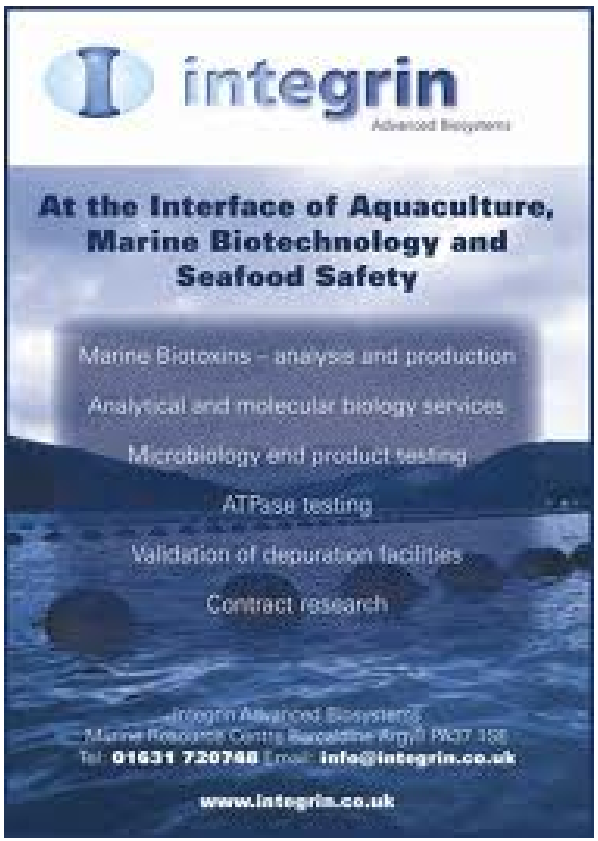
Big is better
or
Small is beautiful?

Centralised or distributed production of algal biomass for fuel production?

Douglas McKenzie
Xanthella Ltd
Concarneau 2012

integrin
Advanced Biosystems



Pharma Mar

FOOD STANDARDS AGENCY

biobest

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New Horizon?

Marine Biotechnology offers a wealth of opportunities but where should we focus? Focus on what makes money (and within a reasonable time frame).

Companies need products with a customer for those products who will buy those products for more than it costs to make them.

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What's the problem?

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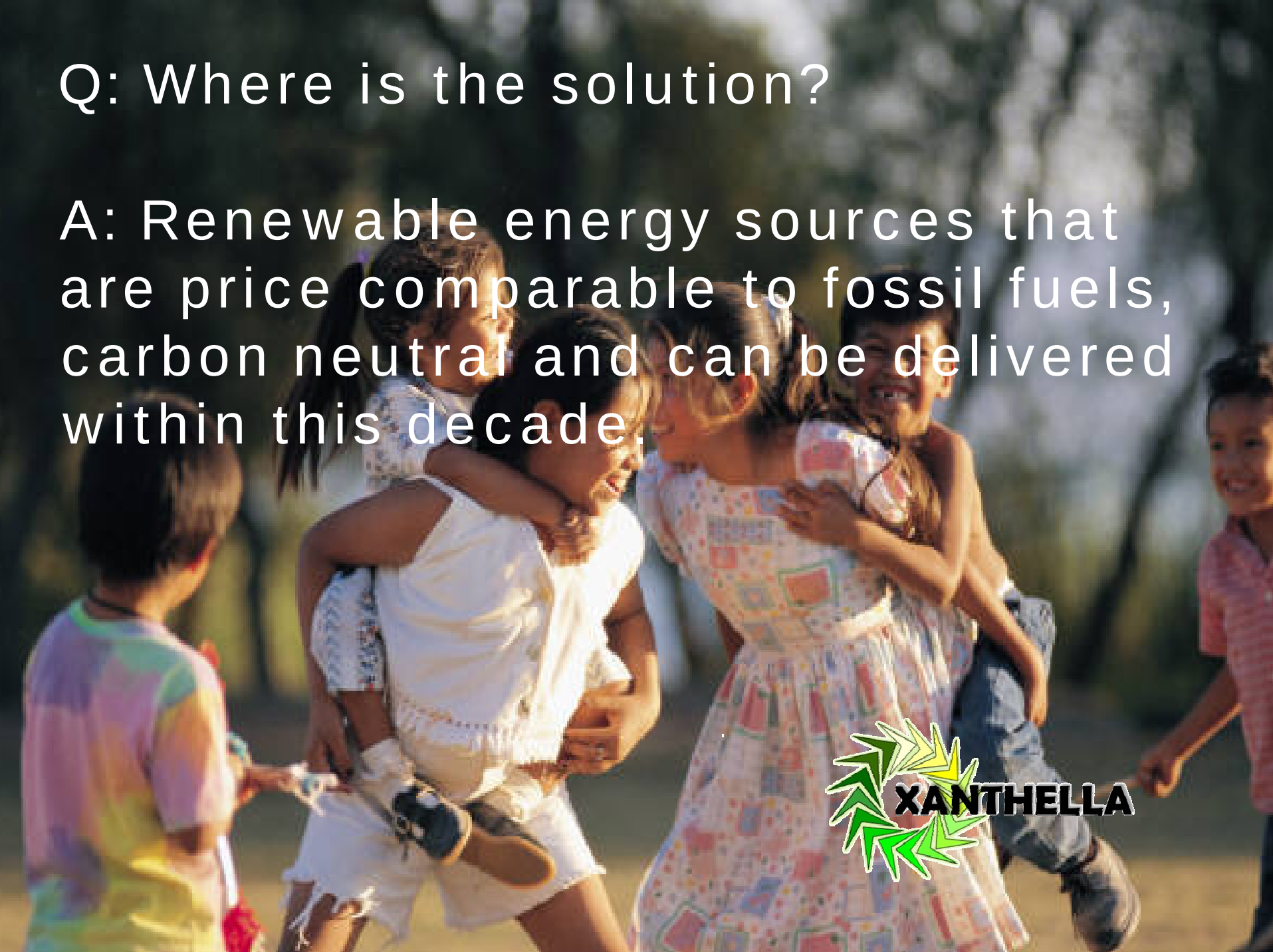
Q: Where is the solution?

A: Renewable energy sources that are price comparable to fossil fuels, carbon neutral and can be delivered within this decade.



Electricity

Hydro; wind, wave, tidal; biomass CHP
AD-fuel cells; solar PV; nuclear

Liquid Fuels

Batteries; hydrogen; biofuels

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First generation biofuels compete for land and water with food crops.
Can become more economic to grow crops for fuel rather than food.
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Solution: oil from microalgae

10x more efficient than terrestrial plants
Can be grown in sea water, brackish water, waste water
High oil yields (>50%) that can easily be converted into “drop in” fuels and other feedstocks (plastics)

Downside: cost

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Biodiesel from Algae

Commercial opportunities

What can develop early stage revenues; is achievable with the resources available to Xanthella (investment, people and location) but has good growth potential?

Design, manufacture and sales of industrial scale (>1000 l), modular photobioreactors (PBR).

Can develop protectable IP; easier to overcome technical problems at medium scale than large scale, flexibility for different markets; lack of established competition and standardisation.

5-10 years for algal biodiesel but existing markets for PBRs and other equipment

The Approach

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Where is the cost in photobioreactors?

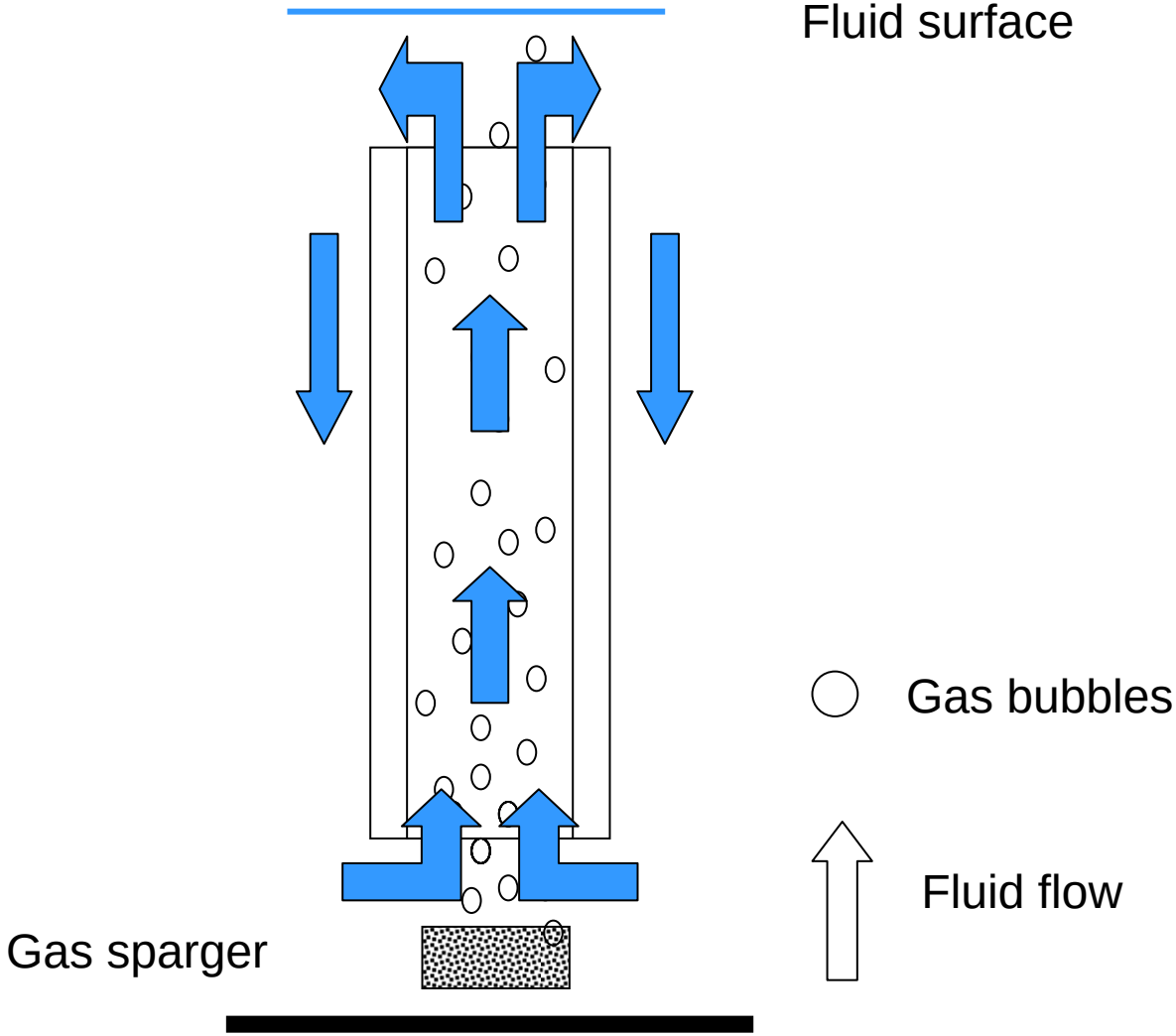
How can we remove these costs?

Remove need for large surface area: turn complex shape into a box.

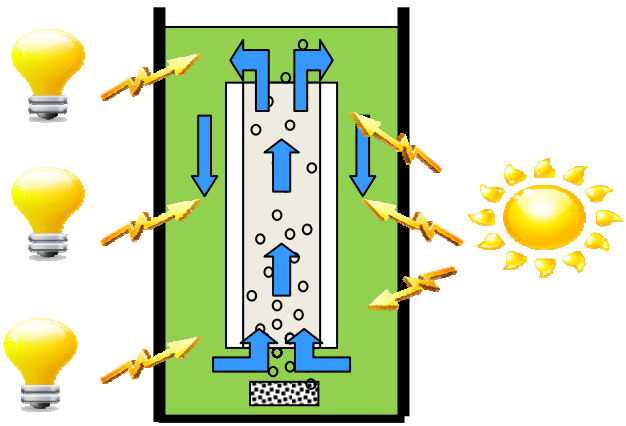
This is an engineering problem.

Focus on cost effectiveness rather than maximisation of growing algae: primary market targets are people interested in producing algal biomass rather than algal research (however…)

Principle of gas lift reactors

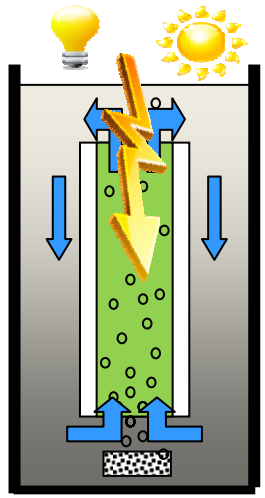


Traditional gas lift PBR



Lighting external to PBR; requires large surface area; problems with fouling of PBR internal surface and loss of energy transfer efficiency

Xanthella's PBR concept



Lighting internal to PBR: either from light guides or internal LEDs; only uplift tube lit; high energy transfer efficiency; PBR can have small surface area. U**plift tube made from the lighting and sparger elements (Goldilocks Component)** Simplifies design considerably and reduces costs

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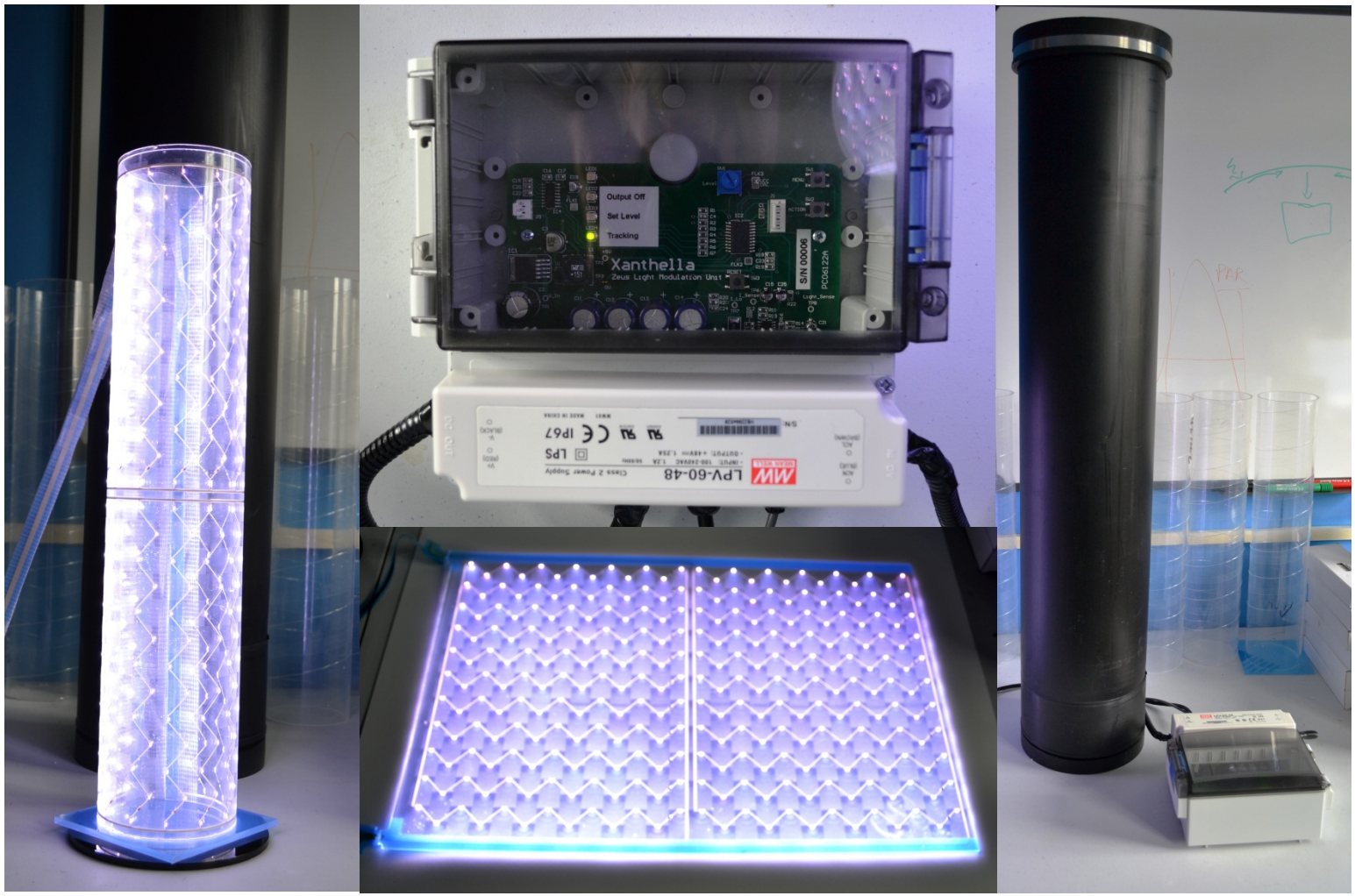
15 l and 3 l Cyclops PBR s

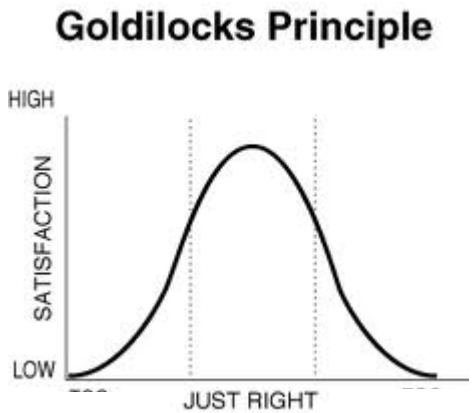


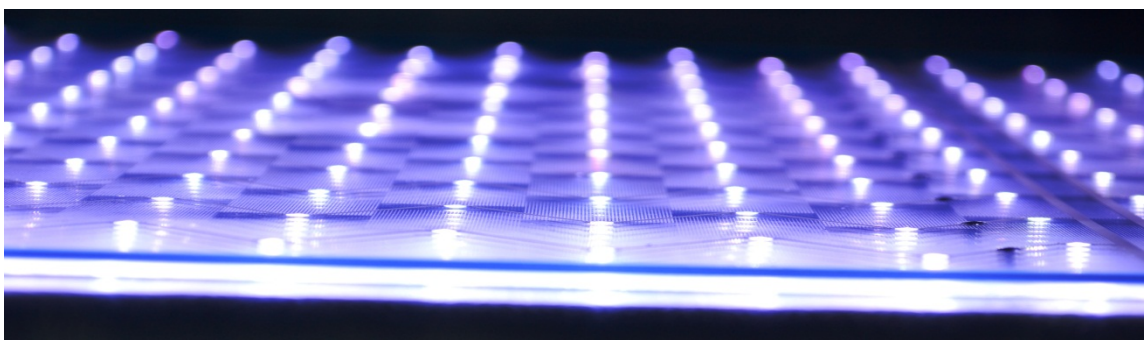
Xanthella “Goldilocks” Component and “Zeus” Controller

Highly efficient light paths; lighting can be optimised for strain and growth phase; light density between 0 and 1500 µmol $m^{-2}s^{-1}$. White light or user specified wavelengths (eg red/blue). In situ variation in λ and intensity possible with fibre optic version (under development).

Standard configuration allows constant output or user defined optimal set level that is automatically maintained by sensor feedback even when algal culture becomes dense. Can be combined with other lighting modes such as flash pulse and ramping daylight cycles

Logs power consumption; RS232 output (other I/O possible)





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Xanthella “Pandora” PBR

Cuboidal PBRs of 250 and 1000 l capacities using multiple Goldilocks (under development 2013)

Features: Same advantages as Cyclops PBRs but much larger volumes.

Modular for deployment in arrays of PBRs taking common input sources (eg CO2).

Single Zeus controller per system

Solar power versions being investigated (primarily with St Andrews University)

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Distributed production of algal biofuels

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Algal Oil is not so much about biology: as it is about energy conversion

I litre of algal biodiesel = 11.8 kWh of energy

Assume 10% efficiency of PAR light to biomass conversion (very optimistic but possible)

Assume algae are 50% oil (not so far fetched)

PAR is around 50% of white light (actually a bit less)

So to make 1 litre of algal oil you need:

11.8 x 10 x 2 = 236 kWh of PAR

11.8 x 10x 2 x2 = 472 kWh of white light (call it 500 kWh = 0.5 MWh)

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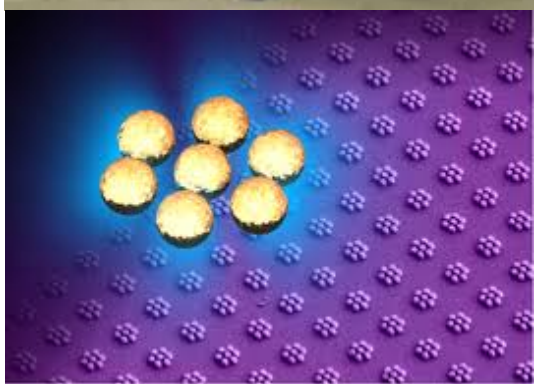
Needs of algal biomass

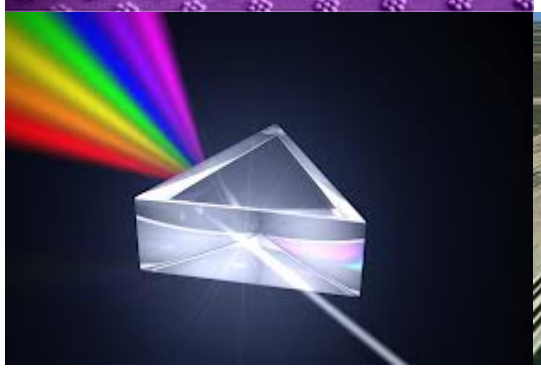
500 MWh of white light for 1000l AO

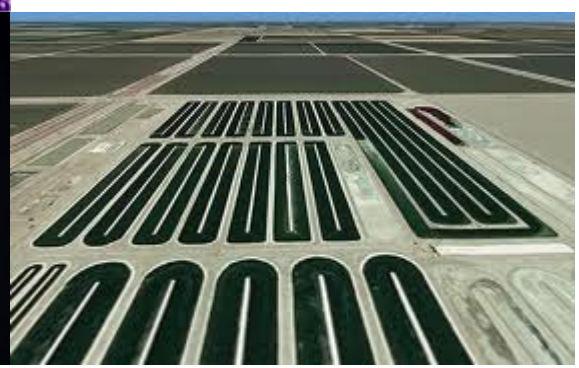
Depends on species and fate of biomass

1.8 tonnes CO2 for 1 tonne of algal biomass

350,000 litres of water for 1000 litre of algal oil (pond): (10,000 – 100,000l PBR)







100l of algae in 1 m3 tank
Energy value = 1180 kWh
Energy to produce = 50 MWh (50,000 kWh)

Over two weeks
5 kWh m-2 so 70 kWh m-2

So requires ~700 m2 of solar gathering surface

(at 5cm deep) = ~ which means it could hold 35m3 of algae. (35 fold inefficiency)

Decouple light capture from light delivery (Apollo Net with St Andrews University Photonics dept)

Large scale is……large!

500 MW coal fired power station produces around 10,000 tonnes of CO2 per day

So needs to produce around 5,500 tonnes of algae per day to completely sequester CO2

This requires 2,750,000 MWh of white light

(The coal plant produces 12,000 MWh per day of electricity)

In Brest solar insolation is 5kWh/m2 per day in August

So would require ~300,000,000 m2 of light gathering surface = 300 km2 (in August!)

Water requirement > 6 million litres per day

BUT: you would get a lot of oil back: (assume 50% oil content) ~3,000 tonnes per day

(200,000,000 tonnes per annum EU: so about 0.5%)

Community Scale:

Population ~800
Fuel usage: 200,000l per annum
Requires: 100,000 MWh white light
Average insolation = 1000 kWh/m2/annum
Needs 100,000 m2 (1km2) of land <1% of land mass

Can also use surplus renewable electricity at night particularly from wind and wave

Hydrogen projects already using this principle. Speeds up production and requires less land

Appropriate Local Scale

Annadale will produce 225 tonnes of CO2 per annum from fermentation and 625 tonnes) from heating.

Needs about 500 tonnes of algae to sequester

Produces around ~300,000 l of algal oil : which is more than distillery uses in heating oil (225,000l)

Requires ~5 million litres of water The distillery will produce 3.4 million litres of waste water so most met from the waste waters. Some of the water can be recycled so the process is not likely to require additional water input.

The waste water will provide sufficient nutrients to support the algal growth.

150,000 MWh of energy: 150,000 m^2.

All requirements can be met at site

Real opportunities are with off grid islands (especially where diesel generators are used to back up renewables) and in remote rural communities (particularly Africa) where existing fuel infrastructure is poor , demand is relatively low but fuel expensive.

Early adopters of algal oil as price differential not so marked.

Combine with (surplus) renewable electricity

Conclusions

1: The feedstocks necessary for algal production are more likely to be available locally when the output requirement is modest

2: While large biorefineries may produce economies of scale over smaller plants, these may be wiped out by the need to transport feedstocks onto the plant site.

3: Smaller plants easier to physically accommodate and thus less likely to be resisted from NIMBYism

4: Billion litre biorefineries will cost billions of Euros rather than millions making them a difficult financial “ask” (witness difficulties in project financing of conventional fuel sources such as nuclear and refineries).

5: Likely outcome is both will be used: mega refineries in the Americas and China, distributed production in Europe.

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Thank You
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