The Nottingham Microalgae Biorefinery

Steve Skill

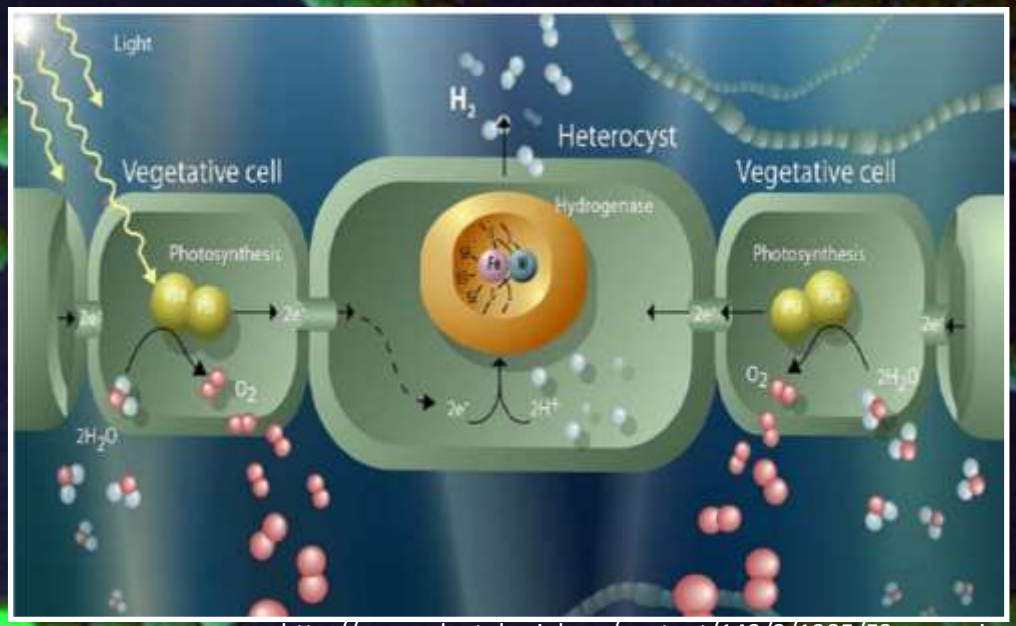
RSC | Advancing the Chemical Sciences

Sustainable Chemicals from Microalgae, Encompassing Biocrude through to Fine Chemicals
Royal Society of Chemistry, The Chemistry Centre, London UK
19th November 2013

Nostoc muscorum

HETEROCYST

VEGETATIVE CELL



http://www.plantphysiol.org/content/143/3/1385/F8.expansion

Steve Skill

Background

Lancaster University 1983

Biochemist- Restriction enzyme characterisation of cyanobacterial plasmids and cyanophage DNA.

BBSRC 3 year project - Research assistant - Isolation and cloning of Heterocyst specific gene sequences.

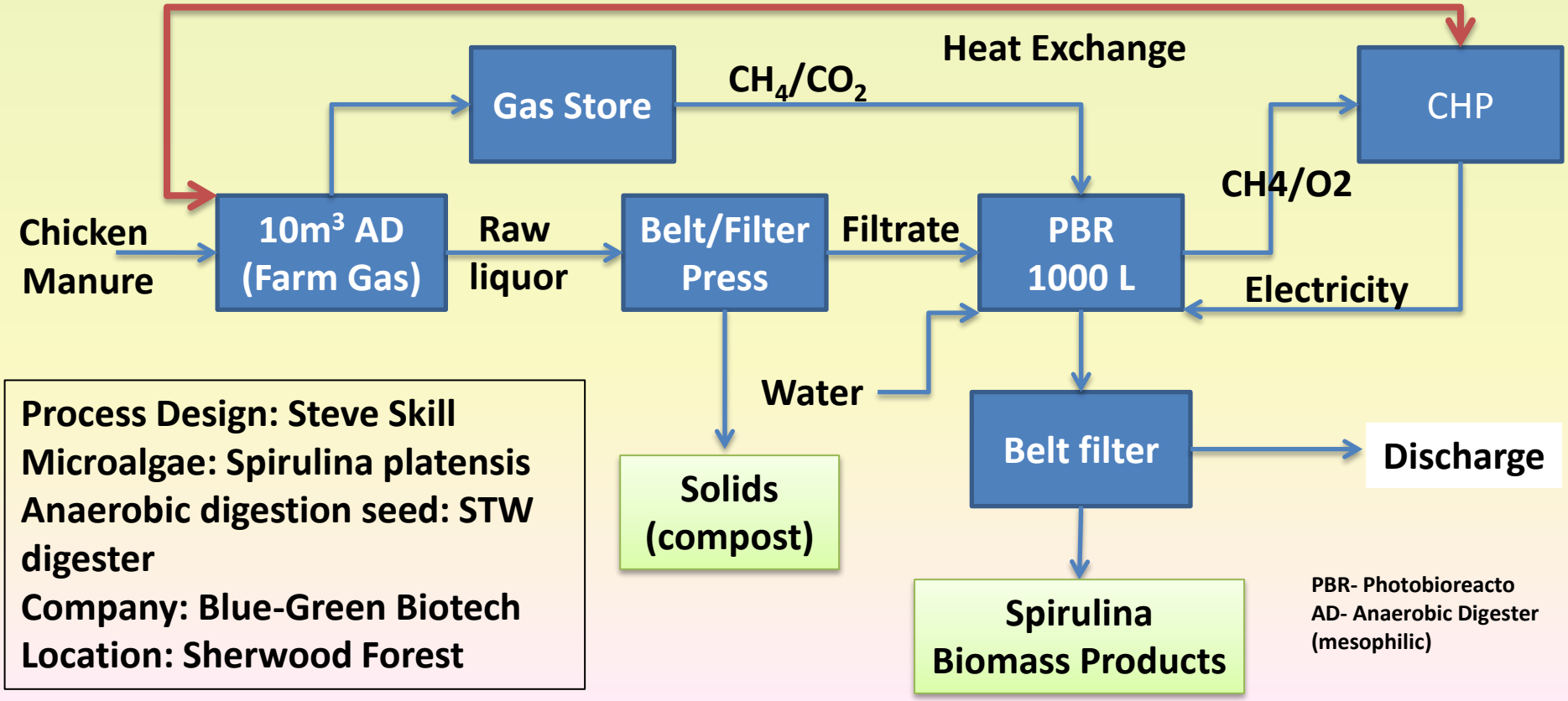
Enhanced H2 production

N fixation in higher plants

Carbon negative fertiliser production ~~Haber Process~~

1983- No Molecular toolkit!!

1986-1988 Sustainable Algae Production Process

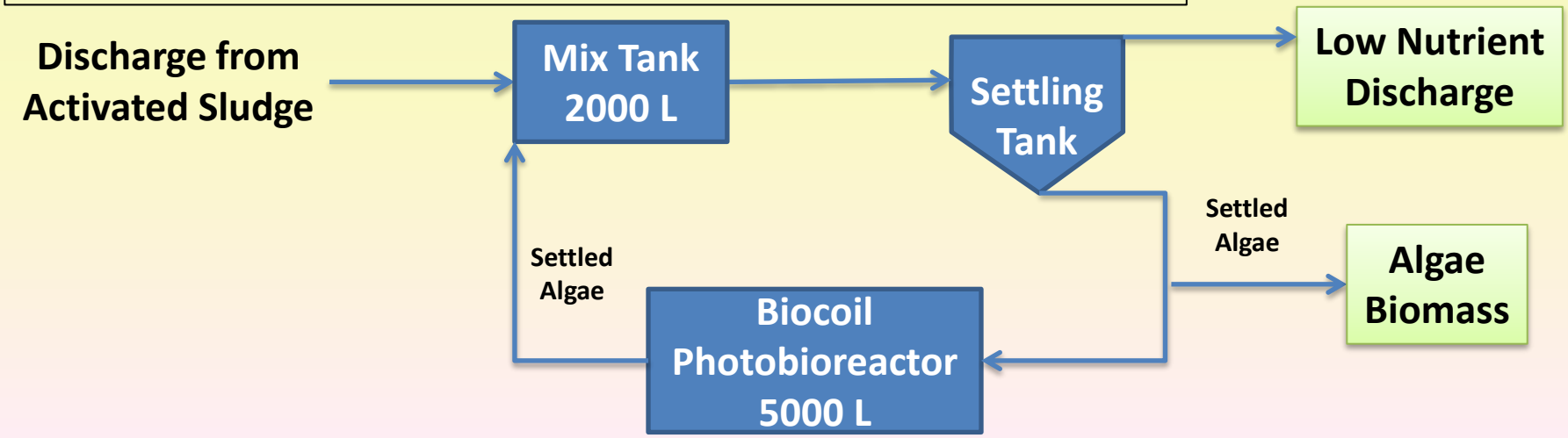


Process Design: Steve Skill
Microalgae: Spirulina platensis
Anaerobic digestion seed: STW digester
Company: Blue-Green Biotech
Location: Sherwood Forest

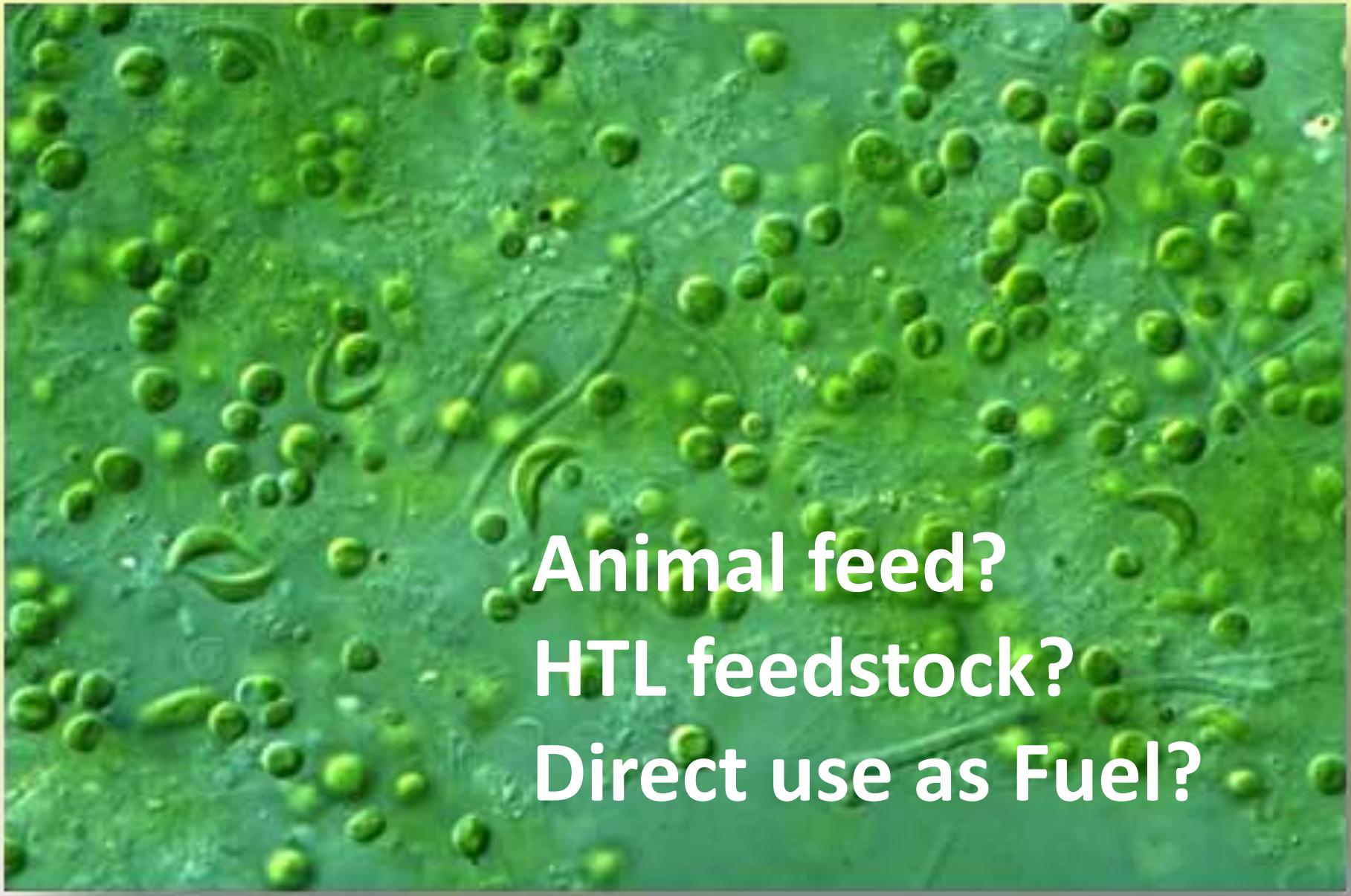
PBR- Photobioreacto
AD- Anaerobic Digester (mesophilic)

1992-1994 Biocoil Photobioreactor, Algae/bacteria consortium Tertiary Sewage Treatment Process

Process Design: Steve Skill
Microbes: Autoflocculating consortia of Chlorella & Scenedesmus
Company: Biotechna Ltd
Location: Stoke Bardolph STW, Severn Trent PLC, Nottingham



1992- Autoflocculating algae consortium (Chlorella/Scenedesmus)



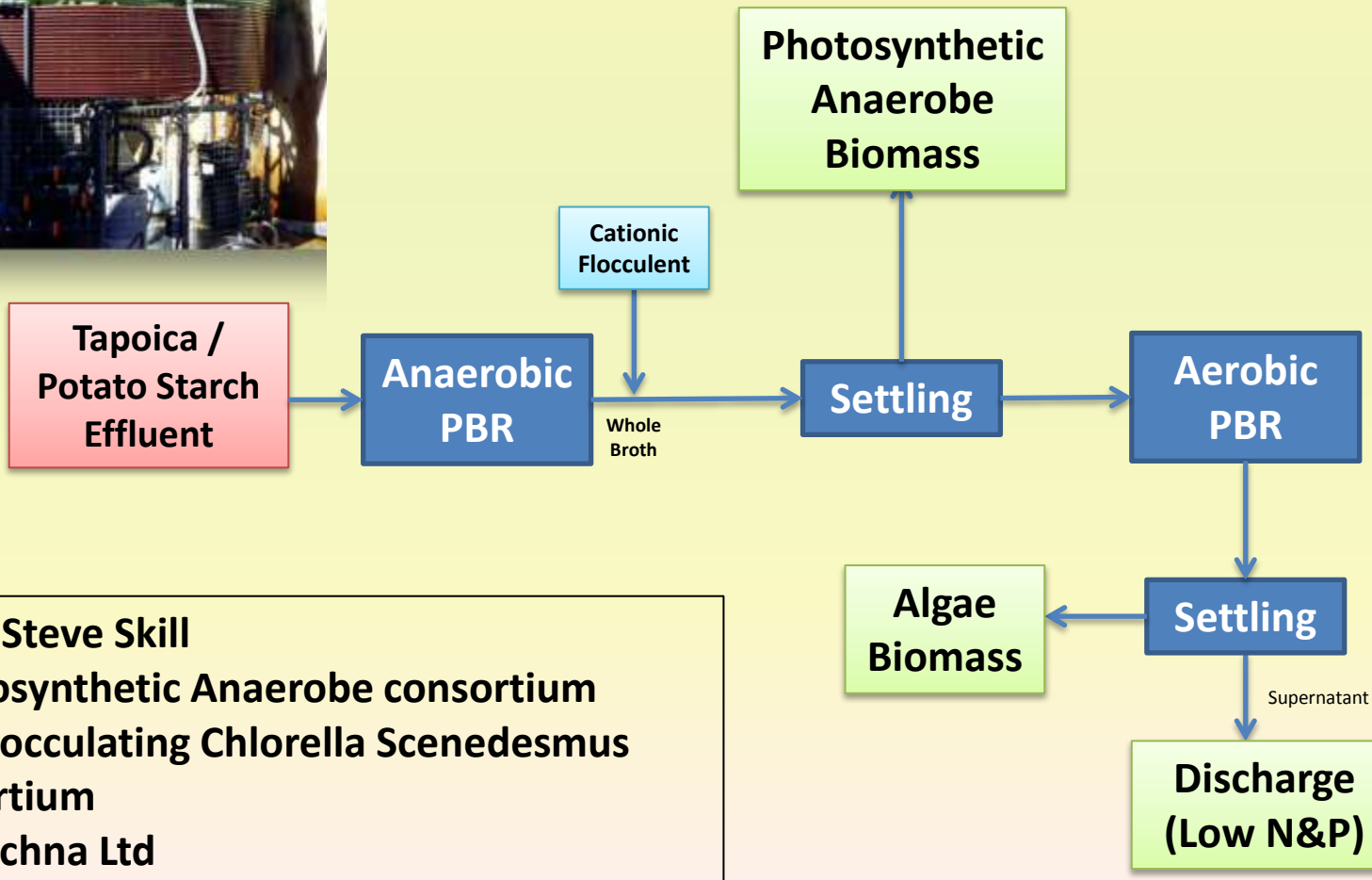
1993 Algae Power Station ?

BBC Tomorrows World 1993. http://www.youtube.com/watch?v=-7N8uBV1byE

1993-1995 Biotechna Graesser Ltd, Greencycle Ltd, Bioxtract Ltd. Escola Superior de Biotecnologia (ESB), Lisboa. (Vitor Verdhelo)

Two stage Biocoil PBR system for the production of Beta Carotene from Dunalliella salina. The unit was constructed in the UK and transported to site near Sines in Portugal.

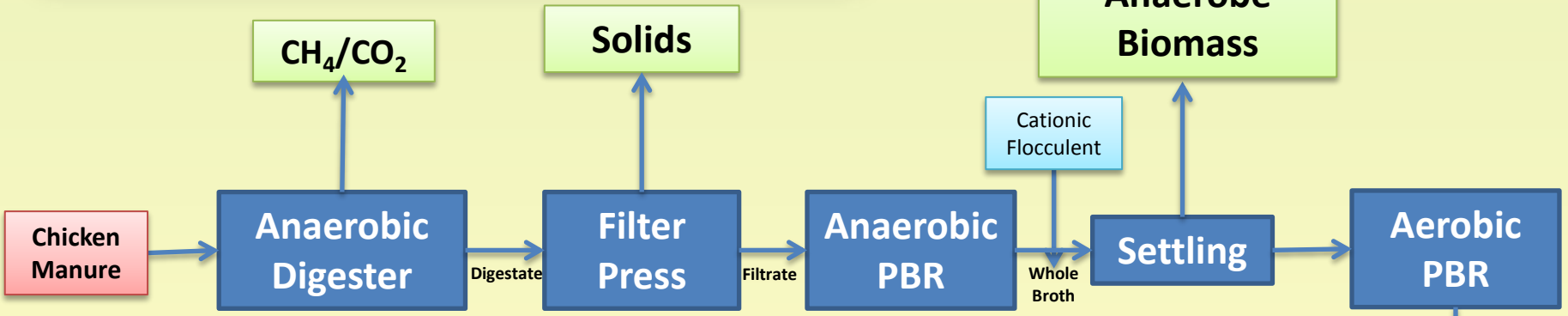
1994-1995 High Strength Wastewater Treatment



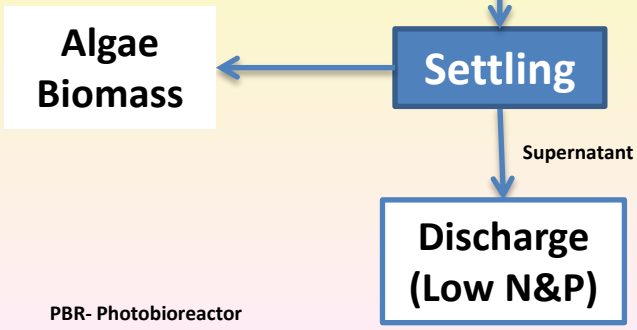
Process Design: Steve Skill
Microbes: Photosynthetic Anaerobe consortium
Autoflocculating Chlorella Scenedesmus consortium
Company: Biotechna Ltd
Location: Dorking, UK.

PBR- Photobioreactor

1994-1996 Digestate Enhancement

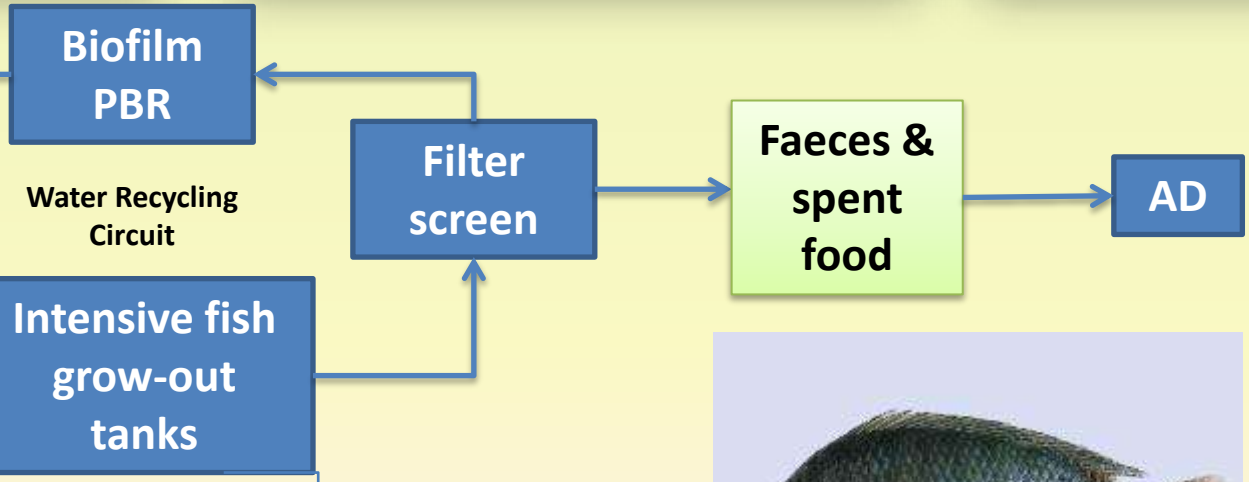


Process Design: Steve Skill
Microbes: Photosynthetic Anaerobe Consortium
Autoflocculating Chlorella / Scenedesmus consortium
Company: Biotechna Ltd
Location: Poultry farm, Cork, Ireland

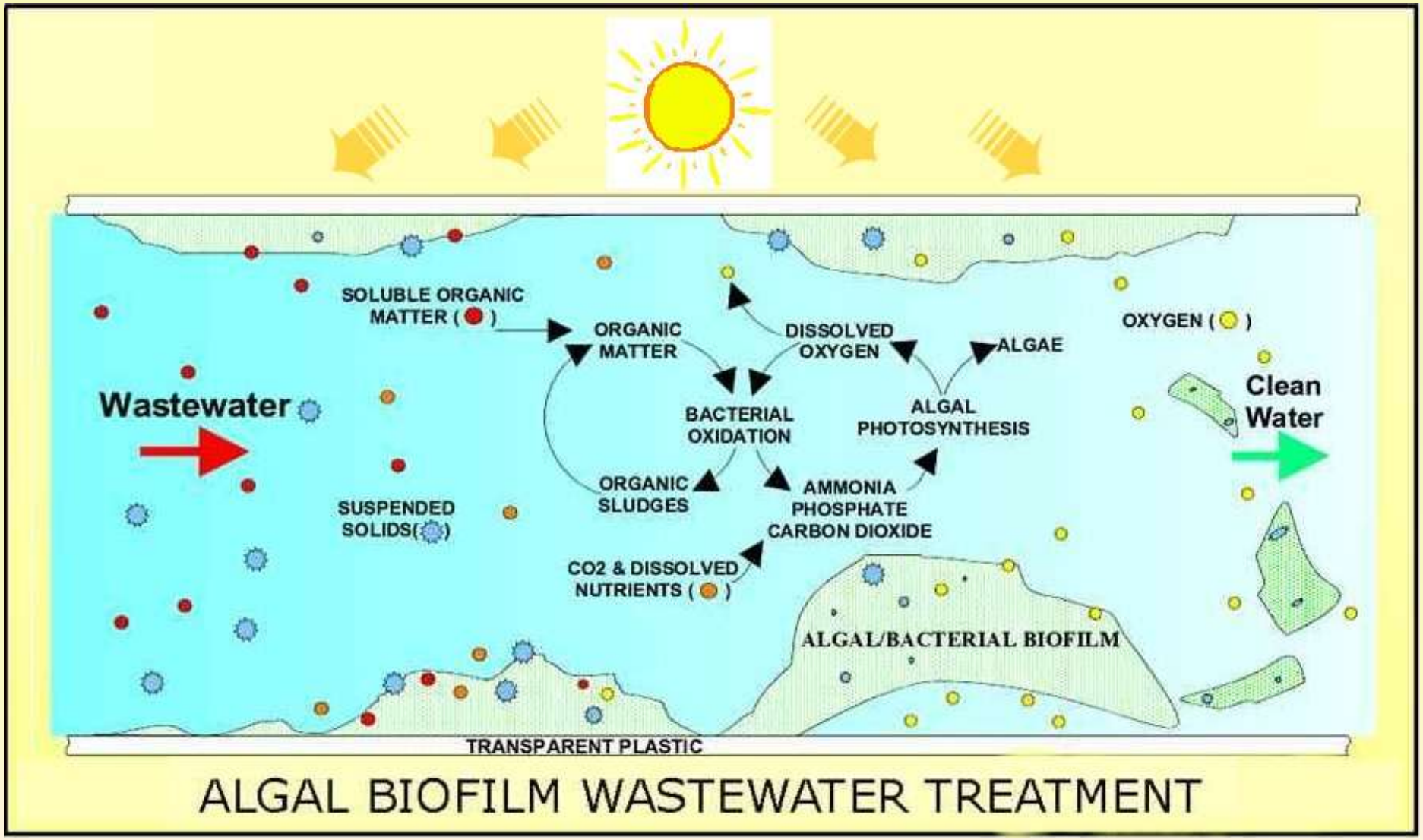


PBR- Photobioreactor

1997-2000 Sustainable Aquaculture



Proprietor: Steve Skill
Microbes: photosynthetic biofilm
Company: Sherwood Forest Tilapia
Location: Nottingham, UK.

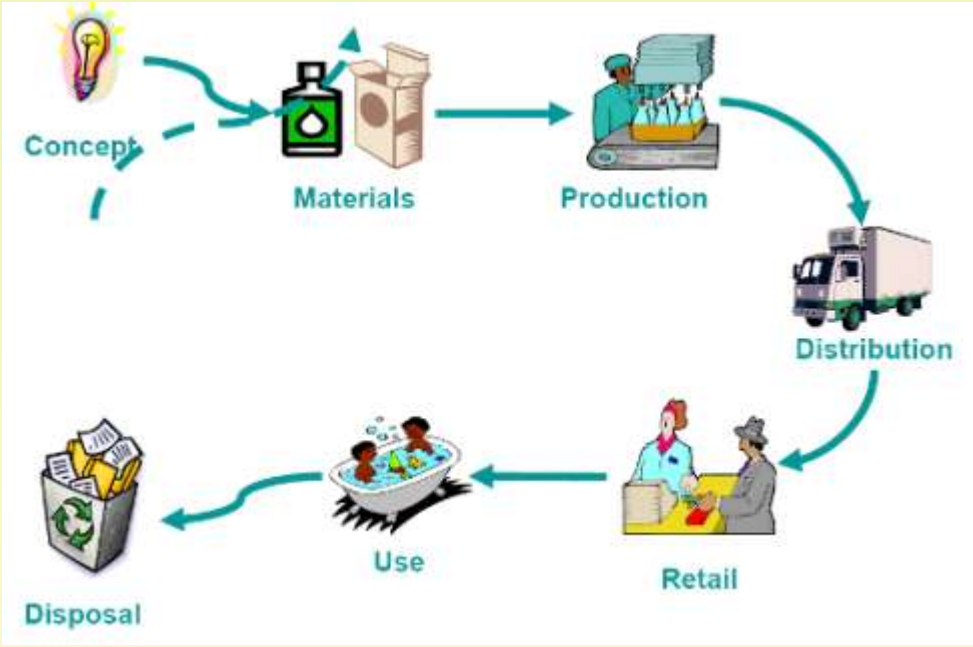


ALGAL BIOFILM WASTEWATER TREATMENT

The Nottingham Microalgae Biorefinery

Microalgal biorefinery - Industry perspective

- What commercially viable biomolecules can we characterise and extract from the algae?
- Can we grow the algae and extract the biomolecules economically?
- Does the consumer want whatever we find?
- Whole supply chain consideration -Can we develop a carbon negative ingredient supply chain?



Potential Microalgae Products and Applications

Anti-oxidants
Anti-inflammatory
Anti tumour
Anti-microbial
Sunscreens & Cosmetics
Pharmaceuticals
Nutraceuticals
Flavours and fragrance

High value bioactives

Biodiesel
Bioethanol
Hydrogen
Methane

Biofuel

CO_2 capture

MICROALGAE

Bioplastics
Materials science

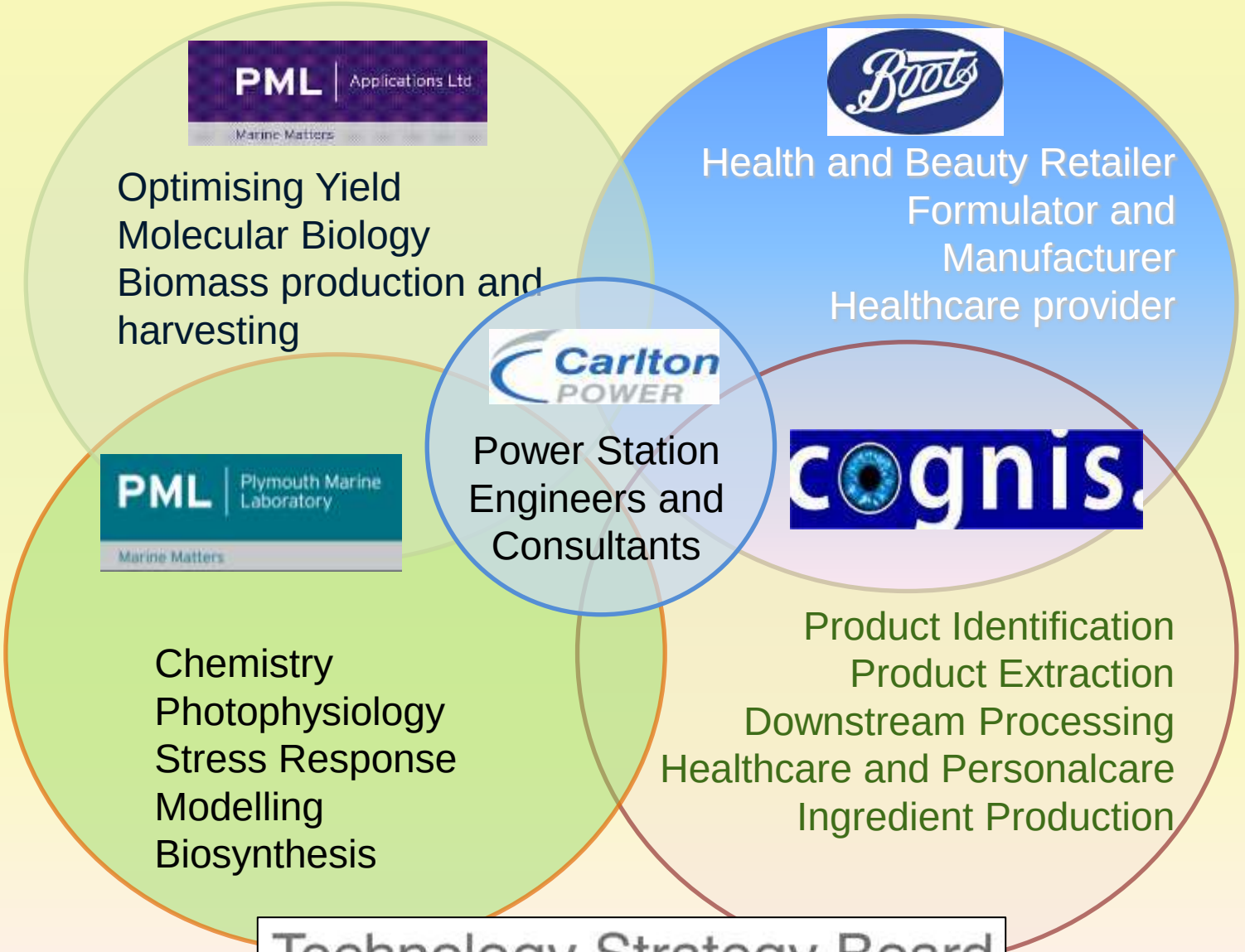
Bulk chemicals
Building block chemicals

Ceramics
Adhesives

Bioremediation

Waste water treatment
Contamination remediation

CCIF Project £2.1m – Steve Skill PI



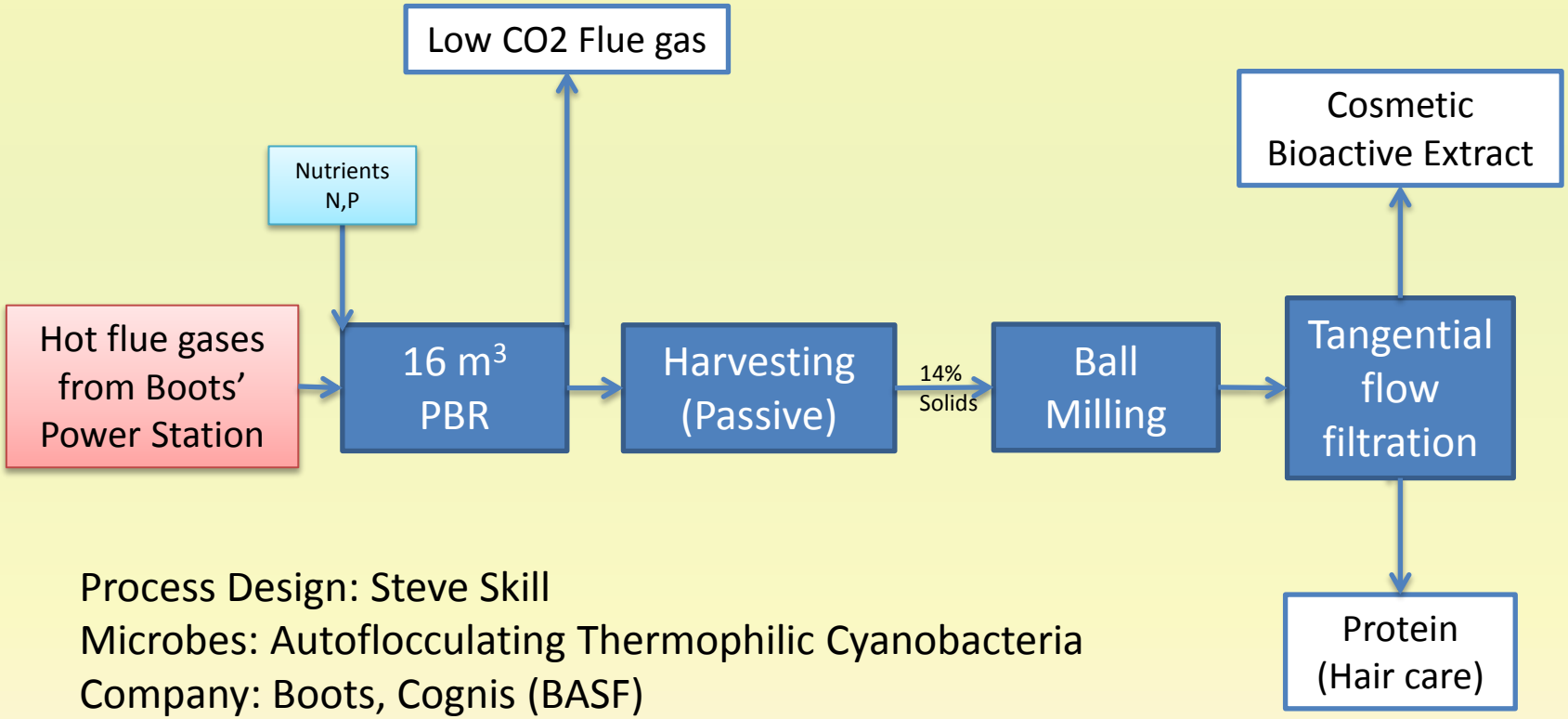
Technology Strategy Board
Driving Innovation

Which microalgal strain?

Screening programme lead to the selection of a ROBUST cyanobacteria (CX68)

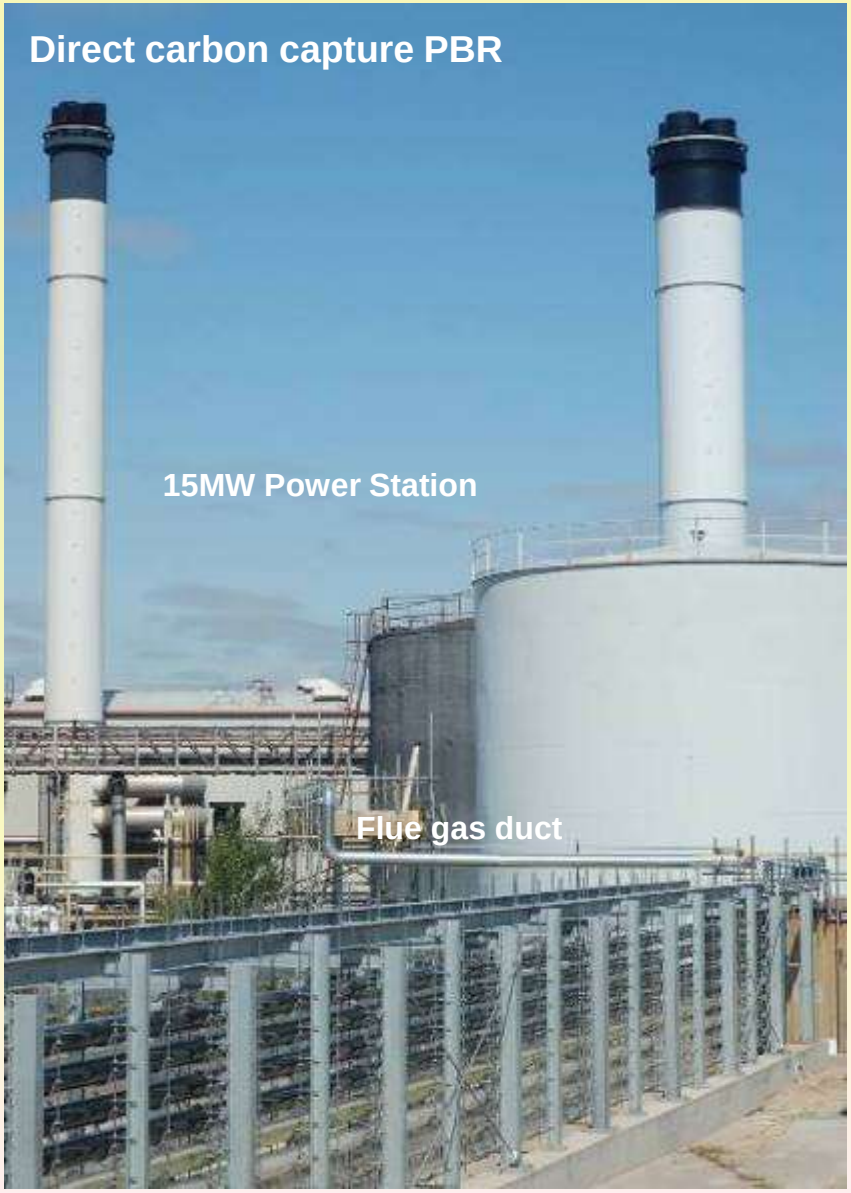
- Auto-flocculation
- Thermophilic
- Robust
- Monoalgal culture
- Storage
- Freshwater strain
- Wild type produces potentially valuable metabolites
- Di-azotrophe
- Prokaryote

2008-2013 Microalgal Biorefinery with Carbon Capture

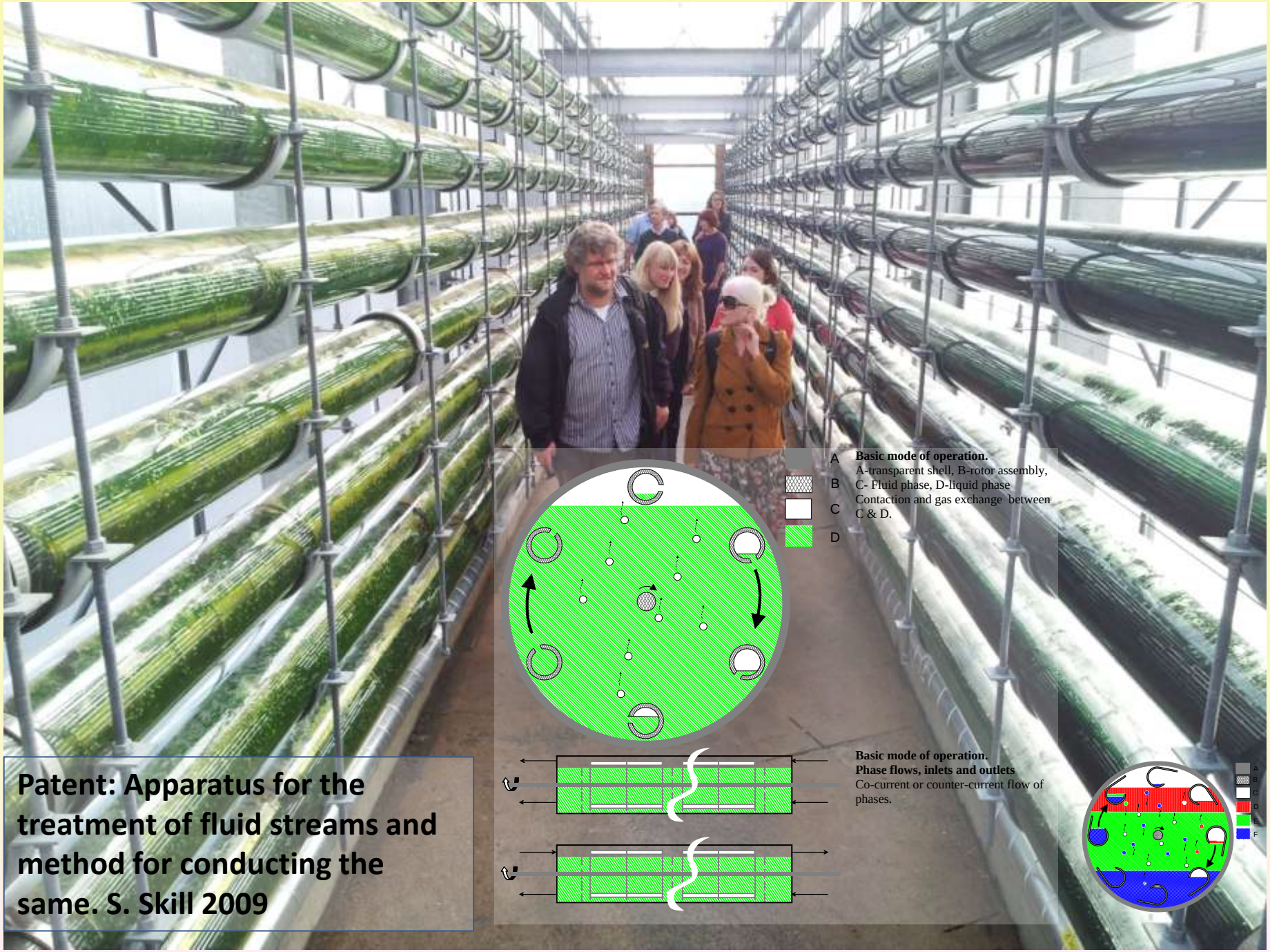


Process Design: Steve Skill
Microbes: Autoflocculating Thermophilic Cyanobacteria
Company: Boots, Cognis (BASF)
Location: Nottingham, UK.

PBR- Photobioreactor


Direct carbon capture PBR
15MW Power Station
Flue gas duct

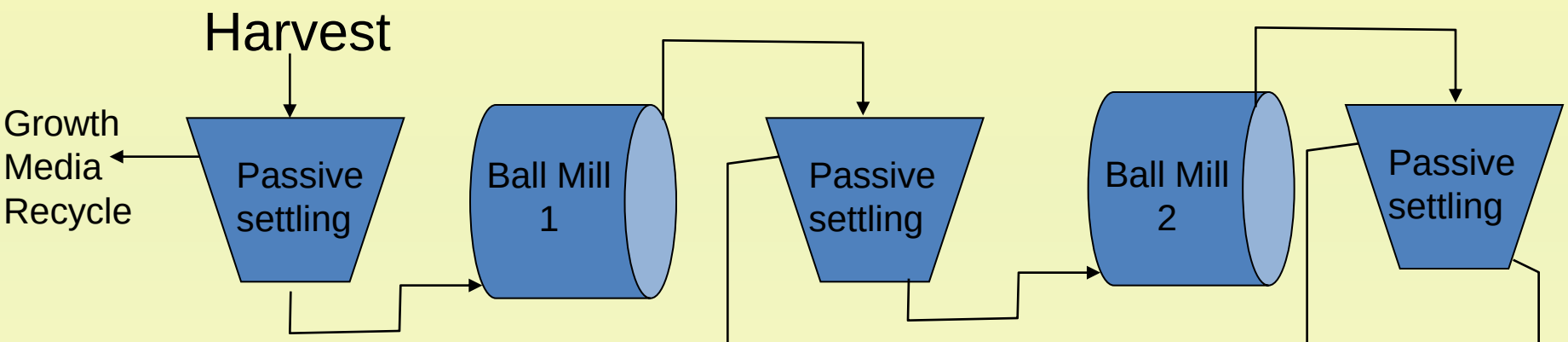

16,000 litre photobioreactor (PBR)
Productivity: 0.3-0.9g/l/day
Energy use: 20-70W/m3


A
B
C
D
Basic mode of operation.
A-transparent shell, B-rotor assembly,
C- Fluid phase, D-liquid phase
Contaction and gas exchange between
C & D.
Basic mode of operation.
Phase flows, inlets and outlets
Co-current or counter-current flow of
phases.
Patent: Apparatus for the treatment of fluid streams and method for conducting the same. S. Skill 2009

Product R&D Focus

- Antioxidants
- UV Protection (Suntan lotions)
- Anti inflammatory
- Anti ageing
- Protein Hydrolysates (hair care)

Multi-stage-stage biorefinery fractionation process using low energy ball mills.



14% solids

Extra-cellular Extract

Sunscreen
Anti-inflammatory
Anti-oxidants
(Anti-ageing)

Lysate

Anti-oxidants
Carotenoids
Natural colours

Protein

Hair Care

Further Fractionation

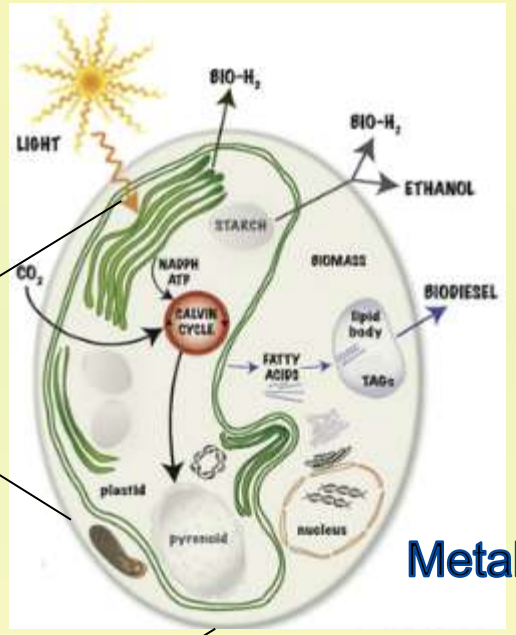
(Crossflow filtration)

Efficacy testing

- A suite of bioassays and analytical protocols have been employed to validate the cosmetic efficacy of extracts recovered from the biomass including; Antioxidant, Lipid peroxidation, anti-inflamatory, UVA & UVB protection and antimicrobial potential.

Developing a platform for sustainable chemical production

CO_2 and sunlight as feedstocks



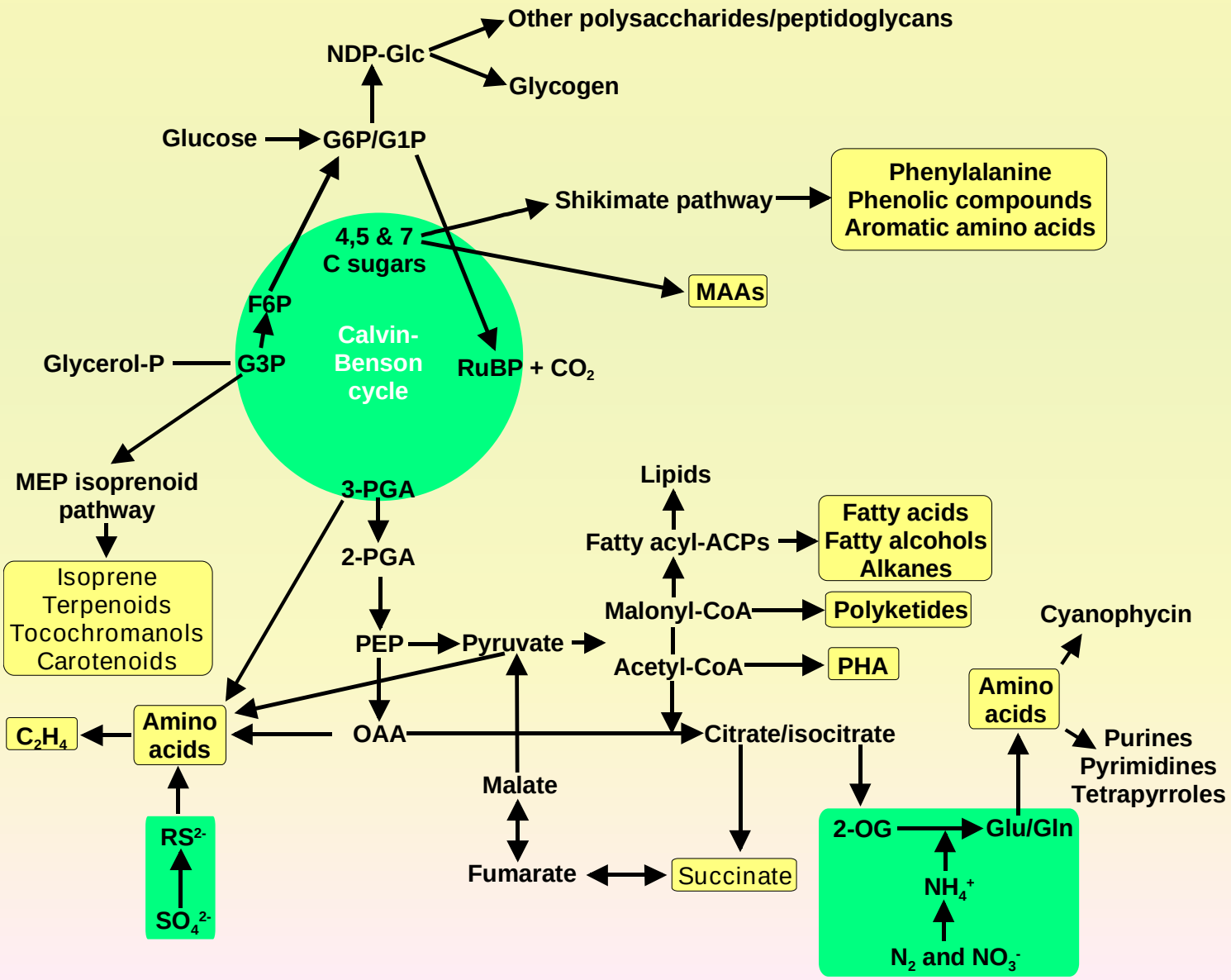
Metabolic engineering

Engineering microalgae for sustainable chemicals

Sustainable Chemicals

CX68
Prokaryote
Genome Sequenced
Transformation protocols

Pathways for manipulation?



Towards the development of a platform for sustainable chemical production

The Nottingham Microalgae Biorefinery

- Robust production and biorefinery system
- Downstream processing
- Molecular tool kit for Cx68
- Metabolic engineering
- Synthetic pathways
- Sustainable chemical production

Thank you..

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microalgae
metabolites
bioactives

Gary Farnham
molecular biology

Bangaru Balasundarm
downstream processing

Technology Strategy Board
Driving Innovation

PML | Applications Ltd
Marine Matters

Boots

Carlton POWER

cognis.

EnAlgae
collaborate innovate communicate