



CPI : Assets and Activities Relating to Seaweed

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Seaweed to Biofuel Workshop
Trondheim 25th-26th September 2012

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Introduction

- CPI : Activities and Role
- Fermentation for biofuels
 - Capability and NIBF assets
- AD with varied feedstocks
 - Capability and ADDC assets
- Thermal processing of seaweed
 - PhD studentship - Durham University & CPI
 - Thermal Technologies Centre (TTC)

Centre for Process Innovation : Activities



Serves the chemicals, pharmaceuticals, food & drink, biotechnology, printable electronics & energy industries.
Uses market knowledge and technology understanding to develop and prototype products and processes



Printable Electronics

Design, development and prototyping for this emerging industry. The focus is on printable electronic materials, ultra-efficient lighting, displays, photovoltaics and integrated smart systems



Industrial Biotechnology

Developing alternatives to traditional chemical processing using cleaner and more sustainable processes on open access facilities from laboratory to 10,000 litre pilot production



Smart Chemistry

Novel mixing and reaction technologies to improve chemical processes. Convert batch processes to continuous processes. The facility is supported by whole process design.



Anaerobic Digestion

Developing processes and testing technologies with a range of pre-treatment, digestion and post-treatment equipment that is rapidly reconfigurable



Thermal Technologies

A collaboration between CPI and Tata Steel to innovate in fuel & energy, high temperature processes, recovery of raw materials & reductions in waste.



Sustainable Engineering

Reduces the risks of adopting innovative technology. The team links engineering, science, economics and systems design to improve whole processes that are cleaner, greener and more sustainable.



Future Technology

Team of experienced senior managers that help partners define practical technology based solutions to long term challenges associated with changing supply chains, resource availability, legislation & regulation.



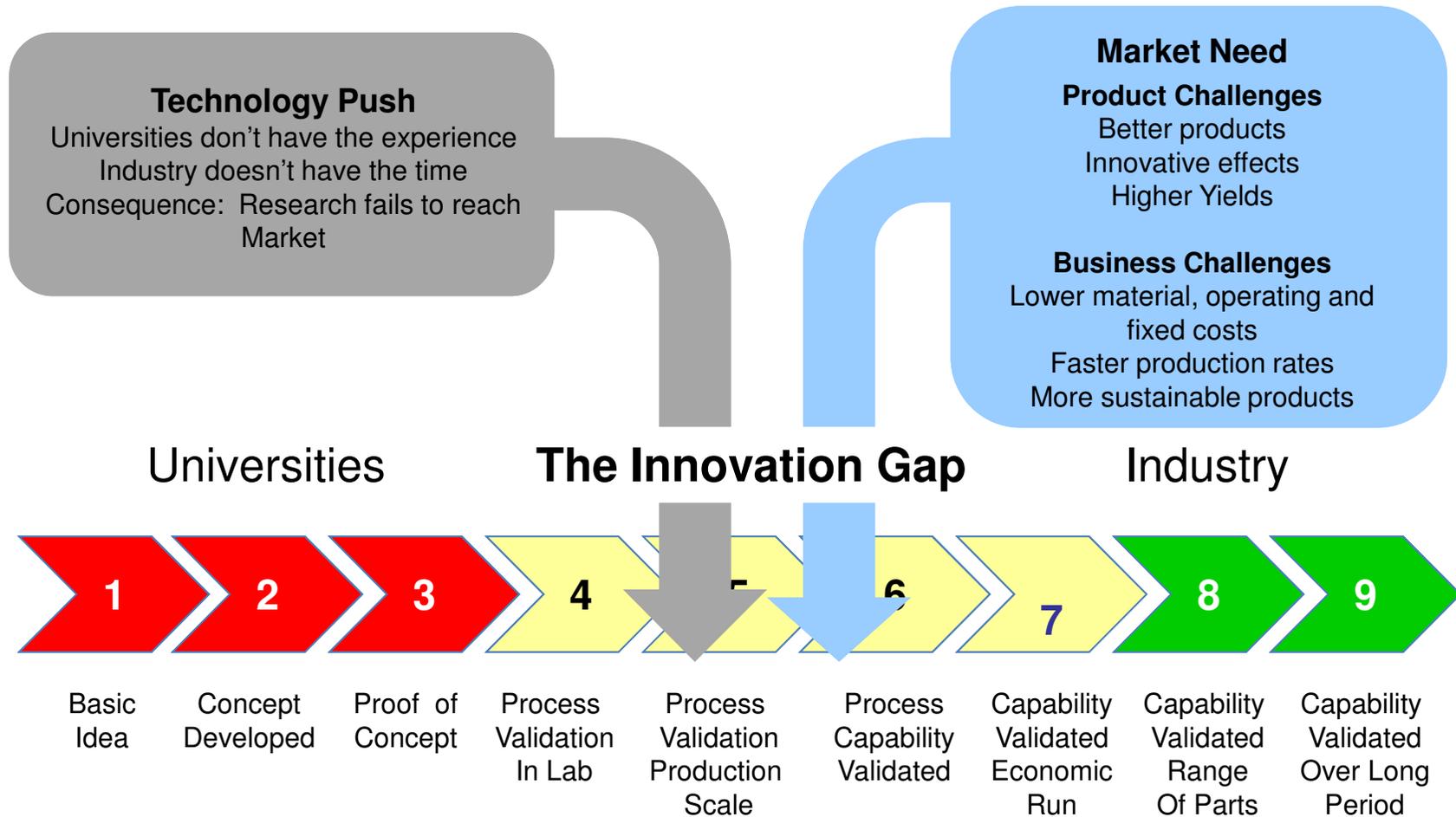
Commercial Support

Support to SMEs to develop new products and processes in the Innovation Accelerator supplying incubator space, business support, training and help with funding. Specialist bid team that helps partners create consortia to secure public private projects.

From innovation to commercialisation



CPI and the Innovation Gap



From innovation to commercialisation

Fermentation for Biofuels

- Experience with varied fermentation feedstocks
 - Starch based and cellulosic feedstocks
 - Structural breakdown (acid, steam) and enzymatic hydrolysis
- Batch and continuous fermentation
- Process development and scale up
 - Variable feedstock, organisms, fermentation parameters
- Broad experience of DSP
 - Centrifugation, membrane separation, distillation
- Evaluation of process economics
 - From feedstock to product

NIBF

1,000l Pilot Facility & Development Labs – Typical Projects/Products

- Process Development of Fermentation & DSP
- Algae culture
- Process Scale Up (50l -750l)
- Extraction of high value chemicals
- Biocatalysts
- High Value Chemicals
- Biopolymers
- Biofuels
- Biosurfactants



From innovation to commercialisation

NIBF

10,000 litre Demonstration Facility :

- Funded by BIS following recommendations from the IBIGT
- Focused on production of chemicals and fuels from renewable feedstocks
- Pretreatment of wet and dry feedstock
- Fermentation at 10000l scale
 - Batch, Continuous, Aerobic, Anaerobic
- Downstream processing for product isolation
 - Filtration, Distillation, Membranes



From innovation to commercialisation

NIBF

10,000 litre Demonstration Facility – Typical Projects/Products

- Scale Up - including from NIBF1
- Continuous Fermentation Processes
- Extraction and Bio/Chemical Processes – utilise route between pre-treatment and DSP (ie by-pass fermentation)
- Anaerobic Digestion Development Centre available for integration trials
- Biofuels
- Biopolymers
- High Value Chemicals



From innovation to commercialisation

Anaerobic Digestion

Opened in Feb 2011, the AD Development Centre is a £1.5million open access facility, which allows clients to assess novel feedstocks and technologies before investing in AD installations.

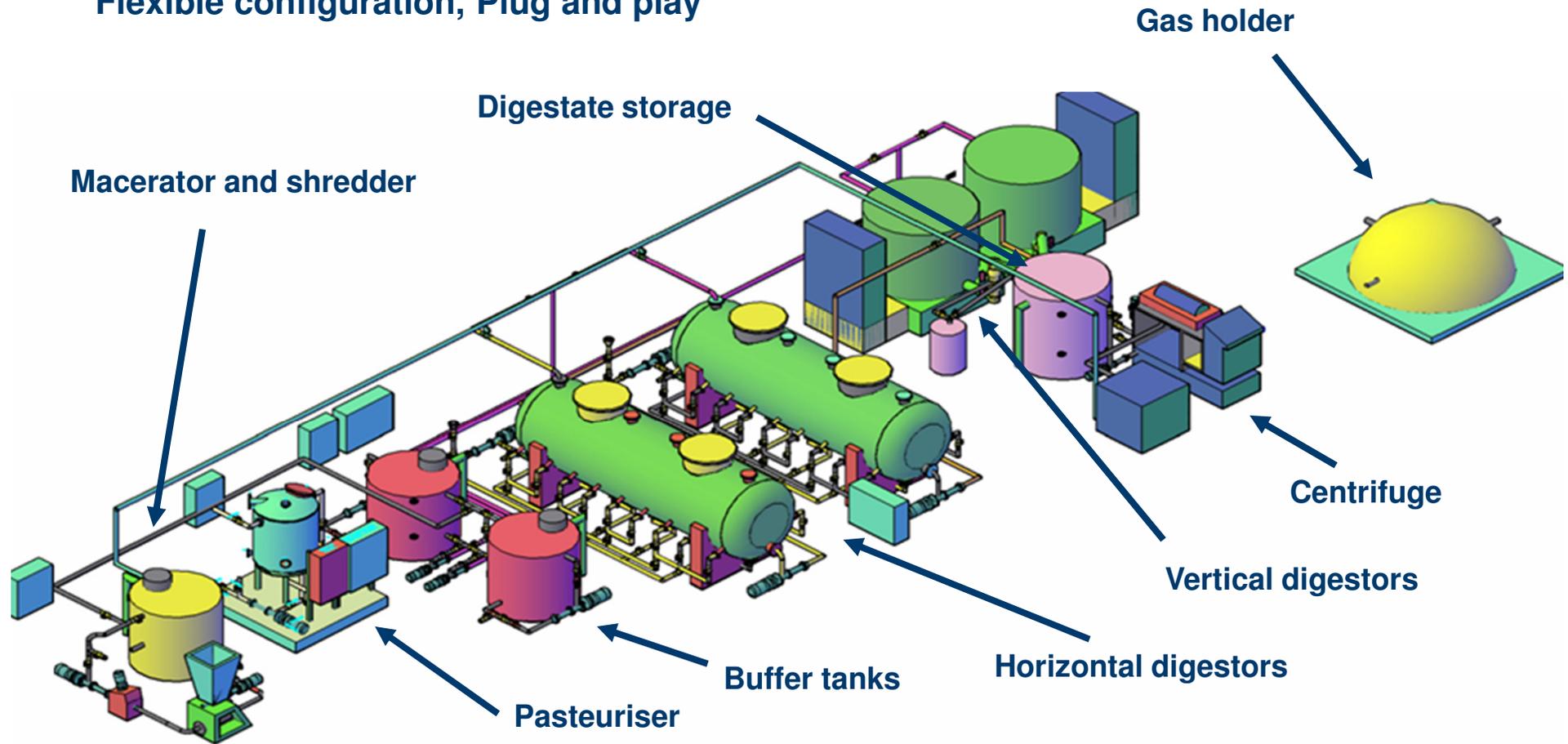
- Experience with varied feedstocks
 - Agricultural, Rural, Light industrial
- Lab-scale evaluation of feedstocks
 - eg Microalgae and dairy slurry
 - Seaweed evaluation also possible
- Pilot Trials
 - Small scale design suitable for distributed use
 - Standard design for benchmarking and scale up trials
- Evaluation of process economics



From innovation to commercialisation

ADDC : Plant Layout

Flexible configuration, Plug and play



From innovation to commercialisation

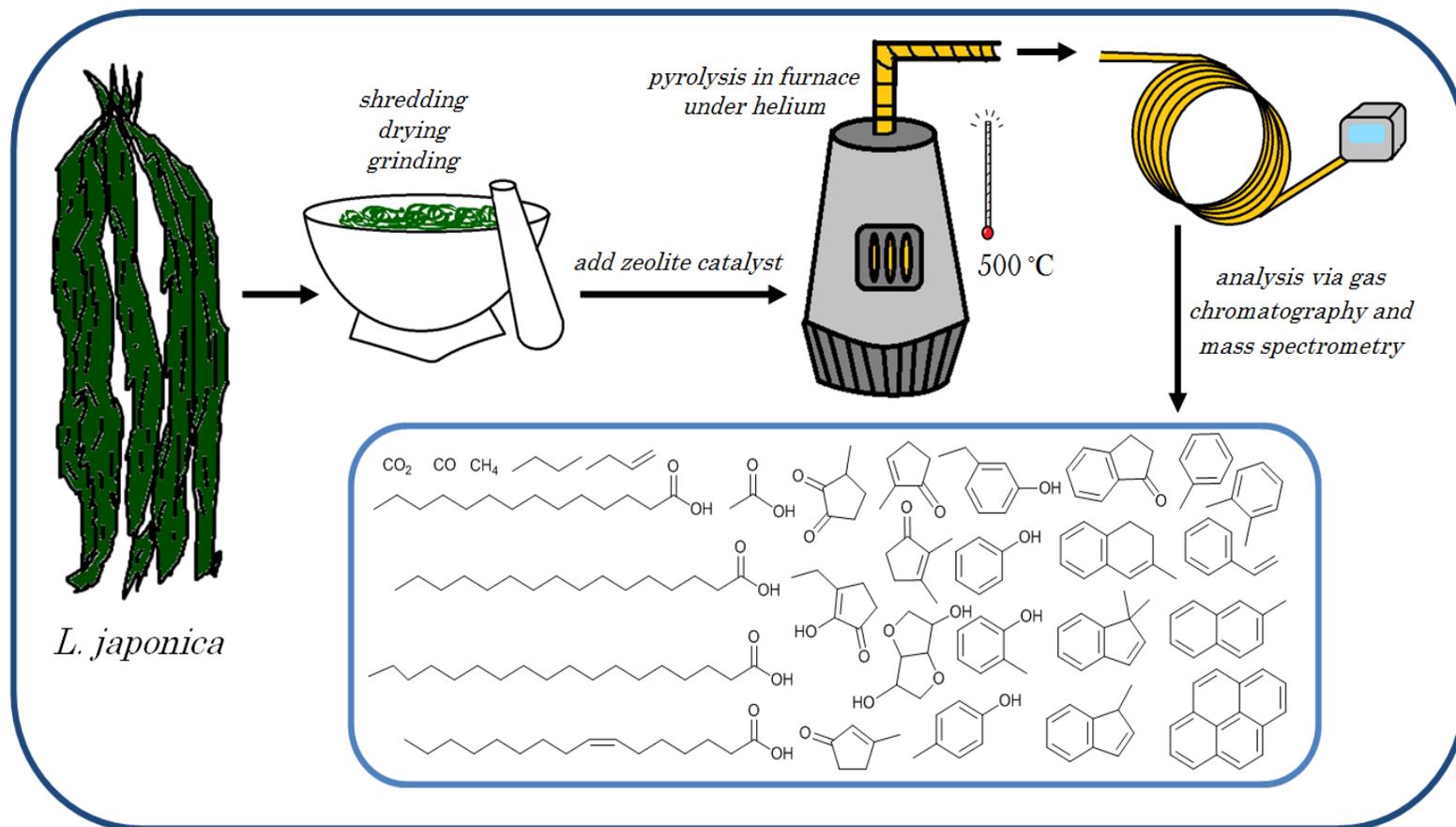


From innovation to commercialisation

Catalysts for the Production of Biofuels *via* Thermochemical Processing of Macroalgae

- Durham University PhD Studentship – with CPI joint funding
 - Jack Rowbotham : *PhD Student*
 - Phil Dyer : *Senior Lecturer/Royal Society Industry Fellow, Dept. Chemistry and CSCP*
 - Chris Greenwell : *Senior Lecturer, Dept. of Earth Sciences and CSCP*
- Fundamental Questions:
 - How does the thermolysis of macroalgae proceed?
 - What are the products from thermolysis of seaweed and how is their formation linked to process conditions?
- Longer Term Considerations
 - Which catalysts can be used to up-grade macroalgae thermolysis products?
 - What is the effect of directly integrating catalysts into the pyrolysis environment?

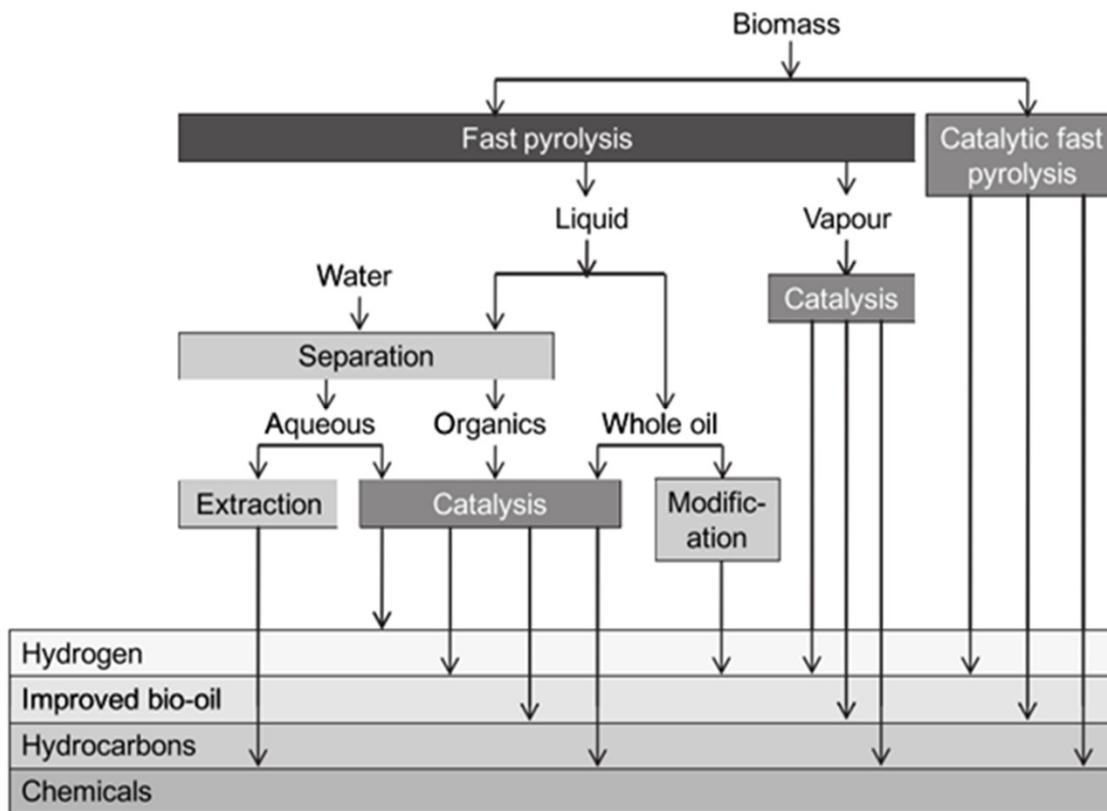
Catalysts for the Production of Biofuels *via* Thermochemical Processing of Macroalgae



Lee *et al.*, *Nanoscale Res. Lett.*, **2011**, *6*, 500

Rowbotham, Dyer, Greenwell, Theodorou, *Biofuels*, **2012**, *3*, 441

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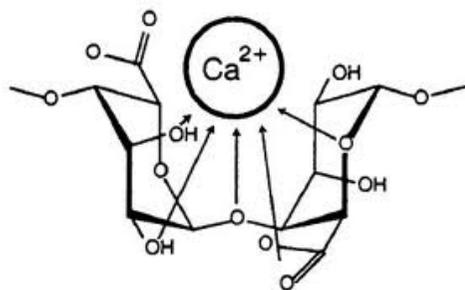
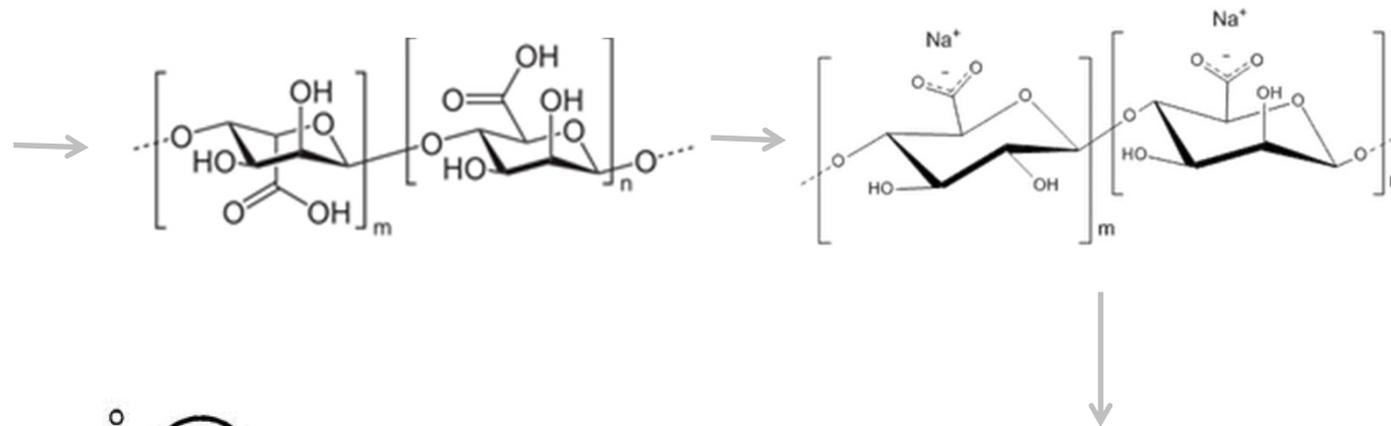
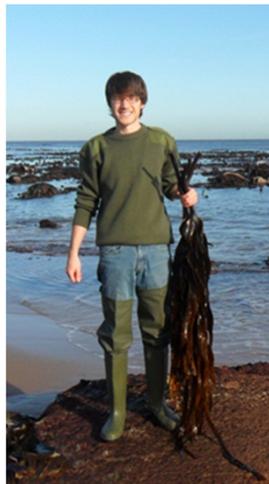


1. Lower E_a of pyrolysis
2. Deoxygenation of products *in situ*
3. Tune product ratios
4. Upgrade products post-reaction

zeolites, metal oxides,
transition metals, ionic
liquids...

Bridgwater, *Biomass & Bioenergy*, **2012**, 38, 68-94

A Starting Point: Metal Alginate Studies



Li⁺, Na⁺, K⁺,
Be²⁺, Mg²⁺, Ca²⁺,
Al³⁺, Ga³⁺, NH₄⁺
Transition metals



TGA
(Eventually Pyrolysis...)

Analysis → Optimisation

Rowbotham, Dyer, Greenwell, Theodorou, *RS Interface*, 2012, manuscript submitted

Thermal Technologies Centre : CPI



- **Laboratory Scale Gasification**
 - 1Kg
 - Fluidised Bed
 - Operating temperature up to 800°C
 - Controlled amount of oxygen
 - Input feedstocks at rates up to 1Kg/Hr

- **Laboratory Scale Pyrolysis**
 - 1 Kg
 - Fluidised Bed or Grate
 - Operating temperature up to 500°C
 - Absence of air
 - Input feedstocks at rates up to 1Kg/Hr

From innovation to commercialisation

Thermal Technologies Centre : CPI & Tata Steel



- **Demonstration Scale**
 - 500kW Gasifier (18m³)
 - Multi-mode: up-draught, down-draught, fluidised bed & tuyere
 - Operating temperature 800 - 1500°C
 - Controlled amount of oxygen
 - Inject feedstocks at rates up to 500Kg/hr
 - Tail gas cleaning and flarestack
 - Feedstocks may include biomass, plastics, etc.
 - Space to accommodate client equipment downstream
 - Before/after tail gas cleaning

From innovation to commercialisation

Thermal Technologies Centre : CPI & Tata Steel



- **Demonstration Scale**
 - 350Kg Static Bed Pyrolysis Furnace
 - Refractory lined
 - Operating temperature upto 1250°C (20°C/hr ramp)
 - Absence of air
 - Batch
 - Feedstocks may include coal, plastics, biomass etc.

From innovation to commercialisation

Thermal Technologies Centre : CPI & Tata Steel

Services

- **Process investigation**
 - In situ measurement in hostile environments
- **Process/product optimisation & development**
 - Modelling of process, process economics + carbon footprint
 - Application of demonstration scale assets
 - Design and build of bespoke demonstration scale assets
- **Fuels and feedstock evaluation**
 - Optimal economic and physical properties
- **Programme development and management**
 - Construction of consortia to bid for FP7, TSB programmes etc

From innovation to commercialisation

Analytical Capability

- **Sustainable Processing**
 - Gas Chromatography
 - GC-MS
 - Liquid Chromatography
 - LC-MS
 - Ion Chromatography
 - Atomic Absorption Spectroscopy
 - Biochemical Analyser

- **Thermal Technologies Centre**
 - Gasification & Pyrolysis
 - Gas Chromatography
 - GC Mass Spectrometry
 - X-ray Fluorescence
 - Elemental analysis
 - Feedstock Assay
 - Proximate and ultimate analyses



- **Anaerobic Digestion**
 - Gas Chromatography
 - Chemical Oxygen Demand
 - Volatile Fatty Acids
 - Total & Volatile Solids
 - Ammonia, Nitrogen, Phosphorus
 - Biogas Production Rate

From innovation to commercialisation

Summary

- Fermentation of a range of feedstocks
 - Starch and Cellulosic
 - Seaweed readily accommodated
- AD with varied feedstocks
 - Labscale evaluations – seaweed planned
 - Pilot scale trials of varied single and mixed feedstocks
- Thermal processing of biomass
 - PhD studentship with Durham University – pyrolysis of seaweed
 - Thermal Technologies Centre