Algae-Derived Biofuels

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Microalgae as a Biofuel Source

- Global shortages of fossil fuel spurring research into sustainable obtainable energy
- Biofuels considered a new energy source
- Algae produce more oil per U.S. cropping area than many other oil crops

Crop	Oil Yield Gallons/acre
Corn	18
Cotton	35
Soybean	48
Mustard seed	61
Sunflower	102
Rapeseed/Canola	127
Jatropha	202
Oil palm	635
Algae (10 $g/m^2/day$ at 15% TAG)	$\boxed{1,200}$
Algae (50 $g/m^2/day$ at 50% TAG)	$\boxed{10,000}$

Hodge, N . (2008) "The Only Biofuel that Can Take on Oil", *Green Chip Stocks*, www.green chipstocks.com

Lipid Production and Extraction

- Lipids are a stored energy source
- Algae produce lipids that are unsaturated and require little to no pretreatment before transformation into biodiesel
- Modified Bligh and Dyer Lipid Extraction Method
  - To extract the organic (lipids) portion of the algae sample

Lipid Content of Algae Strains Expressed on a Dry Matter Basis (%)	
Algae Strain	**Lipid (% dry weight)**
Scenedesmus obliquus	12-14
Scenedesmus quadricauda	1.9
Scenedesmus dimorphus	16-40
Chlamydomonas rheinhardii	21
Chlorella vulgaris	14-22
Chlorella pyrenoidosa	2
Spirogyra sp.	11-21
Dunaliella bioculata	8
Dunaliella salina	6
Euglena gracilis	14-20
Prymnesium parvum	22-38
Tetraselmis maculata	3
Porphyridium cruentum	9-14
Spirulina platensis	4-9
Spirulina maxima	6-7
Synechoccus sp.	11
Anabaena cylindrica	4-7

Becker, E. W. (1994) Micro-algae as a source of protein Biotechnology Advances, Volume 25, Issue 2, March-April 2007, Pages 207-210

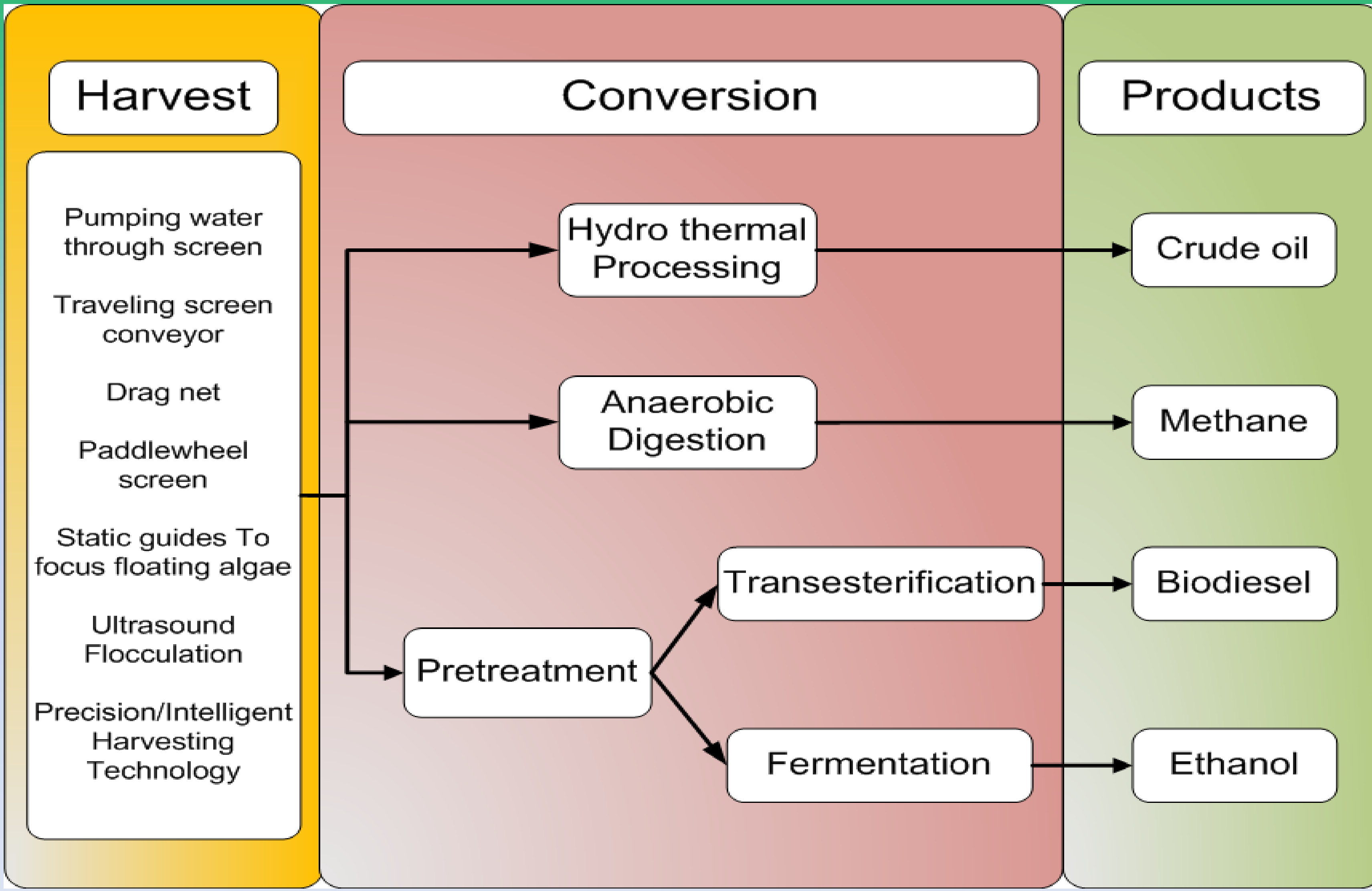
Benefits of Algae as a Biofuel

- More beneficial for the environment than cultivation of crops like corn for biodiesel
- Photosynthesis is an efficient CO_2 sequestration mechanism
- Does not impact human food consumption or use of high percentage of cropping areas
- Can use industrial flue gases that contain CO_2
- Can reduce dependency on fossil fuels and other nonrenewable resources

Countries that Use Algal Oil

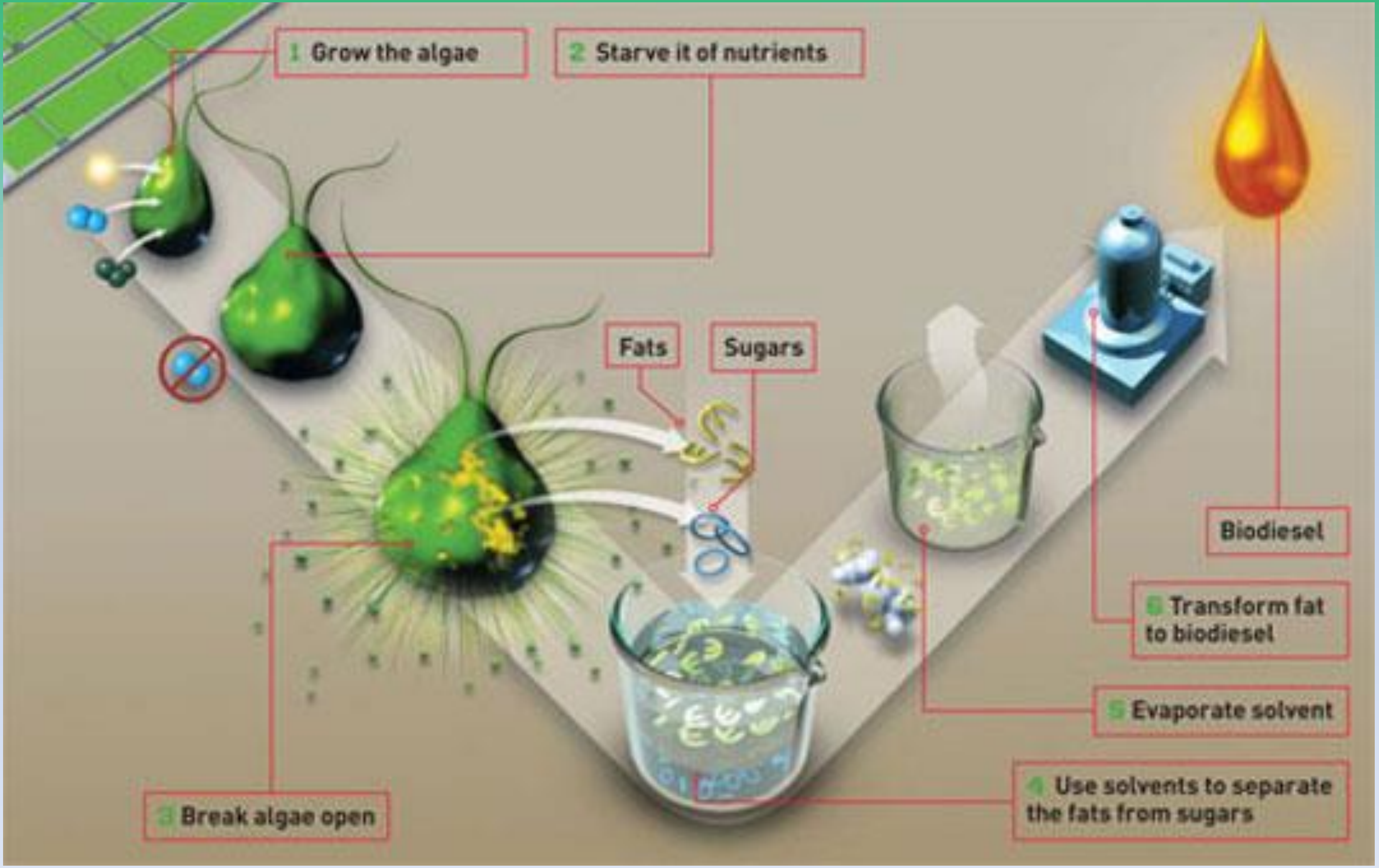
- India
  - Nutritional source, wastewater treatment
- Japan
  - Nutritional and food sources
- Australia
  - Bioenergy initiatives
- Taiwan
  - Photobioreactor systems
- Israel
- EU
- USA

General Process

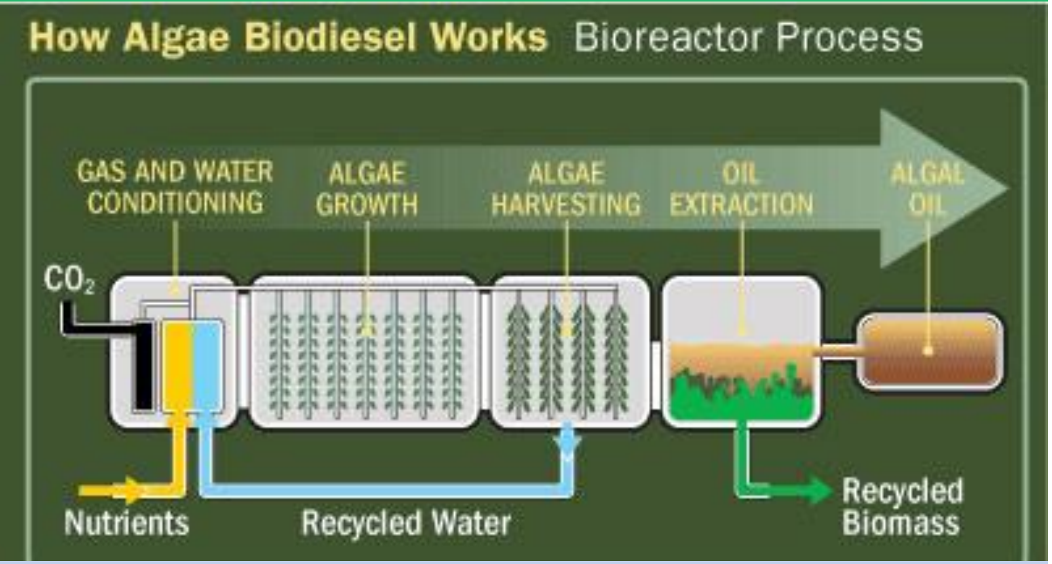


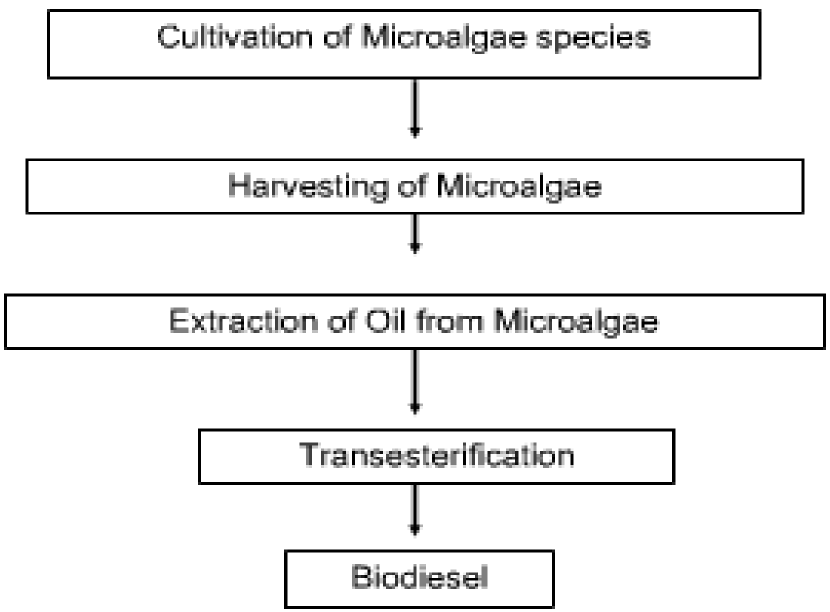
http://biodiesel.org/pdf_files/fuelfactsheets/Production.PDF

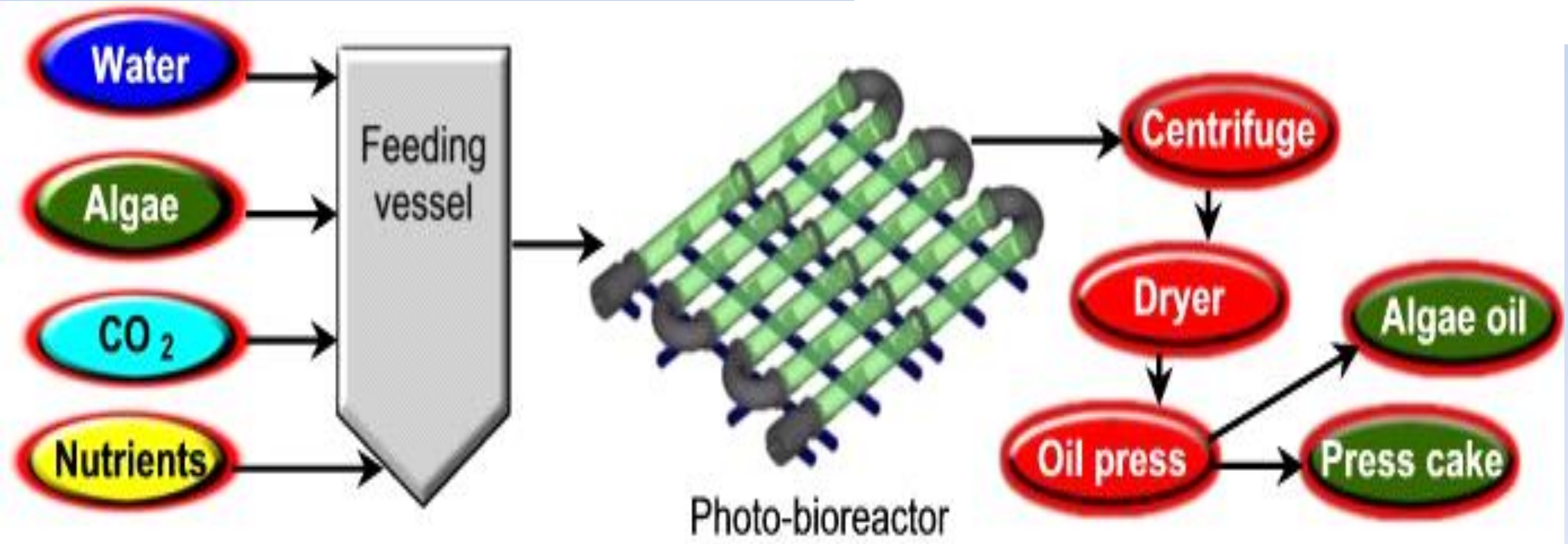
LIPID EXTRACTION



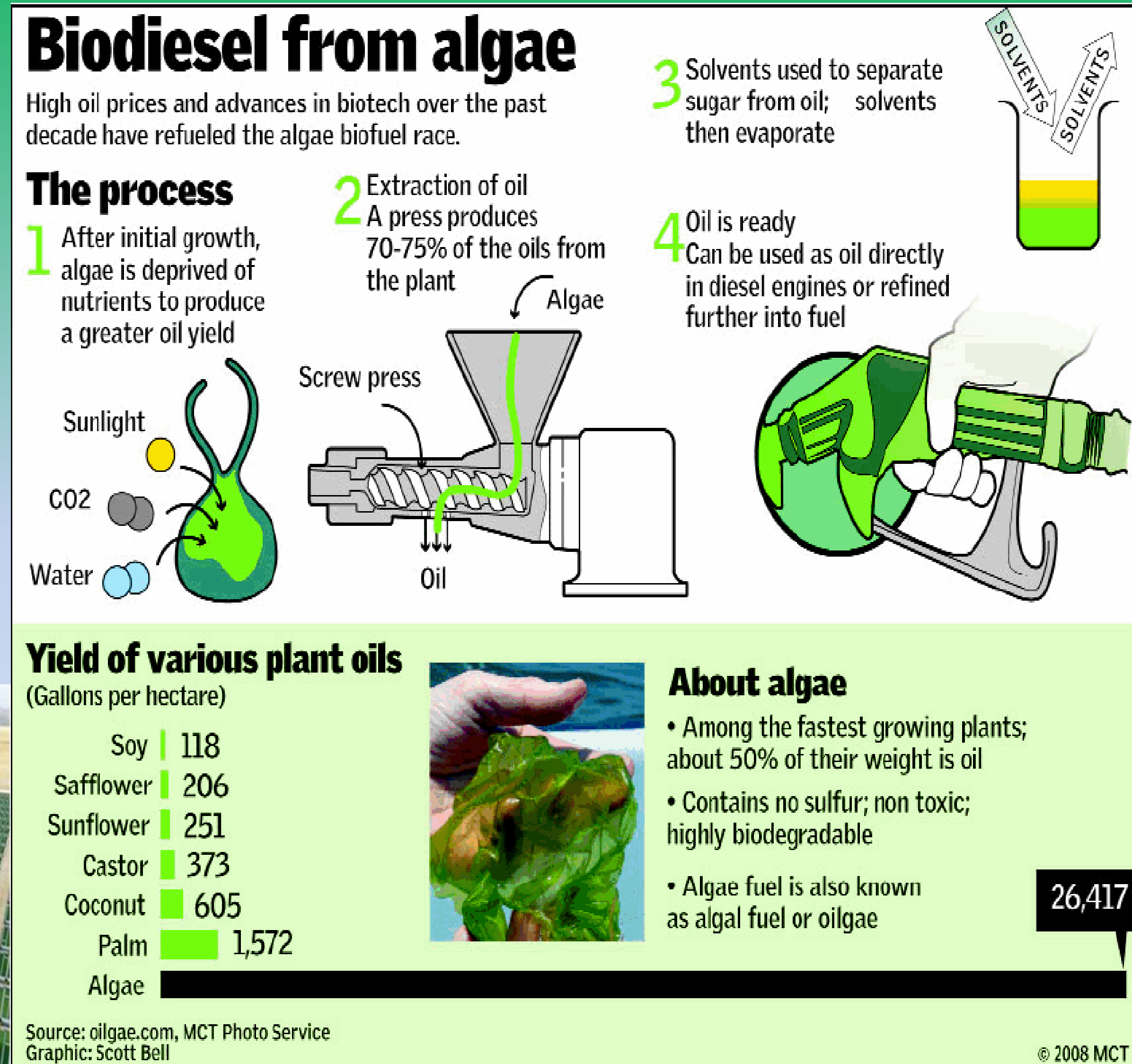
Biodiesel from Algae







Oil from Algae



Pressing oil from the algae

- Dry the algae and press the oil from it.
- Can retrieve up to 70% of the oil.
- While drying must prevent the algae from becoming contaminated.
- Cheapest and simplest method

Chemical Oil Extraction

- Use hexane solvents to remove the oil.
- Hexane is a neurotoxin.
- Must be careful when using.
- Removes oil out of almost all things.

http://forums.biodieselnow.com/topic.asp?TOPIC_ID=3414

Super Critical Oil Extraction

- Most efficient method.
- Uses carbon dioxide at critical pressure and temperature (CO2 is almost a liquid).
- Carbon dioxide.
- Rapid diffusion of the oil.
- Very expensive process.

http://www.organix.net/organix/supercritical.htm

Biodiesel production

Parent oil used in making biodiesel consists of triglycerides (Fig. B1) in which three fatty acid molecules are esterified with a molecule of glycerol. In making biodiesel, triglycerides are reacted with methanol in a reaction known as transesterification or alcoholysis. Transestrification produces methyl esters of fatty acids, that are biodiesel, and glycerol (Fig. B1). The reaction occurs stepwise: triglycerides are first converted to diglycerides, then to monoglycerides and finally to glycerol.

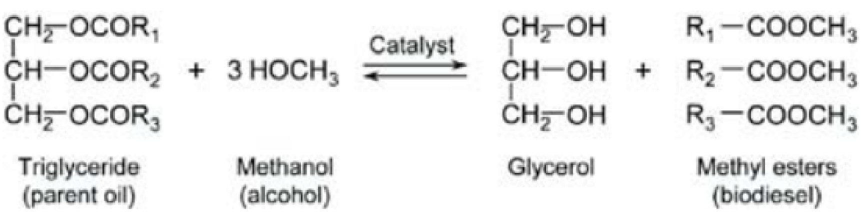
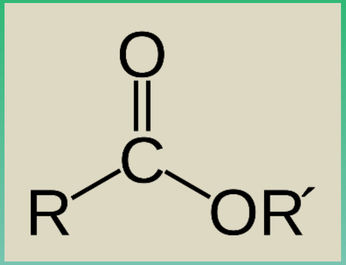
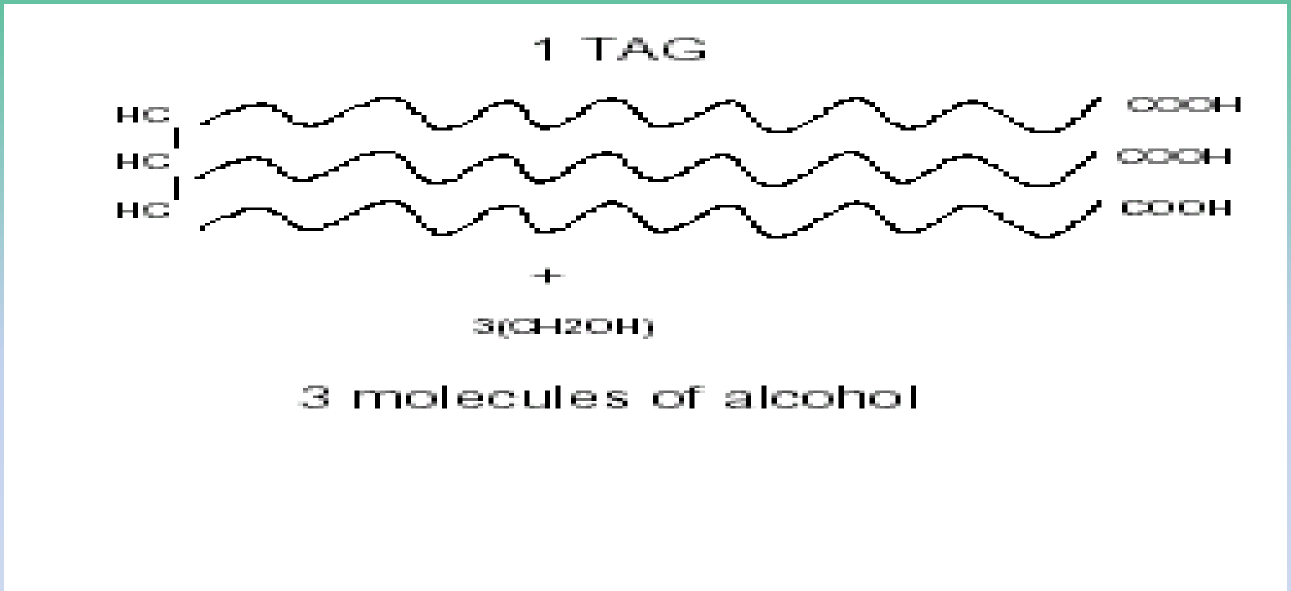


Fig. B1. Transesterification of oil to biodiesel. R_{1-3} are hydrocarbon groups.

Transesterification requires 3 mol of alcohol for each mole of triglyceride to produce 1 mol of glycerol and 3 mol of methyl esters (Fig. B1). The reaction is an equilibrium. Industrial processes use 6 mol of methanol for each mole of triglyceride (Fukuda et al., 2001). This large excess of methanol ensures that the reaction is driven in the direction of methyl esters, i.e. towards biodiesel. Yield of methyl esters exceeds 98% on a



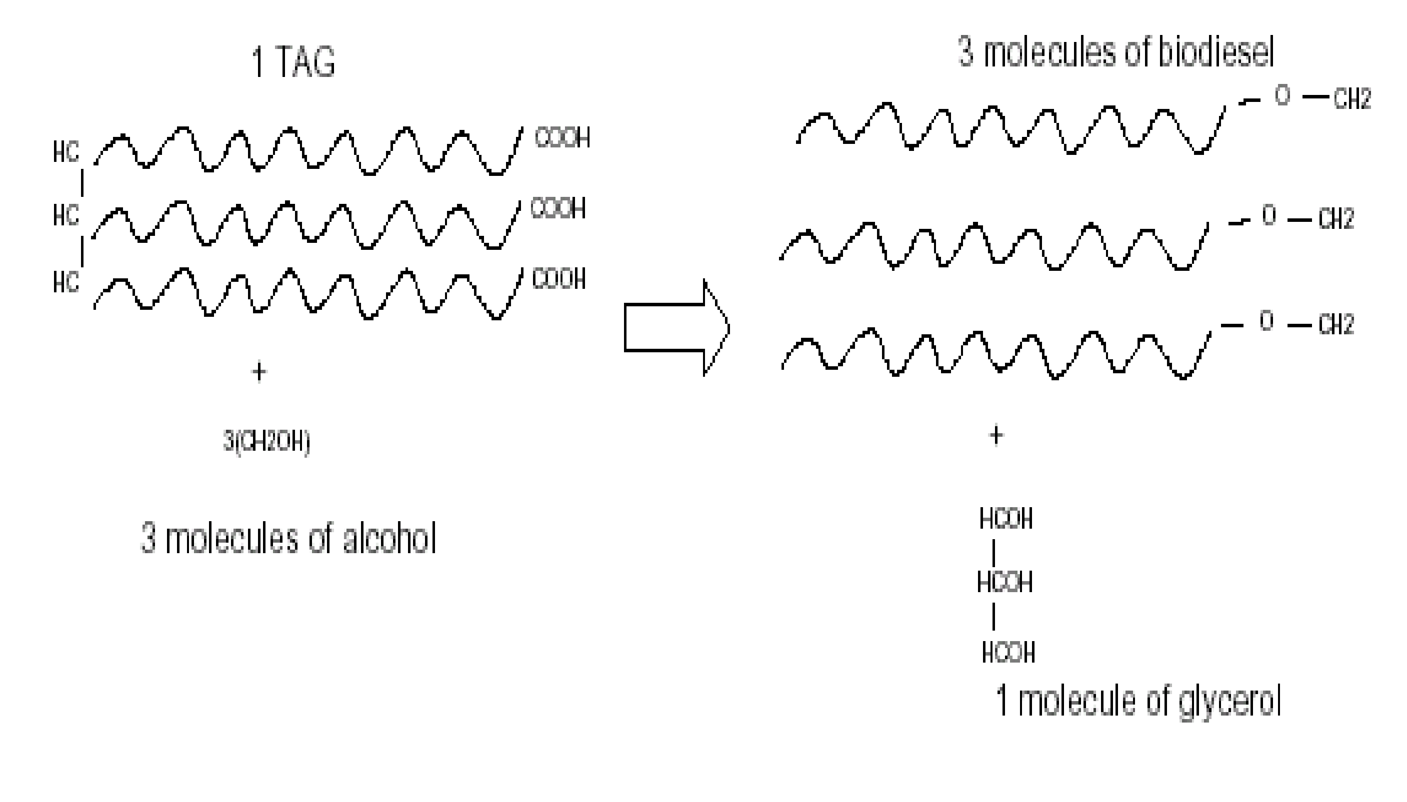
TAG (triacylglycerol)



- Three chains of fatty acids attached to a glycerol
- Natural oil from the algae

http://www.nrel.gov/docs/legosti/fy98/24190.pdf

Transesterification



- **Start with triacylglycerol (TAG)**
- **End up with ester alcohol (biodiesel)**

http://www.nrel.gov/docs/legosti/fy98/24190.pdf

Other Beneficial Uses of Algae

- Removes nitrogen and phosphorus from wastewater
- Used extensively in aquaculture
- Used in nutraceuticals and food
- Cosmetics