Applied Algal biotechnology for the waste remediation

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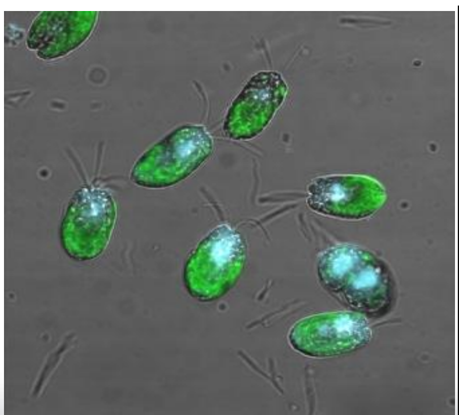
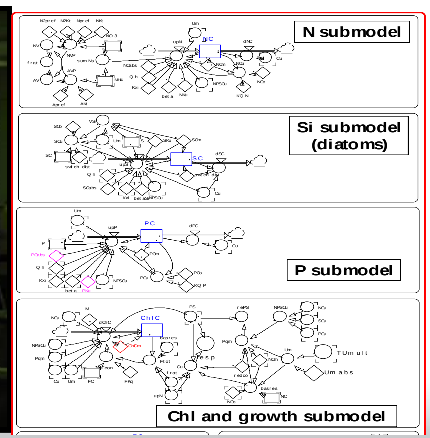
https://algaewales.wordpress.com/





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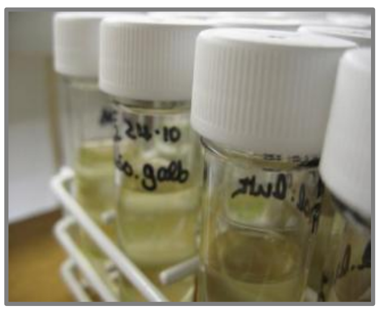
Algal research at Swansea

- History of nearly 4 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 <u>and</u> also with onsite process engineering facilities
- …. factors essential for commercial production.

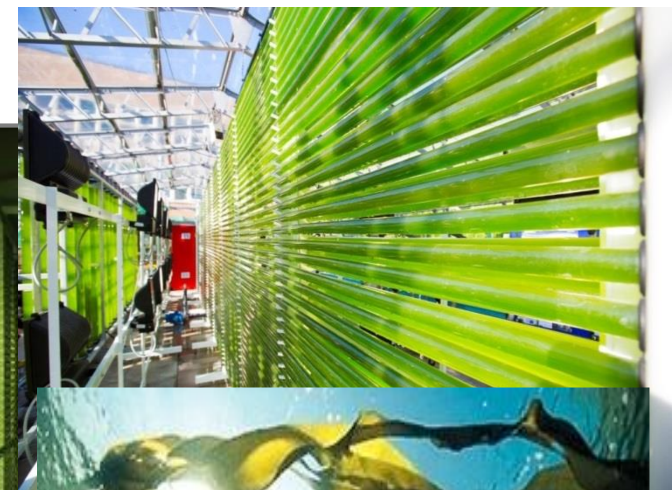
- CSAR now has the largest research photo-bioreactor capacity in the UK …
- .. supported by analytical methods for bulk determinants and ca. £500k equipment ….
- … together with research for harvesting and processing
- … and supplying data for modelling.

Centre for Sustainable Aquatic Research – algal production facilities

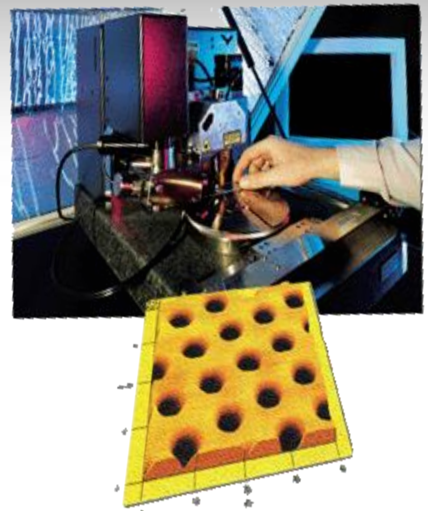
- Algal collections ~ 25 species for mass cultivation (Sterile cultures 20ml → 2L → 20L Carboys)
- 20 x 100L batch culture capacity, controlled environment lab
- 1 x 400L Biofences, controlled environment lab
- 2 x 600L Biofences, greenhouse location
- 1 x 2000L PBR, greenhouse location



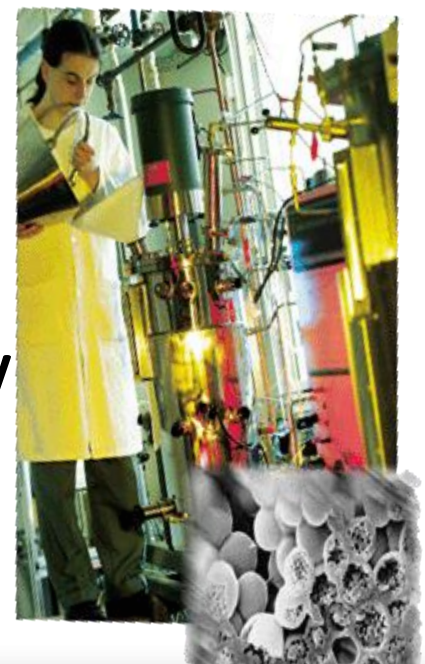



Centre For Complex Fluids Processing



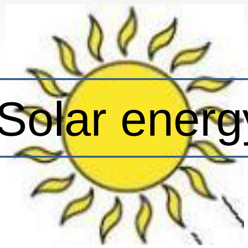
- Selective Separation & Product Recovery
- Advanced Surface & Fluid Characterisation
- Novel Membrane & Structure Fabrication



Membranology - spin out company
http://membranology.com/

Membranology
Advanced Membrane Applications

Microalgae Production



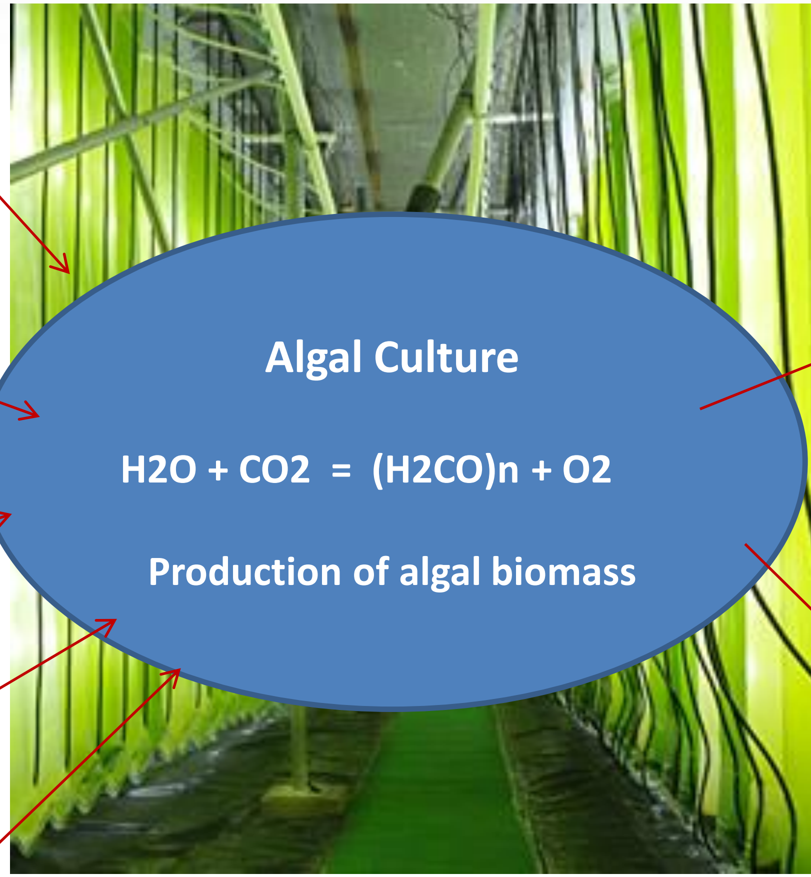
Solar energy

Water:
- Freshwater
- Brackish water
- Sea water

CO_2

N2
Nitrogen fixation

WASTE STREAMS Nutrients



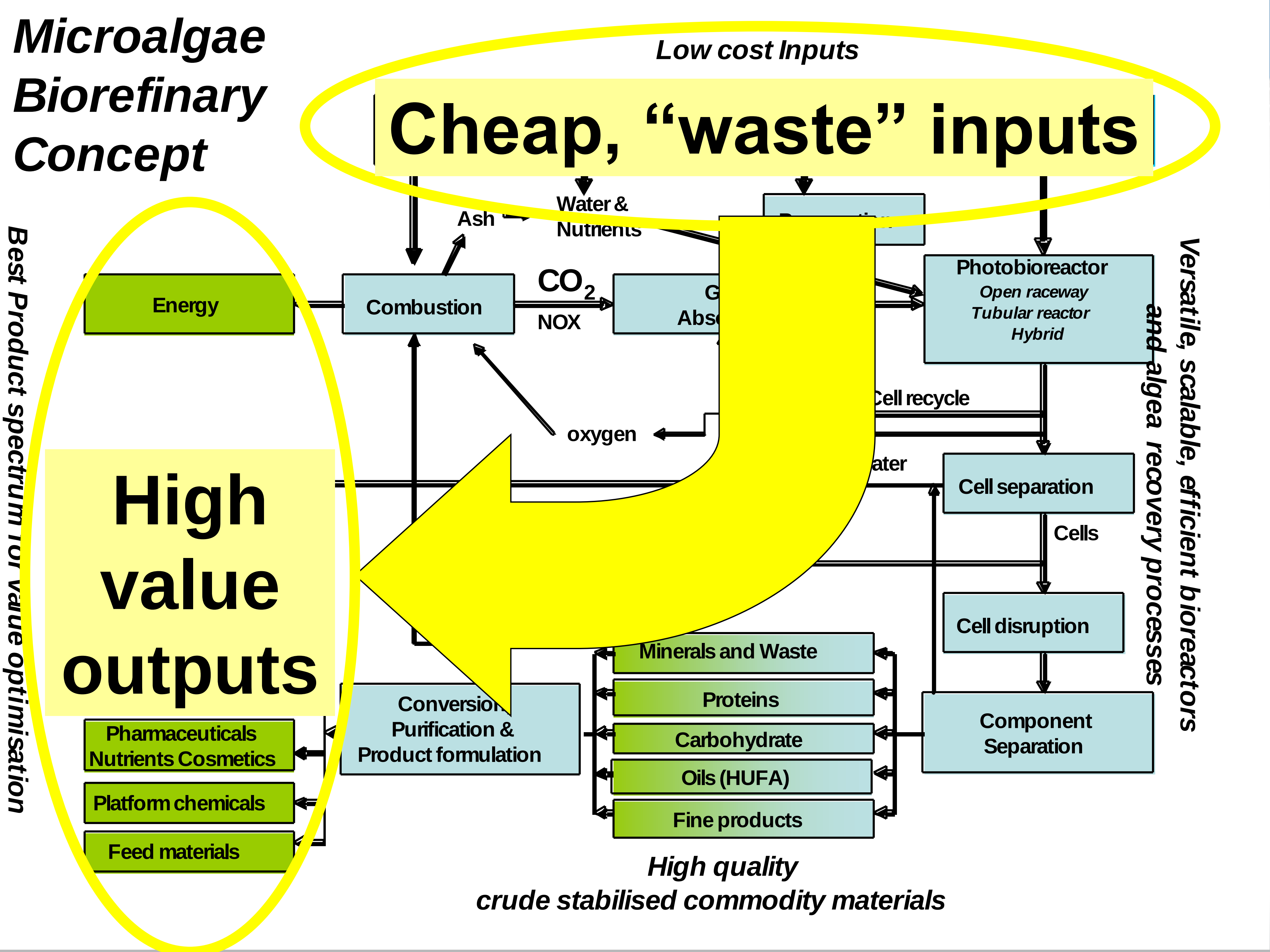
Algal Culture

H2O + CO2 = (H2CO)n + O2

Production of algal biomass

HARVESTING

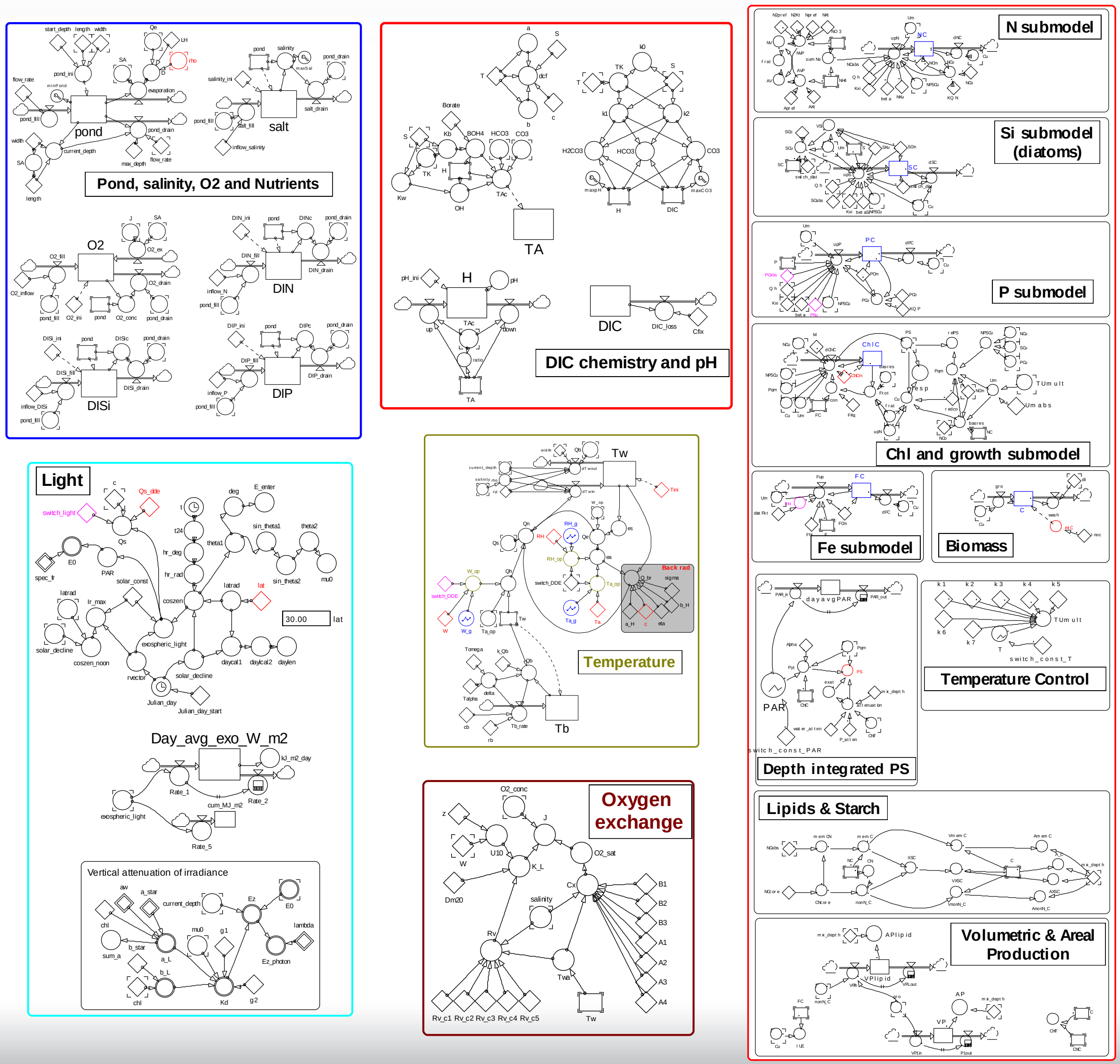
OXYGEN PRODUCTION



Microalgae Biorefinary Concept
Low cost Inputs
Cheap, "waste" inputs
Water & Nutrients
Ash
Energy
Combustion
CO_2
NOX
Photobioreactor
Open raceway
Tubular reactor
Hybrid
Cell recycle
oxygen
Cell separation
Cells
Cell disruption
High value outputs
Minerals and Waste
Proteins
Carbohydrate
Oils (HUFA)
Fine products
Component Separation
Conversion Purification & Product formulation
Pharmaceuticals Nutrients Cosmetics
Platform chemicals
Feed materials
High quality crude stabilised commodity materials
Best Product spectrum for value optimisation
Versatile, scalable, efficient bioreactors and algea recovery processes

Integrated Algal Biomass/Bioenergy Modelling

- Identifying optimal species configuration for selection
- Designing GMO configurations
- Optimisation for production
- Risk analysis
- Life cycle analysis



Algal projects at Swansea

- *Algal Biomass Production and Processing: Modelling, Optimisation and Economic and Life Cycle Analyses* - primarily aimed at oil/energy production system **(Carbon Trust; SU, Bangor U, PML; £500k;)**
- Algal Biotech KTC – industry facing **(WAG A4B; £380k)**
- ACCOMPLISH – coupled flue gas and waste water **(TATA + Welsh Water+ Axium; £400k)**

European and International projects

- ***ShellPlant*** - intensive microalgae cultivation as feed for shell(with Norway, Portugal, Spain; £235k to CSAR)
- ***BioAlgaeSorb*** - *microalgae for waste treatment, energy/fuel production and biomaterials* (with Belgium, Greece, Italy, Netherlands, Norway; £653k to CSAR)
- ***EnAlgae* INTERREG IVB** Energetic **Algae, pilot and networking group (7 countries), CSAR lead partner;** (£1.6m to SU, total project size £13m)
- **ALG-AD INTERREG networking UK, France, Belgium** £5m project (£1.8m to SU)
- **Phycopigments**- Newton Mexico-UK Innovate UK project (£600K total, £120 to CSAR)

Bioremediation

- Human activity –agricultural, municipal and industrial waste streams
- Eutrophication
- Major requirement to waste treatment – removal nutrients and toxic metals
- N, P, CO_2
- Microalgae cultivation- alternative solution to conventional waste water treatment technologies

Waste remediation

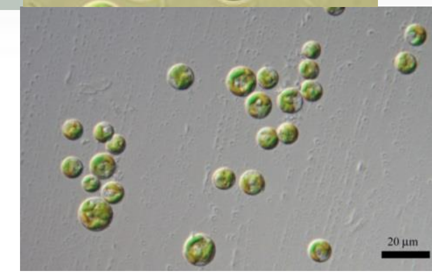
- Test suitability of waste stream use : agricultural, fish farm and AD municipal waste as nutrients source
- Compare the Nitrogen and Phosphorus uptake by different species in different cultivation PBR
- Compare the productivity of species
- Provide the data set for modelling tool

Bioremediation – **Why use waste?**

- A number of cost/efficiency advantages
- Environmental advantages
- Phosphate sources are scarcer and will be economically unviable to mine by 2030
- Waste nutrients source can help to reduce the mining of phosphorous and recycle this valuable mineral

- Difficulties of preparation (e.g. filtration) associated with using liquid and solid waste sources
- Liquid wastes- high in Ammonia -toxic to algae
- Not have an optimal nutrient profile
- Algae need adaptation to the waste source during initial cultivation

Species used



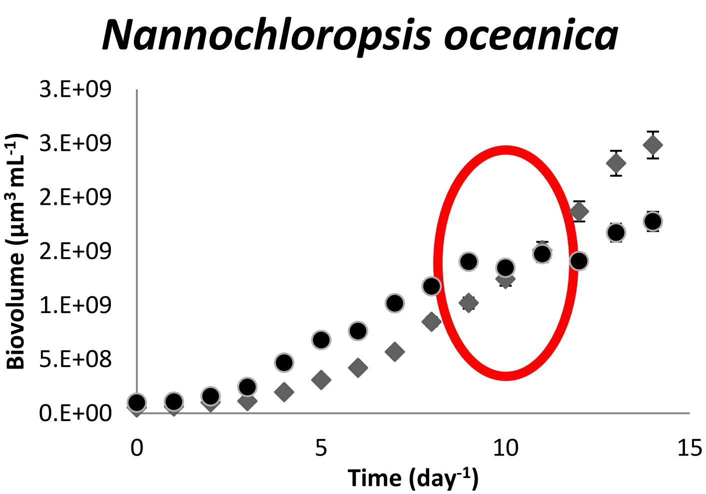
- *Nannochloropsis oceanica*
- *Scenedesmus sp.*
- *Isolate from steel industrial site: Franceia amphitricha*

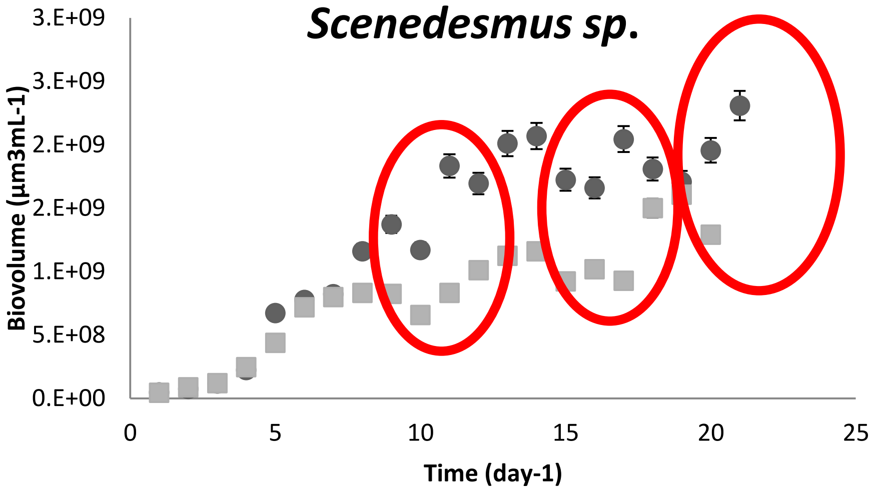
media formulation	µMol L^{-1} N	µmol L -1P	Ratio (N:P)	mL/L	Final concentration N (µMol L^{-1})	Final concentration P (µMol L^{-1})	Ratio
Agricultural waste	55400	4359	12.7	15.9	880.8	69.3	12.7
Trout waste	8870	57468	24.5	1.92	17(+882)	110.3	8.15
AD municipal waste	71394	4486	15.9	20	1428	89.7	15.9
F/2				1	882	36.2	24.5

Experimental conditions

- 15-25 days of cultivation in tubular PBR
- Batch and Semi continuous mode
- Close monitoring of biological parameters –
  cells, biovolume, cellular C:N:P:Chl
- Water chemistry and biochemistry analysis –
  DIN, DIP, pH, T, PFD; lipid, carbohydrates
- Log-in data-
  pH, T; light

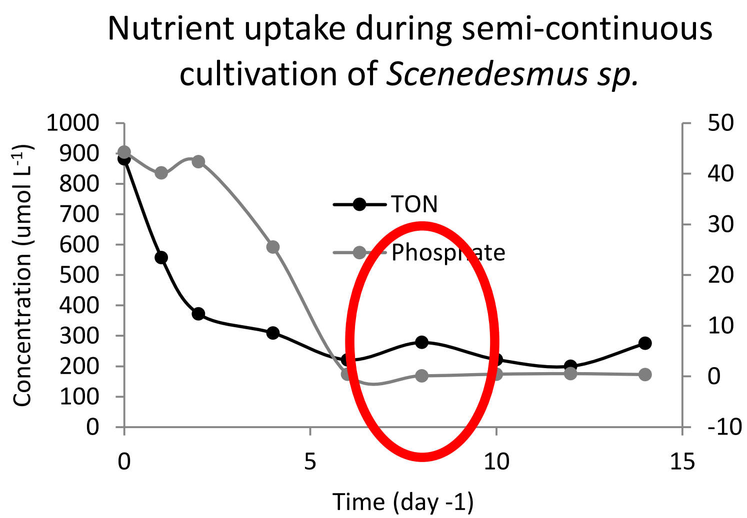
Results of growth

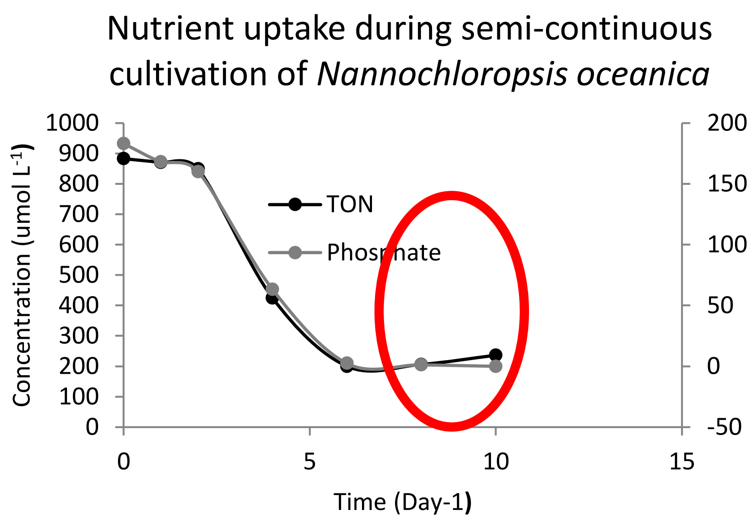




- Cultures were able to grow using waste nutrients
- Cultures again entered a growth phase after partial harvest growth rate

Nutrient uptake by algae





- Waste nutrients are gradually taken up by the algae during cultivation
- P and N uptake (90% after 5 days of cultivation)

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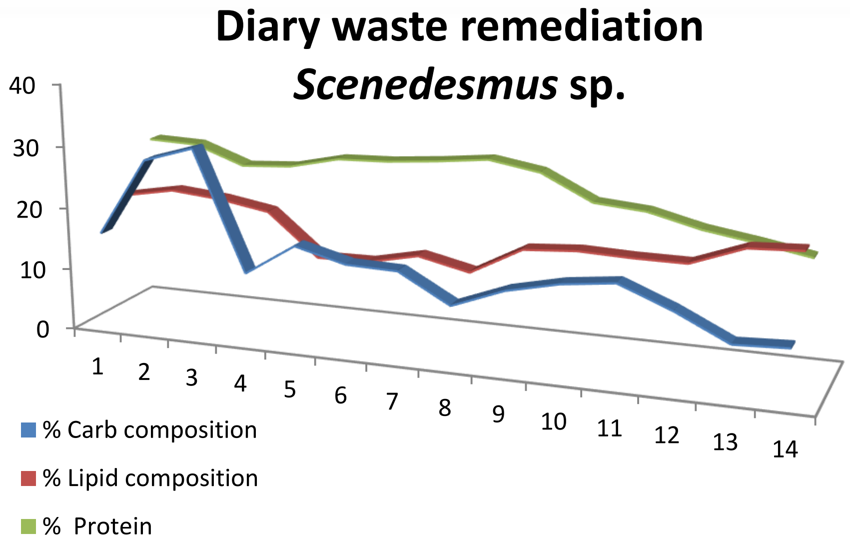
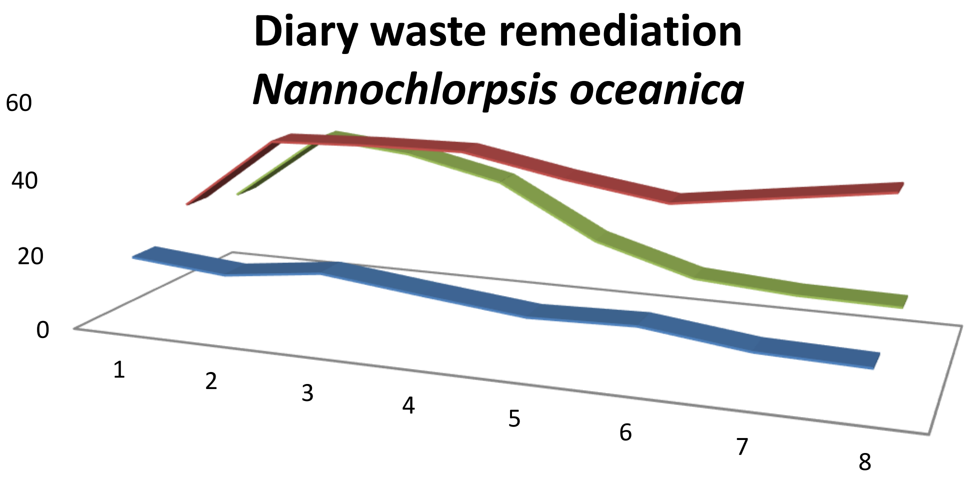
Biochemical composition





- Cultures were successfully grow using waste nutrients
- Nutrient supply after partial harvest boost growth of culture
- Potential exploitation of algal biomass

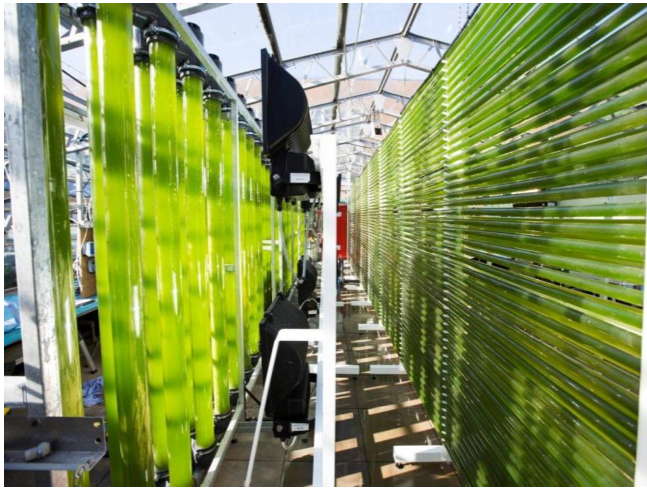
Design of PBR comparison

- Vertical and horizontal

Tubular reactors were compared

- In control and waste remediation

condition, productivity is higher in vertical system with Ø 110 mm (*Causerma et al, 2011*)



- The specific biomass (e.g. reach on lipids) quickly achieved on horizontal tubular PBRØ 43 mm

ACCOMPLISH

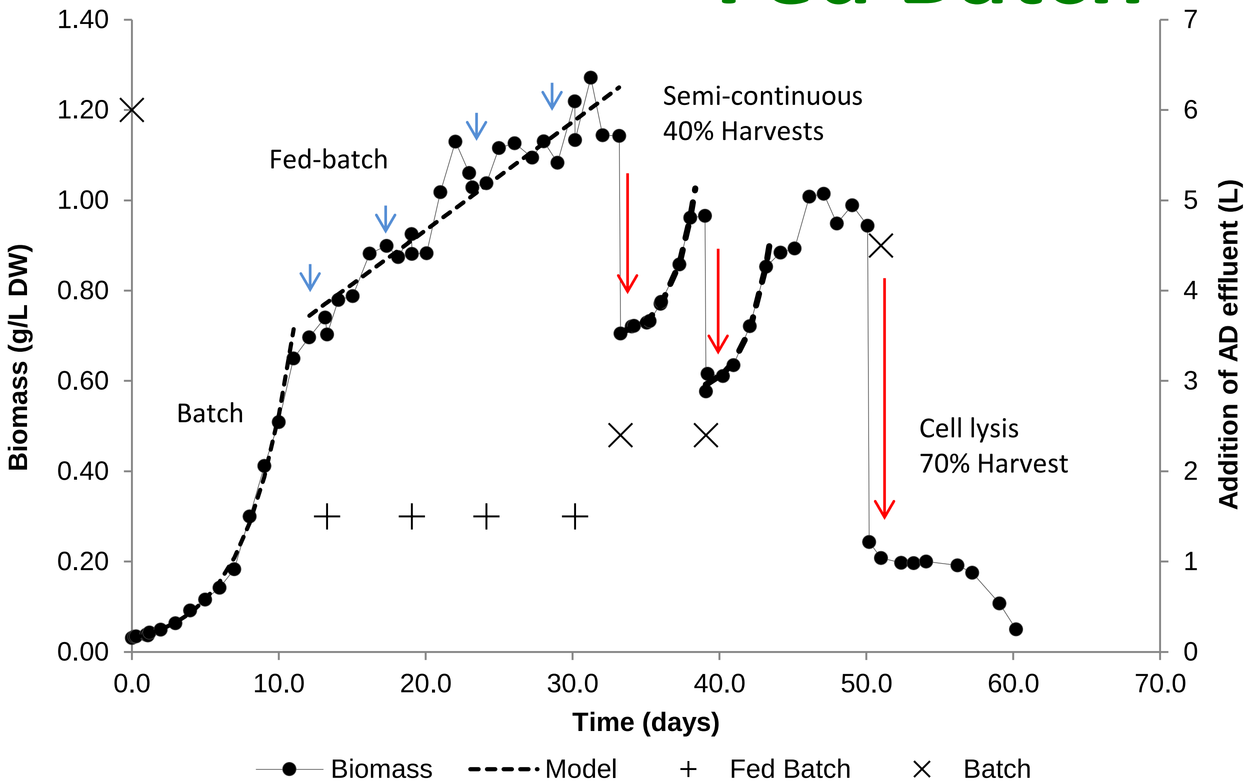
- 3 year project supported by Welsh Government
- Overall value of £670,000

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

Growth using AD municipal waste
Fed Batch



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TATA

axium PROCESS

Dŵr Cymru Welsh Water

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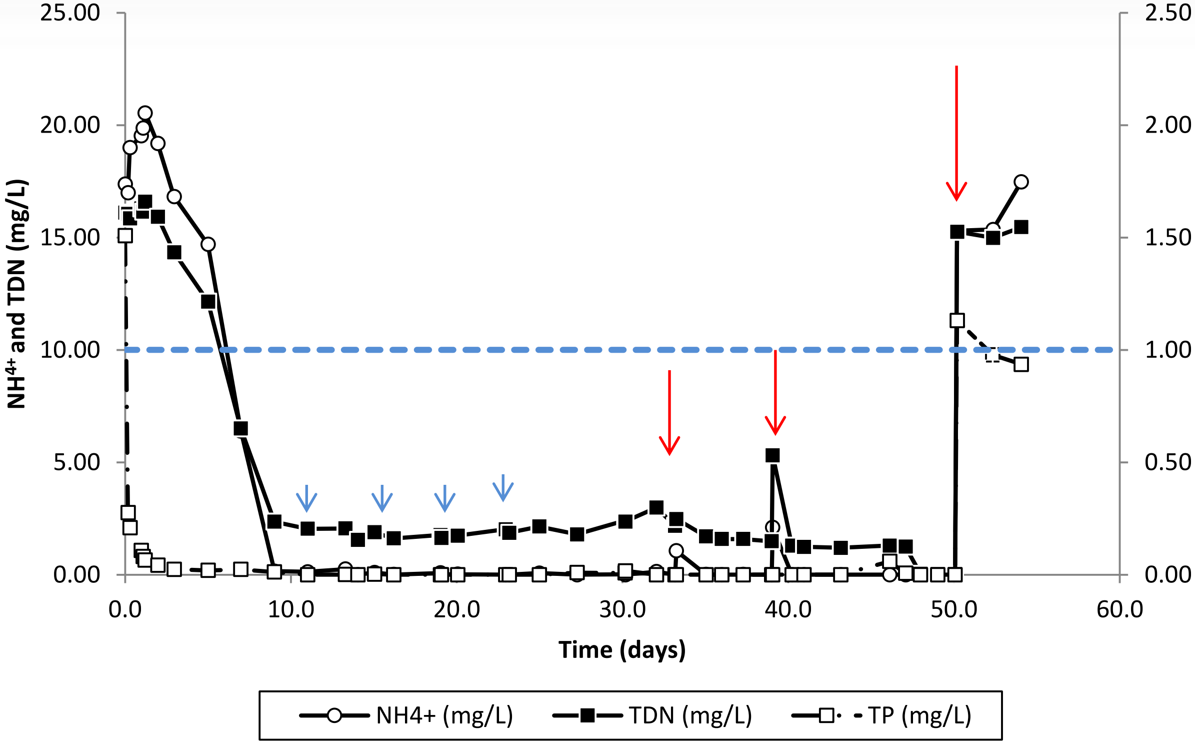
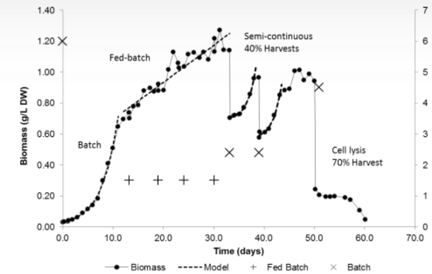
Fed Batch





UK Environment Agency (2016) Standard:

- **TN 10 mg/L**
- **TP 1 mg/L**

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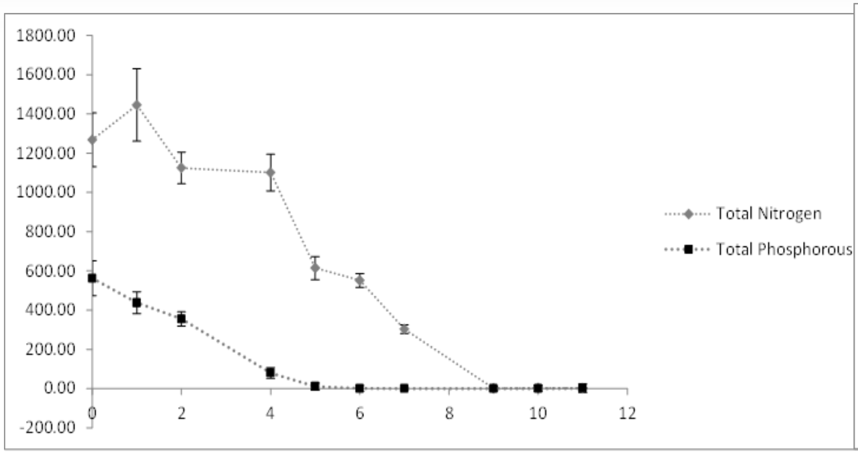
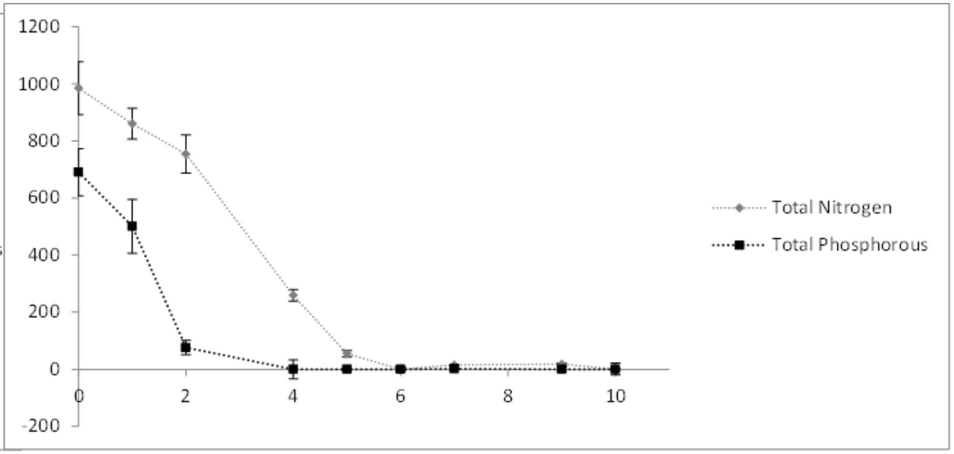
Welsh Water

Nutrients uptake

Average nutrient (standard chemical nutrients) removal



Average nutrient (municipal waste) removal



Biochemical analysis of algal biomass grown using the different form of media.

Nutrients used	% Cellular Lipid	S.D.	% Cellular Carbohydrate	S.D.	% Cellular Pigments	S.D.
Standard F/2 media	11.15	0.4	4	0.12	4.87	0.15
Municipal waste media	7.9	0.2	18.3	2.3	4.66	0.73

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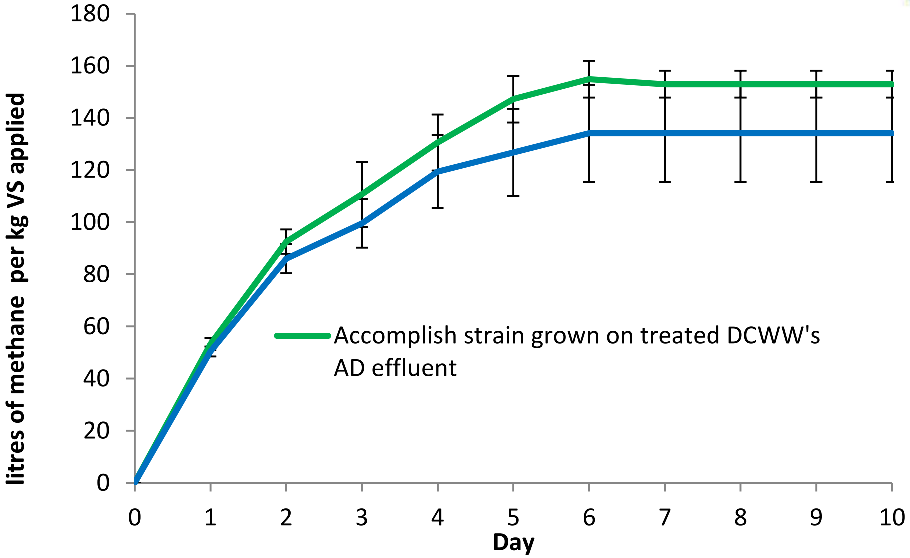
Welsh Water

aqua enviro limited

Energy production



- **Biomethane production test**
- **Algal biomass grown on AD municipal waste**

Comparable results of biomethane production with alternative feed stock

The Biomethane yield 350 CH_4 mLg^{-1}

Summary

Species	Waste nutrient source	N uptake rate (µ Mol L^{-1})	P uptake rate (µ Mol L^{-1})	Max productivity ($g\ L^{-1}$)	Duration of trial (days)	System PBR
Scenedesmus sp.	Agriculture (cow waste)	146	7.09	1.6	18	600
N. oceanica	Agriculture (cow waste)	186	8.1	1.6	18	600
N. oceanica	Aquaculture (trout farm waste)	-	2.73	3	15	1500
ACCOMPLISH strain	AD municipal waste	36	0.74	1.1	16	1500

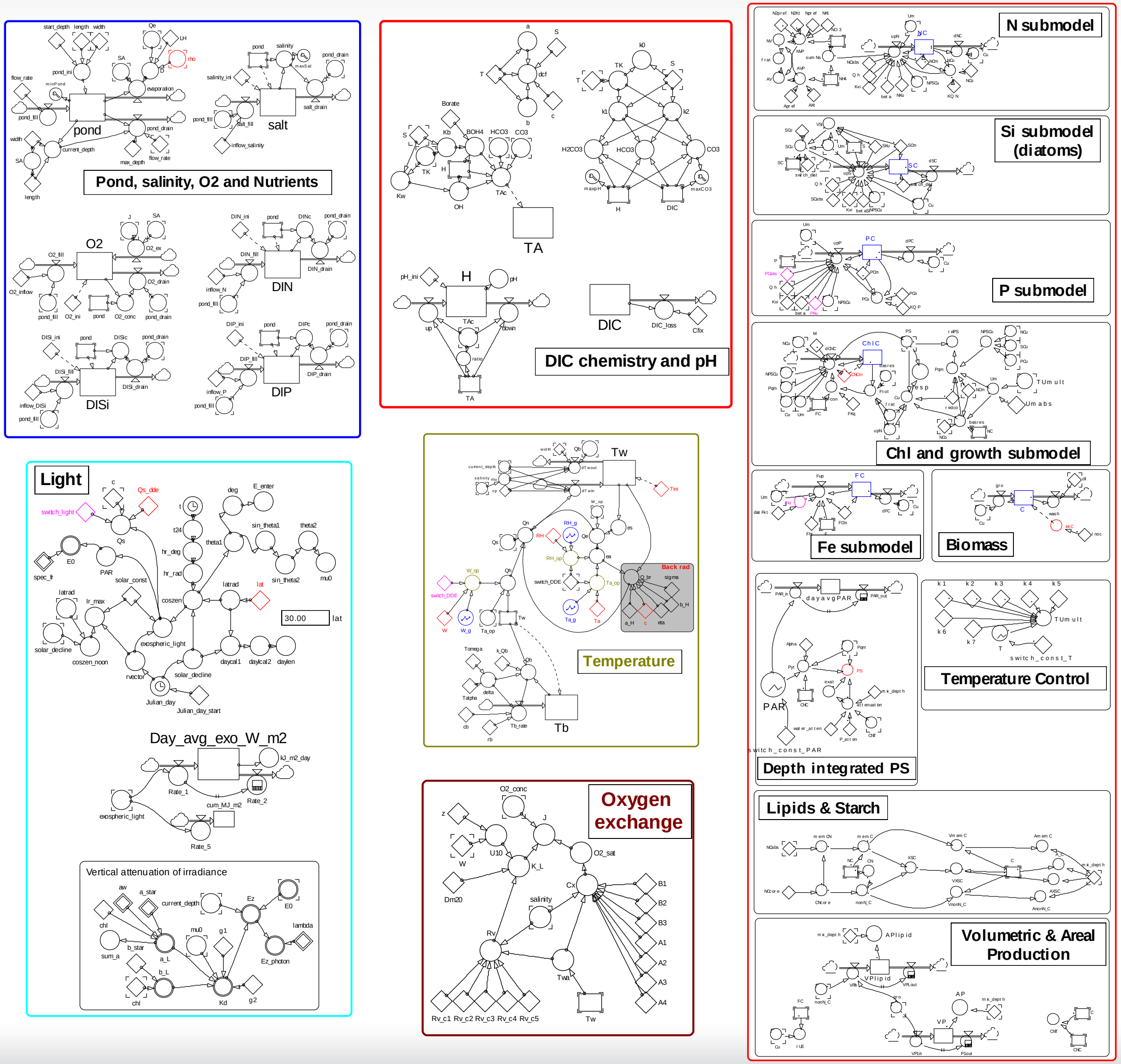
Summary

Table 2: Data from trials performed at Swansea University. Treated effluent was from a municipal waste source.

	Unit	Influent	Effluent	% Recovered	Retention time
TON	µmol L^{-1}	**984.772±93**	**0.684±4**	**99.5%**	**5 days**
Nitrate	µmol L^{-1}	**181.64±23**	**0.52±1**	**99%**	**5 days**
Nitrite	µmol L^{-1}	**0.048±0.0012**	**0.164 ±0.024**	**0%**	**5 days**
Ammonia	µmol L^{-1}	**802.96±69**	**0±2**	**100%**	**5 days**
Total Phosphorous	µmol L^{-1}	**690.36±83**	**0±4**	**100%**	**4 days**

In-silico approaches, Modelling

- Identifying optimal species configuration for growth
- Optimisation for production
- Risk analysis
- Life cycle analysis



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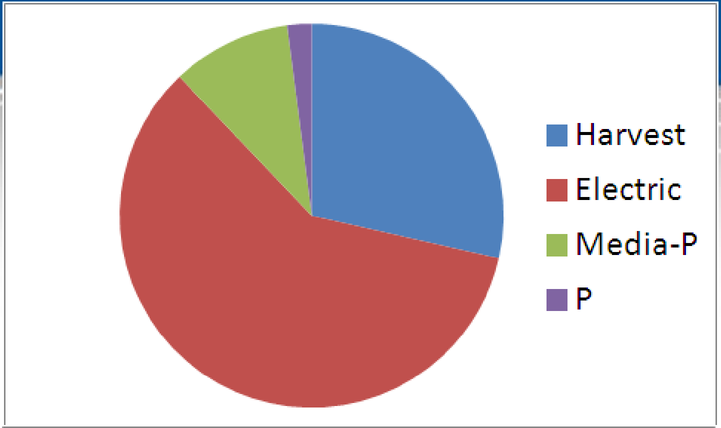
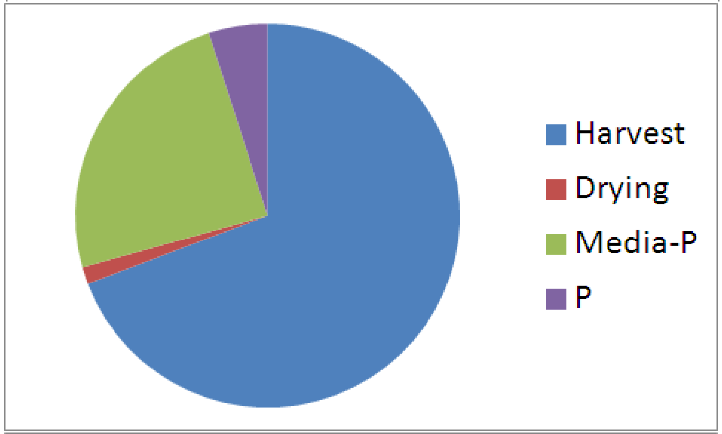
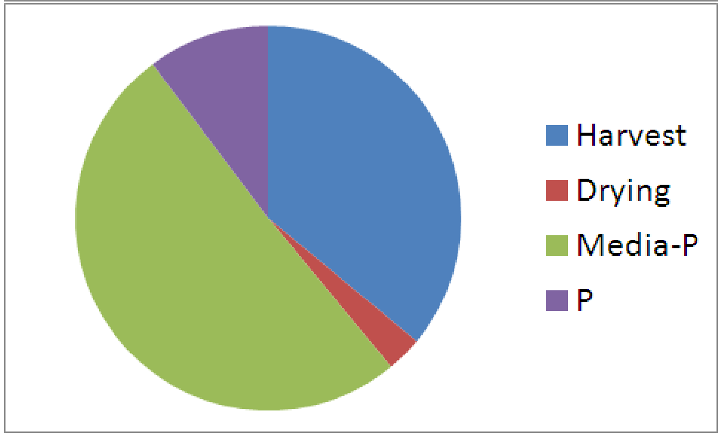
Cost Breakdown

- Electric is mainly lighting to give a back-ground level
- Harvesting is by filtration (~¼)
- Media includes N, trace metals and vitamins (assumes natural sw)
- **Not included** - pH & gas exchange, temperature control, rent & depreciation







- **Industrial Biotechnology & Biorefinery**
  - Algal biotechnology for fuels, CO_2 mitigation
  - Biorefineries for algal biomass, incl high value non-food
  - Systems approach – *in silico* modelling to optimise bioprocesses and biomass compositions

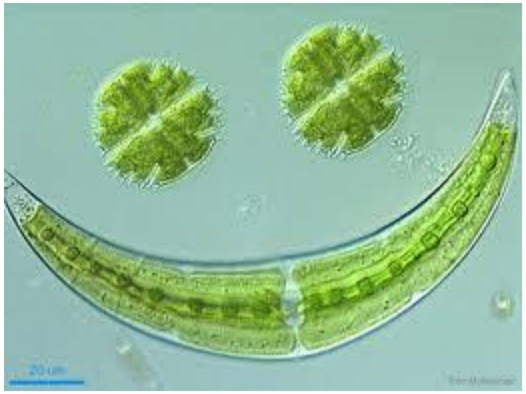
- **Food Security**
  - Sustainable aquaculture feeds
  - Aquaculture animal health and welfare

In summary ...

- Minimise use of virgin resources
- Maximise use of wastes (inc minimising fines for waste generation)
- Recycling/upgrading feedstocks

Спасибо за внимание!

Flickr: sean-b



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