UNIVERSITY of GREENWICH

Algal biofuels

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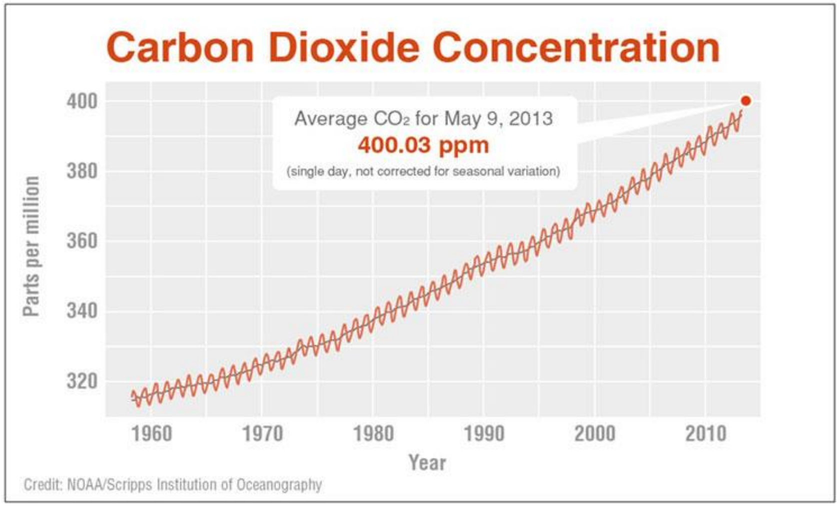
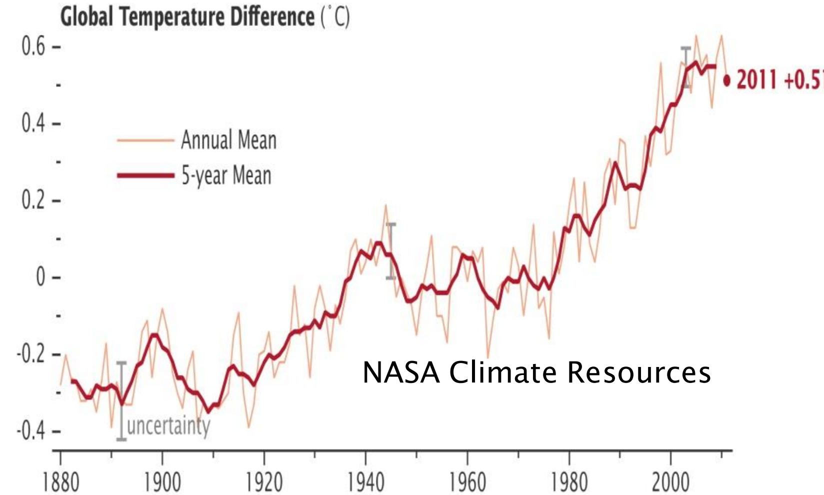
The Oil, Finance & Shipping Symposium
31st August 2016, University Of Greenwich at Medway

Carbon Dioxide levels are Increasing and global temperatures are rising





Climate Change: "The overwhelming majority of scientists agree that the rising concentrations of heat-trapping greenhouse gases in the atmosphere caused by human activities" The Met Office

UK Policy on increasing the use of low-carbon technologies

- 80% reduction in greenhouse gas emissions by 2050.
- 15% of the UK's energy demand from renewable sources by 2020

https://www.gov.uk/government/policies/increasing-the-use-of-low-carbon-technologies

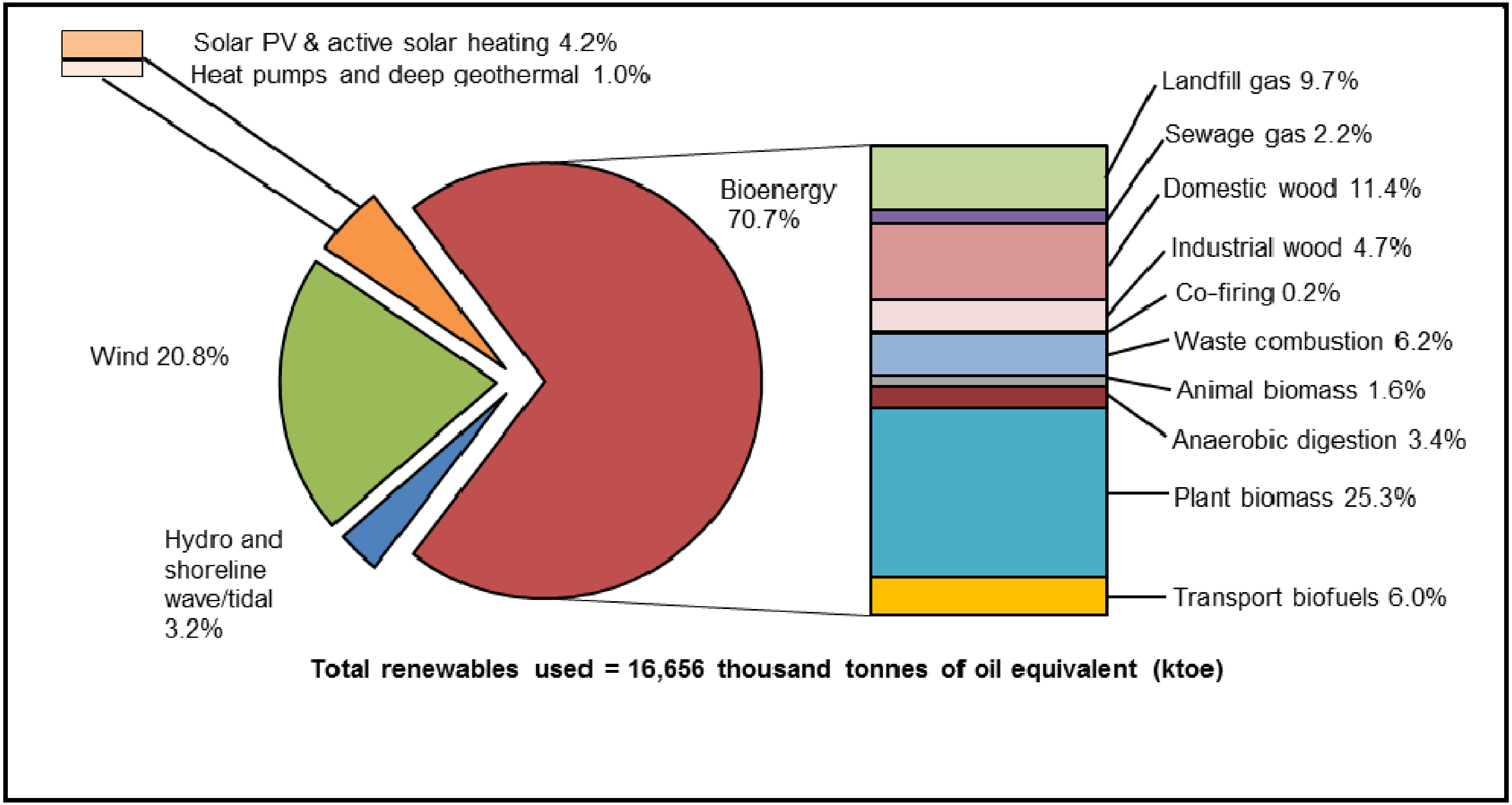
Regulations are driving search for cleaner fuels

- UN's International Maritime Organisation - Sulphur oxides (SOx) – Regulation 14

Wind, solar and hydro together generated 15% of Britain's electrical demand in 2015.

Based on DECC data

UK Renewable energy fuel use 2015



Digest of United Kingdom energy statistics (DUKES)

There is a continuing demand for fluid fuels

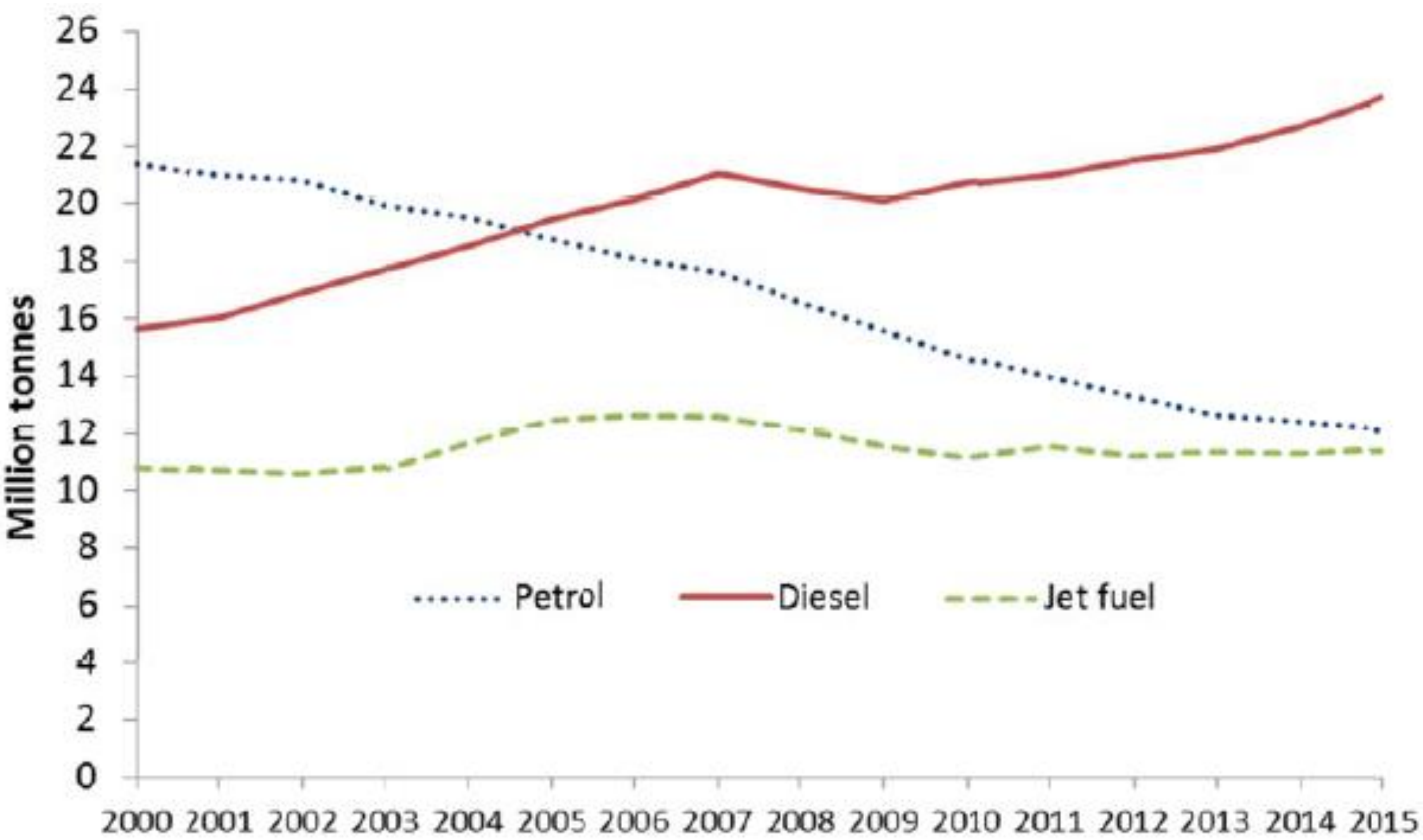
The EU Renewable Energy Directive (RED)

Targets for biofuel energy content in transport fuels

- 2005 - 2%
- 2020 - 10%   ???????????

Only Sweden and Germany met the 2005 target

UK Petrol, Diesel & Jet fuel usage



DECC 2016

Sources of biomass and biofuels

BIOMASS

- Oil crops e.g. rape, sunflower, palm
- Algae
- Sugar crops e.g. cane, beet, sorghum
- Starch crops e.g. wheat, maize, potato
- Herbaceous biomass e.g. switchgrass
- Waste biomass e.g. BMW, food waste, animal slurries, sewage sludge
- Woody biomass

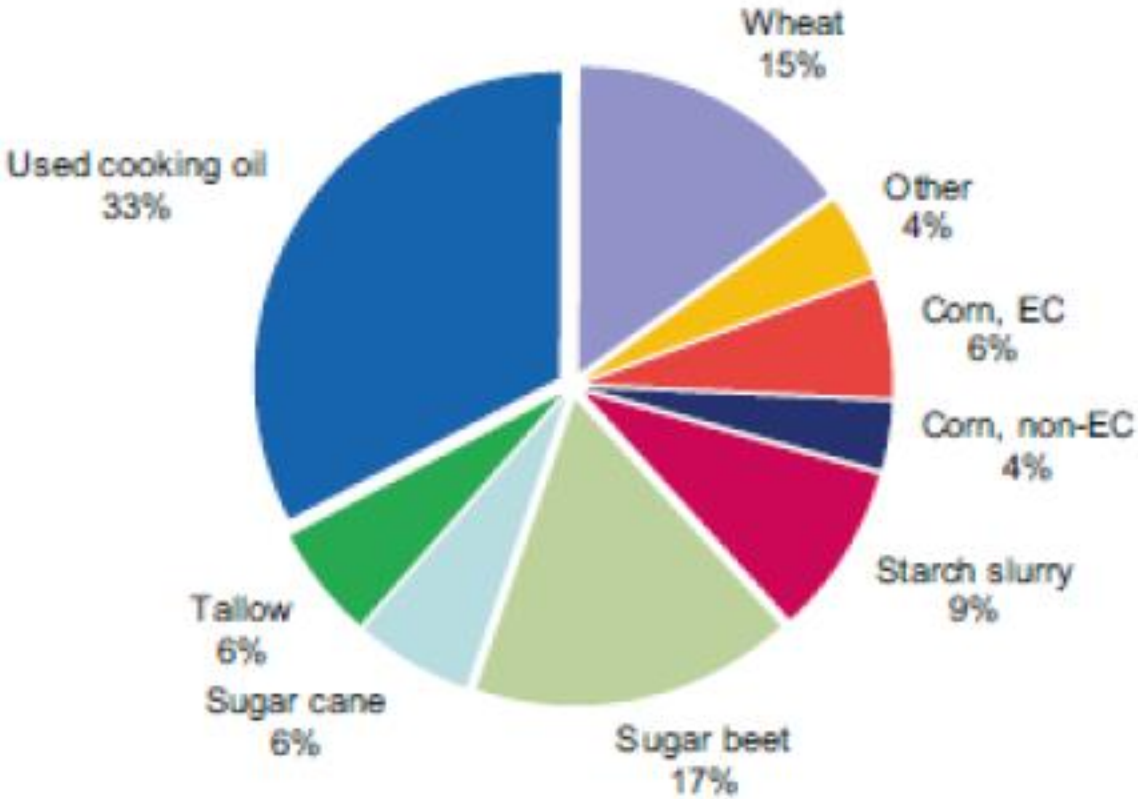
BIOFUEL PROCESSES

- Transesterification
- Ethanol fermentation
- Butanol fermentation
- Anaerobic digestion or fermentation
- Pyrolysis
- Gasification
- Hydrothermal
- Combustion
- Biorefining

BIOFUELS

- Biodiesel
- Glycerol
- Bioenthanol
- Biobutanol
- Biogas
- Biomethane
- Biohydrogen
- Methanol
- Syngas
- Wood

Feedstocks for UK Liquid biofuels



UK biodiesel mainly from Waste Cooking Oil and Tullow

DECC and UKPIA

How “Green” is Biodiesel?

Gallagher Report (2008) - EU target of 10% of transport fuel used by 2020s unlikely to be met sustainably.

The Gallagher Review of the indirect effects of biofuels production, Renewable Fuels Agency , 2008 .
http://webarchive.nationalarchives.gov.uk/20110407094507/renewablefuelsagency.gov.uk/reportsandpublications/reviewoftheindirecteffectsofbiofuels

Directive (EU) 2015/1513

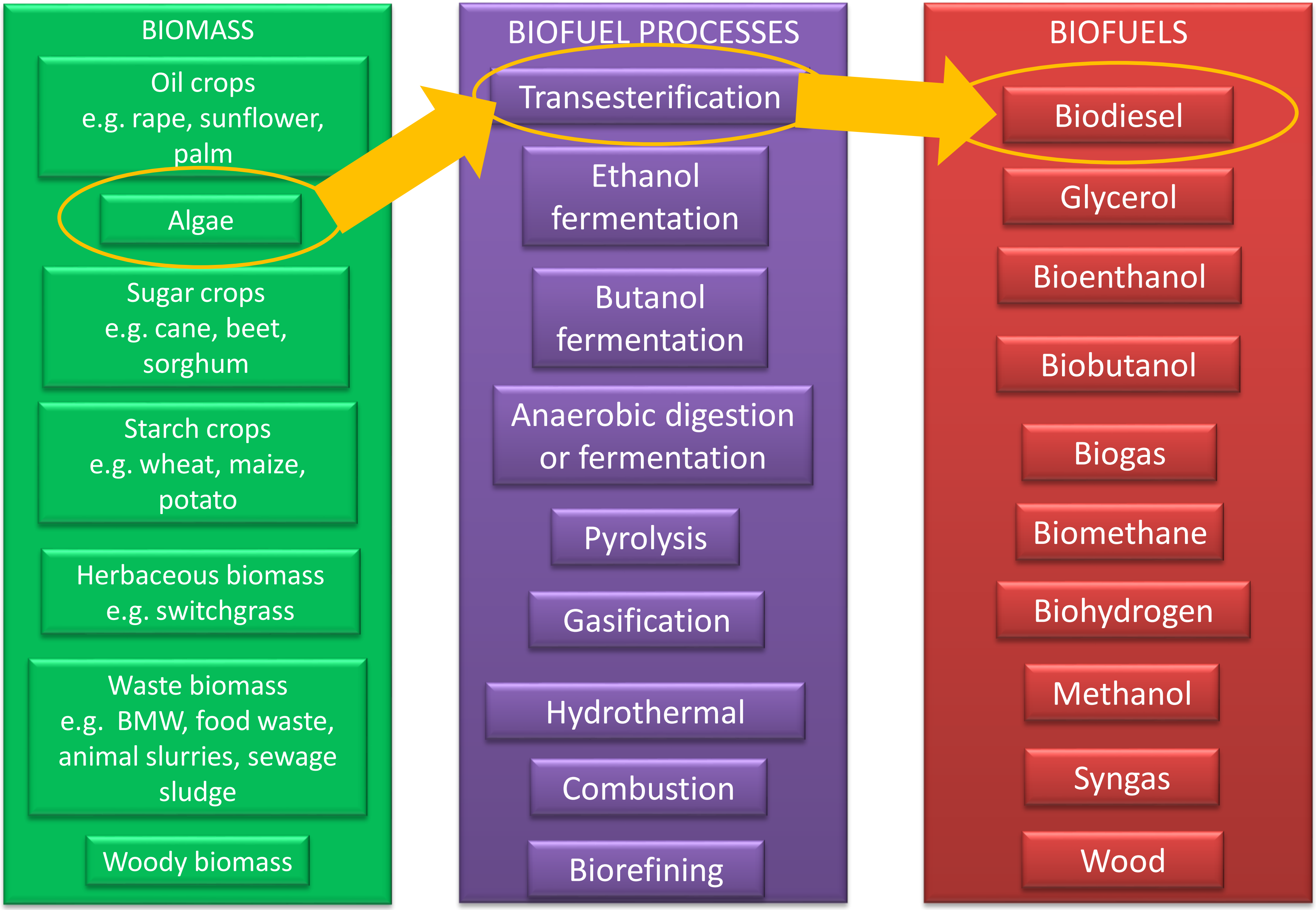
Max 7% contribution by biofuels from 'food' crops

Emphasis on biofuel from:

Waste feedstocks

Advanced biofuels

Sources of biomass and biofuels



What are Algae?

- Diverse range of aquatic ‘plants’, ranging from unicellular to multi-cellular forms,
- Generally possess chlorophyll, but are without true stems and roots.
- Two groups:

  macro-algae commonly known as ‘seaweed’

  micro-algae, microscopic single cell organisms

Seaweed growing on the Medway

Culturing microalgae in flasks

Why Algae?

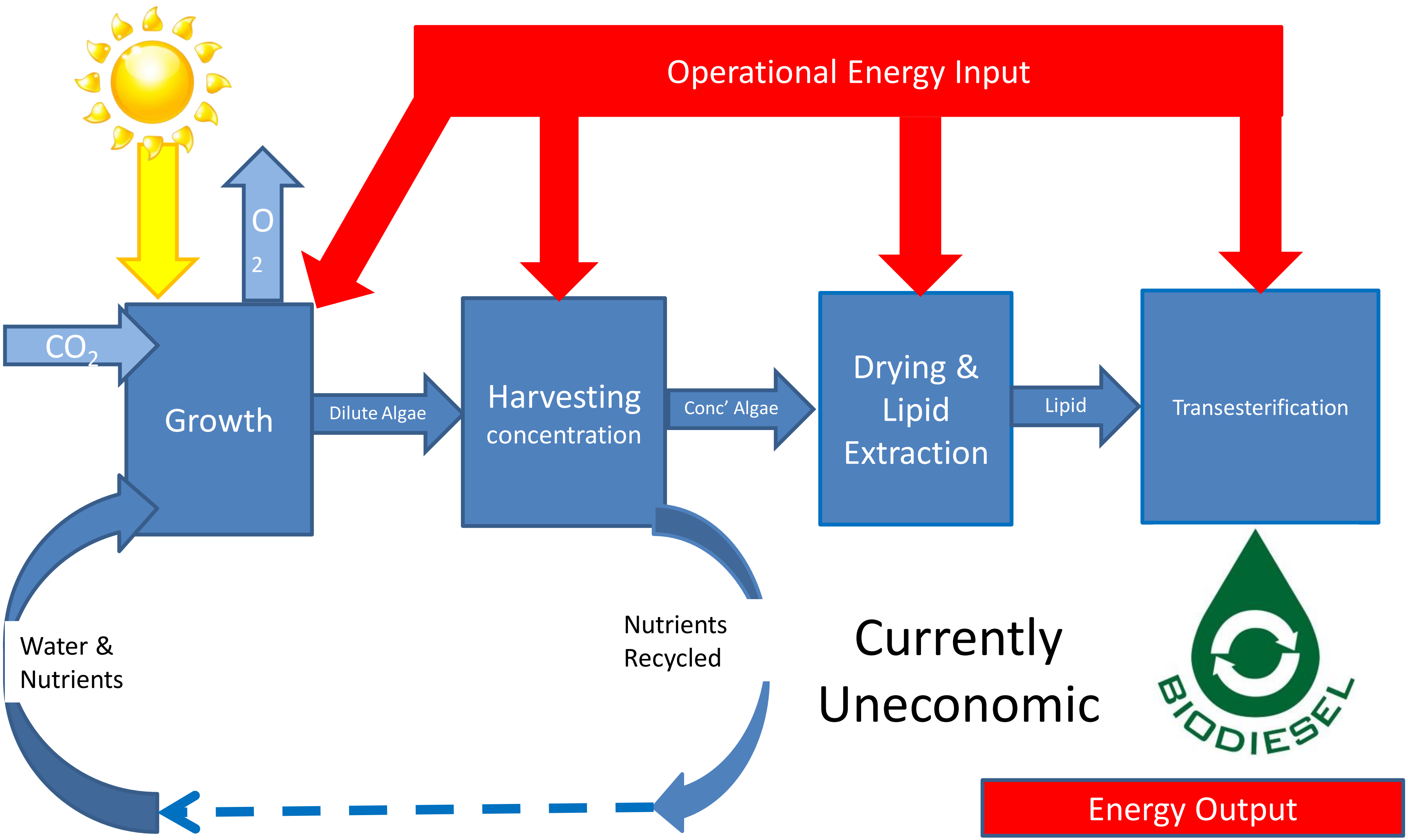
- Algae can be cultivated on non-agricultural land or at sea.
- Many species grow in brackish or salt water.
- Potential productivity greater than terrestrial crops

Microalgae can contain high quantities of lipids (oil)

Nitzschia palea	80%
Botryococcus braunii	75%
Monallantus salina	72%
Chlorella protothecoides	55%
Scenedesmus dimorphus	40%
Prymnesium parvum	38%

Source University of Cape Town

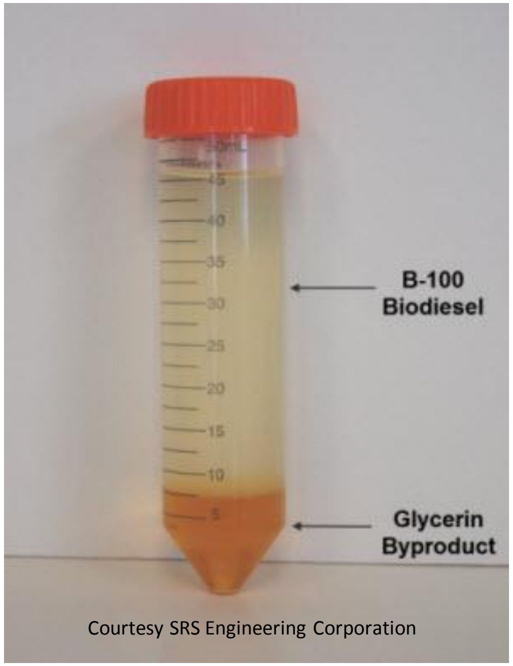
Microalgal Biodiesel Process



Glycerol the byproduct of Biodiesel

Triglyceride + Methanol → Biodiesel + Glycerol
Catalyst

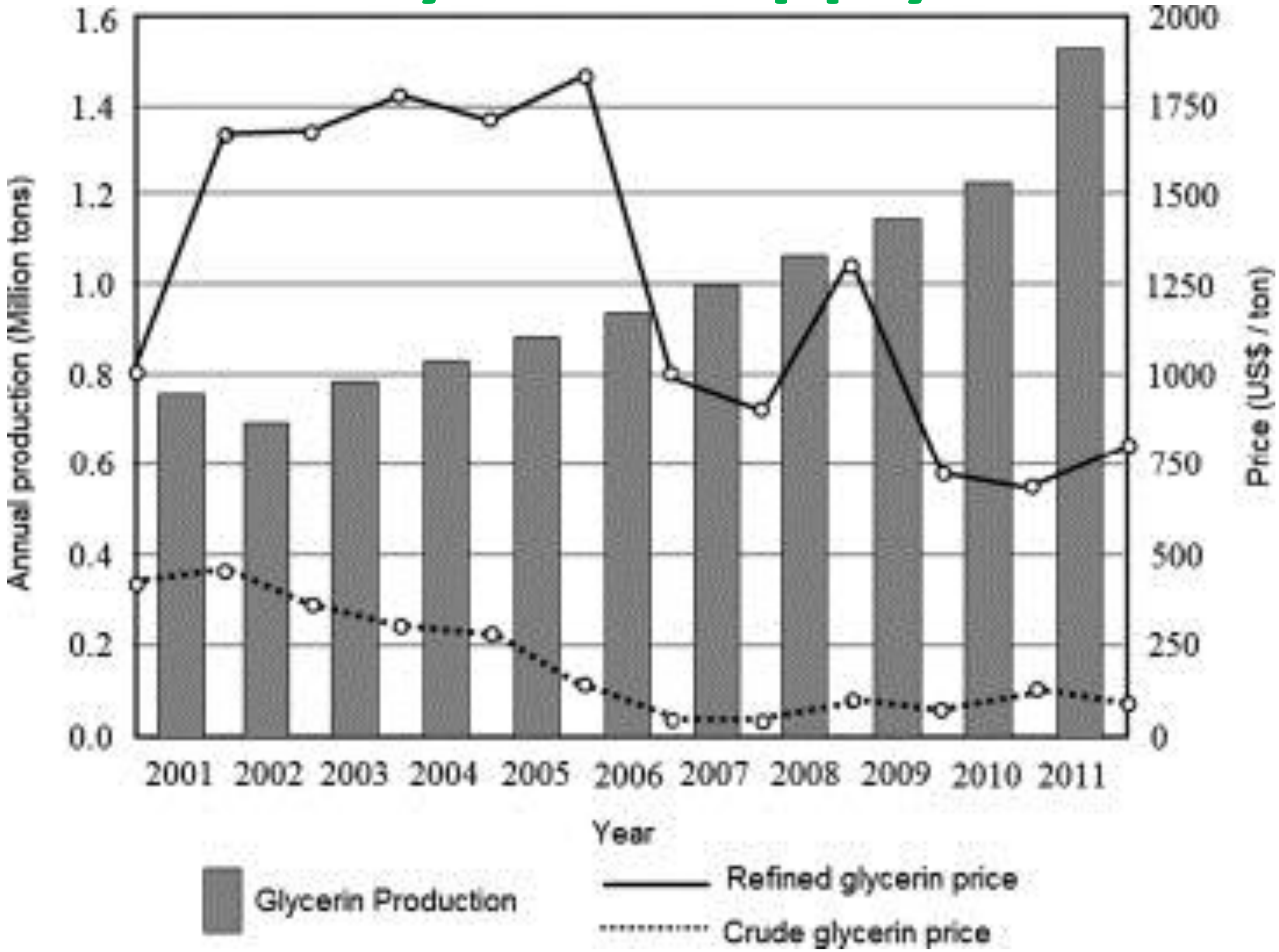
- The glycerol 9 -13% of fats and oils
- ~100 kg of Glycerol from 1 ton of oil



- Biodiesel accounted for only 9% of the supply of Glycerol in 1999 but 64% in 2009

Croda Glycerine Market Brief

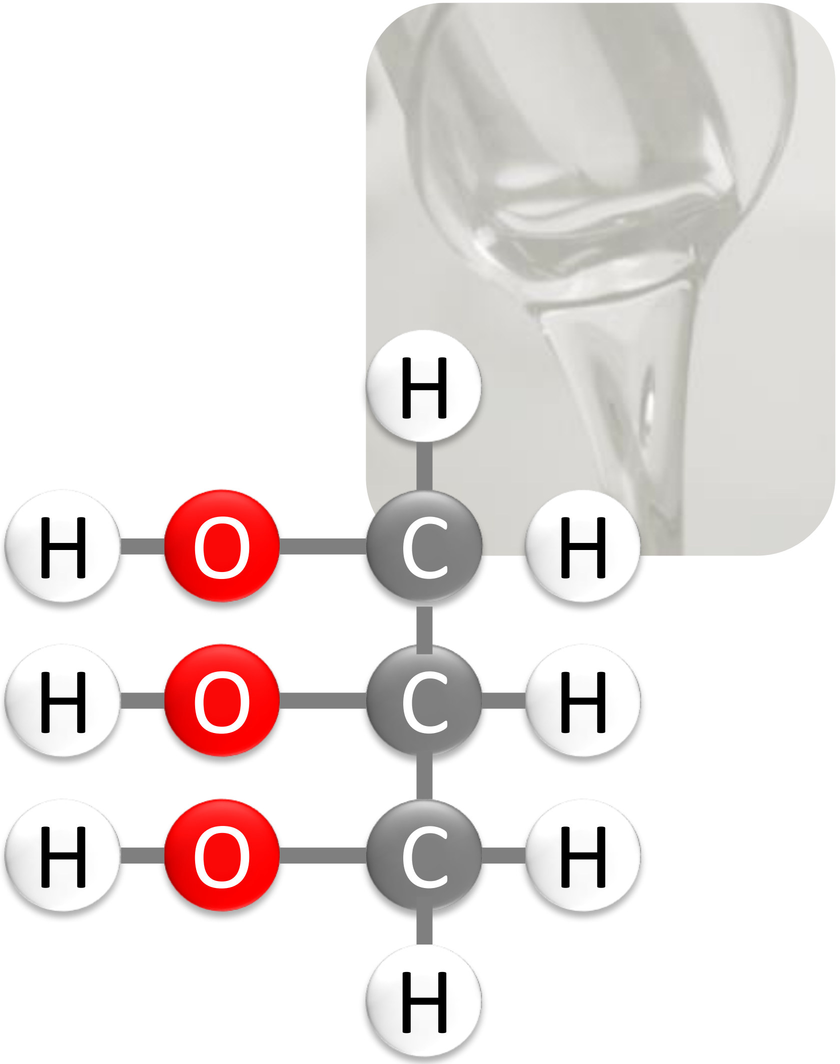
Biodiesel is the Main Driver of Glycerol Supply



Quispe CAG, Coronado CJR, Carvalho Jr JA (2013) Glycerol: Production, consumption, prices, characterization and new trends in combustion Renew and Sustain Energy Rev 27:475-493 d

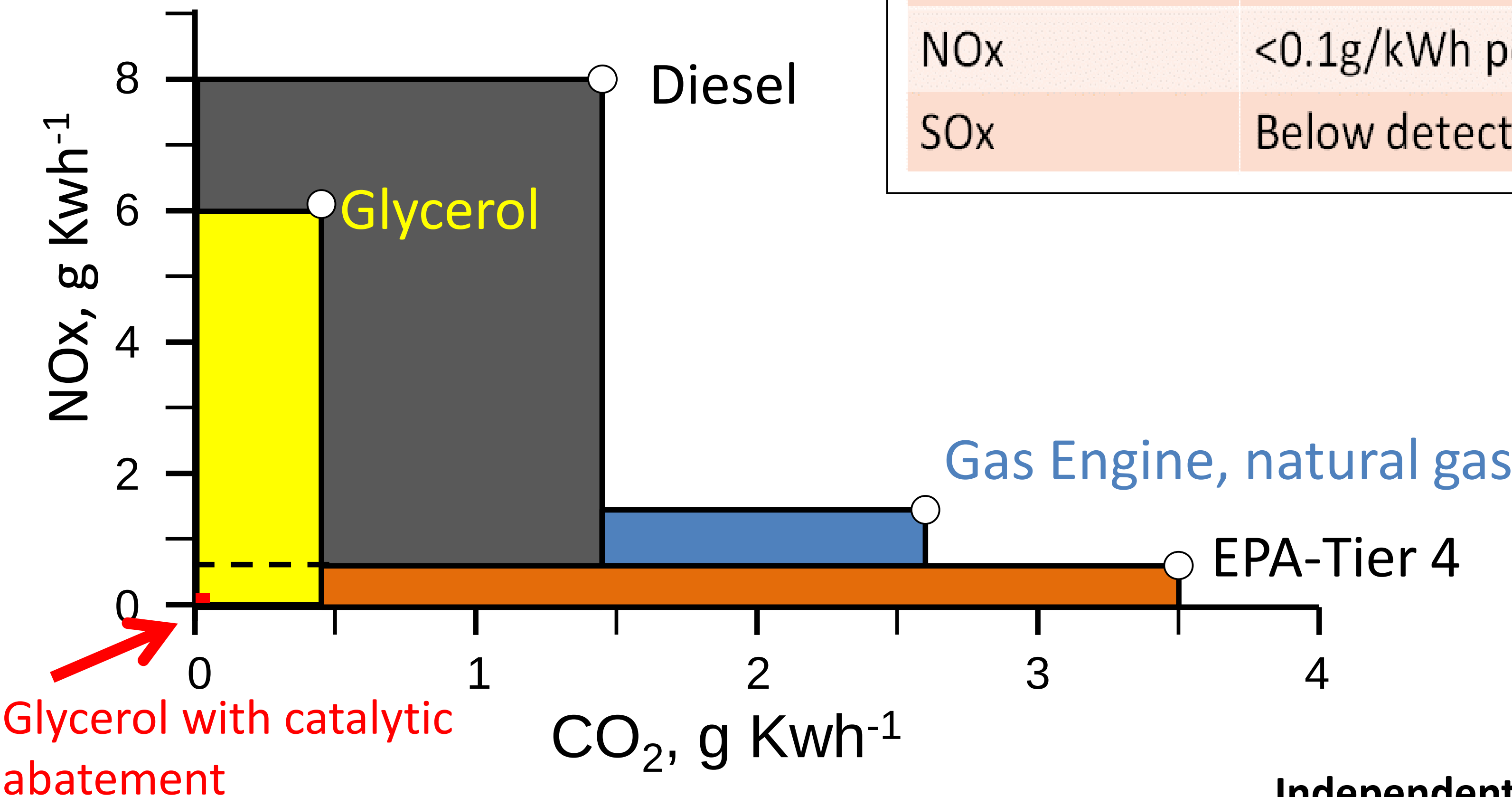
Glycerol

- Water-soluble
- Non-flammable
- Non-volatile
- High boiling point
- Bio-production
- Bio-degradable



Glycerol emissions on combustion

Emissions	Amount
Particulate	Below detection limits
NOx	<0.1g/kWh possible
SOx	Below detection limits



Independently verified

University of Greenwich has installed a glycerol-fired Combined Heat and Power plant at the Medway Campus

This is the first building retro-fit in the world.

france (manche channel) england
interreg

European Regional Development Fund
The European Union, investing in your future

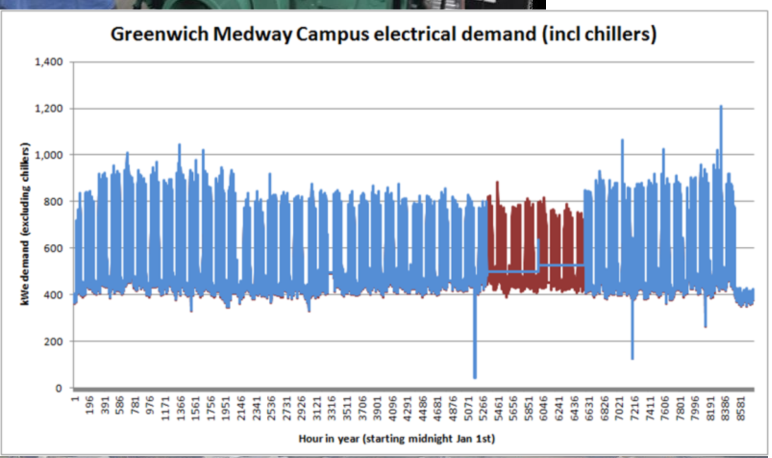
Fonds européen de développement régional
L'Union européenne investit dans votre avenir

Ecotec21

Glycerol -CHP

Combined Heat and Power

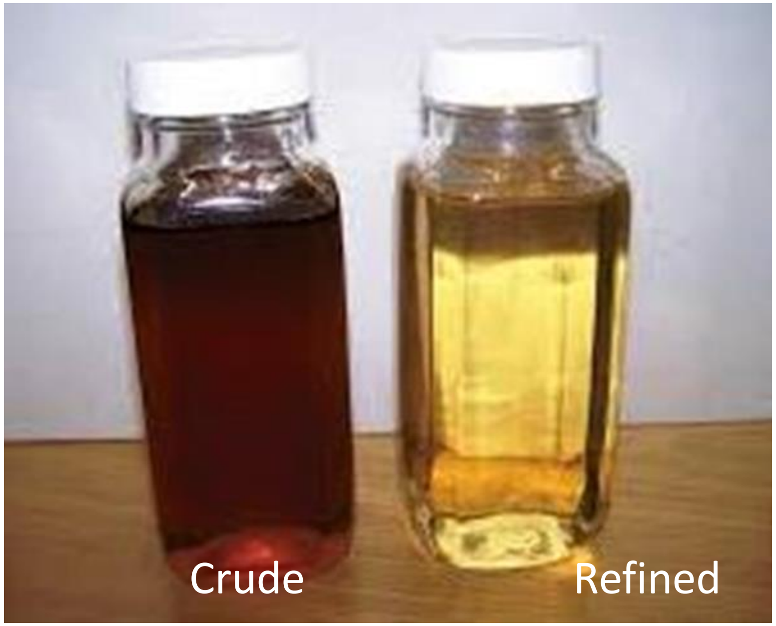
410 kW of Electricity
450 kW of Heating



2600 tonnes per annum

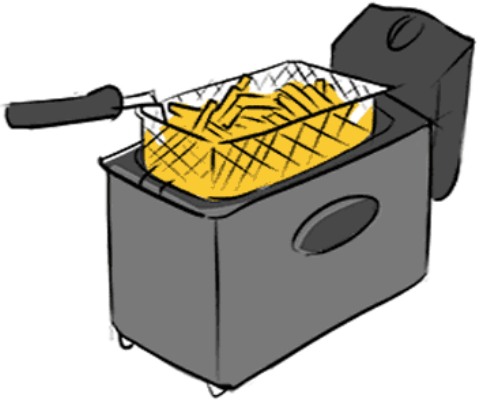
Reduction in Carbon Footprint

Problems



Quality

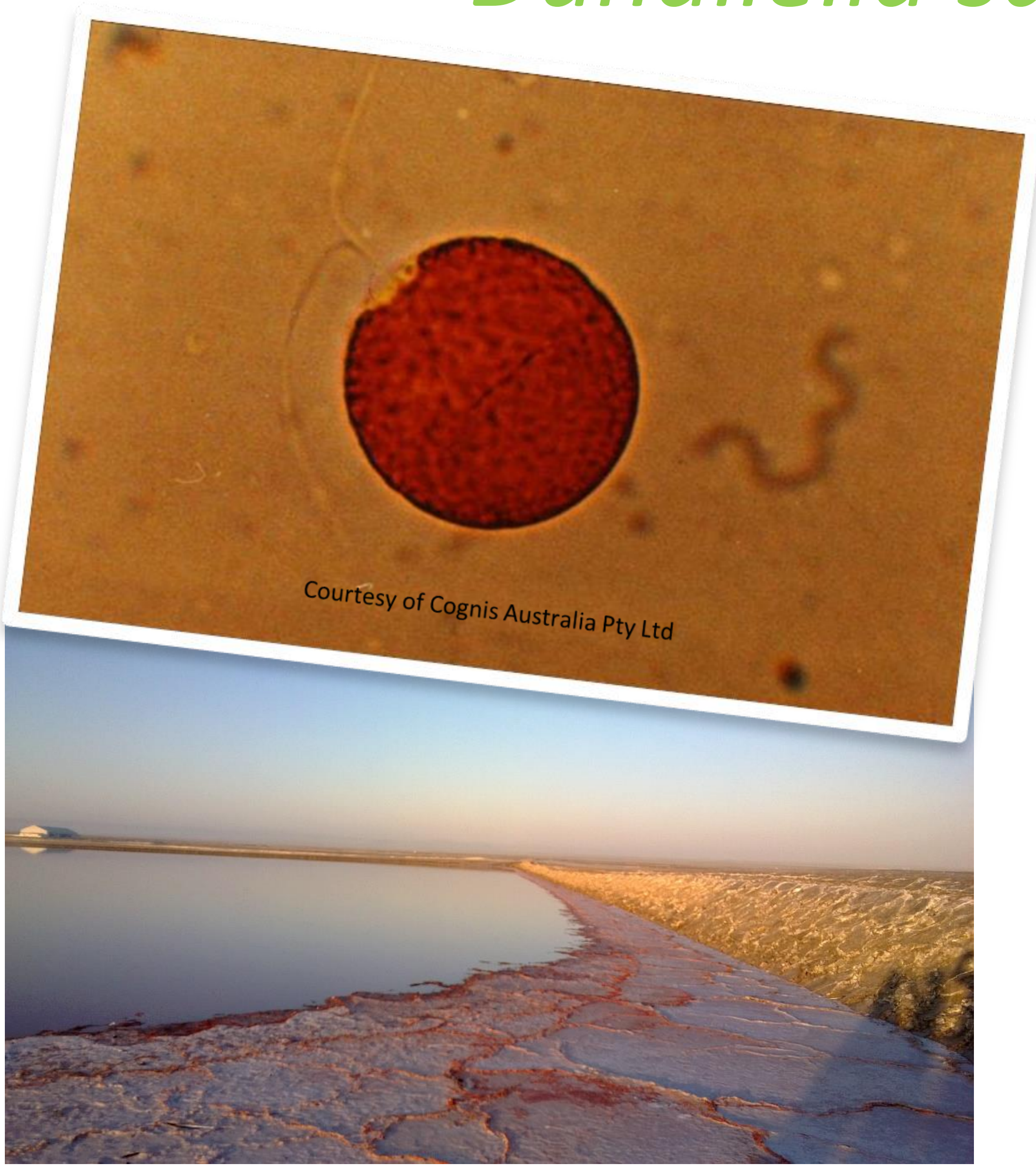
Costly to refine crude glycerol



Future Sustainable supply

Limited waste cooking oil

Dunaliella salina



Microalga

>80% glycerol

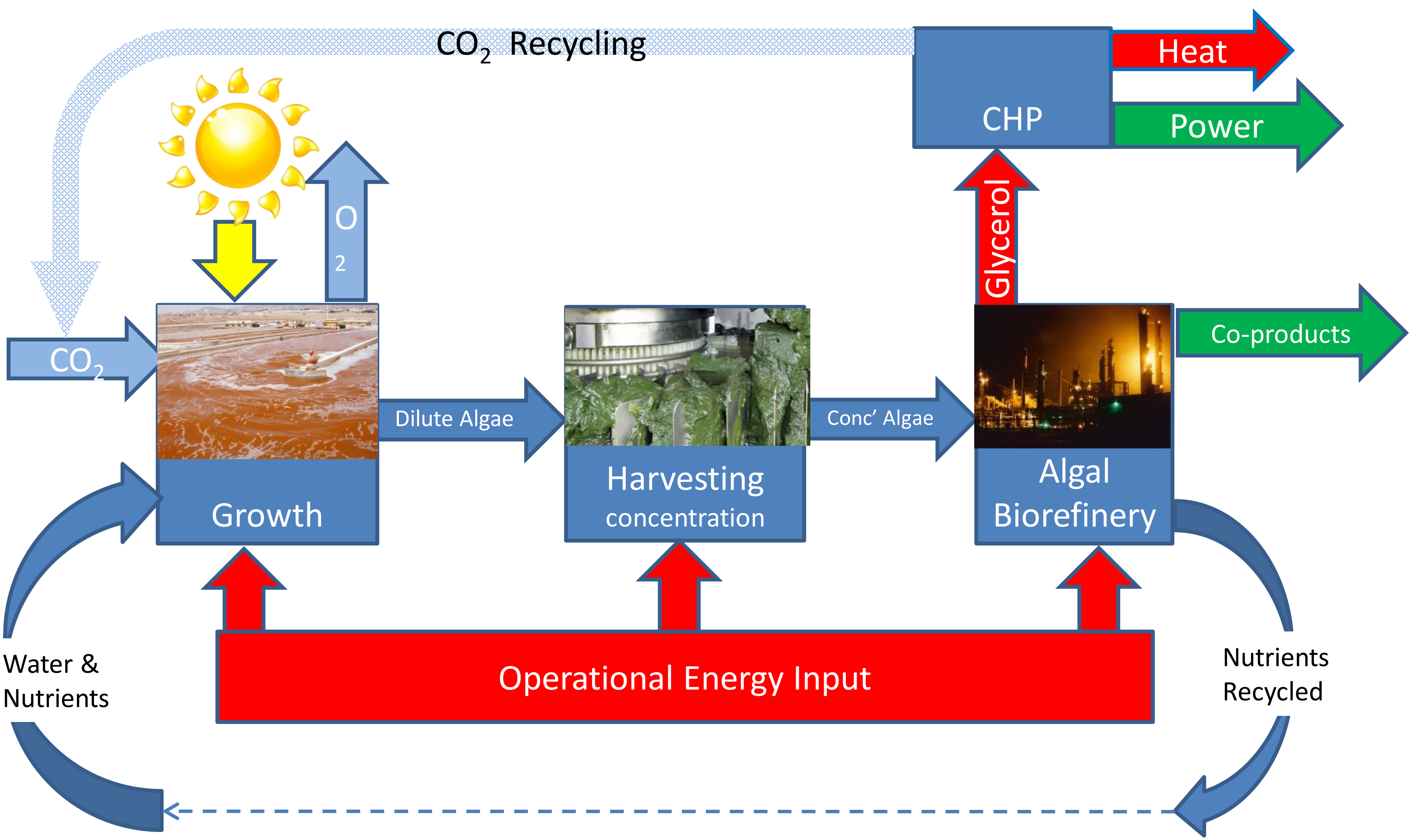
Commercially grown

β Carotene >14 %

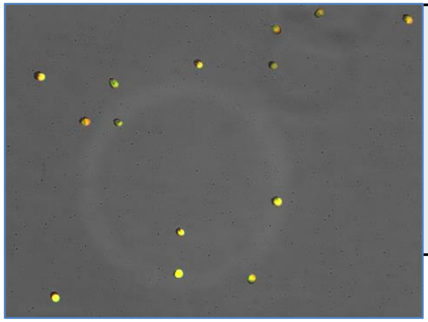
Salt tolerant

Grows in salt-pans

Dunaliella Glycerol CHP

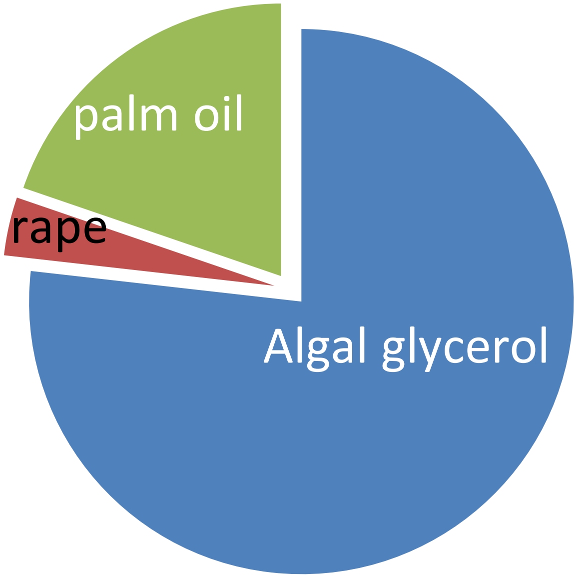


Estimate of annual glycerol production



Average Biomass dry matter yield	$gm^{-2}d^{-1}$	16
Glycerol % in dry matter	%	80
Days per year operational	days	350

annual production	44.8 tonnes ha y^{-1}
annual energy production	850 gJ ha^{-1}



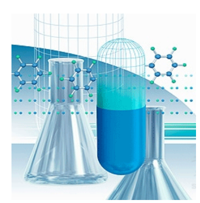
- *8,000 hrs operation*
- *1,800 t glycerol yr^{-1}*
- *~40 Hectares*

The D-Factory for glycerol

KBBE.2013.3.2 (No: 613870)

1. 10 million Euro FP7-funded project
2. 13 partners from 8 countries – 2 universities
3. Flexibly and sustainably produce suites of compounds and fuel from *Dunaliella* to meet market requirements.
4. Showcase a sustainable biorefinery: demo - 2017/8






Macroalgal (Seaweed) Biofuels Research at Greenwich University

Algal Biofuels

Method	Utilises entire algal biomass	Utilises wet biomass	Primary energy product
Direct combustion	✓	✗	Heat
Pyrolysis	✓	✗	Primarily liquid by fast pyrolysis
Gasification	✓	✗ [b] **(conventional)**	Primarily Gas
Biodiesel production	✗	✗ [c]	Liquid
Hydrothermal treatments	✓	✓	Primarily Liquid
Bioethanol production	✗ [a]	✓	Liquid
Biobutanol production	✗ [a]	✓	Liquid
Anaerobic digestion	✓	✓	Gas

[a] Polysaccharides require hydrolysis to fermentable sugars. Some of the sugars produced from the breakdown of seaweed polysaccharides are not readily fermented; [b] Supercritical water gasification (SCWG) an alternative gasification technology can convert high moisture biomass; [c] No current commercial process for the wet trans-esterification of wet macroalgal biomass

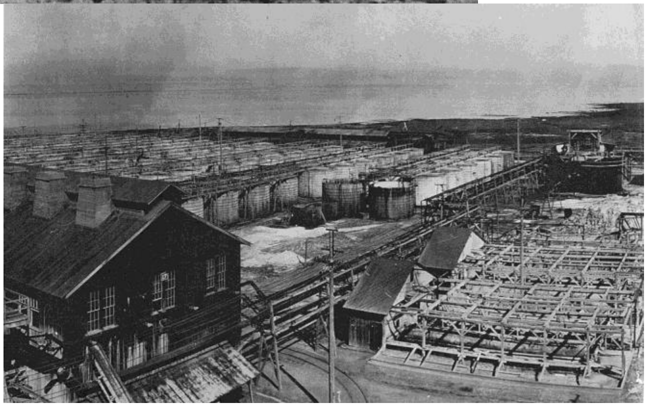
Sargassum muticum feedstock

Season	Ash	C	H	O	N	S	HHV
% total wt.		% dry weight					KJ g^{-1} dw
Spring	29.5	30.7	4.0	29.6	4.9	1.5	16.3
Summer	33.3	30.1	4.2	28.1	3.6	0.8	12.0

- High moisture ~85%
- High ash
- High Sulphur
- HHV lower than terrestrial energy crops

Maintaining Year Round Supply

- Harvesting is seasonal
- Need to preserve and store for a continuous supply



Ensilage

- Used to store forage for animal feed
- Naturally-present bacteria
- Lactic acid fermentation under anaerobic conditions
- pH decreases to preserve cop

Ensiled seaweed composition

	Moisture	C	H	O	N	S	Ash	Salt	HHV
	% total wt.	% dry weight						% of ash	KJ g^{-1} dw
Unensiled	**85.4**	**30.1**	**4.2**	**28.1**	**3.6**	**0.8**	**33.3**	**46.1**	**12.05**
Ensiled whole	**85.5**	**30.0**	**4.2**	**29.3**	**3.3**	**<0.1**	**33.1**	**43.6**	**12.13**
Ensiled chopped	**85.2**	**29.4**	**3.9**	**29.8**	**3.5**	**<0.1**	**33.3**	**45.9**	**12.36**

- No sig difference in CHON, ash and HHV
- Ensiling results in a significant reduction in salt
- Ensiling results in virtual total loss of organic sulphur

Energy Losses due to Ensiling

<8 % original Higher Heating Value

Effect of Ensilage on CH_4 Yield

	Methane production	
	L CH_4 g^{-1} VS	
	Average	StdV
Untreated	**0.10**	**0.05**
Ensiled whole	**0.11**	**0.08**
Chopped prior to ensiling	**0.06**	**0.01**

No statistically significant effect on methane yields

Acknowledgements

- The Engineering and Physical Sciences Research Council EPSRC EP/K014900/1 – MacroBioCrude
- EU FP7 KBBE.2013.3.2 (No: 613870) D-factory
- High Value Chemicals from Plants

Thank you