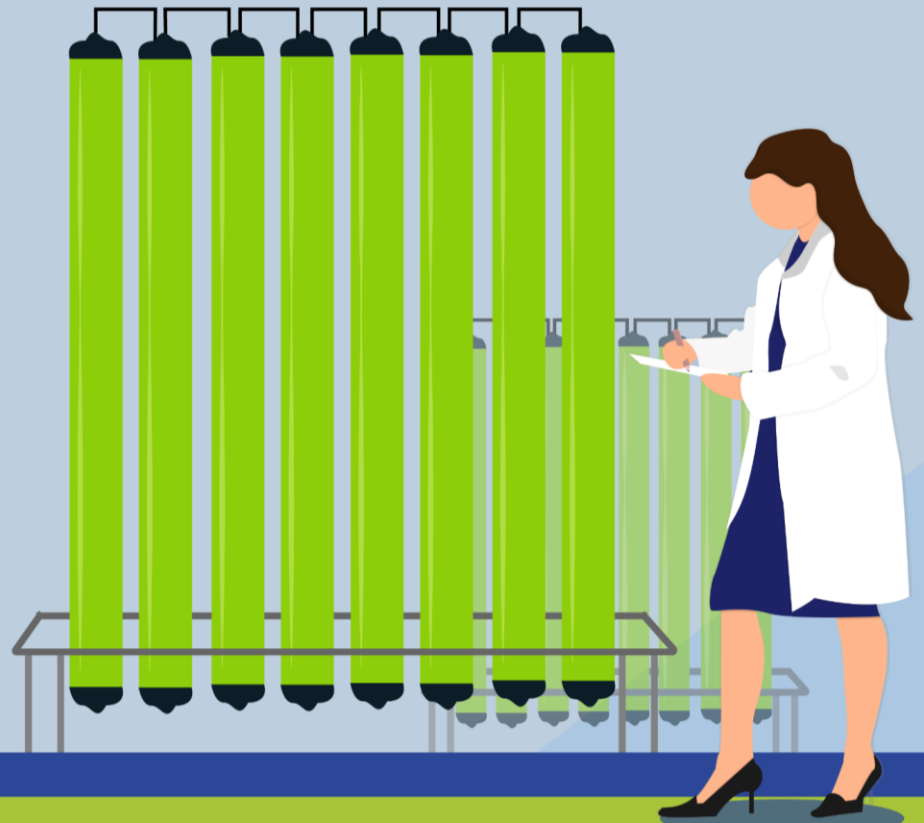
Algal biotechnology application for the water quality improvement and agriculture waste remediation



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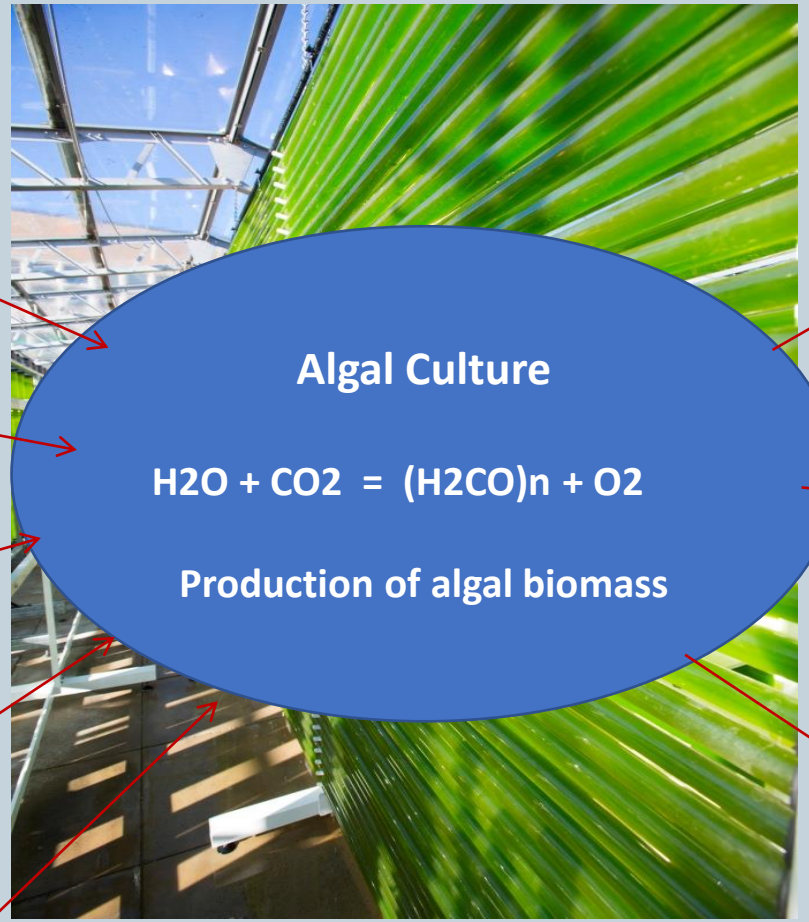
Microalgal production

Solar energy

Water:
- Freshwater
- Brackish water
- Sea water

CO_2

N2
Nitrogen fixation



Algal Culture

$H_2O + CO_2 = (H_2CO)_n + O_2$

Production of algal biomass

WASTE STREAMS Nutrients: N, P and C

TREATED
CLEAN WATER

OXYGEN PRODUCTION

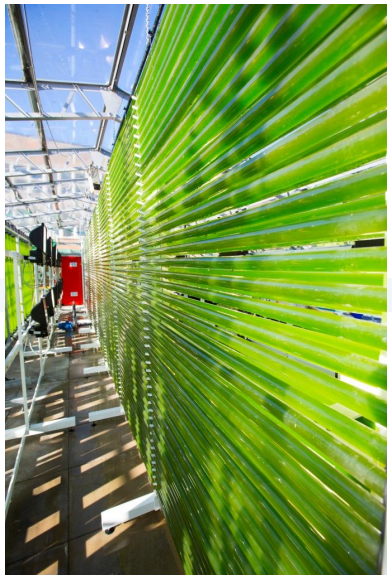
Valuable
BIOMASS

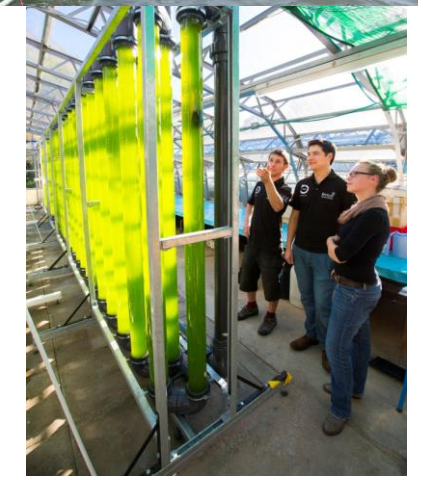
Algal Research in Swansea University

- History of nearly 5 decades.
- Originally pure physiology (SERC), latterly environmental (NERC), now applied through various routes, most involving industry.
- One of the very few remaining centres for the study of whole growth & physiology and also with onsite process engineering facilities
- …. factors essential for commercial production.
- Bioscience department now has the largest research photo-bioreactor capacity in the UK …
- .. supported by analytical methods for bulk determinants and ca. £500k equipment ….
- … together with research for downstream processing

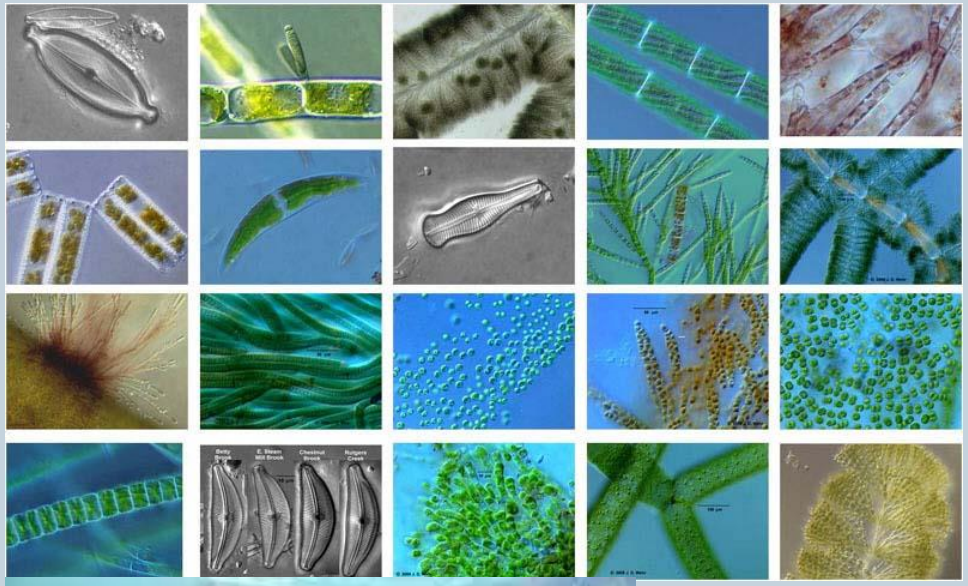
- Algal collections ~ 27 species for mass cultivation (Sterile cultures 20ml → 2L → 20L Carboys)
- 20 x 100L batch culture capacity, controlled environment lab
- 2 x 800L Biofences, greenhouse
- 1 x 1,000L Phyco-Flow glass PBR,
- 1 x 2,000L PBR, greenhouse
- 1 x 4,000L vertical PBR,
- 3 x 3,000L Phycoponds (Raceways)
- Industrial pilot -400L PBR and 1,000LRW

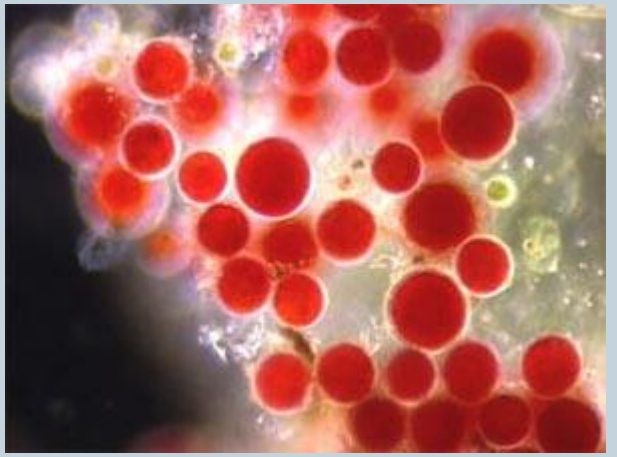
- Pilot dewatering facilities membrane filtration: MF, UF, DF
- Continues flow-centrifuge 200 L/hours
- Industrial freeze dryer /Spray drier
- Homogeniser and bead mill

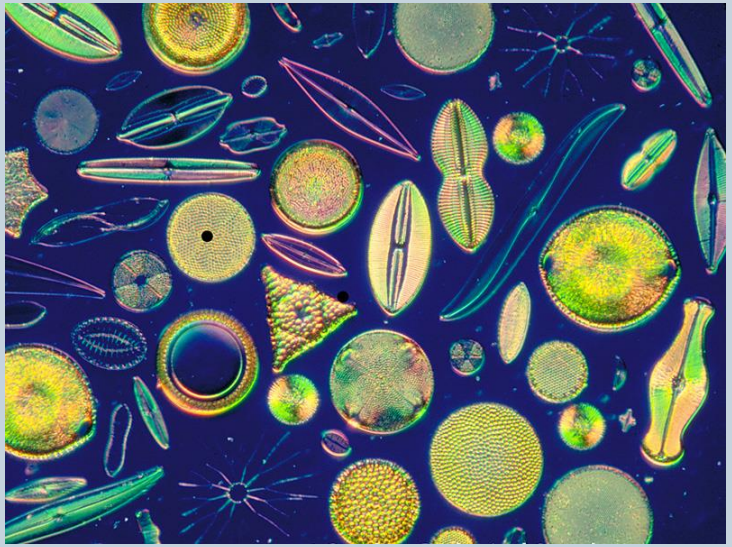




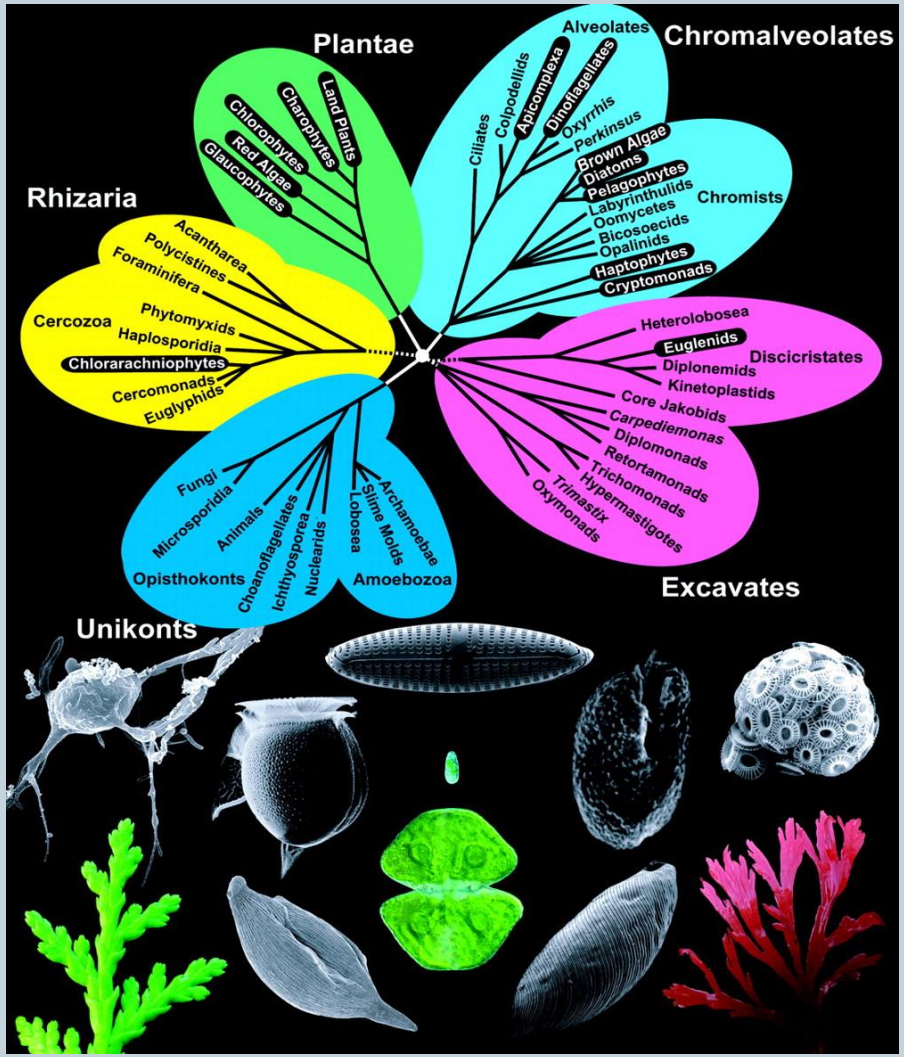
Algal species diversity

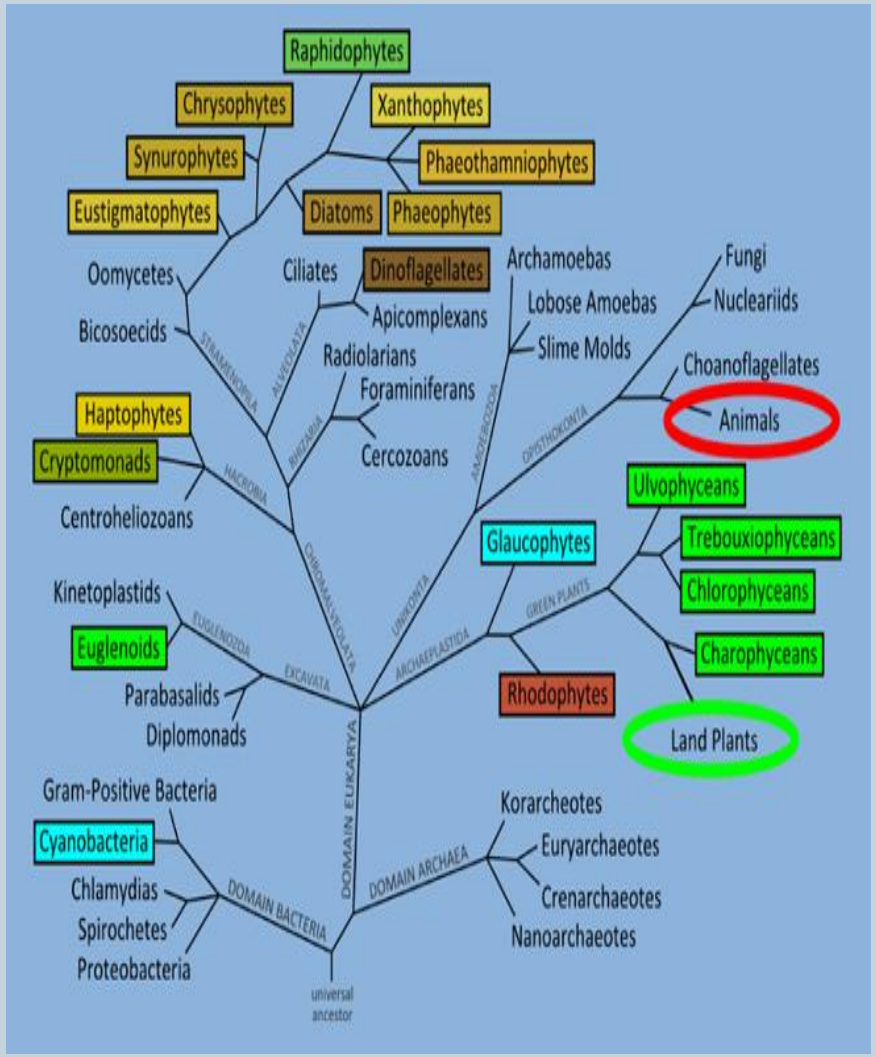




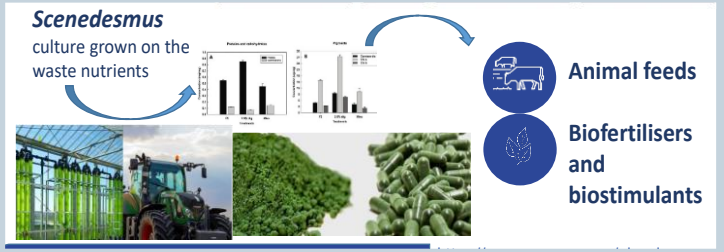


Evolutionary pathway





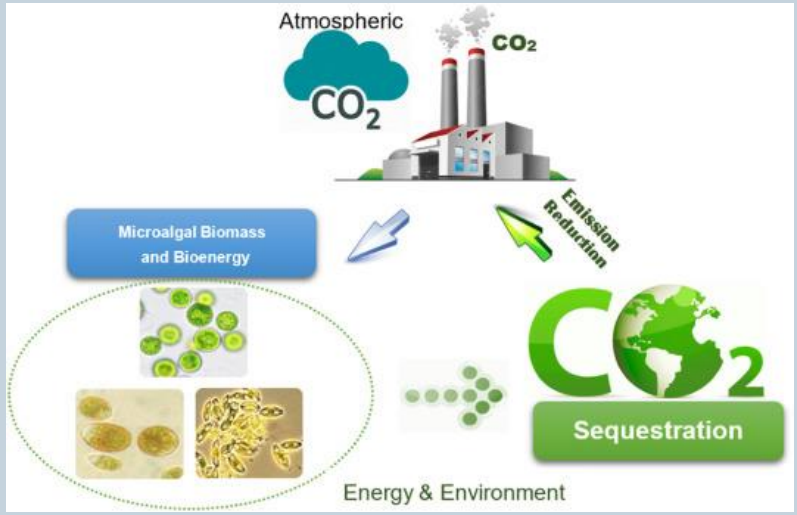
WASTE MANAGEMENT USING ALGAE



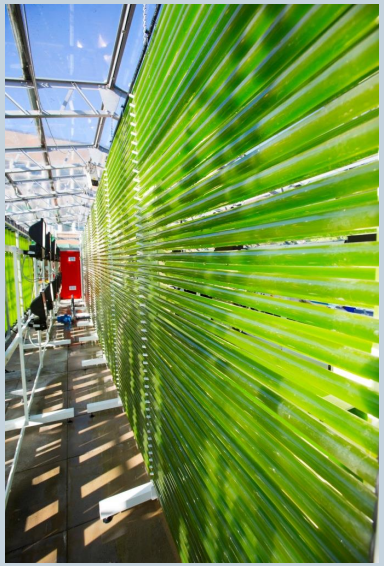
- Highly adaptable organisms
- Variety of growth conditions
- Utilising macronutrients for their growth such as N, P and C
- Tolerance and absorption of metals and other wastewater components
- Photodegradation, Bioabsorbtion and Bioaccumulation by algal cells
- Long track record of multiple projects in SU

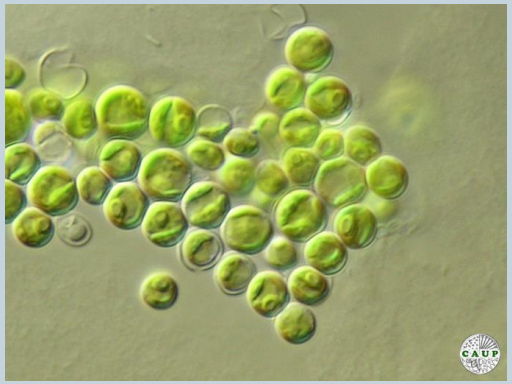
ENHANCE MICROALGAE

Carbon, Nitrogen and Phosphorus remediation by algae



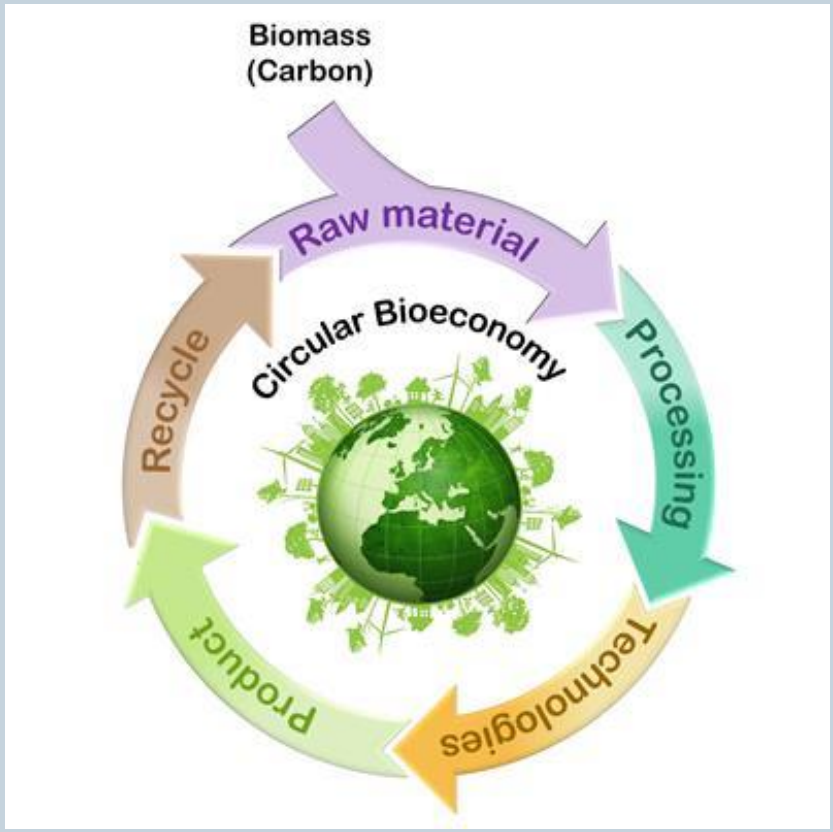
- Algae has an ability to capture and re-use up to **1.8 -2.2kg** of CO_2 per kilogram of algal biomass
- Highly adaptable for high temperature and other flue gases
- CO2;NOx;SOx treatments
- Algae are tolerant to CO ...

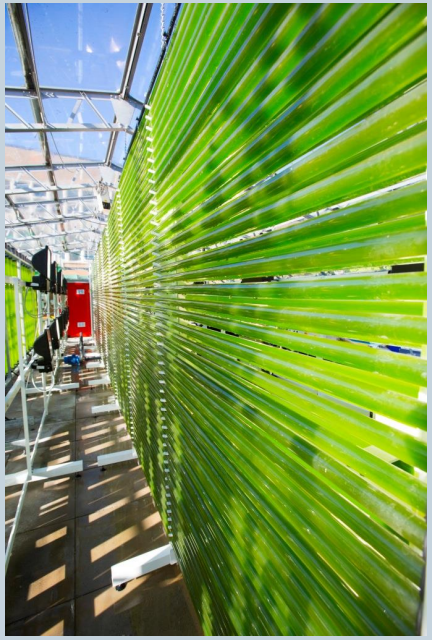


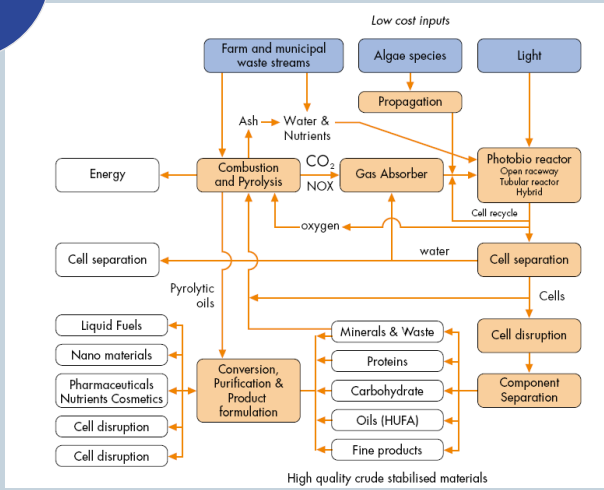


- Mass cultivation systems required...
- The best species are *Chlorella* and *Scenedesmus*- green algae

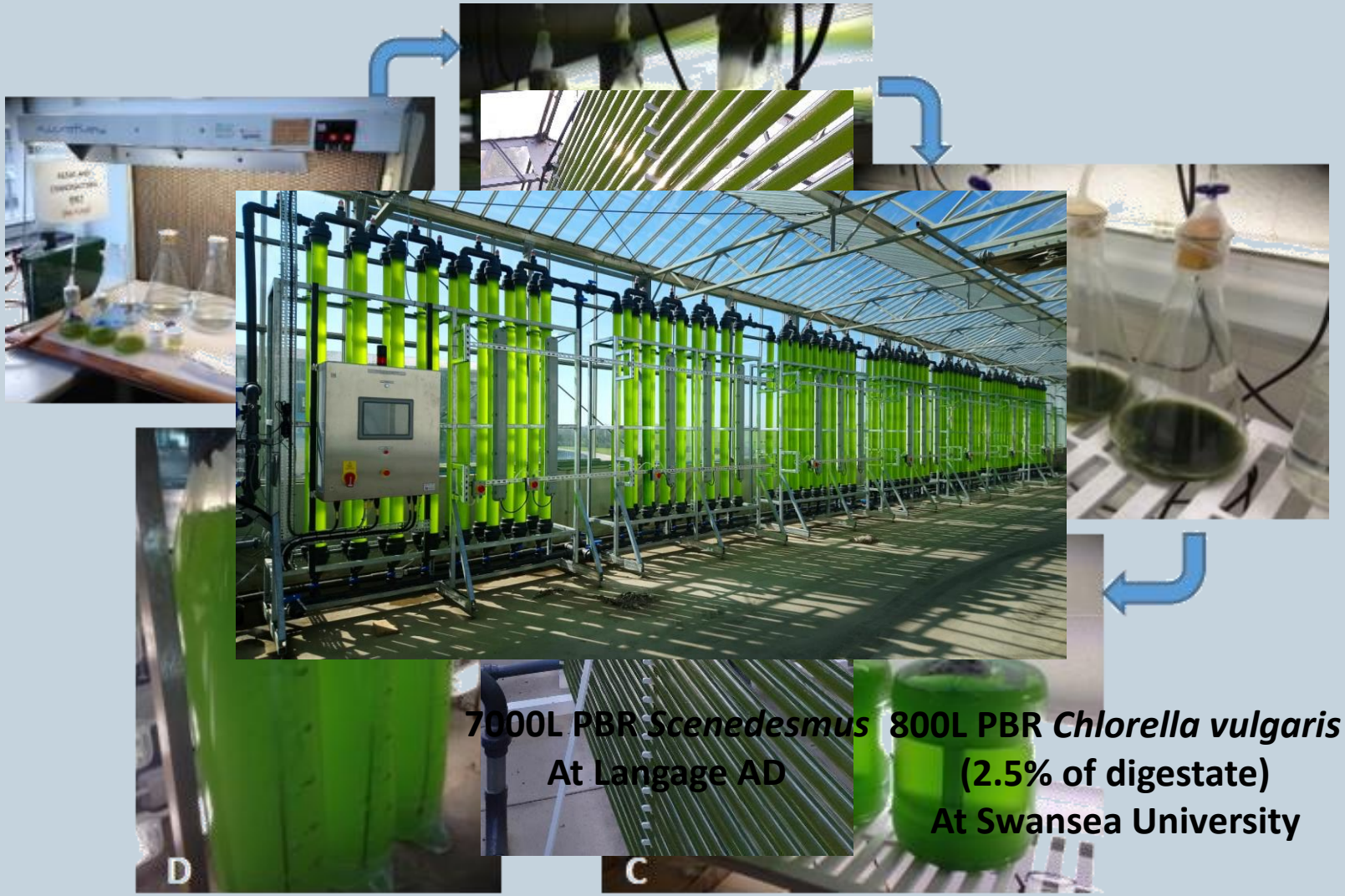
Algal biotechnology for Circular bioeconomy







FROM LAB TO PILOT SITE



7000L PBR *Scenedesmus*
At Langage AD

800L PBR *Chlorella vulgaris*
(2.5% of digestate)
At Swansea University

Previous projects in carbon reduction

ACCOMPLISH

- 3-year project supported by Welsh Government
- Overall value of £670k

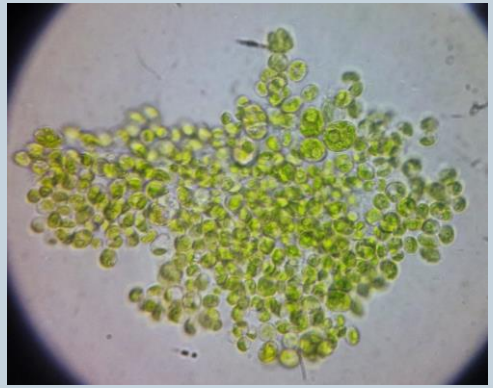
Development of a mobile algal growth laboratory (AGL) at ***Tata Steel Strip Products UK*** for testing of algal carbon capture

Biomass production and harvesting on waste sources using ***Axium Process LTD***'s pilot TF membrane rigs

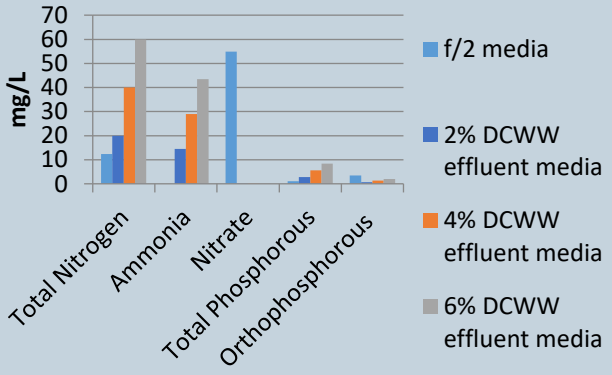
Assessment of algal biomass feedstocks using ***Dŵr Cymru Welsh Water*** Anaerobic Digestion (AD) site specific conditions

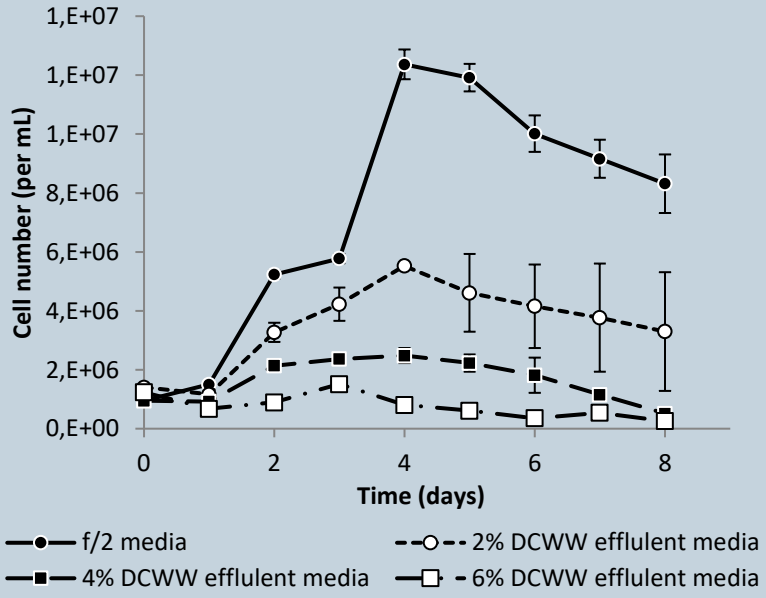
- Algal Growth Laboratory (AGL) and Algal preparation laboratory (APL) installed at TATA steel, Port Talbot
- 12x 80L reactors and 36X 20L carboys or flasks suitable for flue gas trails and culture adaptation experiments
- Trials on high concentration of CO_2 provided the basis for flue gas trails and waste remediation of AD digestate

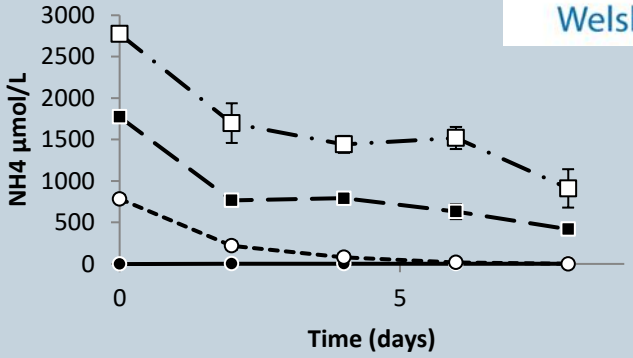
ACCOMPLISH-Waste remediation of AD digestate

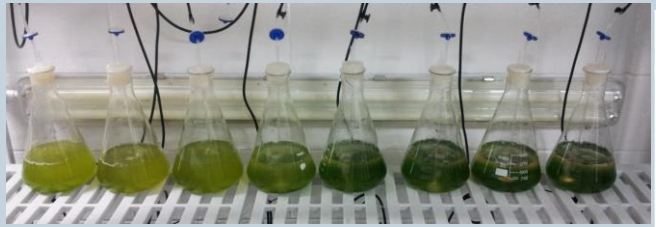


ACCOMPLISH freshwater algal consortium
Lab scale with 2, 4, 6 % of digestate compared to F/2 media
high scale cultivation with the addition to CO2 from flue-gas



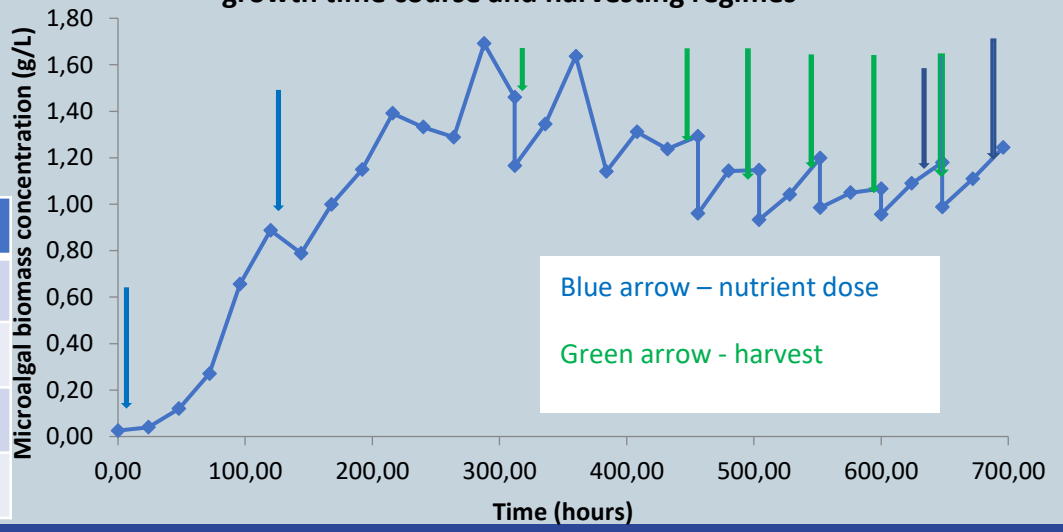




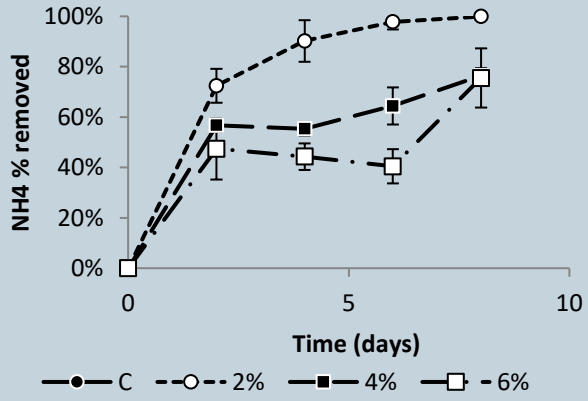


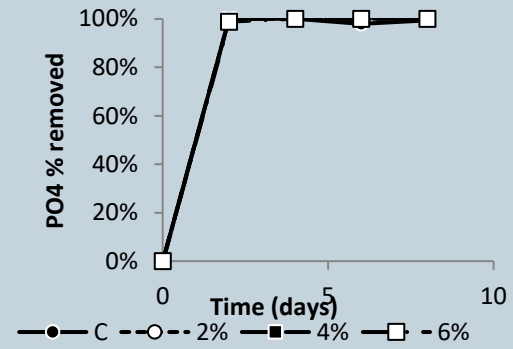
Biochemical groups	F/2	DCWW AD media
Av % Carb	10.51±0.18	9.15±0.89
Av % Lipid	12.27±2.89	17.20±1.93
Av % Protein	47.12±8.32	21.27±8.85
Calorific value	5766.33±35	5789±49

Outdoor BioFence 4% waste based medium fed-batch microalgal growth time course and harvesting regimes

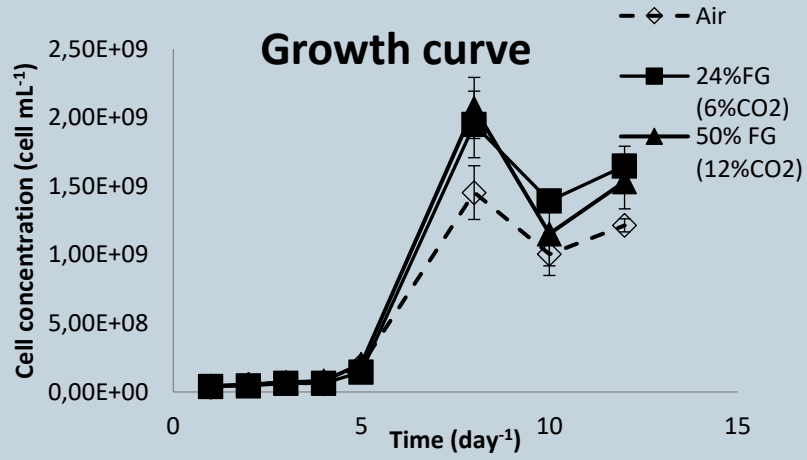


ACCOMPLISH-Portable Algal Growth Laboratory





3 aeration conditions were used:
100% Air – Control
75% air and 25% flue gas(~6% of CO_2)
50% air and 50% flue gas(~12 % of CO_2)



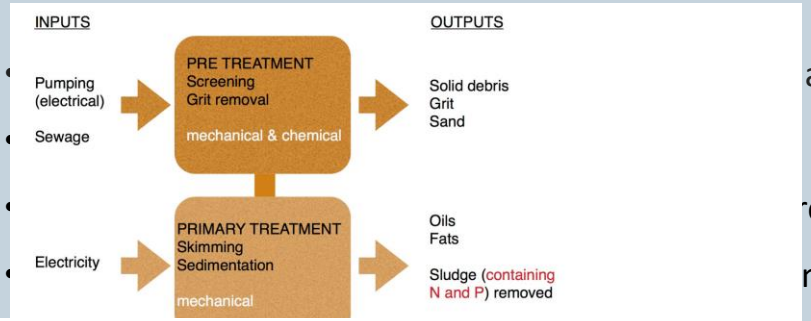
the ACCOMPLISH consortium had CO_2maximum removal rate of 1500-2500 mg L^{-1} d^{-1}

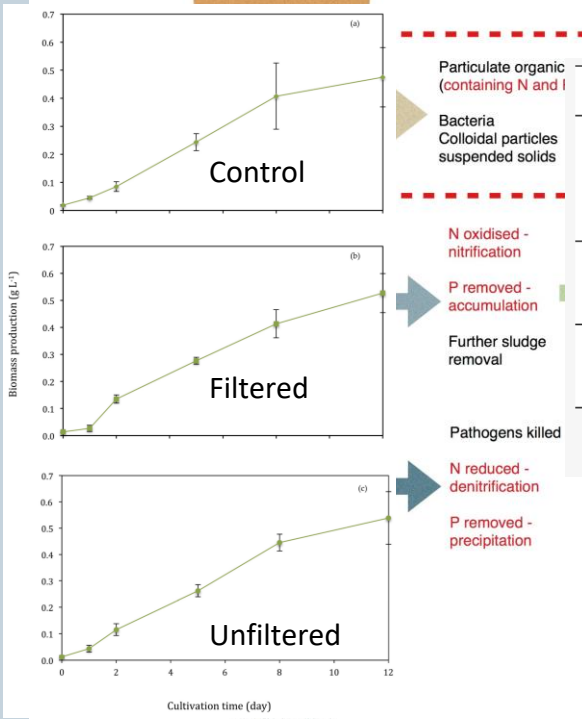
PBRs, gas blenders, gas distribution, HVAC and PBR gas extraction

Comparing Nutrient Removal from Membrane Filtered and Unfiltered Domestic Wastewater Using *Chlorella vulgaris*

- a Welsh Water treatment facility in Southgate, Swansea
- red primary waste waters remediation by algal culture
- ng 12 days of cultivation

a (Control) F2P media in freshwater
b (T1) 100% primary filtered ww
c (T2) 100% primary unfiltered ww



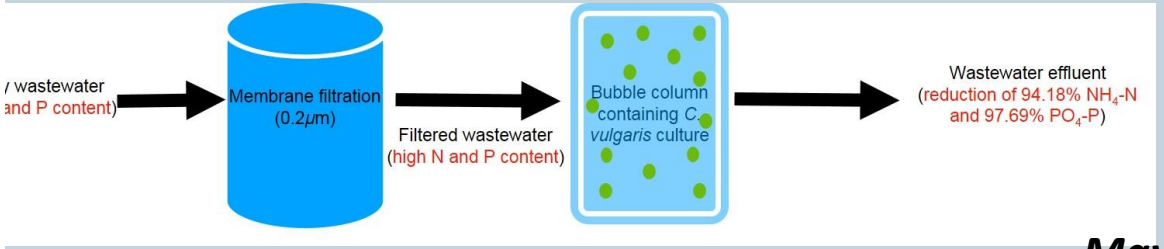


Particulate organic (containing N and
Bacteria
Colloidal particles
suspended solids
N oxidised - nitrification
P removed - accumulation
Further sludge removal
Pathogens killed
N reduced - denitrification
P removed - precipitation
soluble inorganic material (ammonia and phosphate) - released to environment

		Control	Treatment 1	Treatment 2
Initial	N:P	2.4:1.0	7.5:1.0	4.4:1.0
	NH_4-N (mg L^{-1})	5 [1]	85.84	104.51
	PO_4-P (mg L^{-1})	2.47	13.54	23.65
Final	NH_4-N (mg L^{-1})	5 [1]	5 [1]	5 [1]
	PO_4-P (mg L^{-1})	0.256	0.313	0.796
% removed	NH_4-N	NA	94.18%	95.22%
	PO_4-P	89.64%	97.69%	96.63%

[1] Reference to a level at or below 5 mg L^{-1}, as this is the detection limit for NH_4-N.

Effluent low in soluble inorganic material released to environment



- ✓ Growth of *C. vulgaris* in nutrient rich membrane filtered wastewater provides an option for domestic wastewater treatment
- ✓ improve the quality of the final effluent.

Mayhead, Silkina et al, 2018

Conclusions/Future perspectives

- Algal cultivation is proven technology for water treatment
- Algal culture efficient for PO_4- and Nitrogen recovery
- Algal pilot could be installed as a water treatment facilities, where conventional plants impossible to operate
- Combine waste nutrients remediation by algae with carbon sequestration- contributing to Net Zero Gvt requirements
- This technology could be applied to wastewaters from different sectors

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Prifysgol Abertawe

Thank you for your attention

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