

**IEA Bioenergy**

**Task 34 - Pyrolysis**



# **UK Country Report - 2014**

**Tony Bridgwater and Katie Chong  
Aston University, UK**

**IEA Task 34 Meeting: October 2014, Finland**

# Organisations

## UNIVERSITIES

- Aberystwyth University
- Beacon
- Aston University
- Cranfield University
- Edinburgh University
- Lancaster University
- Leeds University
- Liverpool John Moores U.
- Manchester University
- Newcastle University
- Nottingham University
- Sheffield University
- Swansea University
- White Rose University Consortium
- York University

## INDUSTRY

- Biomass Power Plants
- CARE
- Centre for Process Innovation and Tata Steel
- Clean Power
- Future Blends
- Hudol
- New Earth
- Stein Pyrolysis
- Waste Gen

# Aberystwyth U.

## **Slow pyrolysis**

- Biochar production in 600 kg batches,

## **TG-Py-MS**

- Characterisation of biomass



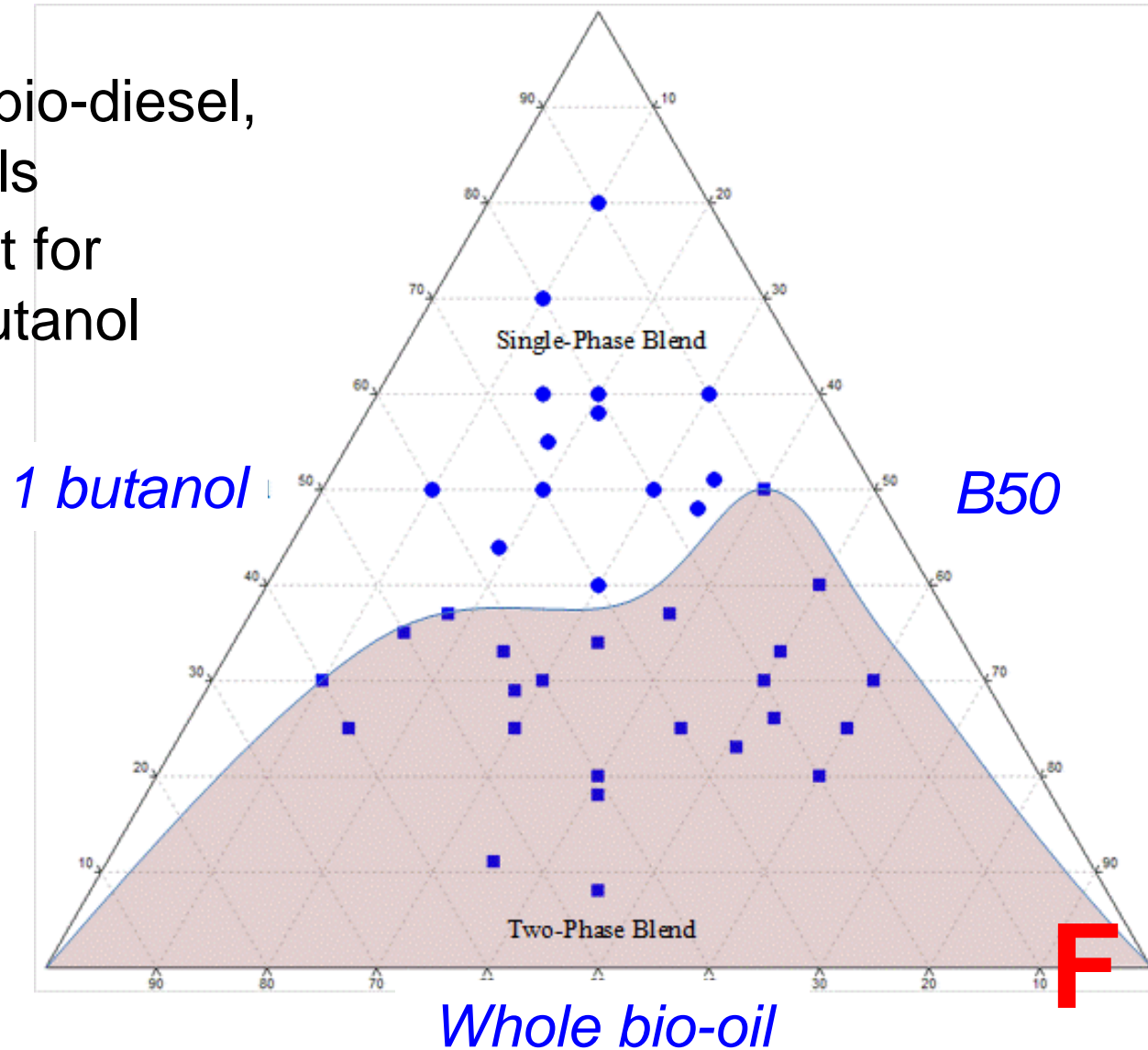
# Aston U. BERG/EBRI Fast pyrolysis (FP)

- **Biomass pretreatment:** reduce ash and dope biomass to study effect on bio-oil properties (*Recently completed*).
- **Fast pyrolysis in fluid bed reactors**
- **HDO** of bio-oil. (*with PNNL and Grace*) (*SUPERGEN*)
- **Cracking** of fast pyrolysis vapours with modified catalysts (*SUPERGEN project*)
- **Kinetics** of fast pyrolysis by drop tube reactor
- **Analytical** pyrolysis with secondary reactor and GCMSFID analysis
- **Esterification** of bio-oil (2013)
- **Blending** bio-oil with biodiesel, alcohol and diesel as 3 and 4 component blends (*New project*)
- **TEA** of biofuel systems (*New project*)
- **CFD modelling**

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# Aston FP 4 Component Blending

- Blends of bio-oil, bio-diesel, diesel and alcohols
- Three phase chart for blends with bio-butanol shown
- Whole bio-oil used
- Blends offer more control over properties.
- Excellent stability



# Aston - Intermediate pyrolysis (IP)

## Intermediate pyrolysis (Pyroformer)

- Twin screw reactor with external heating and internal char recirculation for heat transfer.
- Wall temperature up to 450C.
- Solid residence time controllable
- Phase separated product

**Gasification** or reforming of vapours (*Pyrogas project*)

**Anaerobic digestion** of aqueous fractions of IP and FP products (*SUPERGEN project*)



# Aston Torrefaction

## **Torrefaction (slow low temperature pyrolysis)**

- Evaluation and design studies including mass and energy balances (*SUPERGEN project*)
- Experimentation for mass balances and temperature data



# Aston – catalyst prod'n & characteris'n

- Production of metal loaded zeolites for catalytic cracking
- Testing and characterisation of HDO catalysts  
(confidential industry sponsored project)

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# Cranfield U.

## **Modelling fast pyrolysis fluid bed, liquid collection, and upgrading (Sai Gu)**

A discrete element method to more accurately model pyrolysis including drying, heating and pyrolysis. A hybrid DEM-Eulerian model reduces computation time, gives good predictions and allows the observation of discrete particles. The modelling is being extended to HDO and catalytic cracking. (*SUPERGEN project*)

## **Slow pyrolysis of biomass and wastes (John Oakey)**

A fixed bed reactor is used for slow pyrolysis

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# Edinburgh U.

## Catalytic pyrolysis

- Catalytic pyrolysis to improve bio-oil with a lower O and N content and high levels of aliphatics and H; using activated serpentine (ACSE) and olivine (ACOL) at 430-460 °C.
- Bio-oil HHV increased from less than 20 MJ/kg in the original biomass to 26 MJ/kg. Approximately 70-74 % of the starting energy remains in the bio-oil whereas only 52 % is retained using alumina (ALU) at the same temperature.

doi: [10.1002/cssc.201200245](https://doi.org/10.1002/cssc.201200245).

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# Edinburgh U.

## Pyrolysis biochar systems

- Study effect of pyrolysis process conditions on long term biochar stability and energy content of pyrolysis products  
<http://dx.doi.org/10.1111/gcbb.12137>
- Utilisation of liquid pyrolysis products in anaerobic digestion

## Microwave pyrolysis

- Microwave induced pyrolysis
- Assessment of off-gassing on storage of biomass char



# Edinburgh U. UK Biochar Centre

## Slow pyrolysis for bio-char

- Alongside research on pyrolysis for biochar production the pyrolysis laboratories at the UKBRC are providing material for biochar researchers both within the UKBRC and the UK and international biochar community.
- Collaboration with Newcastle U and Rothamsted Res.



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# Lancaster U.

## **Microwave induced plasma pyrolysis**

- Pyrolysis of waste wood using microwave-induced plasma in a lab-based reactor.
- [DOI: 10.1016/j.fuproc.2012.01.015](https://doi.org/10.1016/j.fuproc.2012.01.015)

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# Leeds U. ERI

## Waste and Biomass Pyrolysis (P Williams)

- Fuels from pyrolysis of wastes
- High value products from wastes - activated carbons, chemicals
- Process engineering for wastes
- <http://www.engineering.leeds.ac.uk/eri/research/renewable-energy-systems-future-fuels/current-research/waste-biomass-pyrolysis.shtml>



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# Leeds U. ERI

## **Analytical pyrolysis (J Jones)**

- Characterisation of solid and liquid fuels

## **Ion chromatography (IC)**

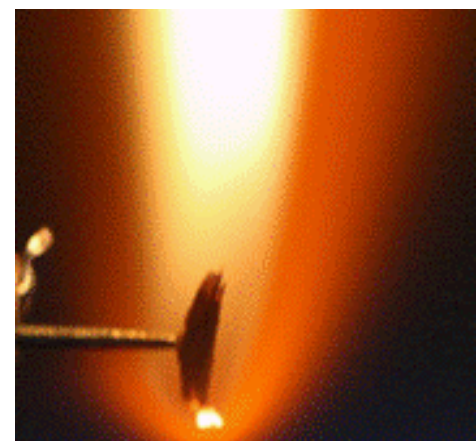
- Halides, nitrite, nitrate, sulphate ammonium, alkali metal and alkali earth metals ions measured to sub-ppm levels. E.g. halogens in pyrolysis oils and determination of sulphur content following bomb calorimetry.

## **Pyrolysis/Gas Chromatography/Mass Spectrometry (Py/GC/MS)**

## **Gas Chromatography/Flame Ionisation Detection (GC/FID)**

## **Size exclusion chromatography (SEC)**

<http://bit.ly/1r8MR1r>



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# Leeds U. ERI

## **Torrefaction (J Jones and A Williams)**

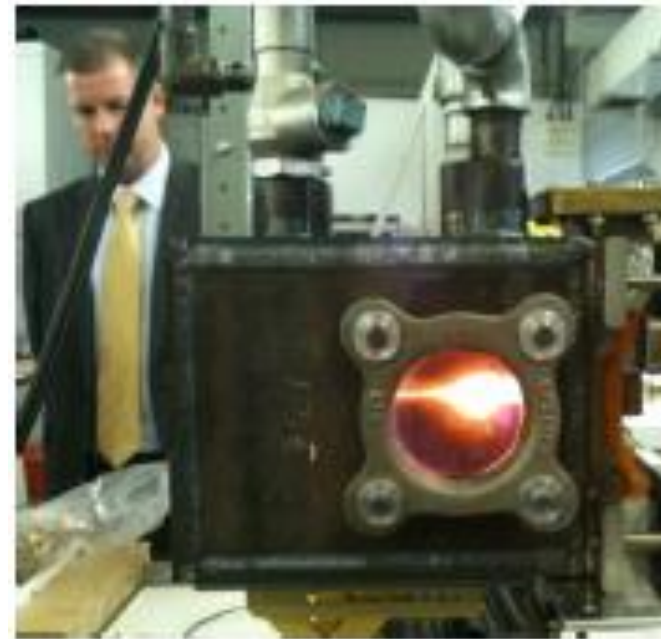
- What are the explosion risks within torrifiers or mills using torrefied biomass?
- What are the effluents from the process (liquid and gas)?
- Can the gas and vapours produced provide the heat to drive torrefaction?
- How does torrified biomass burn in the power station?
- How can torrified biomass be handled in power stations?
- The research also aims to develop a design tool





# Liverpool John Moores U.

- Microwave induced plasma gasification and pyrolysis for the treatment of mixed wastes and biomass in collaboration with Stopford Energy & Environment
- Development of 20kg/h microwave-induced plasma demonstration unit for commissioning in 2015
- Aim to deploy reactor at United Utilities, Ellesmere Port, UK for continuous operation



IChemE website, Conference presentation by Lois Ricketts & Andy Shaw at New Horizons in Gasification 10-13 March 2014, Rotterdam, The Netherlands (accessed 01/10/14) - <http://bit.ly/1nLnKaq>

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# Manchester U.

## Analytical pyrolysis

- Pyrolysis with GC or GC/MS enables analysis of more intractable, non-volatile macromolecules, e.g. lignin, cellulose, chitin, directly from natural materials.
- <http://www.seaes.manchester.ac.uk/our-research/facilities/geochemistry/equipmentandfacilities/pyrolysisgcandgc-ms/>

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# Newcastle U.

## Analytical Pyrolysis

- **Catalytic pyrolysis** of micro algae (Dr Jonathan Lee)
- **Fast pyrolysis** of small biomass samples is carried out as a precursor to thermolysis with analysis of products of pyrolysis by GCMS, NMR, FTIR etc.
- **Slow pyrolysis** facilities are available for pyrolysing batches of biomass both for bio-char and for production of more energy dense materials to facilitate its transportation to centralised facilities for subsequent thermochemical conversion.
- <http://www.ncl.ac.uk/energy/research/themes/Bio-Energy/Pyrolysisandbiochar.htm>

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# Nottingham U.

**Fast pyrolysis** in 15 kg/h circulating fluid bed. No recent information

**Slow pyrolysis of biomass**

**Hydrothermal processing**

**Pressurised pyrolysis / liquefaction** of bamboo

[http://etheses.nottingham.ac.uk/1074/1/Thermal\\_extraction\\_of\\_bamboo\\_with\\_various\\_solvents.pdf](http://etheses.nottingham.ac.uk/1074/1/Thermal_extraction_of_bamboo_with_various_solvents.pdf)

**Torrefaction**

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# Sheffield U.

## **Hydrothermal microwave pyrolysis** of algae

- Prof W Zimmerman

## **Pyrolysis** of residues from bioethanol

- SUNLIBB Project, Prof P Wright

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# Strathclyde U.

Computational modelling and optimization of a pyrolysis reactor for the production of activated carbon



# Swansea U.

## **Biochar** (Prof Alayne Street-Perrott)

- Production and testing of biochar
- Modelling impact of biochar on GHG levels
- Study physical and chemical changes as biochar is weathered in the soil.

## **Pyrolysis** (Dr J Titiloye)

- Catalysis in thermal biomass conversion
- Reactor design for catalytic pyrolysis of biomass
- Synthesis and characterisation of zeolite membranes
- Characterisation of biomass and pyrolysis products

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# White Rose University Consortium

## U. Leeds Sheffield and York

### **Hydrothermal MW pyrolysis of microalgae**

Evaluation of microwave technology as an effective means of producing biofuels or other useful oil-based products from algae, by combining Sheffield's expertise on algae, microwave technology at York and Leeds' research in biofuels.

### **Combining novel methods of biomass pyrolysis with steam-air gasification**

Exploring differences between microwave and conventional biomass pyrolysis on production of syngas and hydrogen in combination with oil reforming.





# York U.

## **Microwave pyrolysis + Supercritical CO2**

Production of waxes or residues or bio-oils high in aromatics, sugars and other high value chemicals.

<http://pubs.rsc.org/en/Content/ArticleLanding/2011/GC/c1gc15560a>

## **Torrefaction and Char**

Slow pyrolysis is approximately three times more energy efficient than microwave pyrolysis. This is more than compensated for by the higher energy content of the condensable and gaseous coproducts from microwave pyrolysis, to generate the electricity required to drive the process. <http://onlinelibrary.wiley.com/doi/10.1111/gcbb.12021/abstract>

**Hydrothermal MW pyrolysis (see White Rose Cons.)**

**Microwave pyrolysis + Supercritical**

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# COMPANIES

# Biomass Power Plants

## **Slow pyrolysis in rotary kiln**

- 3 t/h waste
- Gas is fired in CHP engine
- Under commissioning and few details public



# CARE Ltd

- Detailed chemical engineering and process design of biomass fast pyrolysis systems
- Evaluation of biomass and waste feedstock testing by pyrolysis by independent organisations,
- Techno-economic modelling and evaluation of complete thermochemical conversion systems,
- Works with Future Blends and Biomass Engineering
- <http://www.care.demon.co.uk/projectprofile07.php>
- <http://eu-project.vc/directory/consultants/conversion-and-resource-evaluation-ltd.html>



# Centre for Process Innovation & Tata Steel

## **Thermal Technologies Centre**

- The Centre offers pyrolysis options ranging from laboratory to demonstration scale (1 to 350kg).



# Clean Power Properties

- Focus on recycling and energy from waste
- Up to 13 UK sites with planning applications underway
- These use advanced thermal treatment (pyrolysis) as well as other renewables to maximise recycling and generate renewable energy
- <http://www.cleanpowerproperties.com/projects.html>



# EPI

## **Slow pyrolysis moving bed**

- 1 t/h slow pyrolysis moving bed demonstration plant in Mitcham, Surrey
- This was known to be operating in early 2014
- Very limited information about EPI activities
- Licensees operating in Turkey



# Future Blends

The aim is to develop a fast pyrolysis based technology for cost competitive production of low carbon transport fuels from waste biomass. This includes upgrading bio-oil for use in transport fuels or as a refinery feedstock for the production of transport fuels. The upgrading needs to substantially reduce the acidity, water and oxygen content of the bio-oil to improve its stability.

New facilities are installed at Milton Park near Oxford. A 0.5 kg/h system has been installed and a 5 kg/h system has been designed and built.

The consortium has been working with CARE Ltd and Catal International Ltd

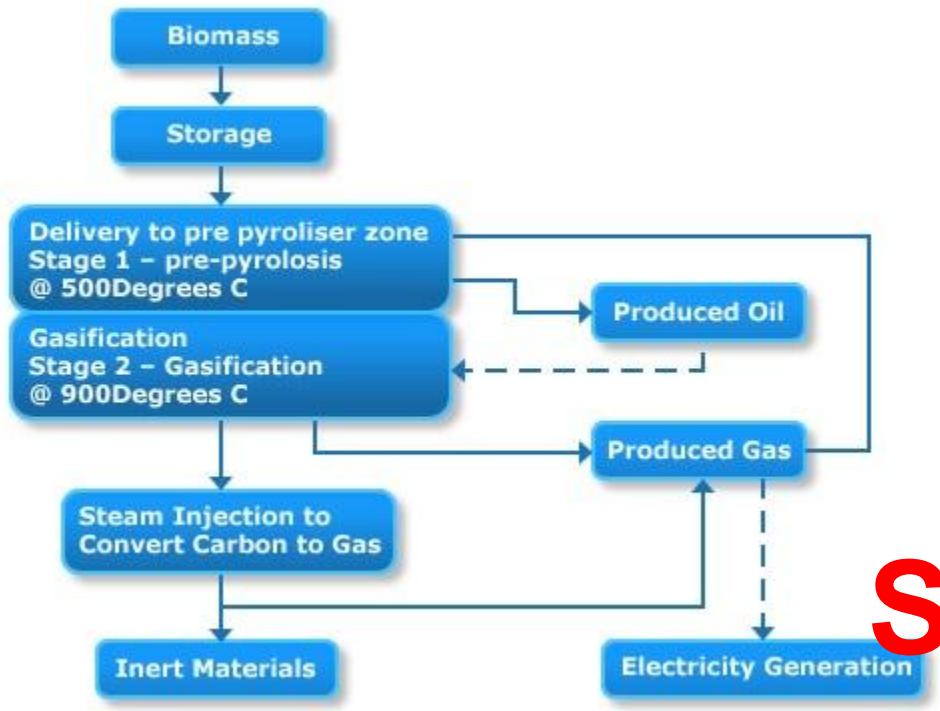
[Society of Chemical Industry website.](#)  
Presentation by C Peacocke 8 November 2012

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# Hudol

- Pyrolysis of biomass and waste for gas production
- Two stage process – low temperature pyrolysis followed by high temperature (pyrolytic) gasification
- 4 t/h
- <http://www.hudol.co.uk/>



# New Earth

- Pyrolysis of refuse derived fuel at Avonmouth UK
- 250,000 t/y waste fuel in 16 units of 1 t/h. 8 are currently operational producing 6.5MWe
- <http://www.waste-management-world.com/articles/2013/06/13-mw-rdf-pyrolysis-gasification-plant-starts-up-in-avonmouth.html>



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# New Earth

- April 2014 – preparing a planning application for second energy facility adjacent to existing operation.
- Proposed facility would process RDF using patented Advanced Thermal Conversion technology, known as ‘NEAT’, to generate up to 13MWe of electricity and heat
- <http://bit.ly/10KftJa>



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# Stein Pyrolysis

- Design and manufacture pyrolysis units, under license
- Stein Pyrolysis Units (SPU) and Vertical Stein Pyrolysis Units (VSPU)
- 0.25 – 8 tonnes per hour
- <http://youtu.be/dlctw1ewfb4>
- <http://www.steinpyrolysis.com/>



# Inactive organisations

- **EPI** – Environmental Power International.
- **GEM** in Scarborough; 1.5 t/h; Not known to be operational
- **Pure Power** in Huntingdon; understood to be in liquidation
- **2G Biopower**; Envergent representative in UK
- **First London Power**
- **Compact Power** – slow pyrolysis; has been taken over
- **Waste Gas** – slow pyrolysis; taken over some time ago
- **Plasmera**
- **Power House Energy**
- **Waste2Tricity**
- **Wellman Process Engineering** now trading as Robey-Wellman Boilers and Furnaces Limited.