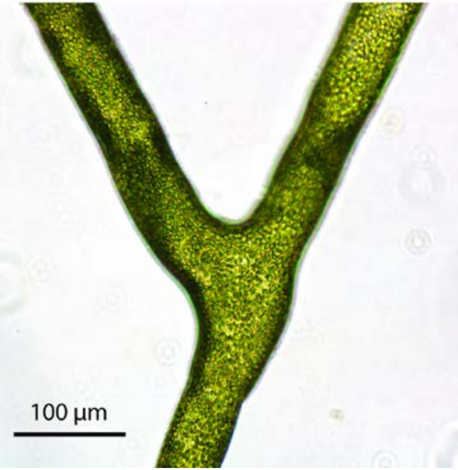
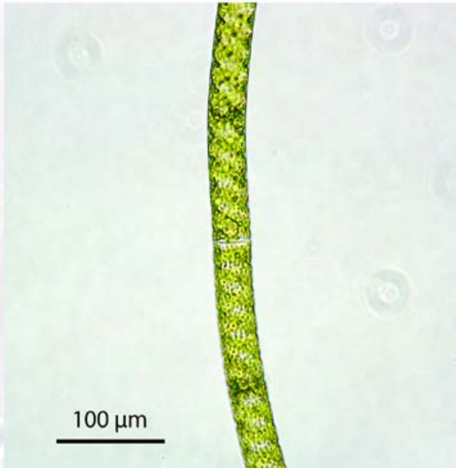
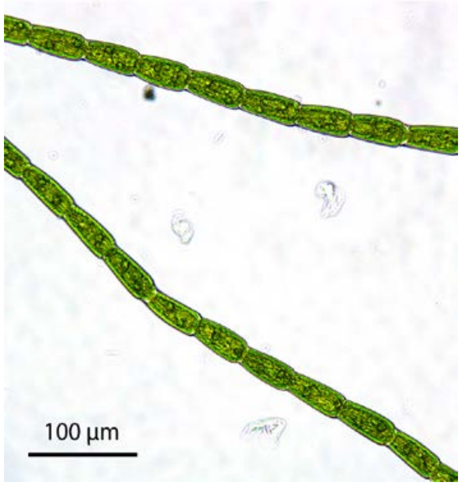
THE UNIVERSITY OF SYDNEY | ARENA Australian Government Australian Renewable Energy Agency | Advanced Manufacturing CRC | MBD ENERGY LIMITED | macro Centre for Macroalgal Resources & Biotechnology | JAMES COOK UNIVERSITY AUSTRALIA

Renewable fuels from algal biomass







Oedogonium

cosmopolitan

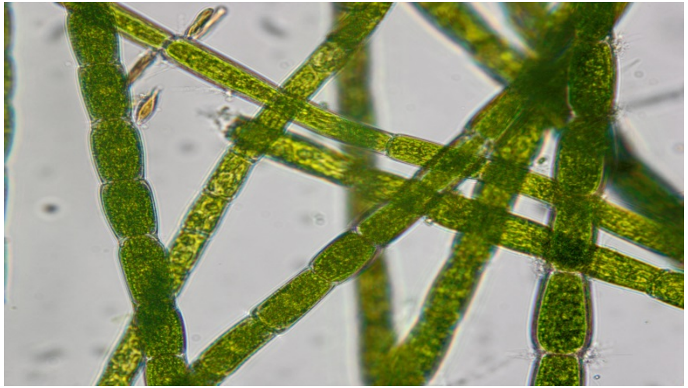
common

diverse[1,2]

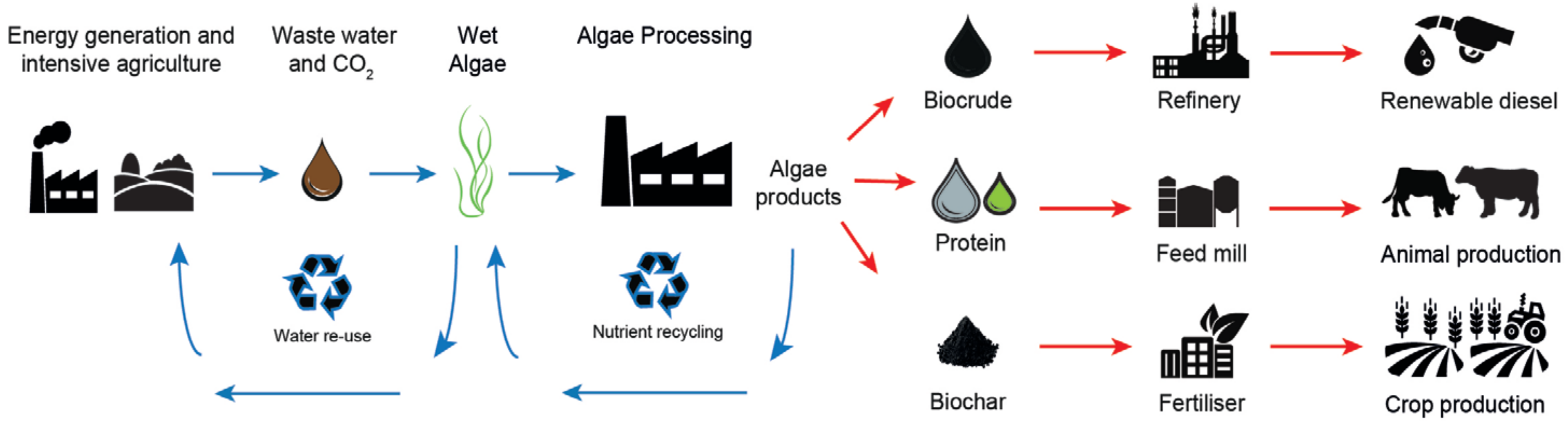
robust[1,2]

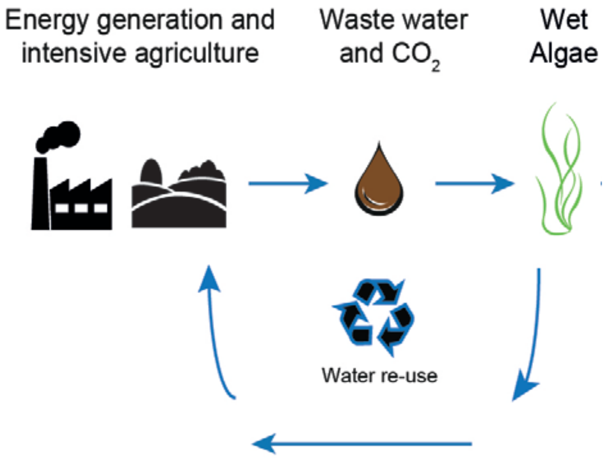
highly competitive[1]

rapidly dominant[1]



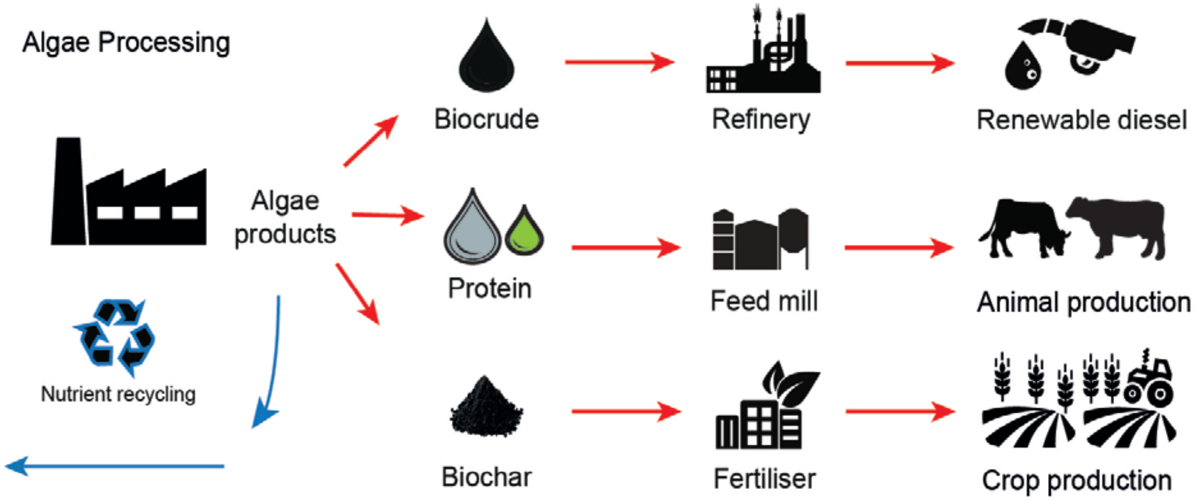
[1]Lawton et al. 2013, PLoS ONE 8(5) e64168, [2]Lawton et al. 2014 PLoS ONE 9(3) e90223


Energy generation and intensive agriculture
Waste water and CO_2
Wet Algae
Algae Processing
Algae products
Water re-use
Nutrient recycling
Biocrude
Refinery
Renewable diesel
Protein
Feed mill
Animal production
Biochar
Fertiliser
Crop production



[3]Roberts et al. 2013 PLoS ONE 8(11) e81631, [4]Ellison et al. 2014 PeerJ 2 e401,

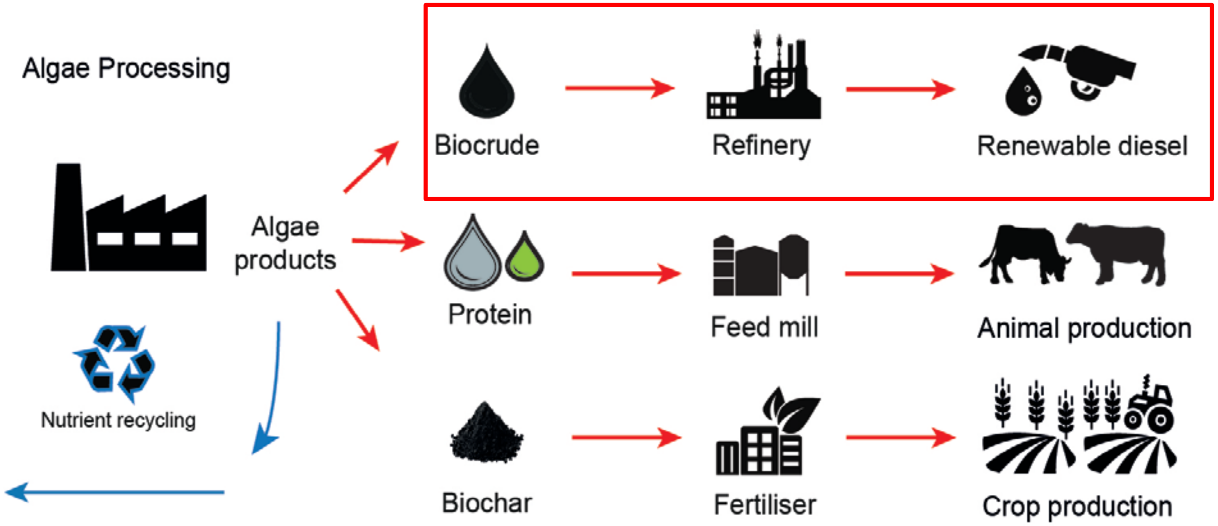
[5]Cole et al. 2014 GCB Bioenergy doi 10.111/gcbb.12097, [6]Cole et al. 2014 PLoS ONE in press



[7]Kan et al. 2014 Energy & Fuels 28, 104-114, [8]Lane et al. 2014 Energy & Fuels 28, 41-51, [9]Zhu et al. 2013, Pro. ACS 1-4,

[10]Neveux et al. 2014 GCB Bioenergy doi:10.1111/gcbb12171, [11]Neveux et al. 2014 Bioresource Technology 155, 334-341,

[12]Kidgell et al. 2014 PLoS ONE 9(6) e94706



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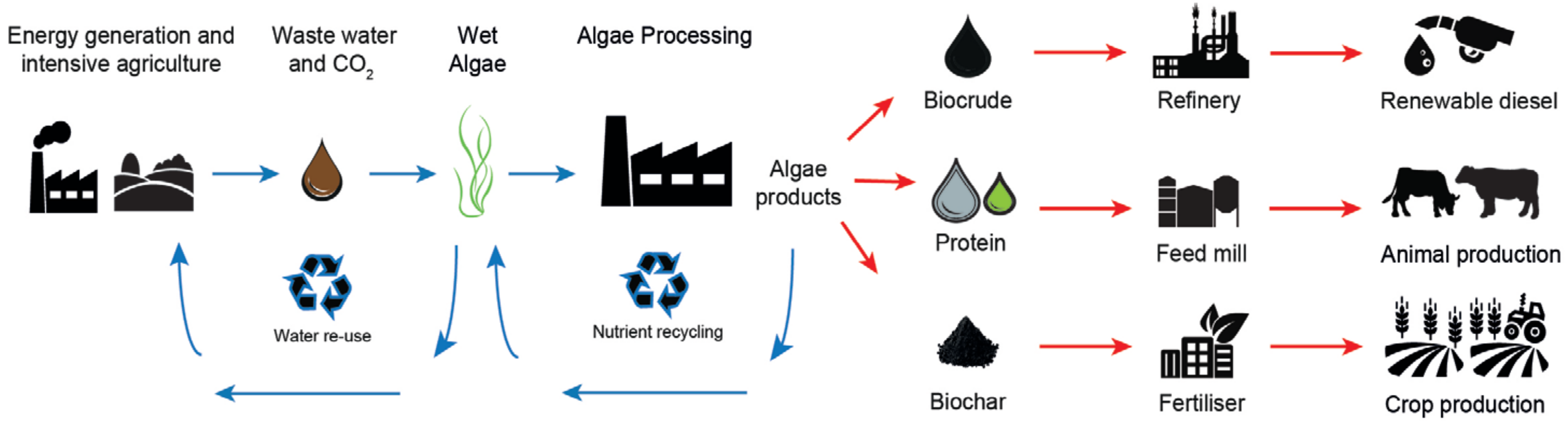
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Oedogonium - integrated production

freshwater (agriculture)

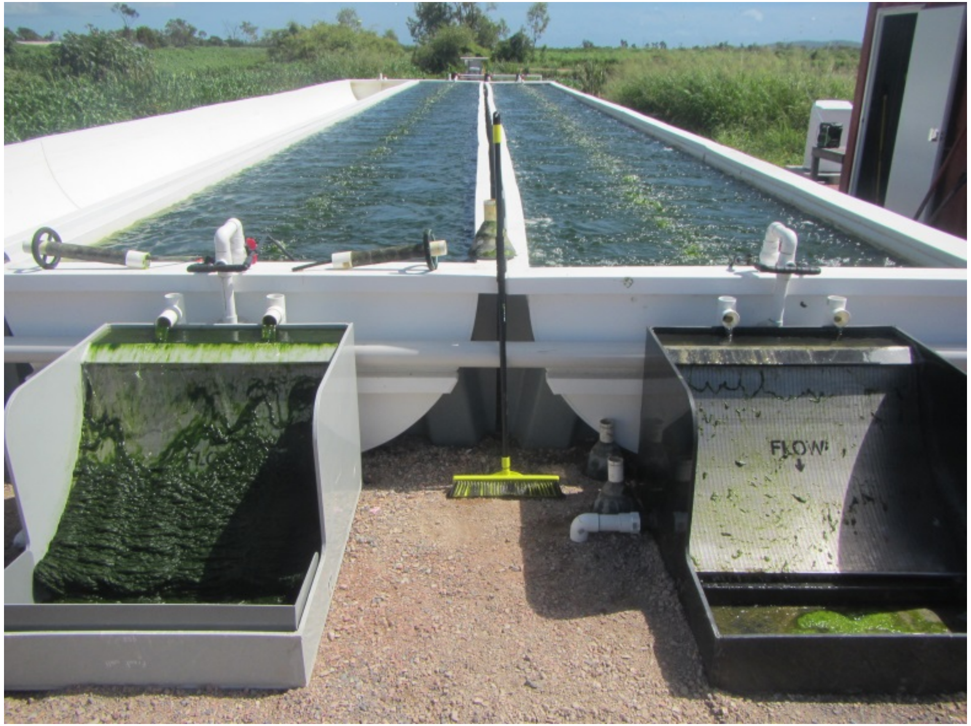
no addition of nutrients

no addition of CO_2

no contamination

self harvesting

rapid growth[5,6]



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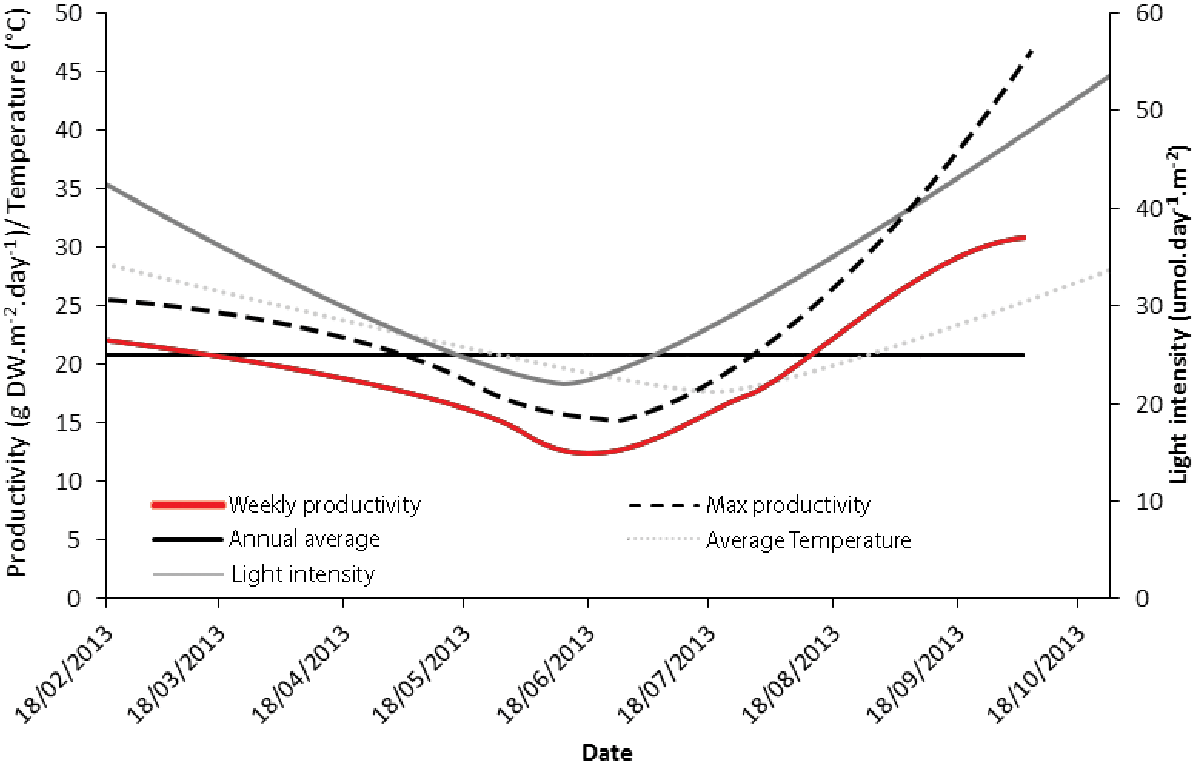
Oedogonium - biomass productivity



Oedogonium - integrated production

freshwater (municipal)

no addition of nutrients

no addition of CO_2

no contamination

self harvesting

rapid growth

Oedogonium

total crude lipids = 8.7 ± 1.5

total fatty acids = 4.9 ± 0.7

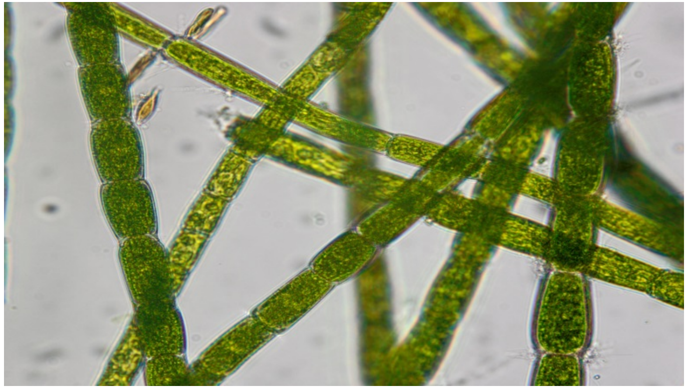
protein = 22.7 ± 3.4

carbohydrate = 45.6 ± 10.7

ash = 20 ± 5.7

HHV = 16.5 ± 2.1

(n = 4 - 46)



Oedogonium - energy options

anaerobic digestion

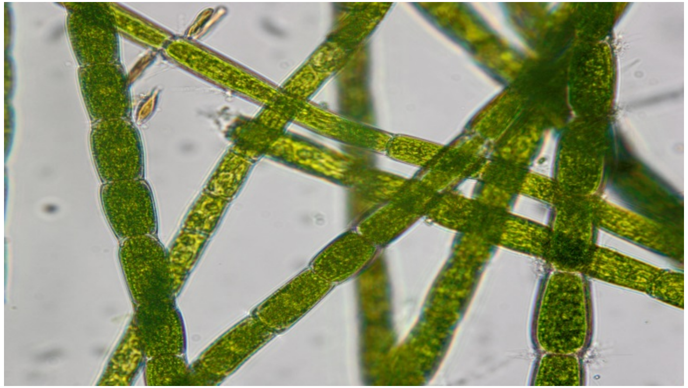
slow pyrolysis

fast pyrolysis[7]

direct combustion[8]

co-combustion[9]

hydrothermal liquefaction[10,11]



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Oedogonium – biomass composition

Macroalgae	Ultimate					HHV
	C	H	O	N	S	$MJ.kg^{-1}$
Oedogonium	**36.6**	**5.7**	**30.9**	**4.8**	**0.4**	**15.8**
C. vagabunda	37.5	5.9	32.9	6.5	1.8	16.4
C. linum	26.5	4.1	31.0	3.4	2.1	10.3
C. coelothrix	30.9	5.0	34.9	5.2	2.3	12.7
D. tenuissima	29.2	4.8	27.4	4.5	2.8	12.4
U. ohnoi	27.7	5.5	41.1	3.5	5.0	11.7

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hydrothermal liquefaction

subcritical water conditions

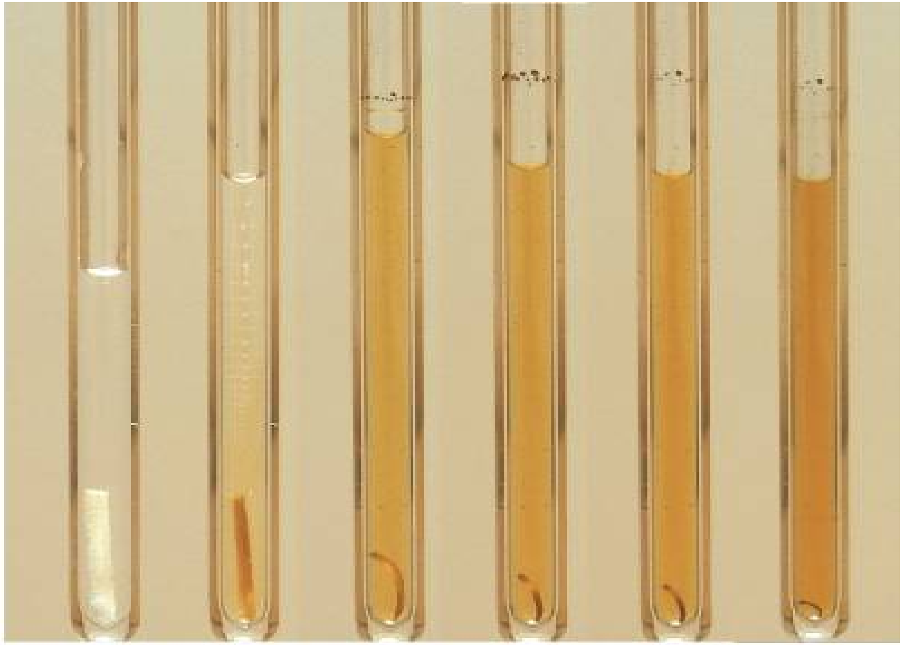
medium temperature (250 – 400^{o}C)

high pressure (10 – 30 MPa)

macromolecule breakdown

water = solvent + reactant

hydrolysis
recombination



Visualisation experiment – Wood in HTL
University Twente – Quartz capillaries Prof. Van der Swaaij

Thermochemical processing - HTL

Research scale

350°C in 3 minutes + 350°C for 5 minutes

150 bar

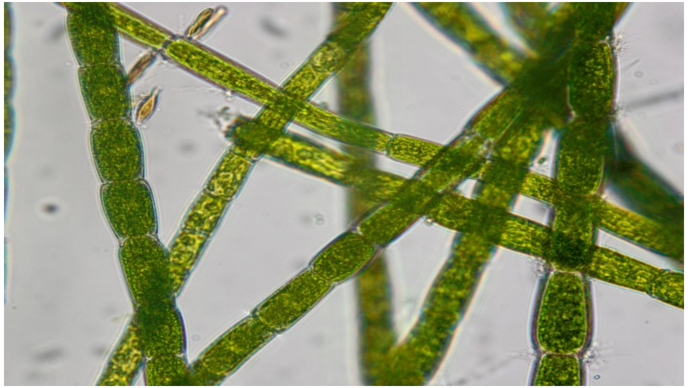
Quenched and quantified

Biocrude

Biochar

Gaseous phase

Aqueous phase



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Macroalgae	Ultimate					HHV
	C	H	O	N	S	MJ.kg^{-1}
Oedogonium	**72.1**	**8.1**	**10.4**	**6.3**	**0.8**	**33.7**
C. vagabunda	71.1	8.3	10.6	6.8	1.3	33.5
C. linum	70.9	7.7	11.4	6.8	0.1	32.5
C. coelothrix	71.6	8.0	10.6	7.1	0.9	33.3
D. tenuissima	73.0	7.5	10.6	6.5	0.7	33.2
U. ohnoi	72.6	8.2	11.0	5.8	0.4	33.8

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C. vagabunda	71.1	8.3	10.6	6.8	1.3	33.5
C. linum	70.9	7.7	11.4	6.8	0.1	32.5
C. coelothrix	71.6	8.0	10.6	7.1	0.9	33.3
D. tenuissima	73.0	7.5	10.6	6.5	0.7	33.2
U. ohnoi	72.6	8.2	11.0	5.8	0.4	33.8

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C. linum	70.9	7.7	11.4	6.8	0.1	32.5
C. coelothrix	71.6	8.0	10.6	7.1	0.9	33.3
D. tenuissima	73.0	7.5	10.6	6.5	0.7	33.2
U. ohnoi	72.6	8.2	11.0	5.8	0.4	33.8

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Oedogonium sp. (20-100,000 L)

Biomass productivity 15 - 30 g $m^{-2}.day^{-1}$

Carbon content 35 - 43%

Biomass energy (HHV) 16 - 20 $MJ.kg^{-1}$

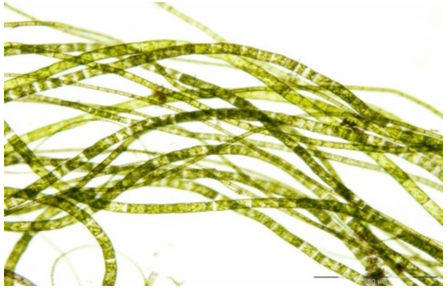
Ash 6-11%

Biocrude yield 30 - 35 %

Biocrude energy 33 $MJ.kg^{-1}$

Continuous Flow HTL (1 - 10 kg)

Pilot-scale commercial HTL (10 – 100 kg)



Renewable fuels from algal biomass