IEA Bioenergy
Task 34 Pyrolysis

PyNe 31

ISSN 2040-2759

July 2012

Welcome to Task 34

By Doug Elliott, Task 34 Leader

The IEA Bioenergy Task 34 for Pyrolysis is hard at work in the new triennium, from 2010 to 2012. Current participants in the Task are Canada, Finland, Germany, Netherlands and the UK with leadership provided by the US. This newsletter is produced by the Task to stimulate the interaction of researchers with commercial entities in the field of biomass pyrolysis.

Inside this issue

Aims & Objectives

The overall objective of Task 34 is to improve the rate of implementation and success of fast pyrolysis for fuels and chemicals by contributing to the resolution of critical technical areas and disseminating relevant information particularly to industry and policy makers. The scope of the Task will be to monitor, review, and contribute to the resolution of issues that will permit more successful and more rapid implementation of pyrolysis technology, including identification of opportunities to provide a substantial contribution to bioenergy. This will be achieved by the following activities:

Priority Topics for Task 34

- Norms and standards
- Analysis – methods comparison and developments
- Country reports updates/ review of state of the art
- Fuels and chemicals from pyrolysis

In this issue of the newsletter, there are several articles from the participants describing the latest developments in fast pyrolysis including work in Finland on the developments at Fortum and Green Fuel Nordic, in the Netherlands on the developments at BTG in tests for autothermal catalytic

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Published by Aston University Bioenergy Research Group

Welcome...continued

steam reforming of bio-oil and Stork burner tests, in the UK from CARE and from the US we have a contribution from the University of Massachusetts-Amherst describing the use of their Thin-Film Pyrolysis technique. There is also an updated calendar of events of interest to the biomass pyrolysis community.

Many of you participated in the round robin on bio-oil viscosity and accelerated aging that was organized by Task 34. The report of the results of the round robin is now available as a journal article in **Energy & Fuels**, *Results of the IEA Round Robin on Viscosity and Stability of Fast Pyrolysis Bio-oils*, Douglas C. Elliott, Anja Oasmaa, Fernando Preto, Dietrich Meier, and Anthony V. Bridgwater. Volume 26, pp 3769-3776, 2012. dx.doi.org/10.1021/ef300384t

In the past you may have seen the short introductory articles from the national team leaders from each of the participating countries summarizing the particular biomass pyrolysis efforts in their countries. These have been moved to direct links on our webpage—please use the tab for Developments for Country Report Updates. Similarly, in the past we have included an overview of the latest Task meeting including information on the developments within each of the Priority Topics. These summaries will now be found on the website by using the Events tab and linking to Task 34 Meetings. We hope you find the website (www.pyne.co.uk) useful.

This newsletter is published twice a year. Comments and suggestions for future input are invited: please contact the editor, Irene Watkinson at i.i.watkinson@aston.ac.uk.

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Experience with firing pyrolysis oil on industrial scale

Overview fron Maarten Rinket (above) and Ardy Toussaint (below) from the Netherlands

In order to promote the use and acceptance of pyrolysis oil as a renewable fuel, a project was initiated in the Netherlands to demonstrate the use of pyrolysis oil as a substitute for natural gas and (heavy) fuel oil in existing industrial scale boilers. Only standard and proven (burner) equipment was used, without tailor-made modifications for pyrolysis oil firing. The overall objective was to show successful combustion of pyrolysis oil with acceptable NO_x and dust emissions and limited effect on fouling of the boiler.

Test setup

The combustion of pyrolysis oil made from pine wood was compared to a reference case of heavy fuel oil (HFO) in the 9 MW_{th} Stork test boiler using a Stork Low NO_x Double Register gas- and oil-burner. A picture of the boiler is shown in Figure 1. The (filtered) pyrolysis oil was delivered by BTG BioLiquids, who also assisted in the oil handling. The main characteristics of the oils used in the tests are given in Table 1.

Figure 1: Stork Technical Services test boiler

For atomization of the liquid fuels, an optimized Y-jet steam-assisted atomizer was used. The pyrolysis oil was preheated to a temperature of 60°C in order to lower the viscosity and thereby enhance the atomization. The heavy fuel oil was preheated for the same reason to a temperature of 100°C.

Flue gas emissions were measured with the in house flue gas analyzers of Stork Technical Services. Dust emission measurements were performed by ECN (the Energy research Centre of the Netherlands), which is well equipped to perform these demanding measurements.

Fly ash deposition and the fouling tendency of boiler tubes were also investigated by ECN. This was done during the test using a mobile

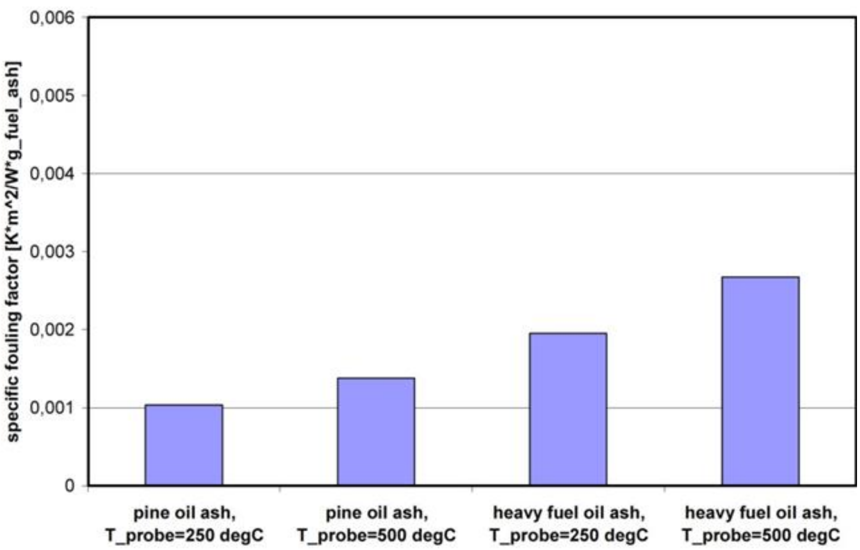

Figure 2: Specific fouling factors of oil ash deposits at different probe surface temperatures

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Experience with firing pyrolysis oil on industrial scale...continued

Table 1: Oil properties

Property	HFO	Pyrolysis Oil
Density [kg/m3]	1050	1150
LHV [MJ/kg]	40.36	15
Nitrogen content [wt.%]	0.42	0.1
Water content [wt.%]	0.7	22
Ash content [wt.%]	1.0	0.03

deposition probe and also at ECN's laboratory using their Lab-scale Combustion Simulator (LCS).

Test results
Pyrolysis oil was successfully fired at 2.6 MWth while HFO was fired at a capacity of 4.7 MWth. The reason for the lower capacity on pyrolysis oil, was the limited amount of available pyrolysis oil in combination with the minimum time required for reliable dust emission measurements.

The flame of the pyrolysis oil stabilized at a larger distance from the impeller than the HFO flame. This is most likely due to the water content of the pyrolysis oil in combination with the lower heating value. It was found that a small natural gas pilot flame of 0.6 MW is required for flame stabilization when firing pyrolysis oil. It is believed that this pilot flame can be reduced or even omitted when preheating the combustion air. Besides natural gas, a liquid fuel may also be used for the pilot flame.

The combustion of the pine oil was homogeneous and no abnormalities were visible. The combustion of the pine oil gave a significant lower NOx emission when comparing it to the HFO emission, which is due to the reduced flame temperature and low fuel nitrogen content. The flame temperature is reduced due to the high moisture content and the low LHV. The measured emission levels for the combustion of pyrolysis oil and heavy fuel oil are shown in Table 2.

Fouling propensities of the liquid fuels have been studied. Figure 2 shows the specific fouling factors of pyrolysis oil and HFO at 250 and 500°C respectively. The figure shows that the fouling tendency of the ash from pyrolysis oil is about half that of HFO.

Taking into account also that the total amount of ash in the pyrolysis oil is 30 times lower compared to HFO, it can be concluded that the combustion of pyrolysis oil will not bring significant problems with fouling of the heat exchanging area.

Based on the test results and the experience gained, Stork Technical Services is capable of designing, producing and installing burners suitable for the combustion of pyrolysis oil on a commercial basis in the typical range of 5 - 100 MWth. Also, existing boiler systems can be retrofitted to make them suitable for pyrolysis oil (co-)firing.

AgentschapNL is gratefully acknowledged for providing part of the funding for this campaign through the EOS KTO framework.

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Table 2: Measured emissions

Oil	Heat total [MW]	Heat oil [%]	Oil flow [kg/h]	O_2 [vol% dry]	CO [ppmvd]	NO_x [mg/m$_0^3$ @ 3%O_2]	Dust [mg/m$_0^3$ @3%O_2]
HFO	4.7	100	411	4.0	<5	550	30
Pine oil	2.6	76	606	3.0	<50	133	13—20

Green Fuel Nordic

Jerkko Starck summarises recent activities at Green Fuel Nordic Oy in Finland

Green Fuel Nordic Oy (GFN) is a Finnish biorefinery company which was established in 2011. Its headquarters is based in Kuopio, in Eastern Finland. GFN's business idea is to refine second generation liquid fuel derived from forest-based raw materials by using commercially proven technology. The company plans initially to build three 400 BDMTPD (Bone Dry Metric Ton Per Day) biorefineries, with a combined annual production capacity of 270 000 tonnes of bio-oil. The amount of forest-based raw material needed for three facilities is one million solid cubic meters per year.

Green Fuel Nordic Oy has announced an investment roadmap for production of second generation bio-oil from sustainable, forest-based feedstocks using fast pyrolysis technology. GFN has signed a memorandum of understanding with Envergent Technologies LCC, a Honeywell company, under which the two companies would collaborate on projects to convert biomass to renewable fuel.

The conversion of pre-treated biomass into liquid biofuel is done by using Envergent's RTPTM (Rapid Thermal Processing) technology. The sizing and drying of feedstock material into desired particle size and moisture content required by the fast pyrolysis system is done in the biomass handling system. Ultimately the produced bio-oil is handled and stored in the bio-oil storage system.

The main applications for liquid biofuel are industrial boilers, district heating and

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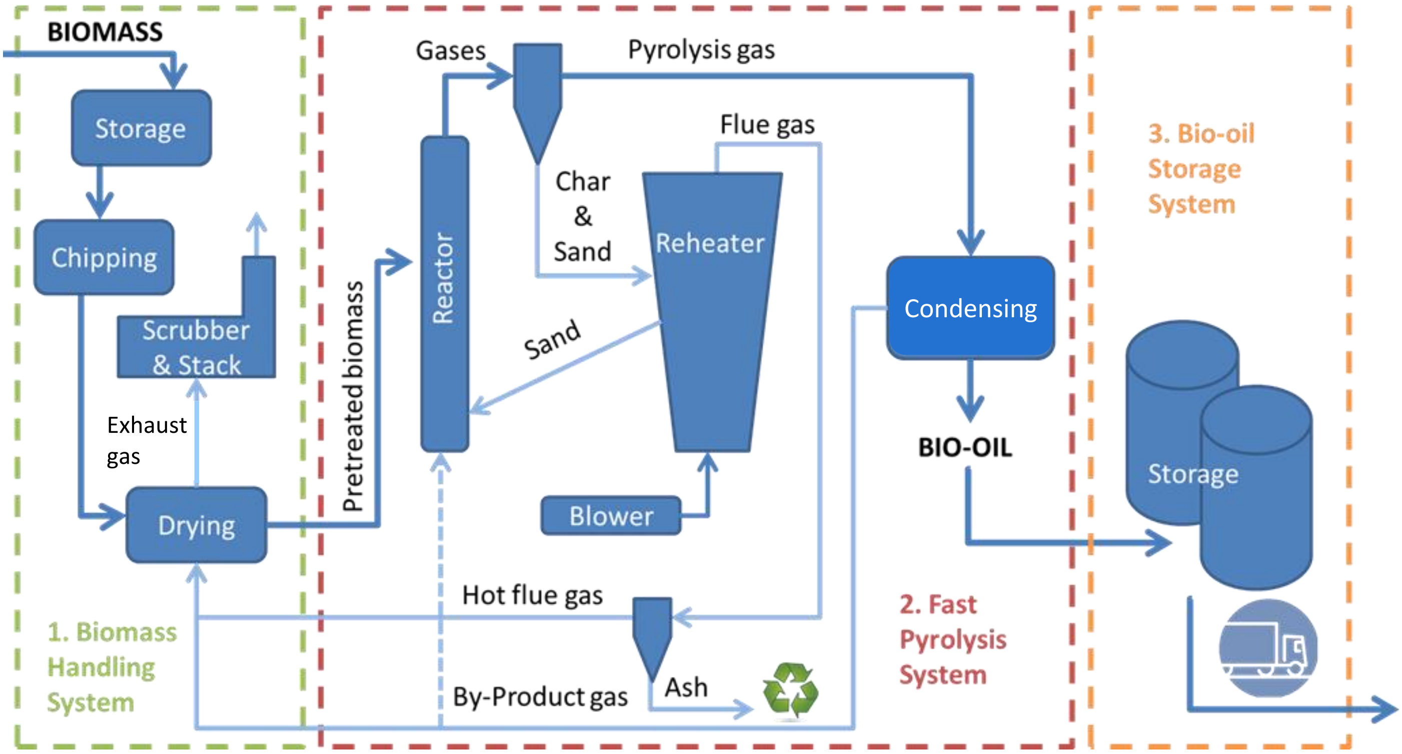

Figure 1: Green Fuel Nordic's Biorefinery concept (© Green Fuel Nordic)

Green Fuel Nordic...continued

lime kilns that can utilize bio-oil with only minor modifications to the existing systems.

Other feasible applications are marine applications, particularly slow- and medium-speed diesel engines. Future applications can be found in upgrading bio-oil into transportation fuel and extraction of chemicals for the use in chemical industry, pharmaceuticals, cosmetics, and many more.

Green Fuel Nordic Oy expects to build multiple biorefineries in Eastern Finland and is currently looking for other potential locations. According to Timo Saarelainen, the CEO of Green Fuel Nordic, the future target is to build up to 20 biorefineries in Finland. The first biorefinery is planned to start commercial operation in the first quarter of 2014.

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Pyrolysis research opportunities

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- Researchers can apply to go to any of the project partners located outside their home country to utilize the thermal biomass conversion facilities

- The project will pay for facility access costs along with a grant for travel and subsistence for those researchers based in an eligible country

Applications for access

If you are interested in applying for access, or require further information please visit the BRISK website

www.briskeu.com

Thin-Film Pyrolysis technique reveals high temperature cellulose chemistry

Paul Dauenhauer of University of Massachusetts Amherst, USA describes the primary and secondary reaction pathways of cellulose pyrolysis

The pyrolysis of cellulose generates a small amount of solid char residue as well as gases and condensable vapors which can be collected and upgraded to biofuels and chemicals. The condensed vapors, referred to as 'bio-oil,' are comprised of a large number of highly oxygenated chemical species which are difficult to catalytically upgrade. Despite the importance of bio-oil to produce renewable fuels, the reactions that generate bio-oil from biomass are unknown.

We reveal in a series of three publications the potential of a new experimental technique called 'Thin-Film Pyrolysis (TFP)' to study pyrolysis chemistry. TFP utilizes micro-scale films of cellulose (2-4 μm thick) within a high temperature reactor to achieve pyrolysis without any heat or mass transfer limitations [1,2]. For cellulose samples smaller than 10 μm, the cellulose achieves temperature changes exceeding one million K/min, and this extreme temperature ramp enables samples to be heated to reaction temperature before the onset of pyrolysis chemistry. Additionally, we have shown that primary volatile chemicals are able to diffuse out of the reacting polymer melt before they re-react [3].

Using the TFP technique, we discovered that α-cyclodextrin (αCD) and cellulose exhibit identical chemistry. Our finding indicates that cyclodextrins can serve as surrogates for cellulose, and they have the benefit of being sufficiently small to be used in simulations (e.g. molecular dynamics) to determine the reacting pathways of cellulose. As shown in Figure 1, one monomer of αCD in a Car-Parrinello molecular dynamics simulation reveals a reacting pathway to produce furans by pyran ring opening and subsequent closing for forming a furan.

α-Cyclodextrin serves as an effective surrogate for cellulose due to its lack of polymer end groups. We have recently shown using TFP that the ratio of polymer end group to interior monomers is a key descriptor for predicting pyrolysis products [4]. This chain length effect is

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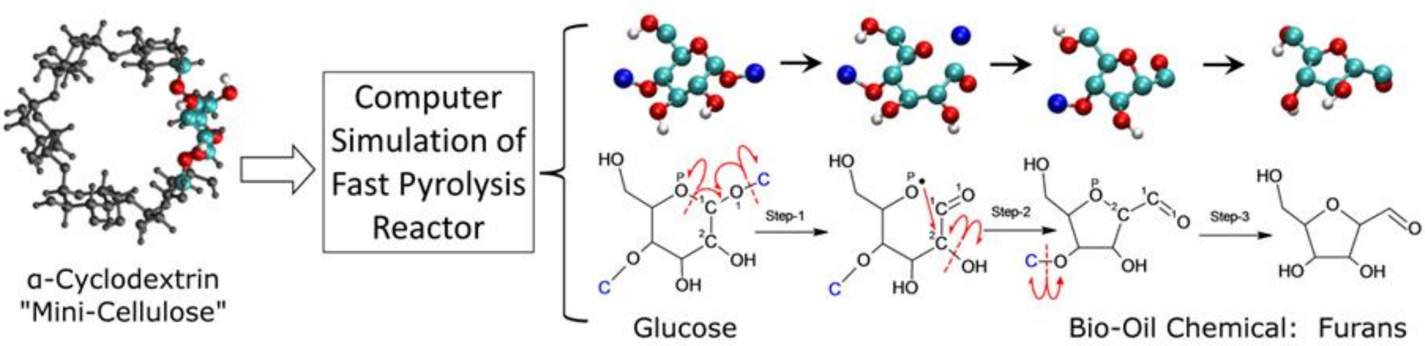

Figure 1: Discovery of cellulose surrogate, α-Cyclodextrin, by Thin-Film Pyrolysis and mechanism of furan formation from cellulose

Thin-Film Pyrolysis technique reveals high temperature cellulose chemistry ...continued

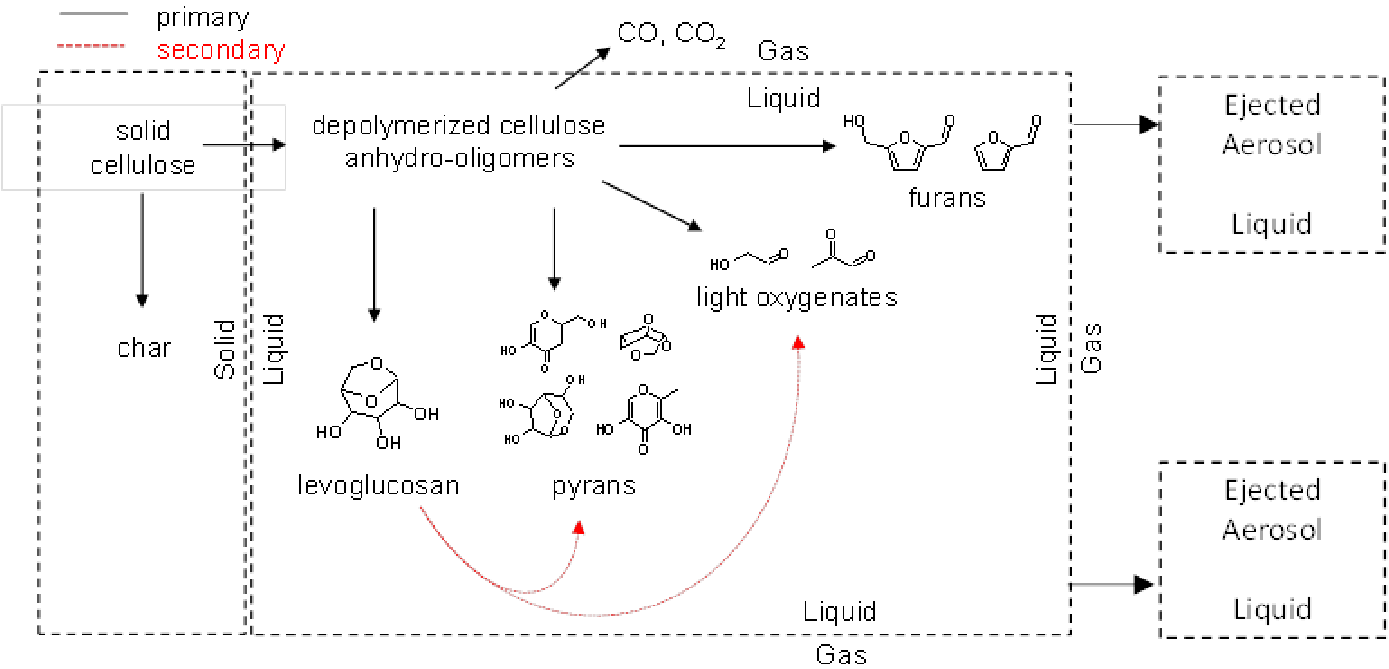

Figure 2: Thin-Film Pyrolysis reveals the primary and secondary reaction pathways of cellulose pyrolysis

extremely pronounced in the smaller cellodextrins (glucose to cellohexaose), where the yield of anhydrosugars and furans can vary by as much as 71% and 22%, respectively. Neither cellulose nor cyclodextrin have a significant fraction of polymer end groups, resulting in similar pyrolysis chemistry and nearly identical volatile product distributions.

Once volatile products are produced within the polymer melt, they must escape to the gas phase or be ejected as aerosols by 'reactive boiling ejection' as shown in Figure 2. In competition with transport to the molten cellulose/gas interface, the volatile products including levoglucosan and other oxygenates can undergo secondary condensed-phase reactions. By comparing TFP with thicker cellulose samples, we have developed a co-pyrolysis technique that reveals the secondary condensed phase reactions of levoglucosan[3].

^{13}C-Labeling reveals that levoglucosan breaks down to form pyrans, other anhydrosugars, and light oxygenates within molten cellulose. Decomposition of levoglucosan to furans was not observed. Further experiments using a deuterated fructose co-reactant reveals that the degree of dehydration within molten cellulose to produce pyrans (DHMP and ADGH) correlates strongly with the degree of hydrogen/deuterium exchange. The dependence of elimination reactions on extramolecular hydrogen exchange is the first evidence for the existence of Brønsted acids within molten cellulose. The combination of all of these results contributes to the development of a complete description of cellulose pyrolysis pathways summarized in Figure 2. This work represents a step forward in molecular-level modeling of biomass pyrolysis which ultimately enables process optimization and improves the overall economics of pyrolytic biofuels.

Support

This work was supported as part of the Catalysis Center for Energy Innovation, an Energy Frontier Research Center funded by the U.S. Department of Energy, Office of Science, and Office of Basic Energy Sciences under Award

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Thin-Film Pyrolysis technique reveals high temperature cellulose chemistry ...continued

Number DE-SC0001004. Additional support was provided by the U.S. Department of Energy Early Career Program, Basic Energy Sciences – Catalysis Award Number DE-SC0006640.

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UMASS AMHERST

Thermochemical pioneer, Tony Bridgwater, wins Clean Energy Award

Tony Bridgwater, Professor of Chemical Engineering at Aston University has been awarded the UK Environmental Capital Peterborough Clean Energy Award. Presented to Professor Bridgwater on 28th May 2012 at Peterborough Town Hall, this award recognises outstanding contributions to the development, implementation and promotion of clean energy technologies.

Peterborough has a long-standing commitment to environmental leadership as the UK Environment Capital. The winner was chosen in collaboration with Peterborough City Council and Cranfield University, and the award was presented to Professor Bridgwater by the Lord Mayor of Peterborough, Cllr. George Simons.

Pioneer

Tony Bridgwater, is one of the most distinguished researchers in bioenergy in the UK today, and has been pioneering the development of thermal biomass conversion and second generation biofuel technologies for over 30 years. His name has been closely attached to "Fast Pyrolysis", a technology to transform biomass to liquid through thermochemical conversion. The last decade has witnessed a phenomenal growth for fast pyrolysis research and is now one of the most topical research areas in the bioenergy field. He almost single-handedly drove fast pyrolysis research in the UK for the last 30 years, and integrated research efforts across Europe during this time. His papers have been cited tens of thousands time and his name is well known in the global bioenergy community.

To date, many of the researchers around the world have been trained or connected to his Bioenergy Research Group. He was Technical Director of the UK Flagship SUPERGEN Bioenergy programmes for over eight years. He has been responsible for winning over £25 million in research grants, which established the foundation for the European Bioenergy Research Institute (EBRI) at Aston University.

www.aston-berg.co.uk

Industrial-scale integrated bio-oil plant in Joensuu, Finland

A synopsis from Anja Oasmaa of VTT (Technical Research Centre of Finland)

Fortum has announced that it will invest in the commercialisation of integrated fast pyrolysis technology by building a bio-oil plant connected to the Joensuu combined heat and power production plant (CHP) in Finland. The integrated bio-oil plant will be unique on an industrial scale. The integrated CHP plant in Joensuu will produce heat, electricity and 50,000 tonnes of bio-oil per year. The bio-oil raw materials will include forest residues and other wood based biomass.

Construction of the bio-oil plant will commence during 2012, and the plant is expected to be in production in the autumn of 2013. Bio-oil production will increase the energy wood consumption at Joensuu power plant almost doubling the use from the existing 300,000 m3 per year.

VTT and its partners have identified considerable potential for the deployment of fast pyrolysis in industries with established infrastructures, such as the pulp and paper and mechanical wood processing industries in Europe [1] and North America [2]. Integration of fast pyrolysis and forest industry boilers is technically viable, and the opportunity is considered industrially relevant.

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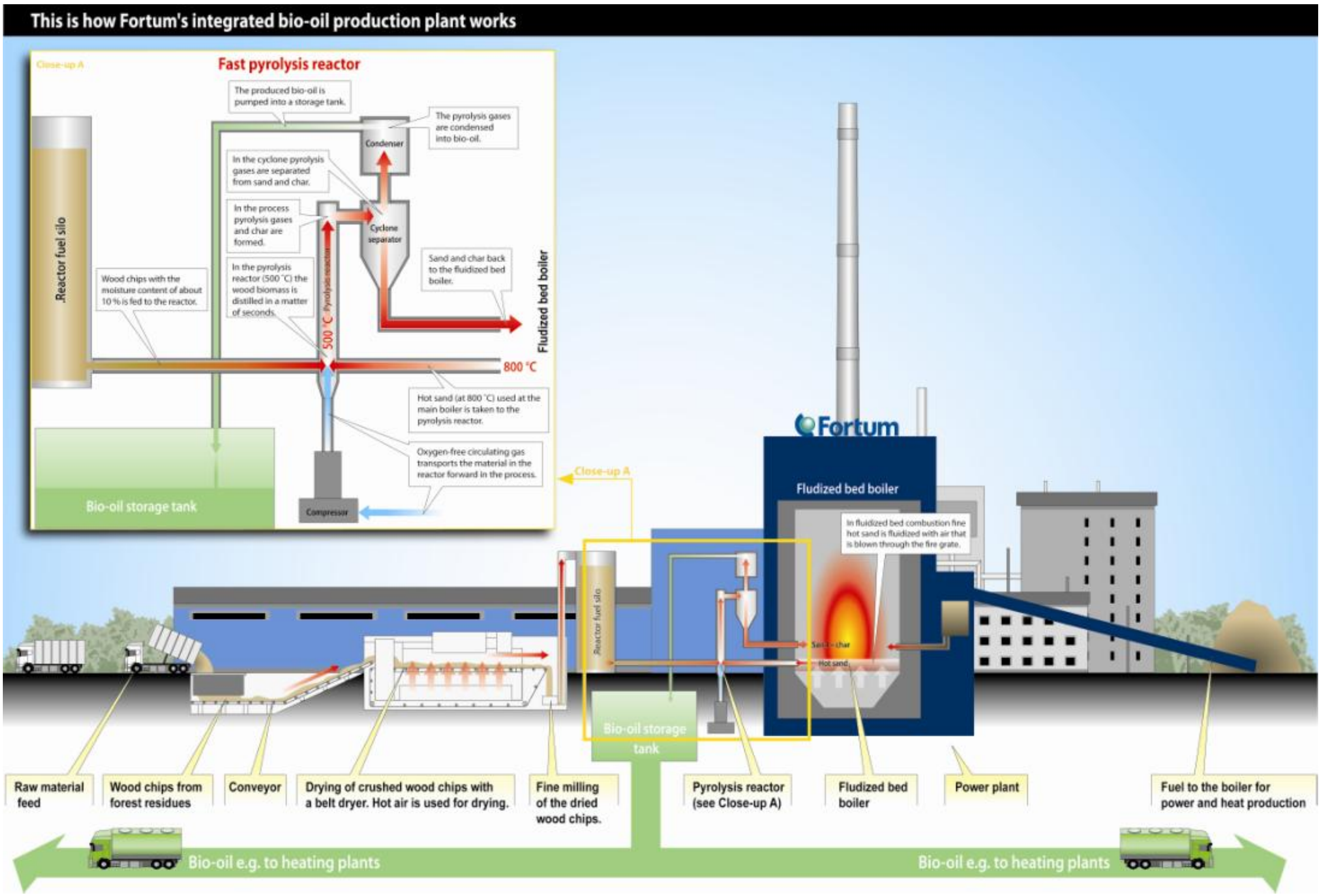

Figure 1: Industrial-scale integrated bio-oil plant in Joensuu, Finland

Industrial-scale integrated bio-oil plant in Joensuu, Finland...continued

The first uses for the bio-oil are in replacing fuel oils in industrial ovens and boilers. However, a longer term goal would be to produce co-feedstock for mineral oil refineries for the production of transportation fuels and petrochemical feedstocks. This approach has been developed, for example, within the EU's recently completed BIOCOUP project [3].

The new integrated concept technology has been developed into a commercial scale concept in cooperation between Fortum, Metso, UPM and VTT as part of TEKES Biorefine research programme. Metso, Fortum, UPM, and VTT have developed the world's first integrated bio-oil production concept, where heat for pyrolysis is transferred from hot sand of a fluidized-bed boiler.

In 2009, the consortium constructed a 7 tpd bio-oil production pilot unit which uses a pyrolysis reactor integrated with a pilot fluidized-bed boiler. The integrated pyrolysis concept enables both high overall efficiency and high bio-oil yield. By-products char and non-condensable gases are utilized in an adjacent boiler to produce heat and electricity.

The integrated concept is easy and smooth to operate, and has good control characteristics. Since 2009 more than 100 tonnes of bio-oil have been produced from sawdust and forest residues at high availability. Around 40 tonnes of bio-oil have been combusted in Fortum's 1.5 MW district heating plant in Masala, Finland, with high efficiency. Flue gas emissions were close to those of heavy fuel oil – at 4% O_2, CO emissions ranged from 0 to 10 ppm, and NOx from 300 to 400 ppm. Organic compounds were under 5 mg/m3n and particulate emissions in the range 150–200 mg/m3n.

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Other articles from Finland

Jerkko Starck summarises recent activities at Green Fuel Nordic Oy in Finland

See Pages 5-6

Anja Oasmaa of VTT: "Guidelines for transportation, handling, and use of fast pyrolysis bio-oil"

See pages 20-22

Conversion And Resource Evaluation Ltd: Experience in fast pyrolysis

Cordner Peacocke of C.A.R.E. Ltd. in the UK provides an insight into their fast pyrolysis activities

Introduction
Conversion And Resource Evaluation Ltd. [C.A.R.E. Ltd.] was formed in 1996 to provide specialist technical services in the bioenergy and waste to energy sectors. Our key expertise is technical and engineering services in thermal conversion systems. We are one of the few companies in the UK with direct technology experience, predominantly in gasification, pyrolysis and some in co-firing for heat, power, renewable chemicals and renewable products.

C.A.R.E. Ltd. can offer a wide range of services in the bioenergy area. The following are examples of what we can offer:

- Detailed chemical engineering and process design of biomass gasification and fast pyrolysis systems from feedstock handling to end use for power, heat and products.
- Organisation and evaluation of biomass and waste feedstock testing by pyrolysis, gasification and combustion.
- Technology surveys, reviews and feasibility studies on thermal conversion processes and products.
- Due diligence of technologies and advice on best available technology to suit the application.
- Techno-economic modelling and evaluation of complete thermochemical conversion systems.
- Market evaluation of the opportunities for renewable products and technologies.
- Assistance with plant trouble-shooting, independent monitoring and evaluation.
- Advice on environmental legislation, process authorisation and compliance with emissions.

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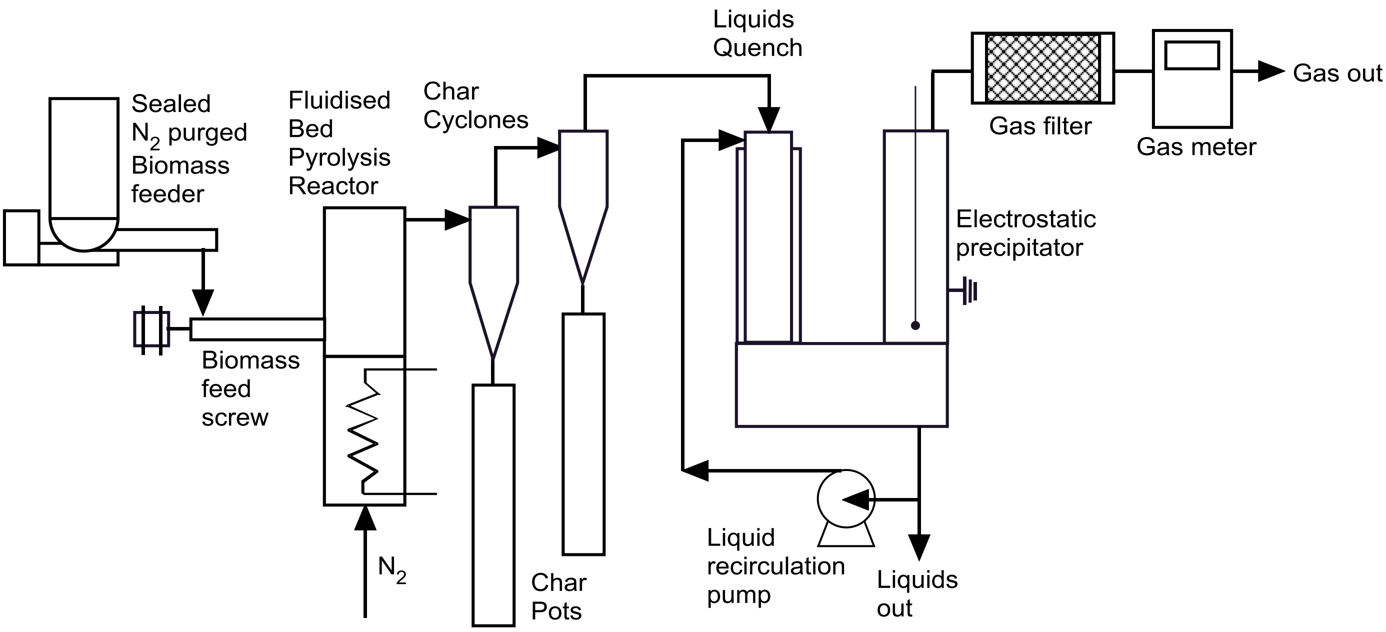

Figure 1: Basic flowsheet for a generic laboratory fluid bed fast pyrolysis plant for liquids

Conversion And Resource Evaluation Ltd: Experience in fast pyrolysis...continued

These services have been provided to:

- International water and gas utilities;
- International energy agencies;
- Private limited companies;
- Engineering companies;
- International utility companies;
- International consultancies;
- Other firms and universities in the UK, the rest of the European Union, Australia, USA, Turkey, Canada, Namibia, South Africa, India and New Zealand

Figure 2: Refurbished 5-7 kg/h fluid bed fast pyrolysis plant at Aston University, UK

Projects in fast pyrolysis
Some examples of completed projects in fast pyrolysis include:

- Techno-economics of production costs of biomass derived fast pyrolysis liquids and subsequent power production using a dual fuel diesel engine [EC contract JOR3-CT97-0197].
- Techno-economics of production of slow release organic fertilisers from biomass pyrolysis products [EC funded contract FAIR6-CT98-4042].
- Techno-economics of production of renewable resin from biomass derived pyrolysis liquids [EC funded project QLK5-CT2002-RENURESIN].
- Provision of flowsheets for a 2 t/h fast pyrolysis plant utilising feedstocks in India.
- Cost benefit analysis of the use of encroachment bush in thermal conversion systems in Namibia – evaluation of options for heat, power and products including fast pyrolysis for liquids for power generation.
- Feedstock evaluation by high temperature pyrolysis (analysis, characterisation, testing, mass and energy balances).
- Design, construction and operation of a 300 kg/h fluid bed biomass fast pyrolysis plant for power production in the UK (project on hold).
- Costs of production of heat, power and biochar by fast and slow pyrolysis in the UK at 5-10 t/h: technology selection, mass and energy balances and overall efficiencies using various configurations (variation in char, liquids and syngas outputs; varying modes of power generation).

Recent and ongoing contracts in fast pyrolysis include:

- Production of liquid transportation fuels from biomass and waste derived fast pyrolysis liquids by subsequent upgrading (Carbon Trust funded project – "The Pyrolysis Challenge"). Sample activities in this project include:
    - The design and build of two fluid bed fast pyrolysis reactors.
    - Extensive process and techno-economic modelling up to 100 kt/y of biomass fast pyrolysis plants and subsequent product upgrading and use.
    - Reviews of catalytic processes for biomass pyrolysis liquids and

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Conversion And Resource Evaluation Ltd: Experience in fast pyrolysis...continued

vapours upgrading.

- Ongoing rig development and new processing pathways.

- Design, specification and re-commissioning of laboratory 5-7 kg/h fluid fast pyrolysis rig. This included re-design and replacement of several unit operations and upgrading of the controls to a full PLC based system.
- High temperature pyrolysis of a range of high ash biomasses for clean syngas production.
- Chemical and process design of an integrated liquids collection system for a 6 t/d fluid bed fast pyrolysis plant.

C.A.R.E. Ltd. therefore has a deep experience of fast pyrolysis, with significant design and practical experience at a range of scales on a range of diverse feedstocks from straws, grasses and clean wood to MSW derived materials, high ash lignocellulosics and highly degraded marine biomass. That experience allows us to effectively carry out work quickly for clients, both at R&D, demonstration and commercial levels.

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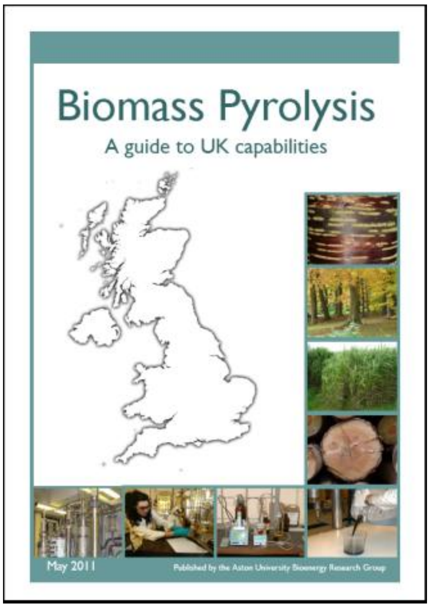
CARE Conversion And Resource Evaluation Ltd.

UK guide on biomass pyrolysis



C.A.R.E Ltd. (see previous article) is also featured in *'Biomass Pyrolysis - A guide to UK capabilities',* which was produced by Aston University last year. It summarises the range of biomass pyrolysis research and commercial activities being undertaken in the UK.

The guide has been devised to act as an aid to all involved in the expanding area of biomass pyrolysis including researchers, companies, policy makers, decision makers and stakeholders.

It also contains a foreword from Professor David MacKay, Chief Scientific Advisor at the UK Department of Energy and Climate Change (DECC), plus contributions from a variety of organisations.

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Visit the 'Publications/Guides' section on the PyNe website to download the guide.

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Aston University Birmingham

Autothermal catalytic steam reforming of pyrolysis oil

An update from Evert Leijenhorst of BTG in the Netherlands

Over the last two decades, BTG Biomass Technology Group B.V. has been actively developing the pyrolysis oil production process, based on the rotating cone reactor technology. Simultaneously, pyrolysis oil application research has been one of the core activities of the company. One of the envisioned applications of pyrolysis oil is as feedstock for the production of renewable syngas, either in an autothermal catalytic reactor system (ACR) or by entrained flow (EF).

In co-operation with the University of Ghent (Prof Prins), Evert Leijenhorst, a full-time BTG employee, has started a PhD project in which the production of syngas form pyrolysis oil is one of the research topics.
The catalytic reforming of pyrolysis oil enables the production of a clean syngas at a relative low temperature of around 850°C. Application of dedicated catalyst seems feasible because pyrolysis oil is a relatively clean product by which rapid catalyst poisoning is avoided. Most of the typical biomass contaminants are already removed in the fast pyrolysis process.

Theoretically, due to the relatively low operating temperature, higher product yields can be obtained than, for instance, in high temperature EF gasification. Furthermore, the catalyst enables the direct production of gas with a tar content that is 1000 times lower than in the case of non-catalytic gasification at comparable temperatures.

To study the ACR of pyrolysis oil experimentally, a setup has been erected for the conversion of up to 1.5 kg/hr of pyrolysis oil to a clean product gas (Figure 1).

Pyrolysis oil is atomized using a commercial spray nozzle. To prevent polymerization and (partial) blockage of the feed, the tip of the atomizer is cooled. The oil is mixed with air and steam, and due to partial oxidation reactions the required temperature in the catalytic reforming zone will be achieved. As a consequence of atomizing and heating the pyrolysis oil, a small amount of char is (unavoidably)

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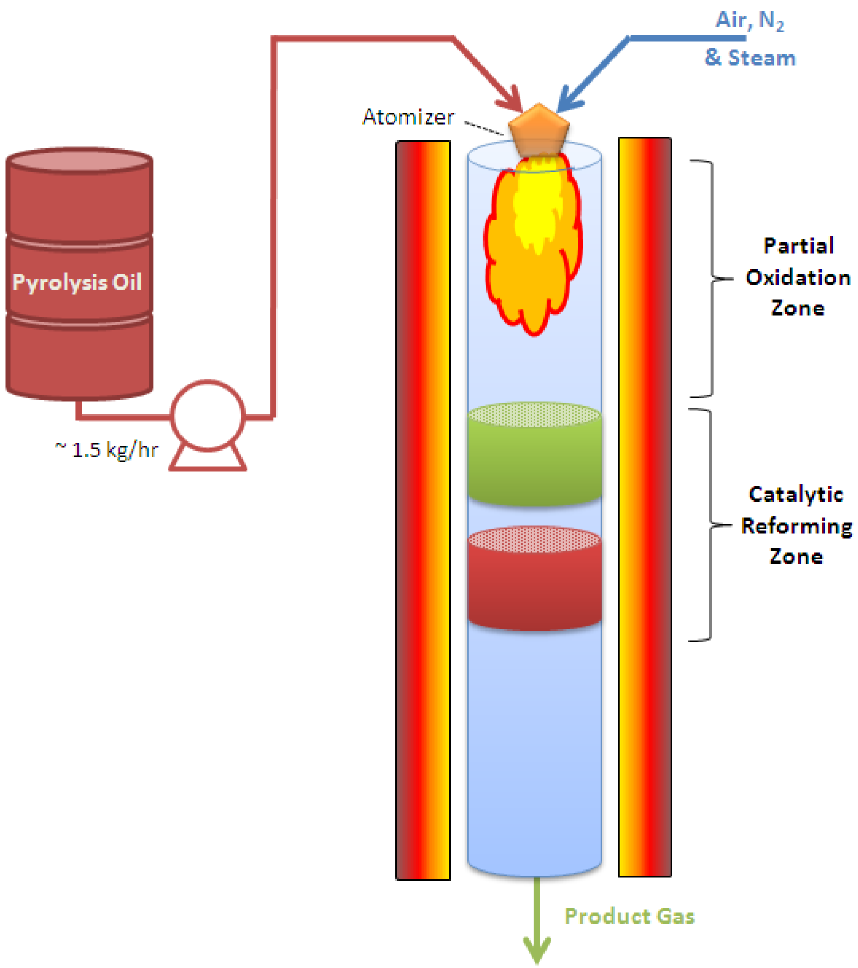

Figure 1: Gasifier schematically represented

Autothermal catalytic steam reforming of pyrolysis oil...continued

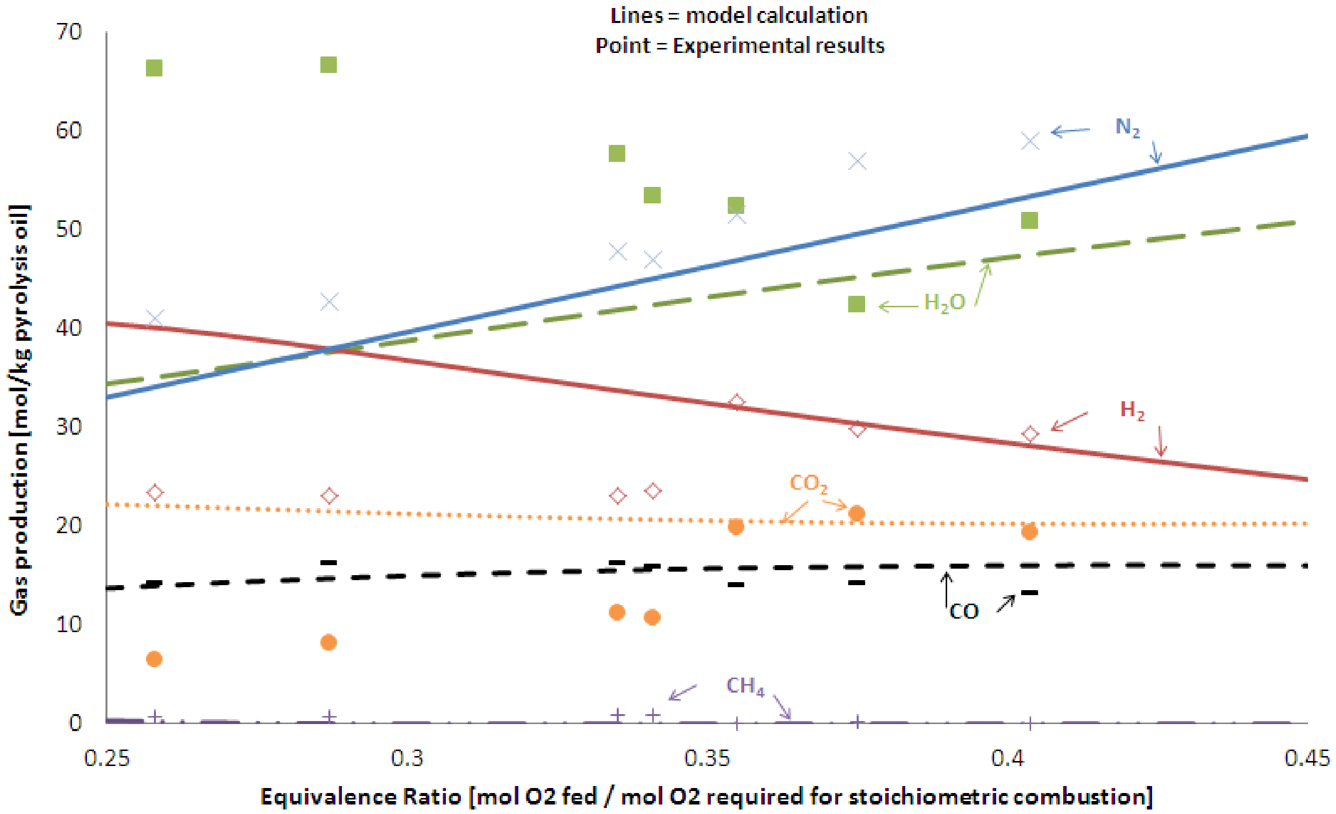

Figure 2: Gas production, equilibrium and experimental results (pine-wood derived Pyrolysis oil, Nickel + Platinum/Rhodium catalyst, GHSV ~ 2500 hr-1, S/C ~ 1.6 mol/mol.)

formed. To prevent blockages in the system, monolithic catalysts are used in the process instead of a fixed bed of catalyst. These monolithic catalysts have the additional benefit of a better heat conductivity, preventing a large, axial temperature gradient over the catalyst bed. Experiments have been carried out while using commercial nickel based catalysts, as well as platinum/rhodium combination catalysts supplied by Johnson Matthey. The combination of both types provided the best results in a preliminary test campaign.

The autothermal behaviour of the process is considered a critical prerequisite in the process development. Because the pyrolysis oil and oxidant feed ratio (Equivalance Ratio, ER and Steam over Carbon ratio, S/C) determines the process temperature, the temperature could not be varied independently. Instead, the process pre-heating temperature is rather a result of the adjusted test parameters. The gasifier was pre-heated using electrical ovens, after which the ovens were used only to compensate for the heat loss from the gasifier during the actual gasification. This power consumption by the ovens was monitored continuously during the actual gasification tests.

To determine whether thermodynamic equilibrium is approached, a simple Microsoft Excel based model was created by which the equilibrium temperature and gas composition can be calculated. It is based on the Water Gas Shift and Methane Steam Reforming equilibrium reactions, and assumes a 100% Carbon to Gas ratio. With this model the process conditions required for autothermal operation can be easily visualized.

It can also be shown for example that S/C values above 1 (excluding water in pyrolysis oil) generate no additional syngas, since each additional mole of H2O consumes a mole of CO in the production of H2. Also, the effect of operating at lower temperature enabled by the use of a catalyst can be quantified. The maximum syngas yield can be increased by 15-30% over a S/C range from 0 to 2 when the process is carried out at 825°C instead of 1250°C.

Continued on page 17

Autothermal catalytic steam reforming of pyrolysis oil...continued

At ER > 0.35 and GHSV ~ 2500 hr-1, the product gas composition was found to be close to equilibrium, see Figure 2. Decreasing ER and/or increasing GHSV resulted in a product gas diverting further from equilibrium. At ER < 0.35, the composition rapidly deviates from the expected composition. This can be ascribed partly to the decreasing Carbon to Gas ratio.

At lower ER values the carbon formation increases. Because the equilibrium model is based exclusively on gas phase reactions and does not take into account any carbon formation, the amounts of CO, CO2 and CH4 produced experimentally cannot be predicted anymore by the equilibrium model. However, even after correcting the theoretical composition with the decreasing Carbon to Gas ratio, a deviation from equilibrium is still observed. Experiments with a GHSV ~ 5000 hr-1 showed incomplete methane conversion and some increase in H2O and CO production and a decrease in H2 and CO2 (not shown in Figure 2).

Figure 3: Photograph of the experimental setup

Future research plans concerning the catalytic reforming include the gasification with pure O2 instead of air, and the application of high pressures, to focus on the development of an industrially applicable process. With respect to EF gasification, BTG is actively participating in the EU funded project SupraBio (www.suprabio.eu), in which several biorefinery options are explored. An important part of the project involves the EF gasification of pyrolysis oil for the production of renewable syngas, with subsequent synthesis of DME and/or FT diesel from pyrolysis oil. Gasification tests on pilot plant scale (up to 100 kg/hr) will be performed later this year at ETC in Sweden. BTG is responsible for the construction of a dedicated pump skid, able to feed the pyrolysis oil in the pressurized gasifier, and including all necessary safety and control features. For these tests several tons of pyrolysis oil will be produced by BTG.

The current work was financed by the Dutch Government in project EOSLT09002, and will be published shortly.

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Biofuels program at Battelle Columbus

Zia Abdullah gives an update on biofuel activities at Battelle Memorial Institute in the USA

"The pyrolysis-hydrotreatment pathway is particularly suitable for broadly deployed small scale systems."

The Battelle Memorial Institute in Columbus, Ohio is executing an internally funded program to develop small scale (100 ton/day) systems for conversion of biomass to hydrocarbons using the pyrolysis–hydrotreatment pathway. Small scale systems have the potential for rapid and broad commercial deployment because of lower project capital cost, lower capital risk, and larger customer base relative to larger systems.

Figure 1: Pyrolysis and vapor phase reactor system at Battelle

Since the cost of feedstock dominates operational economics, small systems also have the potential advantage of lower marginal feedstock costs. The pyrolysis–hydrotreatment pathway is particularly suitable for broadly deployed small scale systems because of its feedstock flexibility and its ability to produce hydrocarbon products that can be blended with conventional finished fuels.

Economy of scale works against a small system. Simply reducing the size of a large system's technology approach generally increases capital cost on a per unit basis, making the technology commercially uncompetitive. Battelle's approach is to use auger based technology, exploiting the opportunity to have lower equipment and operating costs relative to other approaches.

Small scale, auger based systems require less site preparation, thus total project capital costs can be reduced. Standardized design and large scale manufacturing of the systems can further reduce engineering costs and support our distributed biofuel production model.

Our strategy is to deploy small systems that are not only cost -competitive on a capital basis, but avoid a significant disadvantage of larger, conventional biorefineries, namely susceptibility to biomass market forces. A large system must procure significant quantities of biomass.

Transportation costs may limit the economically available supply to the point that the surrounding region's biomass producers can dictate supply costs, eroding or even eliminating profitability. A small system does not

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Biofuels program at Battelle Columbus ...continued

Table 1: Bio-oil properties without and with vapour phase catalyst

	C (wt%)	H (wt%)	N (wt%)	O (wt%)	TAN
No Catalyst	51.6	7.1	0.1	41.2	110
With V.P. catalyst	58.6	7.1	0	34.3	75

appreciably change demand and, hence, the marginal feedstock price does not increase. Further, a small modular system can be redeployed to more favourable locales should market power shift.

Hydrotreatment of fast pyrolysis bio-oil faces the challenge of short catalyst lifespan because of coke formation and support deterioration. Battelle's view is that in addition to developing improved hydrotreatment catalysts, it is also necessary to modify the properties of the bio-oil feedstock entering the hydrotreatment system. This multi-pronged approach is more likely to yield a commercially viable solution more rapidly.

Battelle has developed a heterogeneous catalytic vapor phase reactor to process the pyrolysis vapor prior to condensation. The bio-oil condensed downstream of this treatment has lower acidity and functionality. Hydrotreatment of this intermediate bio-oil both at Battelle and Pacific Northwest National Laboratory (PNNL) has shown significantly improved catalyst performance.

Battelle has established strong institutional alliances with technology and business leaders across the value chain to accelerate deployment of our technology. PNNL has been an integral partner for fundamental catalyst discovery and development, both for pyrolysis as well as for hydrotreatment.

Figure 2: Bio-oil hydrotreatment system at Battelle

ABRI-Tech is a collaborator on auger-based pyrolysis reactor technology. Domtar is providing input on feedstock, and Marathon Petroleum Company is partnering on product assessment and development.

The Center for Research and Innovation in the Bio Economy (CRIBE) has recently approved partial funding for implementation of the pyrolysis and vapor phase technology at Domtar's mill in Dryden, Ontario. Domtar intends to use mill rejects for feedstock and produce bio-oil for use directly in the mill or for blending with other fuel.

In the first phase of this project, Battelle is building a trailer mounted one ton/day pilot system to process biomass from the mill and produce bio-oil for testing and evaluation.

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Guidelines for transportation, handling, and use of fast pyrolysis bio-oil

A synopsis from Anja Oasmaa of VTT (Technical Research Centre of Finland)

"The EU funded BIOTOX project has provided data on the toxicity of biomass derived pyrolysis oils."

The final purpose of this study is to suggest preliminary guidelines for transportation, handling and use of fast pyrolysis bio-oils. The first part [1] of the two papers is focused on flammability, and toxicity. Preliminary guidelines for transportation are suggested. Part 2 will present more new data on material testing and suggestions for an improved MSDS, after which guidelines for transportation, handling, and use of fast pyrolysis bio-oil may be drawn.

Even though valid for several biomass derived liquids and other fuels, the method for flash point is not suitable for fast pyrolysis oils because they contain a high amount of water evaporating significantly below 100°C and extinguishing the possible flame caused by volatiles with low flash point. Therefore, another test method to measure flammability appropriately for fast pyrolysis oils is needed.

In some cases, the producer may be able to justify a case where the liquids are not subject to dangerous goods requirements for shipment, i.e. *"Liquids meeting the definition in 2.3.1.2 with a flash point of more than 35°C which do not sustain combustion need not be considered as flammable liquids for the purposes of these regulations. Liquids are considered to be unable to sustain combustion for the purposes of these regulations (i.e. they do not sustain combustion under defined test conditions) if: (a) They have passed a sustained combustibility test (see 'Sustained Combustibility Test' prescribed in the Manual of Tests and Criteria, Part III, sub-section 32.5.2."* Various pyrolysis oils were tested by the method and it was proven that pyrolysis oils are incapable of sustained combustion and can be classified as non-flammable liquids.

The EU funded BIOTOX project [2] has provided data on the toxicity of biomass derived pyrolysis oils. The data combined both fast and slow pyrolysis oils. In IEA Bioenergy Task 34 this data was forwarded to toxicity experts and conclusions relevant for fast pyrolysis oils were drawn. The available data indicates that acute oral toxicity from a single dose is high (>2,500 mg/kg) which puts it in the "slightly toxic" category.

The most severe adverse effect was the irritation/ corrosion changes observed when it was applied dermally to a rabbit. Because of the severity of the dermal changes (erythema/edema i.e. burns) and for ethical reasons the eye irritation test was not run. These effects are most likely due to phenols, aldehydes and/or ketones shown to be present in the test material. Thus, skin and eye protection will be necessary for plant workers.

The mutagenic activity gave a slight positive response in the bacterial forward mutation assay, a modest response in the mouse lymphoma cell culture assay in the absence of metabolic activation, but was negative in the mouse bone

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Guidelines for transportation, handling, and use of fast pyrolysis bio-oil ...continued

Table 1: Summary of transportation guidelines [1]

Property	Transport Classification	Existing test methods	Limit values	Fast Pyrolysis Bio-Oils	Conclusion
Flammable	Class 3, Flammable liquids	Flashpoint	<=60° C (closed cup test)	This method does not apply to bio-oil	If the product does not sustain combustion, it need not be classified as flammable liquid
		Sustained combustibility	Sustains/ does not sustain combustion	Does not sustain combustion	
Corrosive	Class 8, Corrosive substances	Full thickness destruction of intact skin tissue	OECD Tests	Slightly corrosive for rabbit pH > 2.5	Probably slightly corrosive (PG III)
		Metal corrosion of steel/ aluminium	UN Test Manual	Not corrosive for steel Corrosive for aluminium	
Toxic	Class 6.1, Toxic substances	Rat testing	LD_{50} <= 300 mg/kg (oral)	>2000 mg/ kg (oral, rat)	Not classified as toxic substance
Environmentally hazardous	Class 9, Miscellaneous dangerous goods	Aquatic toxicity Bioaccumulation Degradation	10 mg/l 10 mg/l OECD tests	Algae 72 h 100 mg/l Daphnia 48 h 100 mg/l Aerobic bio-degradability 28 days/42%	Not classified as environmentally hazardous
Other transport classifications	Not relevant for this product				
Classification of mixtures	Not relevant for this product because only one type of hazard				

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Guidelines for transportation, handling, and use of fast pyrolysis bio-oil ...continued

marrow micronucleus test. Based on these results it is recommended that a life span skin painting assay be conducted to determine whether the test material is carcinogenic.

This is especially important since the test material contains measureable amounts of PAHs including benzo(a)pyrene and benzo(a)anthracene, both known carcinogens. Additionally, around one half (46 wt %) of the test material has not been characterized with respect to chemical composition. These are important considerations since skin contact is a likely route of exposure for plant workers.

It will also be important to consider additional toxicological testing as the technology progresses toward commercialization. This should include likely routes of exposure (probably dermal and inhalation) and endpoints such as neurotoxicity, reproductive effects, and teratogenicity.

"It is the duty of each bio-oil producer to prove that the classification suggested in this paper is valid also for their product."

At the moment it seems that the product should be classified as Class 8 (Corrosive) product. To make a final classification, all required tests should be done according to relevant transport regulations, referring to the UN Manual of Tests and Criteria, OECD test, and others as applicable. It also appears that the variations between different products could lead to different classifications. It is the duty of each bio-oil producer to prove that the classification suggested in this paper is valid also for their product.

For bio-oils there is no UN number assigned at the moment. If further testing shows that the properties for bio-oils are mostly the same, it may be possible to suggest a new UN number for the product. This suggestion should be made to UN, normally by a competent authority, or an association. A suggestion for transport classification is (Material Safety Data Sheet, Section 14 Transport Information):
UN NUMBER: 3265, PROPER SHIPPING NAME: CORROSIVE LIQUID, ACIDIC, ORGANIC, N.O.S. (contains x, y*), CLASS: 8, PACKING GROUP: III, ENVIRONMENTAL HAZARDS: NO.

It is the oil producers responsibility to show that their bio-oil meets the same classification as shown here.

More research is needed on material testing using a standard or well proven method at relevant test conditions.

References

[1] A. Oasmaa, A .Källi, C. Lindfors, D. C. Elliott, D. Springer, C. Peacocke, and D. Chiaramonti. Guidelines for Transportation, Handling, and Use of Fast Pyrolysis Bio-Oil. Part 1 – Flammability and Toxicity. Energy & Fuels, ASAP 2012.

[2] An assessment of bio-oil toxicity for safe handling and transportation. EU-BIOTOX. EU Contract no. NNE5-2001-00744-BIOTOX Part I: Publishable Final Report. September 2005. http://www.pyne.co.uk/Resources/user/docs/BIOTOX%20Final%20Publishable%20report.pdf.

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Pyrolysis research at the University of Twente

Sascha Kersten provides an insight into research activities at the University of Twente in the Netherlands

Overview

At the University of Twente (the Netherlands), pyrolysis is studied by three groups: the Catalysis Group of Prof Seshan, the Energy Technology Group of Prof Brem and the Sustainable Process Technology Group of Prof Kersten. Our main research lines are:

- Observing and understanding the initial pyrolysis reactions and products.
- Improving pyrolysis products by catalysis, staged condensation and feed reforming of pyrolysis oil pretreatment.
- Process development.
- Upgrading of pyrolysis oil via, for example, hydrotreatment or esterification.
- Combustion of pyrolysis oil and upgraded pyrolysis oil in gas turbines and engines.
- Gasification and reforming of pyrolysis oil.

At present, 10 PhD / post-docs are focusing on pyrolysis. In Table 1, a selection of our publications is listed. The University of Twente is well equipped for this research; there is a Sustainable Energy Lab (SEL) with advanced high pressure facilities, a biofuel testing lab and a catalysis lab. There are many collaborations with industry regarding pyrolysis and the utilization of pyrolysis oil. In fact, currently there is a plan under development to supply 50% of the electricity demand (~1.5 MW) of the university campus by a pyrolysis oil-fed gas turbine. In this scenario, the turbine is delivered by OPRA (www.opra.no) and the oil is produced in the EMPYRO plant of BTG-BTL (www.btg-btl.com).

Pyrolysis for the production of chemicals and fuels

This account further deals with a new pyrolysis process under investigation in the Sustainable Process Technology Group. In this process, the biomass is not only liquefied, but also fractionated into several streams that are more suitable for subsequent refining.

Conventional fast pyrolysis can be regarded as a process that converts biomass, with a high yield, into a single liquid. With this configuration the produced liquid a) may be used as such as feed for turbines, boilers and engines or b) may be upgraded to serve as feed for fuels and chemicals. In the new process, it is envisaged that within the pyrolysis process several liquid streams are produced which are concentrated in targeted compounds. Concentration of the target compounds is achieved by staged condensation in combination with improvement of the selectivity of the pyrolysis reactions. We aim at the

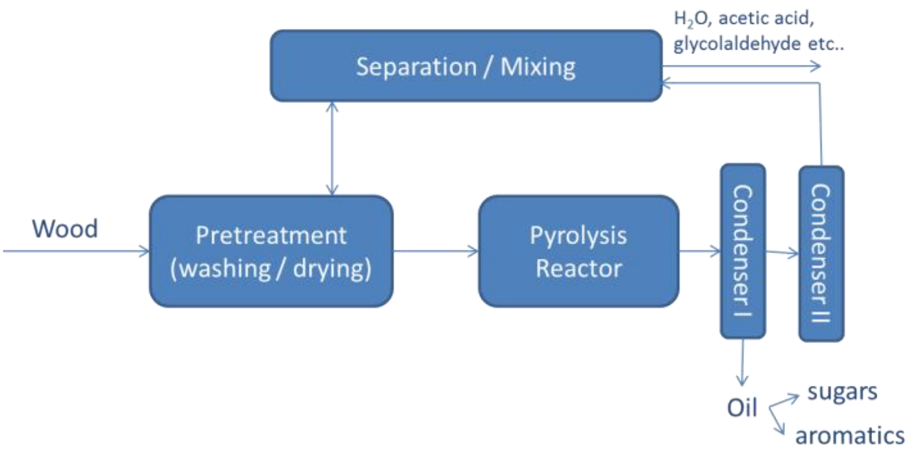

Figure 1: Process layout

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Pyrolysis research at the University of Twente...continued

production of acetic acid, acetol, glycolaldehyde, fermentable sugars and aromatics. The latter might be split in to heavies and lights.

Figure 1 shows a simplified process layout for fresh (green) wood with a moisture content of ca. 50%. The process includes a staged condensation system which already has proven to provide a good separation between "lights" and "heavies". Operating the first (counter-current spray column) condenser at 80°C and the second at 20°C results in an oil (1st condenser) containing the oligomers and the vast majority of the mono-sugars and mono-aromatics and hardly any water, and an aqueous stream (2nd condenser) with oxygenated chemicals such as acetic acid, acetol and glycolaldehyde.

Figure 2 shows the acetic acid distribution over the condensers when pyrolysing (not pretreated) pine wood at 480°C. From this aforementioned aqueous stream, oxygenated chemicals can be obtained via a combination of extraction and distillation processes. Concentrations of the target compounds in this aqueous stream are significantly higher when compared to an oil obtained in a single condenser at ca. 25°C (or the water extract of it). Moreover, it is less "contaminated" with sugars and phenolics. The aqueous stream collected from the second condenser is used, but not (hardly) consumed, as washing liquid to remove the minerals from the feed.

It has turned out that this acid stream is as effective in removing the minerals as any mineral acid (HNO3 or H2SO4). Hence, in our process the biomass is washed with an acid produced from the biomass itself. The "washed" biomass depolymerizes more selectively resulting in a levoglucosan yields of 15-20% and less oligomeric cross-linked sugars and aromatics (pyrolytic lignin). Also with respect to increased selectivity the bio-based washing liquid is as effective as mineral acids. As a result of staged condensation and more selective depolymerization the liquid obtained from the first condenser contains up to 50% levoglucosan (pyrolysis at 530°C). A typical composition of this liquid is given in Figure 3. The pyrolytic lignin can be removed by precipitation which leaves the sugar-aromatics separation as a challenge. The process development for this concept is still in its early stages.

Many items, such as ash removal, dewatering & drying methods and optimal washing conditions have to be further investigated. First results were recently presented at the 19th International Symposium on Analytical and Applied Pyrolysis (Linz, Austria 21-25 May 2012) by Stijn Oudenhoven of the Sustainable Process Technology Group and will be published in a special issue of Analytical and Applied Pyrolysis.

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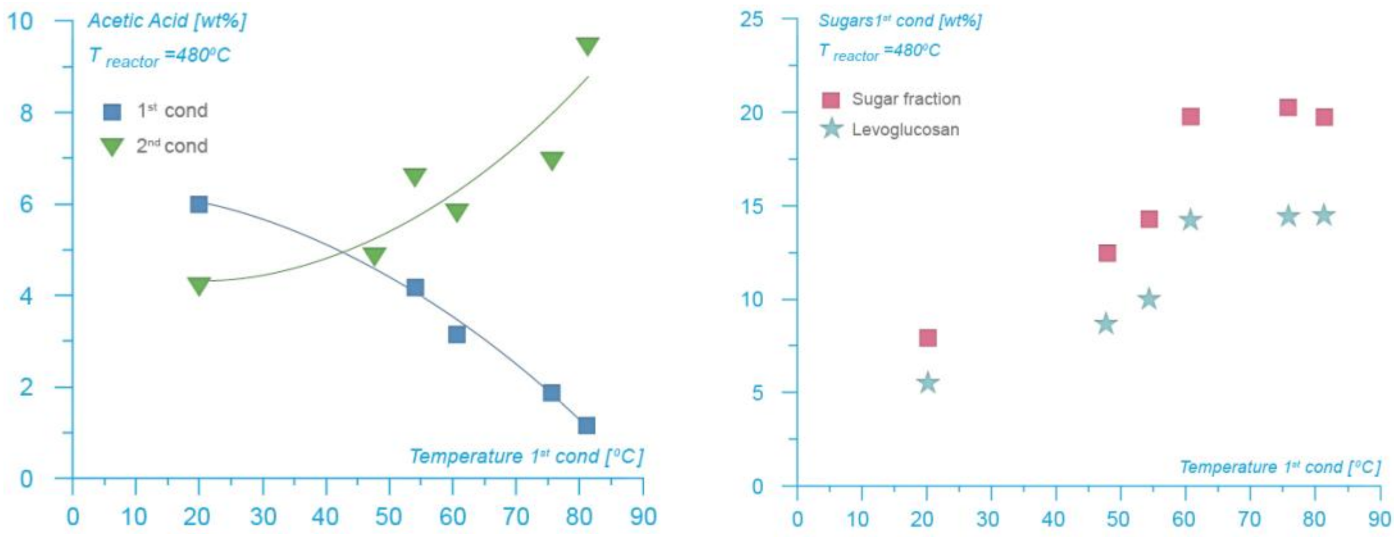

Figure 2: Acetic acid and sugars concentration as function of the temperature of the first condenser. Pyrolysis of not pretreated pine wood at 480°C.

Pyrolysis research at the University of Twente...continued

Table 1: Selected papers concerning pyrolysis

Paper title	Year	Publication
Biomass pyrolysis in a fluidized bed reactor. Part 1 & Part 2	2005	Industrial and Engineering Chemistry Research 44 (23), pp. 8773-8795
Catalytic and non-catalytic gasification of pyrolysis oil	2007	Industrial and Engineering Chemistry Research 46 (12), pp. 3959-3967
Pure hydrogen from pyrolysis oil using the steam-iron process	2007	Catalysis Today 127 (1-4) , pp. 278-290
Controlling the water content of biomass fast pyrolysis oil	2007	Industrial and Engineering Chemistry Research 46 (26) , pp. 9238-9247
Fast pyrolysis of biomass in a fluidized bed reactor: In situ filtering of the vapors	2009	Industrial and Engineering Chemistry Research 48 (10), pp. 4744-4756
Production of advanced biofuels: Co-processing of upgraded pyrolysis oil in standard refinery units	2010	Applied Catalysis B: Environmental 96 (1-2), pp. 57-66
Evaporation of pyrolysis oil: Product distribution and residue char analysis	2010	AIChE Journal 56 (8), pp. 2200-2210
Hydrodeoxygenation of pyrolysis oil fractions: Process understanding and quality assessment through co-processing in refinery units	2011	Energy and Environmental Science 4 (3), pp. 985-997
Catalytic pyrolysis of microalgae to high-quality liquid biofuels	2011	Biomass and Bioenergy 35 (7), pp. 3199-3207
Effect of particle geometry and microstructure on fast pyrolysis of beech wood	2012	Energy and Fuels 26 (4), pp. 2274-2280
Fast pyrolysis in a novel wire-mesh reactor: Design and initial results	2012	Chemical Engineering Journal 191, pp. 45-58

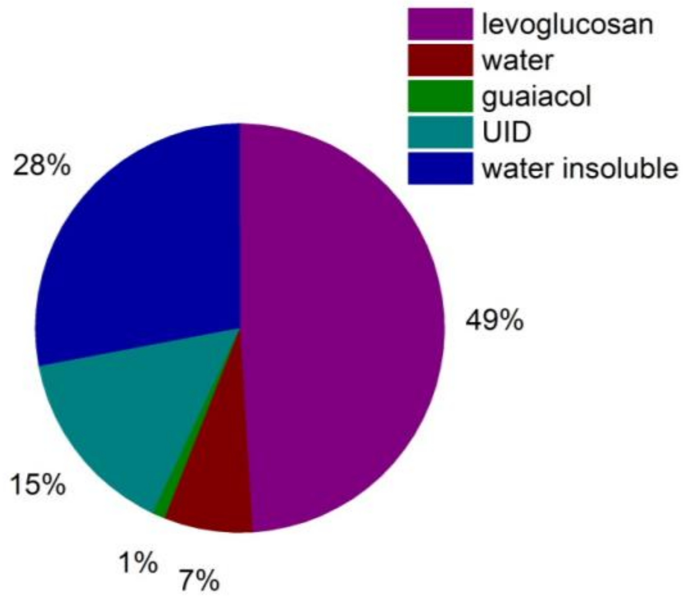

Figure 3: Typical composition of the oil collected in the first condenser. Pyrolysis of washed pine wood (with 2nd condenser liquid) at 530°C.

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UNIVERSITY OF TWENTE.

Tony Bridgwater outlines two bioenergy research initiatives containing pyrolysis related activities

EERA Bioenergy

The European Energy Research Alliance (EERA) Bioenergy activities focus on joint strategies and the creation of joint research project proposals that support large research infrastructure, human mobility, promotional and dissemination activities.

Currently there are four Sub Programmes (SP) in the EERA Bioenergy Joint Programme, as follows:

- Thermochemical processing
- Sugar platform
- Biofuels from algae
- Cross-cutting issues in bioenergy

Pyrolysis and EERA Bioenergy
Within the EERA Bioenergy Sub Programme 'Thermochemical Processing' there is a Work Package focusing on 'Biomass Upgrading', which focuses on the following activities:

- Upgrading of biomass feedstock into solid or liquid bioenergy carriers with superior properties in terms of logistics and end-use.
- The three technologies considered are torrefaction (+ densification), pyrolysis and hydrothermal processing.

EERA Bioenergy is open to new complementary RTD organisations in Europe (EU Member States and Associated Countries).

www.eera-bioenergy.eu

For information on either of the EERA Bioenergy or SUPERGEN Bioenergy initiatives contact:

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SUPERGEN Bioenergy III

From July 2012 a new EPSRC-funded SUPERGEN Bioenergy hub in the UK will bring together industry, academia and other stakeholders to focus on the research and knowledge challenges associated with increasing sustainable bioenergy deployment.

The hub will be led by Dr Patricia Thornley at the Tyndall Centre for Climate Change Research, University of Manchester, and partners will include Aston University, University of Leeds, Rothamsted Research Institute, Newcastle University and the University of Bath.

Aston University will lead the following research activities:

- Turning biomass into transport fuels is a significant research challenge as substantial processing and upgrading are required to meet biofuel specifications. One way of stepping towards that objective is to produce bio-oil by **fast pyrolysis** and upgrade that only to the minimum extent required to allow it to be mixed with mineral oil in a conventional refinery. New approaches to this will be evaluated experimentally to establish the feasibility and potential greenhouse gas reductions.

- There are many different pathways from woody biomass to biofuels, some of which are only just emerging and it makes sense to focus research effort on the more efficient and lowest cost processes, as well as those most likely to deliver significant and cost effective greenhouse gas reductions. Whole systems analysis of novel biofuel technologies will be carried out to screen for the most promising technology options.

www.supergen-bioenergy.net

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European Biomass Conference and Exhibition 2012—Milan

Review by Irene Watkinson of Aston University, UK

The 20th European Biomass Conference was held on 18—22 June 2012 at the Milano Convention Centre in Italy, and consisted of:

- 1550 attendees from 63 countries.
- 332 keynote, plenary, oral and parallel events presentations.
- 12 parallel events covering all aspects of biomass and bioenergy.
- 400 poster presentations.

The Exhibition showed the newest products and technological developments in the biomass sector with 64 exhibitors and 28 exhibitor presentations.

The discussions focused on current topics like Biomass Resources, R&D on Biomass Conversion Technologies for Heating, Electricity and Chemicals R&D on Processes for Solid, Liquid and Gaseous Fuels from Biomass, Industrial Demonstration and Business Concepts, Biomass Policies, Markets and Sustainability.

Pyrolysis

During the five-day event there were several oral and visual presentations relating to pyrolysis (see Table 1 below and on next page - for a summary of the oral presentations on pyrolysis of special feedstock, pyrolysis technologies and products).

Visit www.conference-biomass.com/

Table 1: Pyrolysis-related Oral Presentations at 20th European Conference and Exhibition, Milan, Italy; 18—22 June 2012

Pyrolysis of special feedstock	
Intermediate pyrolysis of microalgae in a batch pilot plant	*D. Chiaramonti, A.M. Rizzo, L. Bettucci, I. Marsii Libelli, M. Prussi, F. Martelli.* *RE-CORD, University of Florence, Italy* *F. Lenzi. SEA Marconi, Turin, Italy*
Flash pyrolysis properties of algae and lignin residue	*T.N. Trinh, P.A. Jensen, K. Dam-Johansen.* *Technical University of Denmark, Lyngby, Denmark*
Biowaste to liquid: Utilization of biogenic residues and wastes in thermo-chemical systems for the provision of fuels	*N. Tröger, D. Richter, R. Stahl* *Karlsruhe Institute of Technology, Eggenstein-Leopoldshafen, Germany*
LIBRA, Pyrolytic lignin valorisation as key-issue for a profitable biorefinery	*P.J. de Wild, R. Wilberink, R. van der Laan.* *ECN—Energy research Centre of the Netherlands, Petten, the Netherlands*
Conversion of residue straws using intermediate pyrolysis for decentralised off-grid electricity generation in India	*S. Sagi, A. Hornung, A. Apfelbacher* *European Bioenergy Research Institute, Aston University, Birmingham, UK* *A. Patel, H. Singh* *Indian Institute of Technology, Rupnagar, India*

Continued on page 28

European Biomass Conference and Exhibition 2012...continued

Table 1: Pyrolysis-related Oral Presentations at 20th European Conference and Exhibition, Milan, Italy; 18—22 June 2012

Pyrolysis and other biomass liquefaction technologies	
Influence of the previous pyrolysis step (biomass source, pyrolysis temperature and technology) on the catalytic steam reforming process of biomass pyrolysis aqueous fractions using A Ni-Co/al-Mg catalyst	*J. Remón, L. García. J. Arauzo University of Zaragoza, Spain F. Broust, J. Valette CIRAD-Persyst, Montpellier, France*
Accuracy and potential use of a developed CFD-pyrolysis model for simulating lab-scale bio-oil production	*P. Mellin, Q. Zhang, E.Kantarelis, C.Zhou, W. Yang KTH, Stockholm, Sweden*
Hydrothermal treatment of cellulose as a model compound in quartz capillaries for the production of fuels and chemicals	*M. Kröger, M. Klemm German Biomass Research Centre, Leipzig, Germany*
Modelling microwave-induced pyrolysis of wood	*A. Galgano. Instituto di Ricerche sulla Combustione, CNR, Naples, Italy C. Di Blasi. University of Naples 'Federico II,' Italy*
Pyrolysis of centrimetric wood particles	*G. Gauthier, T. Melkior, B. Spindler, M. Grateau. CEA, Grenoble, France S. Salvador. Ecole des Mines d'Albi-Carmaux, Albi, France*
Pyrolysis products	
Acid-catalysed pyrolysis of biomass for furfural production	*C. Branca, A. Galgano. Combustion Research Institute, CNR, Naples, Italy C. Di Blasi University of Naples 'Federico II', Italy*
Fractional condensation of biomass fast pyrolysis vapours: an important process step in a pyrolysis based biorefinery	*S.R.G. Oudenhoven, R.J.M. Westerhof, D.W.F. Brilman, S.R.A Kersten University of Twente, Enschede, Netherlands*
Technical scale fixed-bed pyrolysis of several biomass species: deep characterisation of solid bio-char	*A. Dieguez-Alonso, A. Anca-Couce, N. Zobel, F. Behrendt Berlin University of Technology, Germany*
Turbiscan as a tool for studying phase separation tendency of pyrolysis oil	*D. Kaombe, M Hägg, W. Glomm. Norwegian University of Science and Technology, Trondheim, Norway K. Toven, M. Lenes Paper and Fibre Research Institute, Trondheim, Norway*
Characterisation of the tar produced during pyrolysis of common reed: a comparative study between on-line and off-line measuring method approaches	*F. Patuzzi, T. Mimmo, M. Baratieri. Free University of Bolzano, Italy D. Roveda. Graz University of Technology, Austria. J. Karl. University of Erlangen-Nürnberg, Germany*

Pyrolysis 2012—Linz, Austria

Review by Tony Bridgwater of Aston University in the UK

Pyro 2014

The next International Symposium on Analytical and Applied Pyrolysis will be held in 2014, in Birmingham, UK

Contact:
a.v.bridgwater@aston.ac.uk

The 19th International Symposium on Analytical and Applied Pyrolysis was held at Johannes Kepler University, Linz in Austria from 21st to 25th May. The conference described the latest research in all areas of pyrolysis and attracted academia and industrial researchers with over 300 participants.

Topics included:

1. Analytical pyrolysis (biomass, polymers, cultural heritage etc.)
2. Applied pyrolysis (biomass, waste, bio-oil, biochar etc.)
3. Catalysis in pyrolysis
4. Pyrolysis kinetics and mechanisms
5. Reactive pyrolysis (methylation, hydrogenation etc.)

Keynote speakers included:

- *Geoffrey Abbott*
  Newcastle University, UK
  "Advances in thermally assisted hydrolysis and methylation (THM) for the study of organic carbon in terrestrial ecosystems."

- *Tony Bridgwater*
  Aston University, UK
  "Evaluation of feedstocks and catalysts for biofuels."

- *Colin Snape*
  University of Nottingham, UK
  "From heavily degraded oil to black carbon: the diverse analytical applications of hydropyrolysis."

- *Curt Wentrup*
  University of Queensland, Australia
  "Reactive intermediates and unusual molecules formed by flash vacuum pyrolysis."

Publication
Papers presented at the conference will be published in a special issue of the Journal of Analytical and Applied Pyrolysis after the usual reviewing process.

Further information can be found at:

www.pyrolysis2012.com

Figure 1: Delegates attending a plenary session at Pyro 2012

Worldwide Events

JULY 2012

1st-6th
15th International Congress on Catalysis
Munich, Germany

8th-11th
CAT4BIO - advances in catalysis for biomass valorization
Thessaloniki, Greece

10th-11th
DOE-EERE Biomass 2012 Conference
Washington DC, USA

17th-20th
Plant and Seaweed Polysaccharides Symposium
Nantes, France

23rd-25th
Africa Sustainable Waste Management
Lobito, Angola

AUGUST 2012

19th-23rd
8th Symposium on Hydrotreating/Hydro-cracking Technologies
Philadelphia, USA

27th-30th
The EWLP 2012—12th European Workshop on Lignocellulosics and Pulp
Espoo, Finland

27th-31st
Bioenergy from Forest
Jyväskylä and Jämsä, Finland

SEPTEMBER 2012

5th
Algae World Advanced Research and Development (AWARD)
Berlin, Germany

10th-12th
European Biomass Market Forum
Amsterdam, Netherlands

10th-13th
WasteEng 2012 - Biomass and Waste Valorization
Porto, Portugal

16th-20th
The 4th International Biochar Congress
Beijing, China

17th-18th
Bioenergy Finance Forum
London, UK

17th-19th
ISWA World Solid Waste Congress
Florence, Italy

18th-19th
World Biofuels Markets
Sao Paulo, Brazil

24th-27th
Algae Biomass Summit
Denver, Colorado, USA

25th-26th
Biomass for Energy
Kiev, Ukraine

26th-27th
Lignofuels 2012
Stockholm, Sweden

OCTOBER 2012

2nd-5th
Science for Biomass Feedstock Production and Utilization
New Orleans, USA

8th-11th
Gastech
London, UK

10th-11th
EBEC: European Bioenergy Expo and Conference
Warwickshire, UK

23rd-25th
4th Nordic Wood Biorefinery Conference
Helsinki, Finland

29th-31st
Advanced Biofuels Markets
San Francisco, USA

NOVEMBER 2012

12th-15th
Energy from Biomass and Waste - 4th International Symposium
Venice, Italy

12th-15th
IEA Bioenergy ExCo 70
16th
IEA Bioenergy Task 34 Pyrolysis
Vienna, Austria

13th-16th
BioEnergy Decentral
Hanover, Germany

19th-20th
Biofuels for Sustainable Development of Southern Europe (Bio4SuD)
Thessaloniki, Greece

21st
Gasification 2012
London, UK

21st-23rd
RENEXPO® South-East Europe
Bucharest, Romania

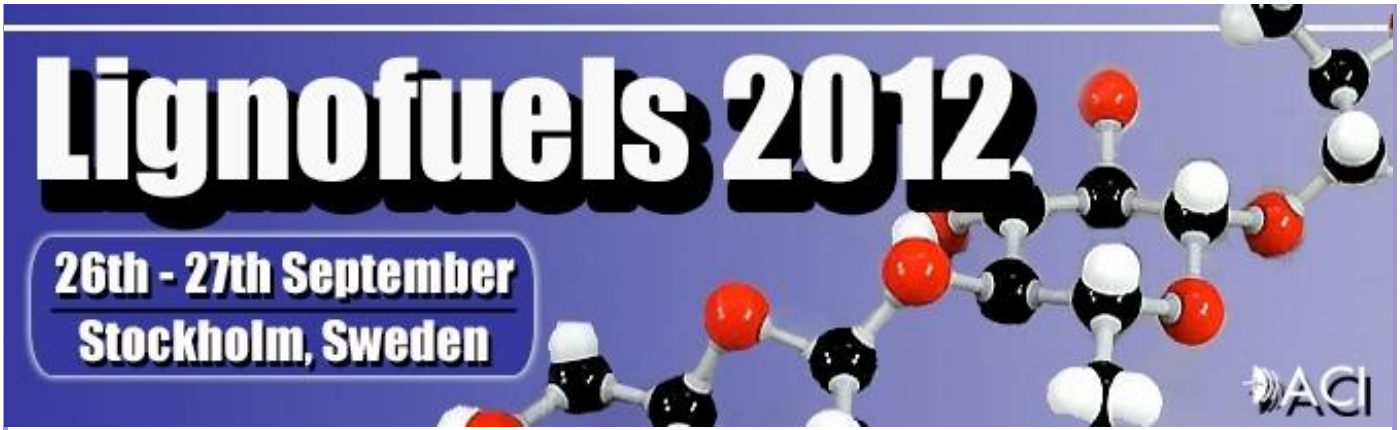
27th-29th
National Advanced Biofuels Conference & Expo
Houston, USA

DECEMBER 2012

3rd-5th
Canadian Renewable Fuels Summit 2012
Westin Ottawa, Canada

3rd-7th
CHEMREACTOR-20
Luxembourg

Events...continued



ACI's 3rd Annual Lignofuels Summit will bring together key industry stakeholders to discuss ways of integrating processes and technologies for production of fuels from lignocellulosic feedstocks.

During the afternoon of Tuesday 25th September a limited number of conference attendees will have the opportunity to attend an exclusive site visit to Chemrec's BioDME plant as well as SunPine's CTO plant.

For further information contact:
Dimitri Pavlyk

Tel: +44 20 7981 2503
Email: **dpavlyk@acieu.net**

Visit
www.wplgroup.com/aci/conferences/eu-eef3.asp

IEA Bioenergy Conference 2012

13 - 15 Nov 2012
Vienna University of Technology

will provide to stakeholders in R&D, industry and policy an insight into the recent research and market developments in bioenergy. The conference includes all topics dealt with by IEA Bioenergy as well as by partner organizations like FAO, GBEP and UNDP.

Presentations will address all stages in bioenergy systems: from growth of biomass, to conversion to energy carriers and, to use for energy services. Cross cutting topics like sustainability (GHG emissions), socio-economy and trade will also be discussed. Policy makers will benefit from the latest conclusions on policy recommendations based on a global scientific energy technology network. Participants will be presented the latest information on promising bioenergy technologies in the stimulating and enjoyable surroundings of

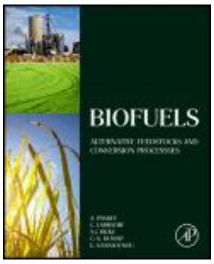
Task:
32: Biomass Combustion and Co-firing
34: Pyrolysis of Biomass
36: Integrating Energy Recovery into Solid Waste Management
38: Greenhouse Gas Balances of Biomass and Bioenergy Systems
39: Commercialising Liquid Biofuels from Biomass
42: Biorefineries: Co-production of Fuels, Chemicals, Power and Materials from Biomass
43: Biomass Feedstocks for Energy Markets
ExCo

Contact:
Dr Arthur Wellinger
Nova Energie GmbH
Tel: +41 52 365 4310
Email: arthur.wellinger@novaenergie.ch

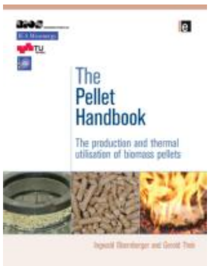
www.ieabioenergy2012.org

Publications

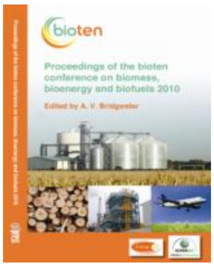
Biomass and Bioenergy: Special Issue, Volume 38
Overcoming Barriers to Bioenergy: Outcomes of the Bioenergy Network of Excellence 2003 – 2009
Edited by A.V. Bridgwater
Publisher: Elsevier
Publication Date: March 2012



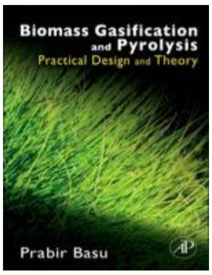
Biofuels - Alternative Feedstocks and Conversion Processes
Edited by: Ashok Pandey, Christian Larroche, Steven Ricke, Claude-Gilles Dussap, Edgard Gnansounou
Publisher: Elsevier
Publication Date: July 2011



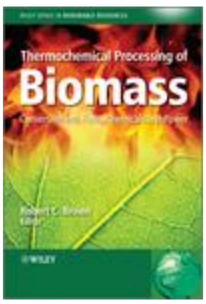
The Pellet Handbook - the Production and Thermal Utilization of Biomass Pellets
Authors: Ingwald Obernberger and Gerold Thek
Publisher: Earthscan
Publication Date: September 2010



Proceedings of the Bioten Conference on Biomass, Bioenergy and Biofuels 2010; Bioten
Edited by: A.V. Bridgwater
Publisher: CPL Press
Publication Date: October 2011



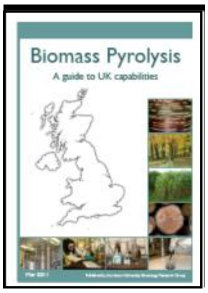
Biomass Gasification and Pyrolysis - Practical Design and Theory
Author: Prabir Basu
Publisher: Academic Press
Publication Date: June 2010



Thermochemical Processing of Biomass: Conversion into Fuels, Chemicals and Power
Edited by Robert C Brown
Publisher: Wiley
Publication Date: March 2011

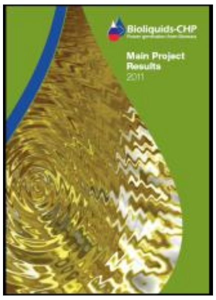
Continued on page 33

Publications…continued

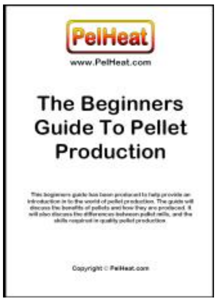


Biomass Pyrolysis - A guide to UK capabilities
Edited by A.V. Bridgwater and I.I. Watkinson
Publisher: Aston University
Publication Date: May 2011

Biofuels: Ethical Issues
Publisher: Nuffield Council on Bioethics
Publication Date: April 2011



Bioliquids-CHP
Power Generation from Biomass
Main Project Results 2011

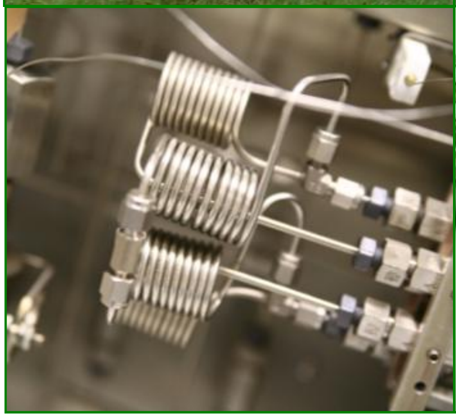


Beginners Guide to Pellet Production

Publisher: PelHeat
Other free guides produced by PelHeat include:
Pellet binders and lubricants
The benefits of precise moisture control
The effect of die thickness
The importance of particle size

Visit the PyNe website to see latest Country Reports and Task Minutes.



Further Information

If you require further information about the PyNe newsletter or would like to contribute to future editions, please contact the Editor:

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IEA Bioenergy

Task 34 Pyrolysis