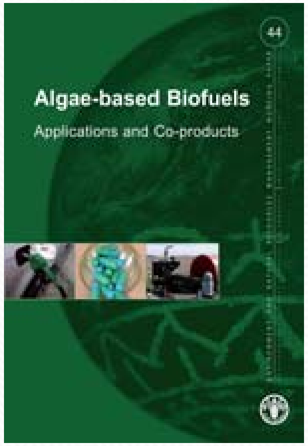
Scope:

- Understand the current state of aquatic biofuels research and technologies and their relevance to being applied and managed in developing countries.
- Facilitating linkages between regional organizations, private sector and governments as well as promoting a north-south and south-south collaboration.
- Disseminate knowledge about bioenergy production from algae and fish waste and its suitability in poor areas to improve energy access. through networks, where appropriate.

FAO on algae-based biofuels

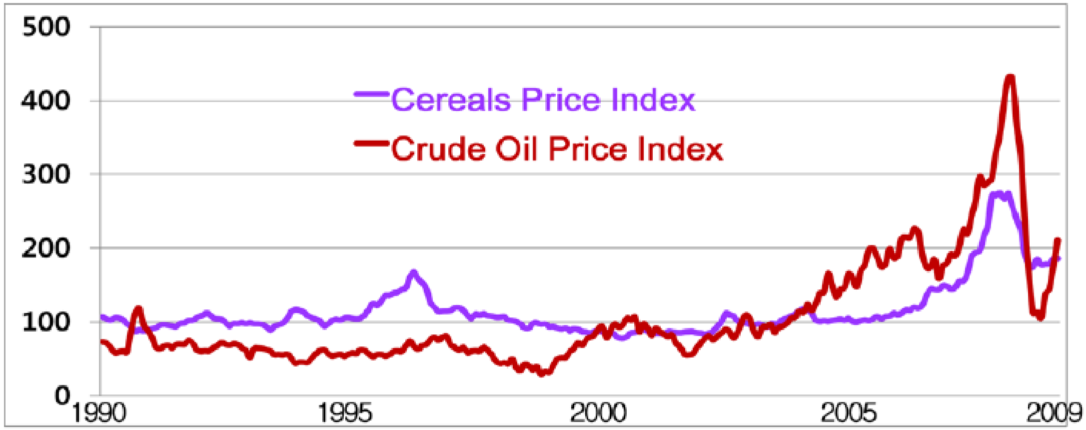
Two working papers produced:

- Algae-based biofuels - A Review of Challenges and Opportunities for Developing Countries
- Algae-based biofuels – Applications and Co-products
- Available at www.fao.org/bioenergy/aquaticbiofuels



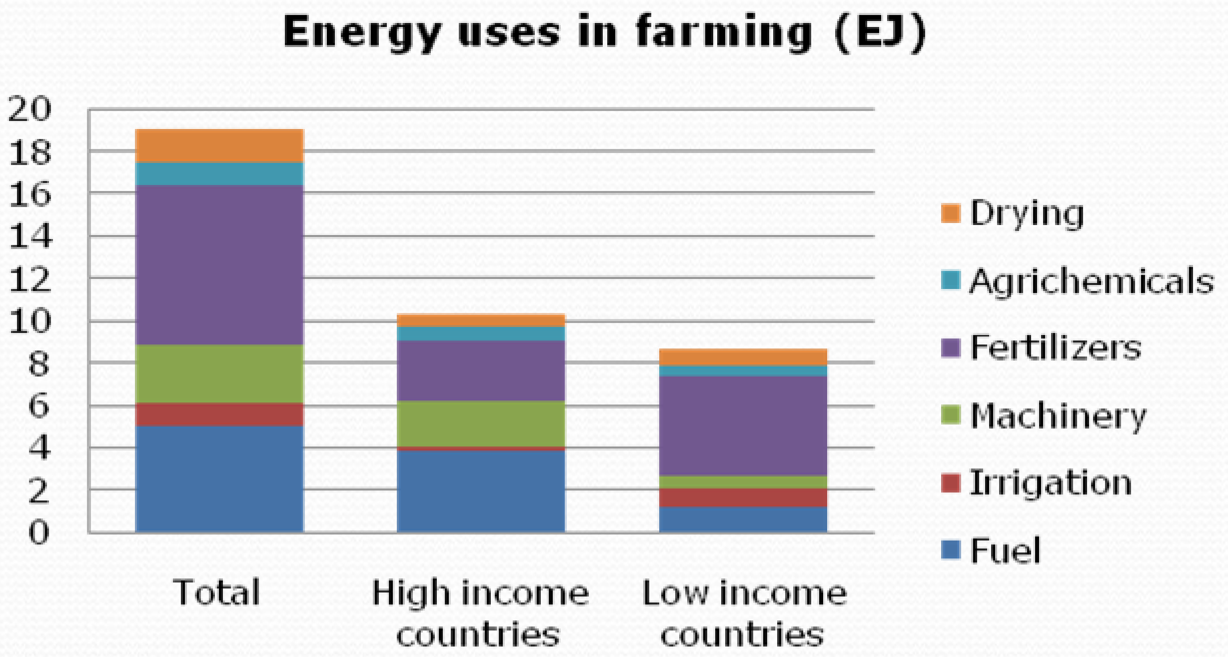
Context

- Agricultural production expected to increase by 70% by 2050 to meet future food demand (mainly through yield increase)
- Fossil fuel prices expected to be higher and more volatile in the future
- Agri-food chain heavily dependent on energy, mainly indirect energy subsidies
- FF prices pass-through food prices and poor farmers highly exposed to price shocks

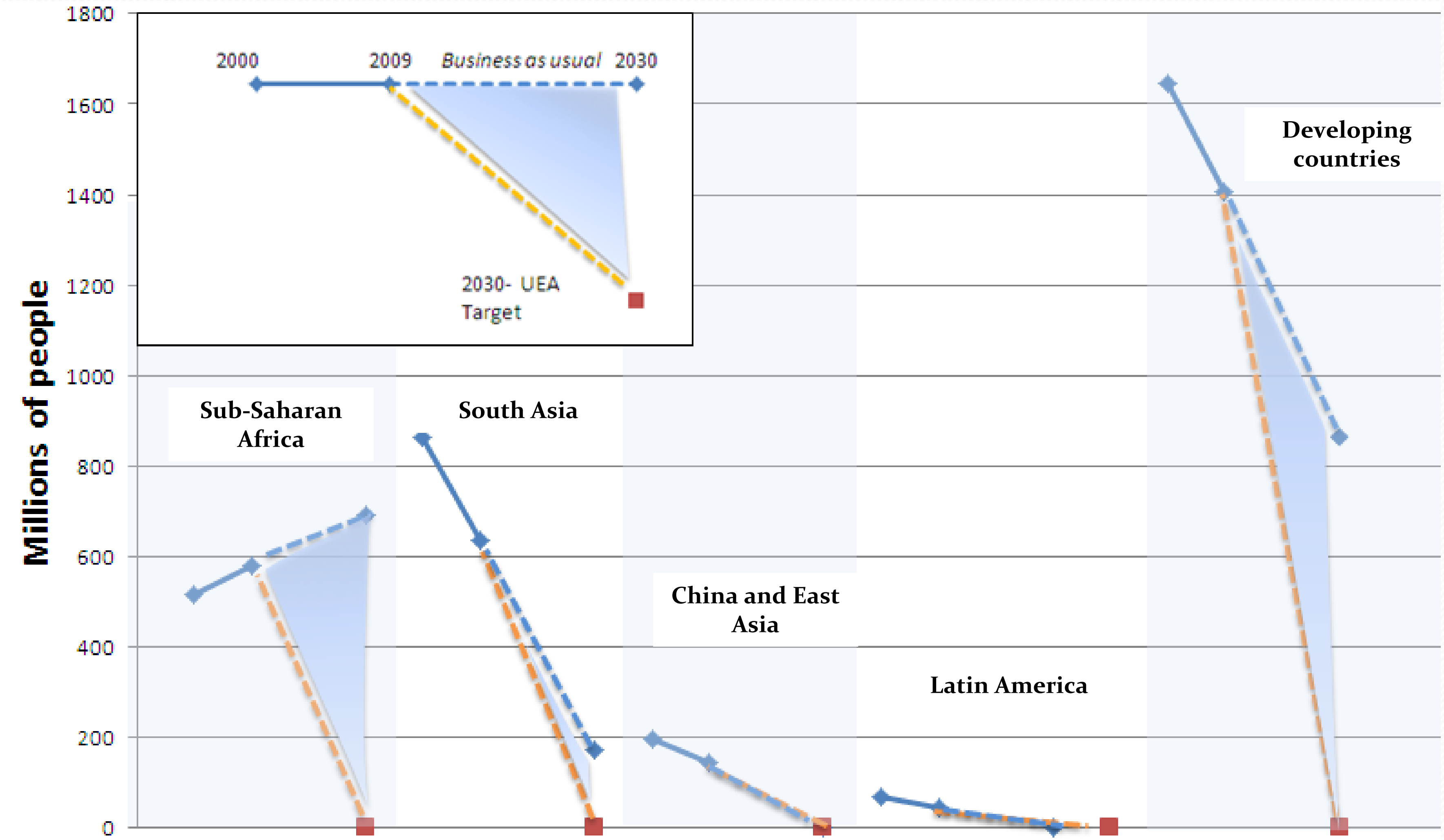


Trend comparison of oil price and cereals price index (Kim, 2010)

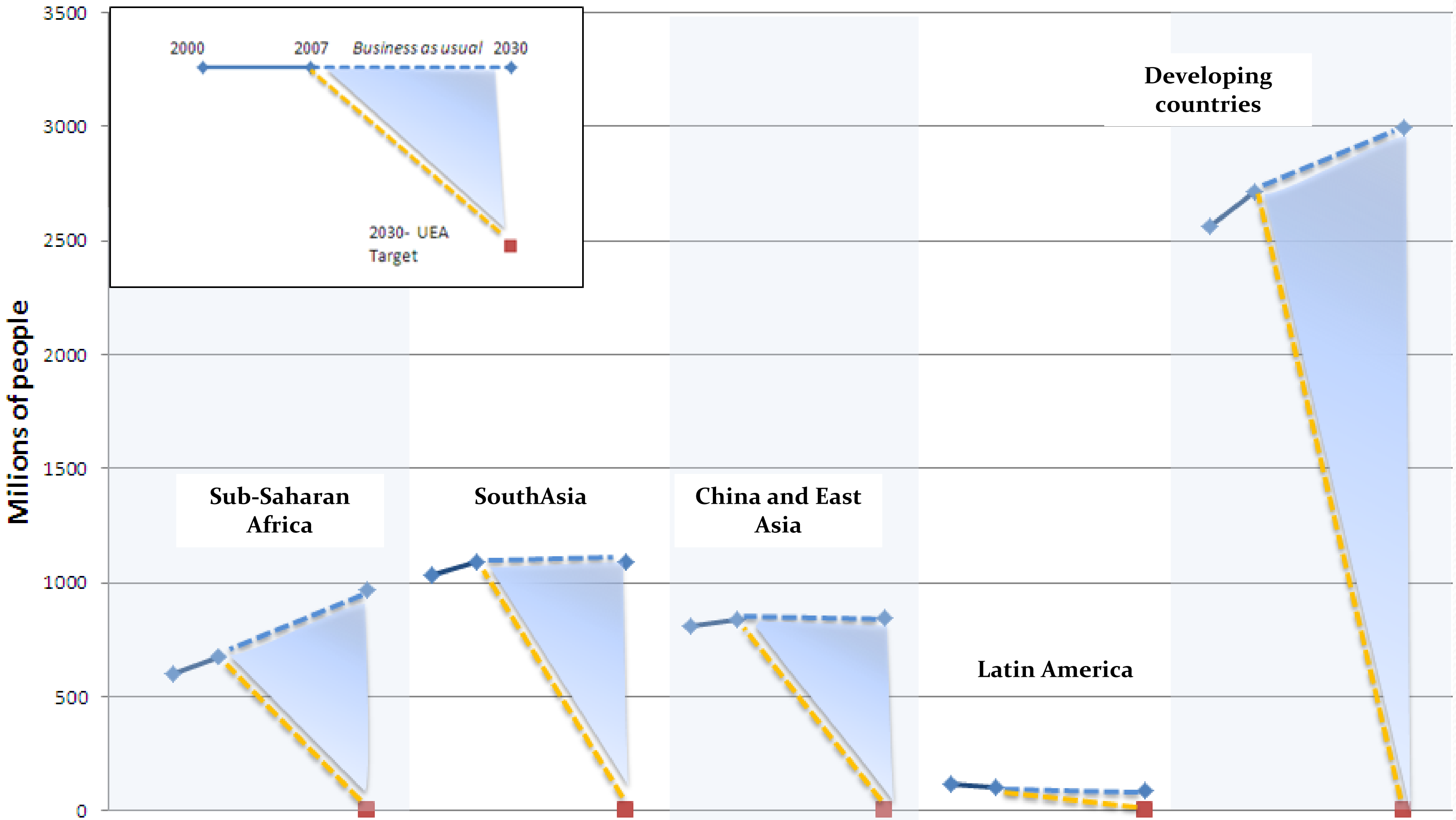
Becoming 'energy-smart'



- In farming, (direct and indirect) energy is mainly needed for **fertilizer production** and as **fuel** for machinery
- Also heat for drying and electricity are important, especially in rural areas

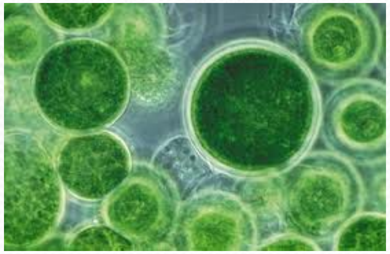


People without access to electricity compared with progress towards Universal Energy Access by 2030 - Source: Poor People's Energy Outlook 2012

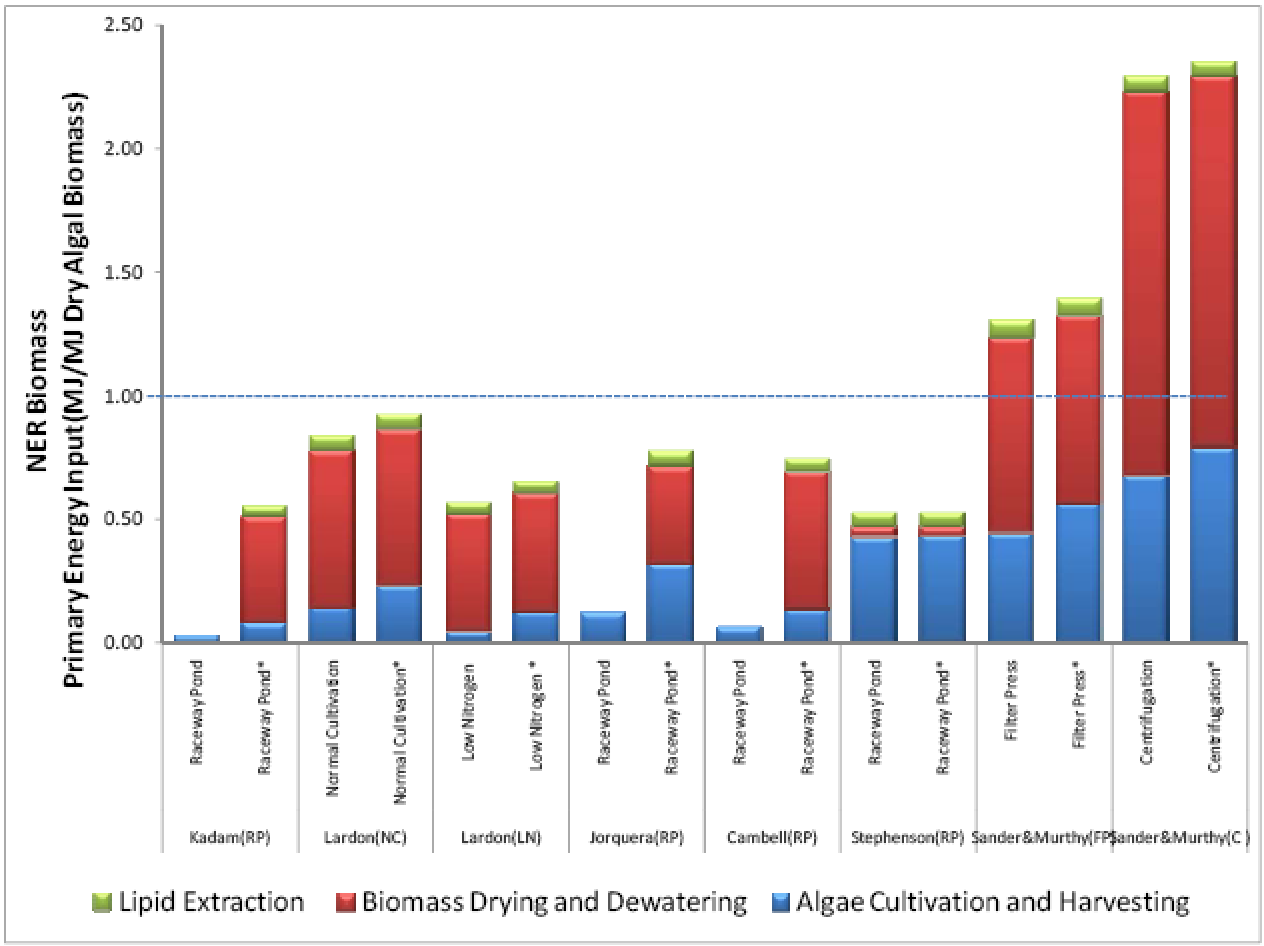


People without access to "modern fuels" for cooking compared with Universal Energy Access by 2030 - Source: Poor People's Energy Outlook 2012

Biofuel from algae?



Biofuel from algae?



NC: Normal Cultivation; LN: Low Nitrogen Cultivation; FP: Filter Press; C: Centrifuge; RP: Raceway Pond

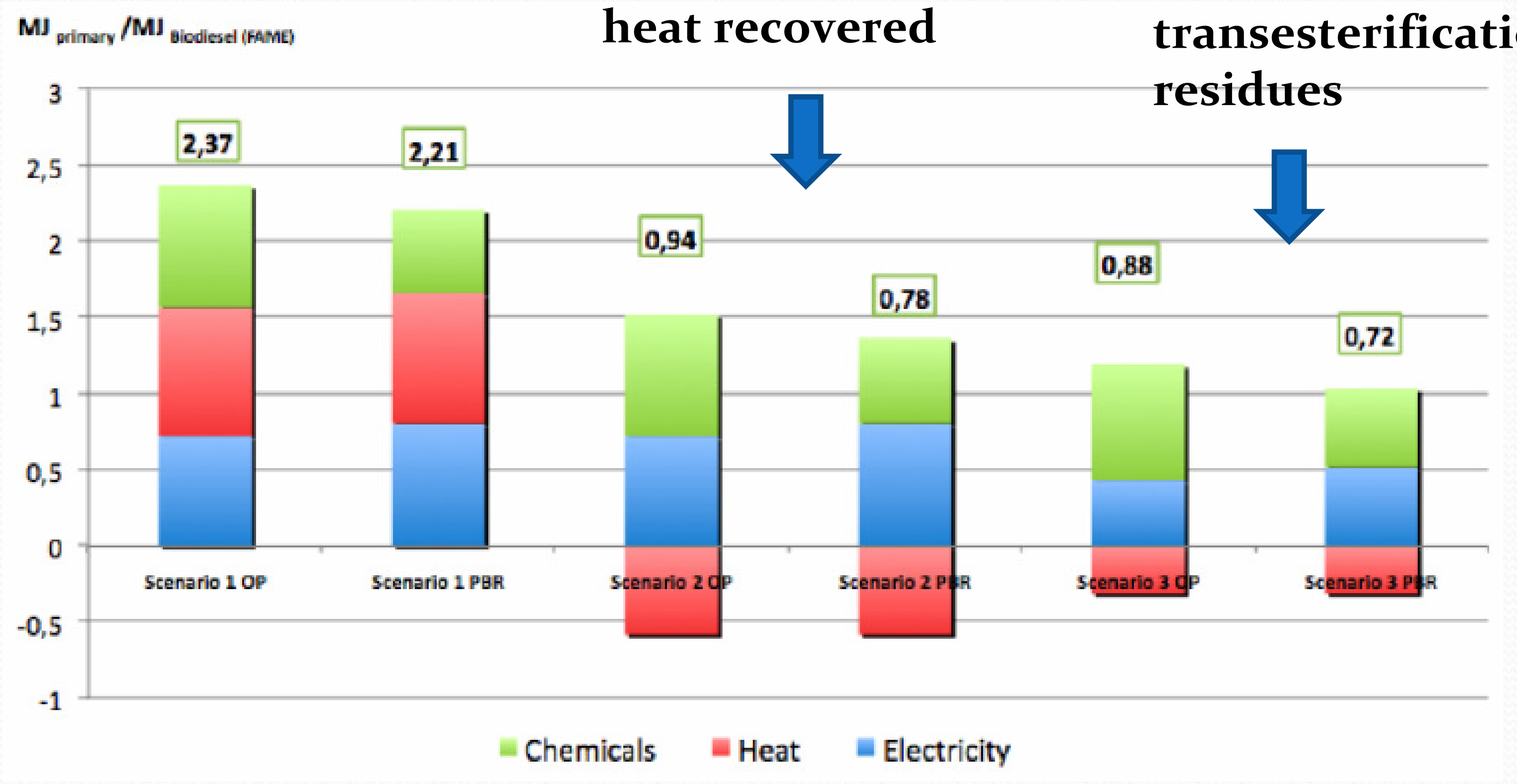
**=Normalised system boundary*

Source: Aquafuels 2011

Biofuel from algae?

Burning of residues after extraction and heat recovered

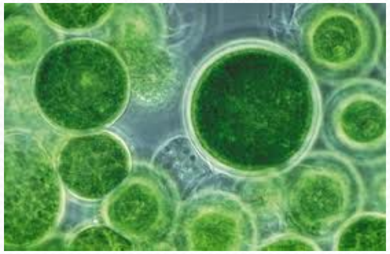
No drying before oil extraction
Residues for biogas for CHP
N reuse
Additional heat from transesterification residues



Source: IEA 2009

Biofuel from algae?

- Raw oil
- Biodiesel through transesterification
- Ethanol 1G
- Ethanol 2G
- Biogas through fermentation

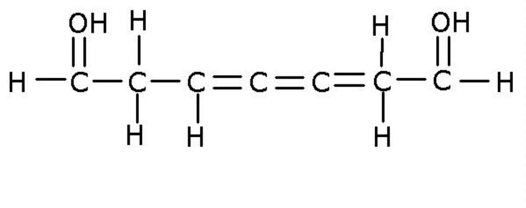


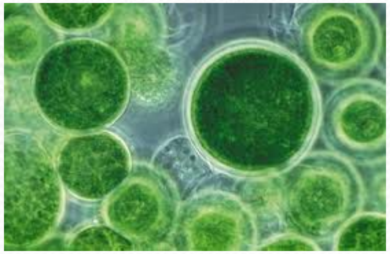
- Pyrolysis oil
- Syngas (CH_4, H_2) through hydrothermal gasification
- Bio-Oil through hydrothermal liquefaction
- Biochar through hydrothermal carbonization
- Gasification? OTHER?

Just biofuel from algae?

Pigments

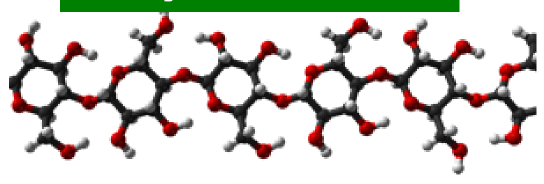
PUFAs



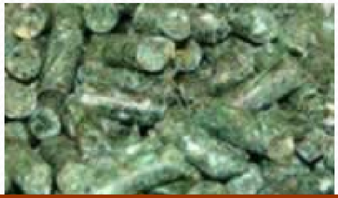


Staple food

Polysaccharides



Livestock feed



Fish and shellfish feed

Cheap nutrients from algae

Food item	Protein content per 100 g (g)	Cost per 100 g of protein (Rs)	Comparative ratio of cost of protein with Spirulina	Comparative ratio of cost of lysine with Spirulina	Comparative ratio cost of cystine with Spirulina	Comparative ratio cost of tryptophan with Spirulina
Spirulina	66	1.38	1	1	1	1
Egg	13.2	11.20	8.23	5.10	5.11	3.82
Milk (100 ml)	3.3	15.15	10.97	6.19	11.98	6.62
Cluster beans	3.2	31.25	22.64	14.67	26.13	15.09
Eggplant	1.4	57.14	41.41	44.45	78.52	19.48
Carrot	0.9	88.88	64.41	10.10	28.90	14.13
Potato	1.6	62.50	45.28	26.56	95.97	7.55
Onion	1.20	66.66	48.30	46.30	96.66	13.88
Mutton	18.50	16.21	11.75	6.31	26.45	1.68
Notes:	Only the cost of protein from consumed foods other than staple food is compared here. The costs per unit of vitamin A, nicotinic acid, riboflawin, thiamin, vitamin B12 and iron are cheaper in Spirulina than from other sources. The protein content of Spirulina is based on a dry weight whereas the protein content of other food sources is reported on a wet weight basis.					

Spirulina protein content compared with other staple foods in (vegetarian) South India, 1991 (Babu and Rajasekaran 1991)

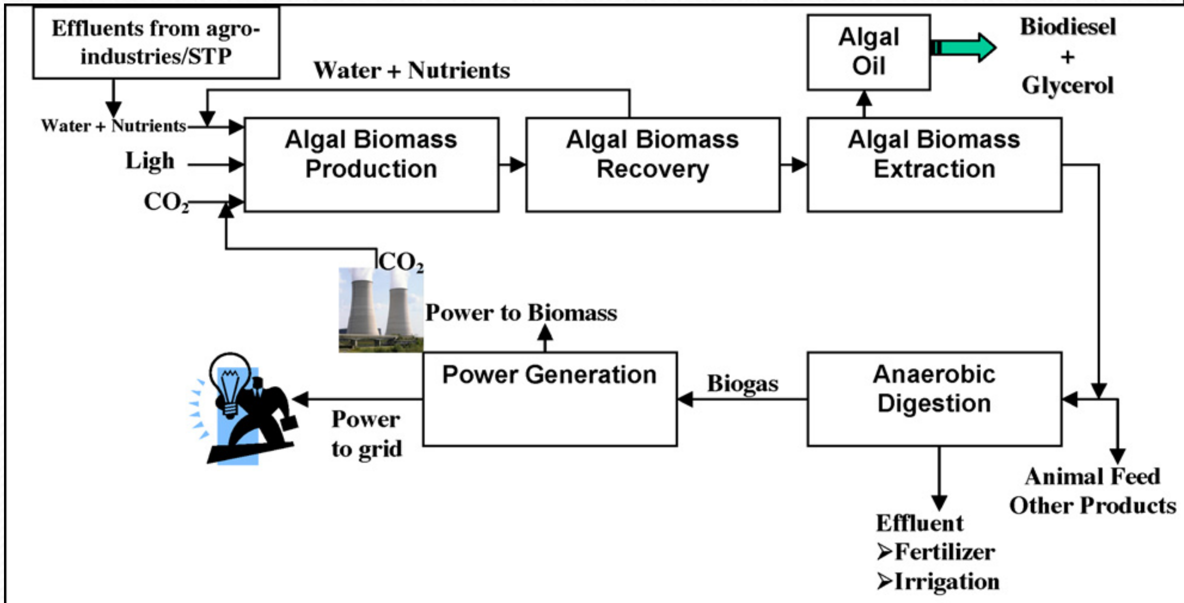
Just biofuel from algae?

Food / feed	Staple food, Pigments, PUFAs, Polysaccharides, Livestock feed, Aquaculture
Chemical industry	• in the process to produce ethanol/butanol • bio-plastics / paints • will initially focus on cheaper feedstock
Cosmetics	• used in the skin care market (*Arthrospira* and *Chlorella*) • gaining commercial importance in lipid-based cosmetics (lotions)
Fertilizers	• seaweed used worldwide in coastal regions (N fixing species) • nutrients still present after extraction of oil or carbohydrates • nutrients released slowly
Fibres for paper	• process/quality improvement (mech strength, cooking times,…) • lower material cost • applicable to wastewater

Systems integration is key

- Multiple resource use through the <u>diversification</u> of land use and production (e.g. systems that co-produce fish, bioenergy, fertilizers. Mild conditions. Slower and more expensive)

- Multiple resource use through the <u>full utilization</u> of by-products/residues



Integrated algal production concept with various co-products (Khan, Rashmi et al. 2009)

Integrated systems / compatible markets

Applications	Price / Kg biomass	Market volume
Nutraceuticals (human consumption)	€ 100	€ 60 million
Nutraceuticals (animal and fish feed)	€ 5-20	€ 3-4 billion
Bulk chemicals	€ 1-5	> € 50 billion
Biofuels	< € 0.40	> € 1 trillion

Potential markets

(Source: Wijffels 2008)

Wijffels, Barbosa et al. (2010) have chosen a random combination of microalgal products with bulk-scale market. Assuming 40% lipids, 50% proteins and 10% carbohydrates, a quarter of the lipids is sold to the food and chemical industry for €2/kg, the rest for biodiesel at €0.50/kg, soluble proteins (20%) for food at €5/kg, the rest (80%) for feed at €0.75/kg.

Biorefinery yields €1.65 /kg algal biomass, relying solely on products with a low market value and large market size.

Markets should be compatible!

Developing countries experience

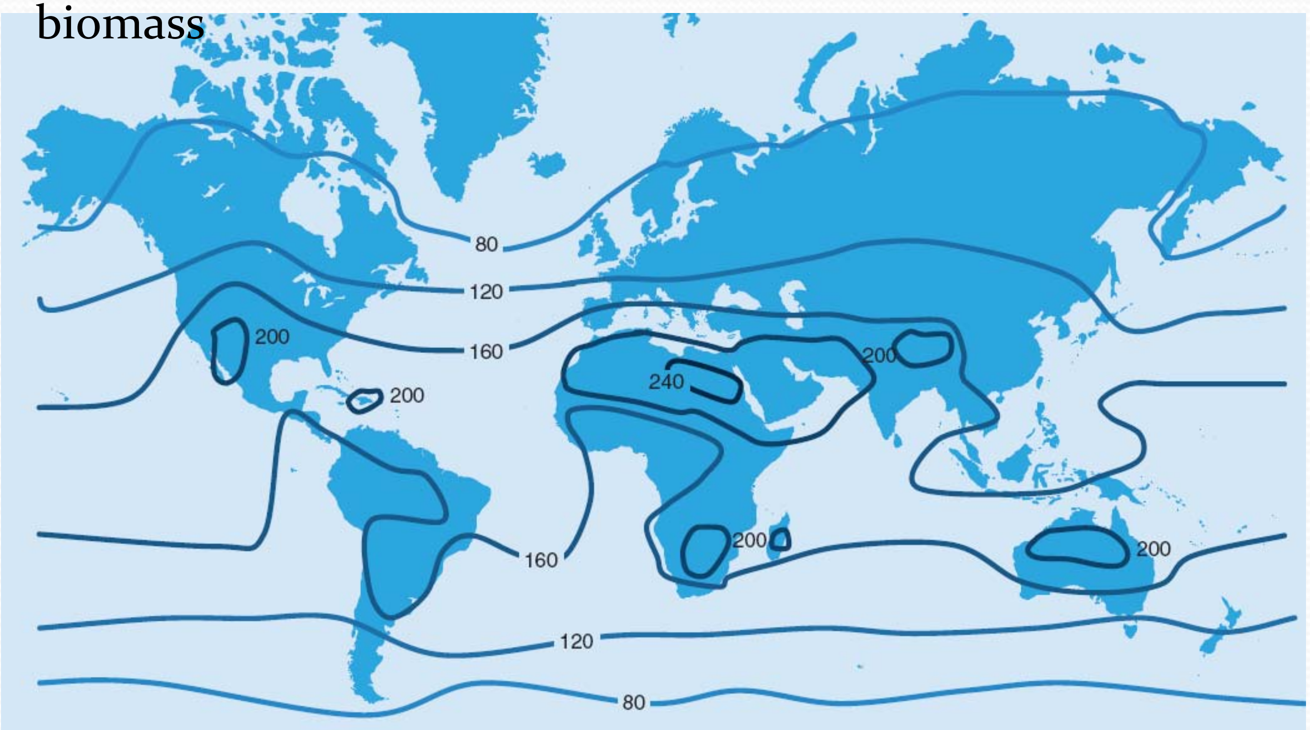
- Most commercial microalgae operations are located in China, Taiwan and India.

- In 1997 there were around **110** commercial producers of microalgae in the Asia Pacific region, with capacities ranging from 3 to 500 tons /year.

- Experiences in China, Taiwan, Thailand, Philippines, Indonesia, Myanmar, Vietnam, South Korea, Mexico, Chile, Cuba, Chad, South Africa (mainly for food, fertilizers, aquaculture, wastewater treatment)
  No willingness to pay for 'greener' products!
  Opportunities to adapt current production systems to bioenergy co-production

Productivity

World map of algae biomass **productivity** (tons/ha/year) at 5% photosynthetic efficiency considering an energy content of 20 MJ/kg dry biomass



≠ grow rate

40-80 tons DW /ha/year

Source: Tredici 2010

The future of ABB

↔

?

Two scenarios for scale of operations

Algal biofuels plant
> 1000 ha (Um and Kim 2009)

Small-scale, community operated systems

Open ponds
(Limited no. of species)

Filamentous species
Fish feed

Sun or no drying
Mech. press

Some key messages 1/2

TECHNOLOGY

- No solution at present to achieve large yields comparable to C4 plants and No company has a mature technology to compete with transport FF

- Systems integration is fundamental for economic viability and sustainability

RESEARCH NEEDS

- [Lack of collaboration and information-sharing leads to inefficient use of capital due to overlap and duplication of research]

- High yields and large scale production can be successfully achieved only through a comprehensive and well-funded RD&D programme which promotes business models that look not only at algae to displace the transportation fuels, but also consider the cascading of algae chains with other valuable products

Some key messages 2/2

ENTRY POINTS FOR DEVELOPING COUNTRIES

- Where experience in algae cultivation exists, bioenergy co-production can increase incomes (avoided cost)
- Small scale integrated systems to satisfy local needs, esp in rural areas

Thank you for your attention!

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