IEA Bioenergy

Task 34 Pyrolysis

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IEA Bioenergy Task 34: Welcome

By Doug Elliott, Task 34 Leader

The IEA Bioenergy Task 34 for Pyrolysis has been approved for the new triennium from 2010 to 2012. Current participants in the Task are Canada, Finland, Germany, 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 activities listed below:

Priority Topics for Task 34

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

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Welcome...continued

In this issue of the newsletter you will find short introductory articles from the national team leaders from each of the participating countries summarizing their particular efforts in the field. Also there are several articles from around the world describing the latest developments in fast pyrolysis including work at Mississippi State University and the Eastern Regional Research Center of the Agricultural Research Service of the Department of Agriculture in the US; a review provided by Pyrovac of recent developments in vacuum pyrolysis in Canada; plus a summary of process research in pyrolysis at the Karlsruhe laboratory in Germany - to name but a few.

This electronic newsletter is expected to be 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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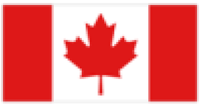

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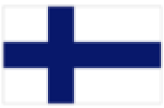

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EMPYRO Project Summary

Gerhard Muggen of BTG-BTL in the Netherlands outlines the EMPRYO project

Figure 1: Polygeneration pyrolysis plant EMPRYO, Hengelo (Ov), the Netherlands.

Project objectives

The aim of the project is to build and demonstrate a 25 MW_{th} poly-generation pyrolysis plant to produce electricity, process steam, organic acids and fuel oil from woody biomass *(see also figure 2 on the following page).*

The EMPRYO project will be supported by the 7th framework program from the EU in the Polygeneration call.

Polygeneration through pyrolysis: simultaneous production of oil, process steam, electricity and organic acids.

Project partners:

- BTG Bioliquids BV (Netherlands)
- BTG Biomass Technology Group BV (Netherlands)
- AkzoNobel Industrial Chemicals BV (Netherlands)
- Amandus Kahl GmbH & Co.KG (Germany)
- Bruins & Kwast Recycling BV (Netherlands)
- Jan Rusaas (Denmark)
- Stork Thermeq BV (Netherlands)
- HoSt BV, (Netherlands)

Project justification

The European chemical industry consumes large amounts of energy, which can account for up to 60% of production costs of chemicals. In addition, this industry accounts for 12% of EU energy demand and consequently contributes to the total CO_2 emission of the EU.

Thus, it is important for the chemical industry to move away from fossil fuels in order to reduce the impact of volatile prices of fossil fuels and to continue its efforts in terms of GHG reduction.

The use of biomass for energy can contribute to reducing the impact of volatile prices of fossil fuels and to reducing the GHG emissions. Following this approach, the project will build and demonstrate a polygeneration pyrolysis plant that will use woody biomass to produce electricity, process steam and pyrolysis oil.

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EMPYRO Project Summary...continued

Specific objectives

1. To demonstrate this European technology on a full scale of 120 t/day.
2. To establish warranty conditions for commercial systems with respect to:
    - Environmental impact and health and safety aspects;
    - Technical performance specifications;
    - Accurate manpower requirements and skills for operation and maintenance;
    - Accurate capital and operating costs;
    - Plant availability;
    - Plant variability in relation to demand (steam, electricity and pyrolysis oil).
3. To set-up a training and education center around the demonstration plant, and create a Pyrolysis Platform (Pyrolysis academy) for further expansion.
4. To set-up and initiate the business roll out of the pyrolysis.

Project background

The core conversion process is a flash pyrolysis plant based on the BTG technology. In Europe, no large scale pyrolysis oil production plant based on biomass is in operation. The plant will be based on the design and experience gained by BTG through the construction of a 50 t/d pyrolysis plant in Malaysia. The plant design will be further scaled up to a commercially attractive scale of 120 t/d (~ $25MW_{th}$). The feedstock will be local woody biomass and/or residues.

The plant will produce electricity, process steam, pyrolysis oil and aqueous organic acids in an industrial environment to make optimal use of the biomass feedstock.

Objectives

- To construct and operate on a continuous basis a 25 MW_{th} polygeneration pyrolysis unit.
- To provide warranty conditions for the process outcomes.
- To demonstrate the use of the pyrolysis oil in natural gas or HFO fuelled energy systems.
- To demonstrate the recovery of acetic acid from the pyrolysis oil.
- To have the ability to test new feedstocks in the future on a large scale.
- To develop a reference plant that can be used for education and knowledge sharing purposes, as well as for commercial purposes.

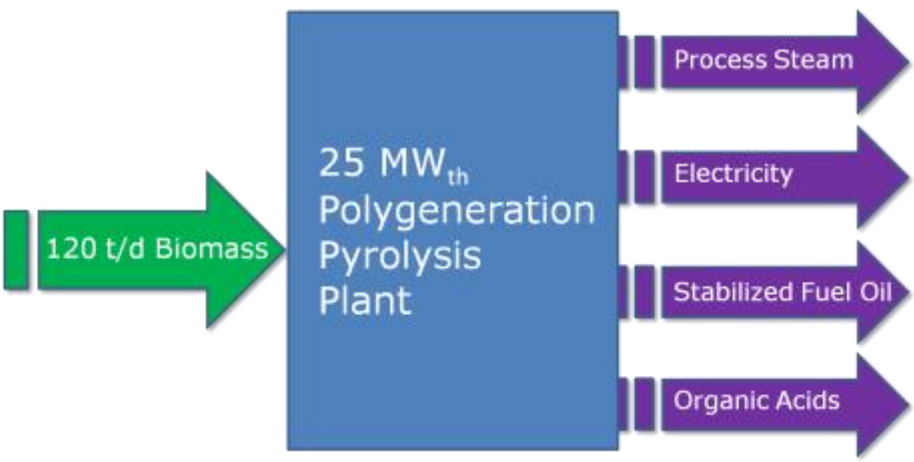

Figure 1: Empyro BV, polygeneration means in this case the production of four end products from biomass.

Demonstration activities

The project consortium will construct and operate a 25 MW_{th} polygeneration pyrolysis plant at the site of AkzoNobel in Hengelo, the Netherlands. At least electricity, steam and pyrolysis oil will be produced on site. A "first of a kind" extraction of organic acids from pyrolysis oil unit will be constructed as well, based on research which is partly conducted within the EU EMPRYO project.

The biomass collection and pretreatment area is located in Goor (approx. 20km from Hengelo). From Goor it will be transported by trucks to the site in Hengelo.

Applications

Combustion of pyrolysis oil will be demonstrated for several applications:

- Application in boilers in industries and district heating in several cities in the province of Overijssel and customers in Belgium;

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EMPYRO Project Summary...continued

- Application in 1.7 MWe gas turbine for combined heat and electricity in the district heating plant in Hengelo.

In all cases natural gas will be substituted.

Research activities: acetic acid recovery
Research activities of the project focuses on the recovery of acetic acid from the aqueous fraction of pyrolysis oil.

Since no substantial quantities of pyrolysis oil have ever been available in Europe for large-scale application and research, such recovery is by default innovative. The work therefore starts with RTD work at laboratory scale to design and construct an acetic acid recovery demo system.

Expected results of the project
- Demonstration plant and commercial production of pyrolysis oil.
- The production of large quantities of pyrolysis oil for the commercial market (between 20,000 and 25,000 t/y of pyrolysis oil).
- CFD model for pyrolysis oil combustion.
- Pyrolysis oil combustion operational experience within the European regulation.
- Hands on experience pyrolysis oil transport and logistics within Europe.
- Design of organic acid recovery unit.
- Demonstration of organic acid recovery unit.
- Financial, environmental and sustainability assessment of the EMPYRO concept.
- Training facility and visiting centre.
- Establishment of the Pyrolysis platform.

Expected impacts of the project

- Implementation and operation of the first (partial) commercial large scale biomass pyrolysis unit.
- Best practices for innovative polygeneration using renewable energy sources for industrial applications.
- Improved energy and environmental performance and efficient use of natural resources. Improved potential for investments of enterprises in such energy technology.
- Replacement of natural gas and acetic acids by pyrolysis oil and organic acids respectively.
- More straightforward ways of using biomass resources, with limited modification to existing equipment.
- Reduction of investments costs to build new plants based on the EMPYRO concept.
- Increased availability of pyrolysis oil for the European research community.

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btg-btl biomass-to-liquid

ARS-USDA Biomass Fast Pyrolysis Research at ERRC

Akwasi Boateng of the United States Department of Agriculture reviews the biomass fast pyrolysis program at the Eastern Regional Research Center

"Behind every successful venture are its dedicated people."

The United States Department of Agriculture's (USDA) biomass fast pyrolysis research program is based at the Eastern Regional Research Center (ERRC) in Wyndmoor, Pennsylvania, just outside of Philadelphia, part of the Agricultural Research Service (ARS).

The program that started modestly by its lead scientist and chemical engineer, Dr. Akwasi (Kwesi) Boateng, in 2004, has quickly grown into one of the leading pyrolysis research programs in the USA. Kwesi is quick to point out that these efforts could not have been possible without the help and motivation from some of the key members of PyNe. He attended his first PyNe meeting in Innsbruck in September 2005, a year after he joined ARS, by the invitation of the US ExCo member and accompanied national team lead Doug Elliott (PNNL) with Prof. Robert Brown (Iowa State). Through subsequent participation in the network activities USDA is now a co-participant with the US Department of Energy (DOE) in Task 34 – Pyrolysis.

ARS facilities now include a pilot scale (5 kg/h) fluidized bed fast pyrolysis reactor system dubbed "The Kwesinator", analytical and lab scale pyrolysis reactors, and an extensive analytical lab fully equipped for the characterization and analyses of pyrolysis oil and co-products. Within this short tenure the program has produced over 25 peer-reviewed journal articles and was a full participant in the lignin round-robin studies recently published by Task 34. It has been the subject of several press and newswire including a radio magazine.

Obviously behind every successful venture are its dedicated people. In addition to Dr. Boateng, key personnel on the project include mechanical engineer Neil Goldberg, and chemists Dr.

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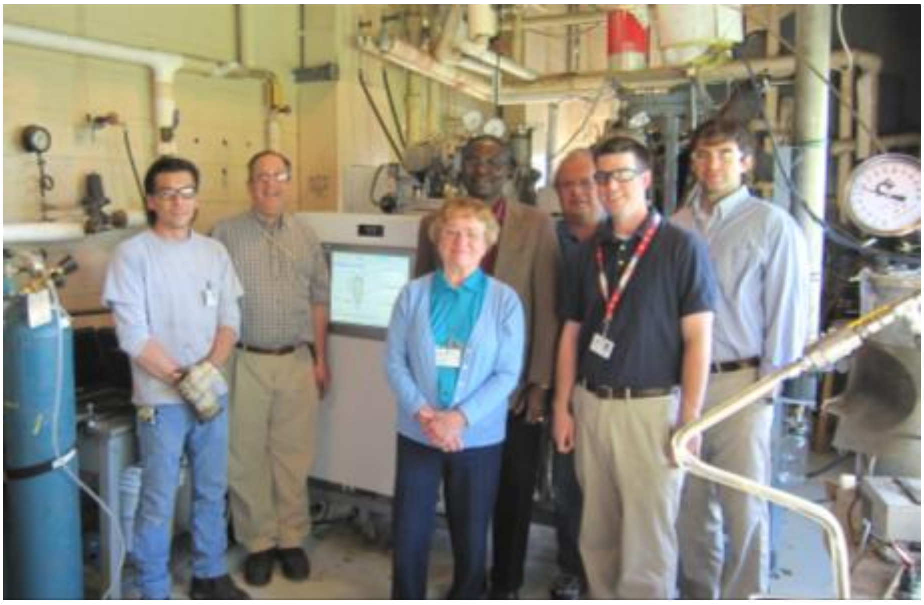

Figure 1: The ERRC Pyrolysis Team
Left to right: Kenneth Schafer, Neil Goldberg, Jacqueline Kenny, A.(Kwesi) Boateng, Michael Dallmer, Charles Mullen, David Mihalcik.

ARS-USDA Biomass Fast Pyrolysis Research at ERRC...continued

Charles Mullen (PyNe, Vicenza, 2007 attendee) and Dr. David Mihalcik, not to mention the tremendous administrative support from the center's research leader in sustainable biofuels and coproducts, Dr. Kevin Hicks, and the National Program Leader, Dr. Robert Fireovid. The program has attracted and continues to attract faculty and students who flock the ERRC hallways during summers, some of whom have gone on to pursue graduate education in pyrolysis science.

With increasing demands by ARS stakeholders including over 34 letters from interested collaborators, the program was expanded and renewed in 2009 with the approval and certification of a new ARS appropriated five year research project, titled "Distributed-Scale Pyrolysis of Agricultural Biomass for Production of Refinable Crude Bio-Oil and Valuable Coproducts."

Major research thrusts for the project are developing both catalytic and non-catalytic processes that can produce stable, refinable bio-oil on or near the farm, identifying and quantifying agricultural factors (biomass composition, agronomic factors, etc.) that affect fast pyrolysis processes and product quality, and improving the quality of bio-char for soil amendment applications. The ARS pyrolysis group has partnered with petroleum industry catalyst giant, UOP LLC, leading control systems developer, Siemens, and Biofuels Manufacturers of Illinois (BMI) through Corporative Research and Development Agreements (CRADA).

Additionally, they have signed over 10 material transfer agreements (MTA) with companies, farmers, and university research groups that would like to test feedstock or receive bio-oil or bio-char for analysis. The program is included in the UOP's partnership with Ensyn, Pall Corporation, NREL and PNNL that was awarded one of the five DOE-funded pyrolysis oil stabilization contracts in 2008. It is also part of the National Advanced Biofuels Consortium (NABC) which was recently awarded $34 million by the DOE to conduct cutting-edge research to develop infrastructure compatible, fungible "drop-in" biomass-based hydrocarbon fuels. The ARS pyrolysis researchers will work with UOP on catalytic pyrolysis.

On the local level, the program is making a difference and the neighbors have heard and are responding. Farmers of Pennsylvania Farm Bureau of Montgomery county and the South Eastern Pennsylvania Resource Conservation and Development (RC&D) representing seven PA counties are working to mobilize support and funding for the development of regional distributed pyrolysis systems using the ARS pyrolysis technologies – stay tuned.

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United States Department of Agriculture

Fast Pyrolysis in the bioliq® process

Dr Nicolaus Dahmen gives an insight into the bioliq® process developed at Karlsruhe Institute of Technology in Germany

The bioliq® process, developed at the Karlsruhe Institute of Technology (KIT), aims to produce synthetic fuels and chemicals from biomass. Syntheses based on synthesis gas require pressures of up to 10 MPa. Therefore, gasification already at elevated pressures may omit expensive gas compression and ease gas cleaning and conditioning. High pressure entrained flow gasification provides high quality tar-free syngas with low methane contents. For that purpose a feed is required, which can easily be fed to the gasifier at elevated pressures being atomized by oxygen as the gasification agent.

Fast pyrolysis was chosen as a most promising process to obtain such a feed by mixing pyrolysis condensates and char to a so called bioliqSyncrude®, exhibiting a sufficiently high heating value, and being suitable for transport, storage and processing. This slurry-gasification concept has been extended to a complete process chain via a pilot plant erected on site at KIT.

The three subsequently constructed parts of the plant, funded by the German Ministry of Food, Agriculture, and Consumer Protection, consist of the fast pyrolysis and biosyncrude production, the 5 MW_{th} high pressure entrained flow gasifier operated at up to 8 MPa (both in cooperation with Lurgi GmbH, Frankfurt), as well as the hot gas cleaning (MUT Advanced Heating GmbH, Jena), dimethylether and final gasoline synthesis (Chemieanlagenbau Chemnitz GmbH). The last components aim at the improvement of syngas utilization by saving energy, simplifying process technology and improving product quality.

The general project was launched in 2005, when design of the pyrolysis plant

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Figure 1: Glance at the reactor section with hot gas cyclone and quench (left side).

Fast Pyrolysis in the bioliq® process... continued

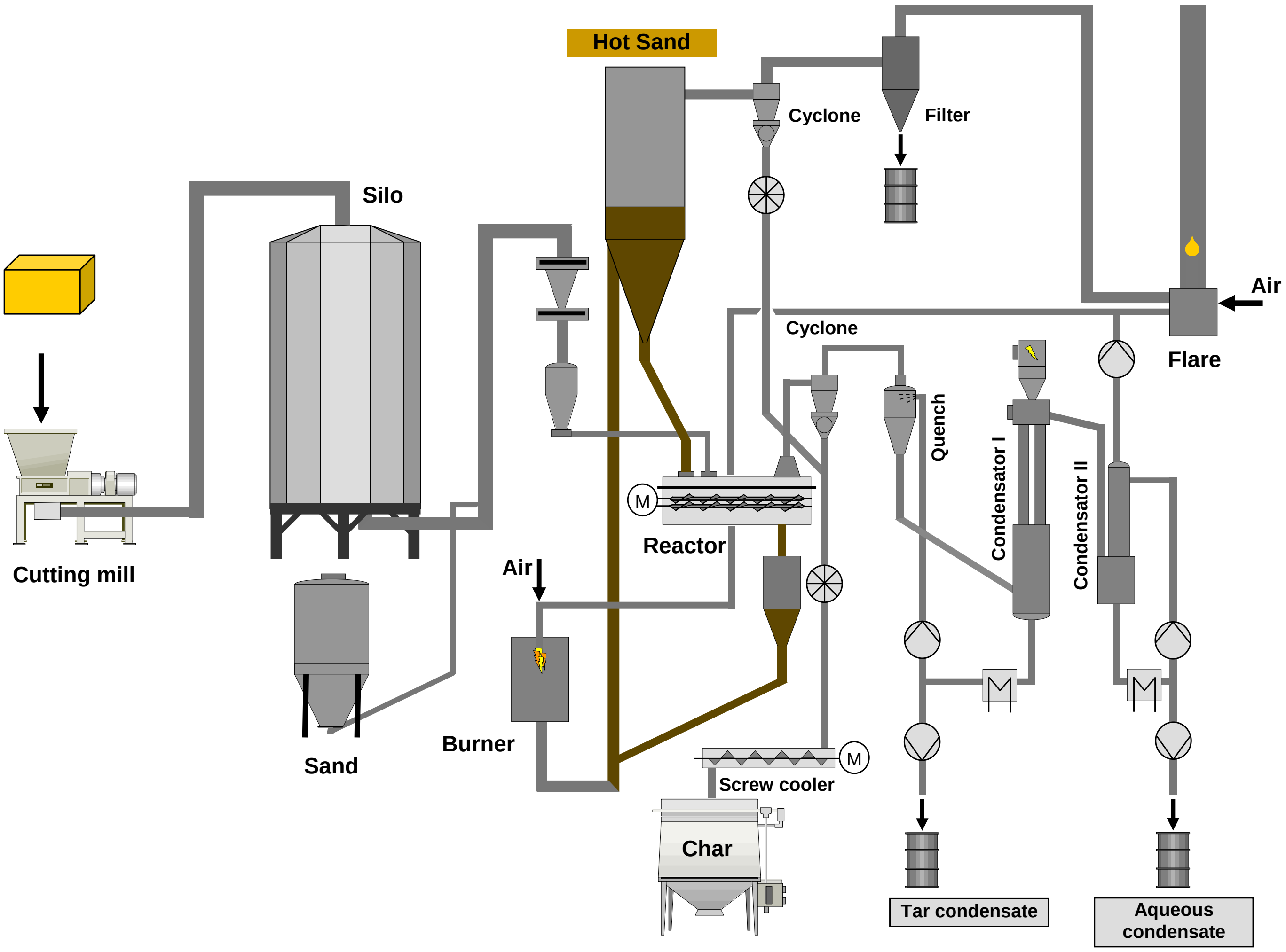

Figure 2: Flow scheme of pilot plant.

commenced, followed by mechanical completion in 2007 and commission in 2008. Gasification, gas cleaning and syntheses production plants will be completed by the end of 2011.

In order to use a broad variety of residual biomass typically having low volumetric energy content (e.g. straw, hay, or residual wood from agriculture, forestry and land cultivation), fast pyrolysis plays a key role in the process. The technical concept of the pilot plant in Karlsruhe is based on the Lurgi-Ruhrgas mixer reactor, previously devoted to coal degassing or heavy crude coking. The intentional design of biomass conversion was based on a series of tests with several types of straw and wood conducted in relevant bench scale plants of KIT and Lurgi Lentjes, Frankfurt. The actual flow scheme is depicted in figure 2 above.

In the first plant section, biomass is cut into particles (e.g. straw reduced to below 1 cm of length) by a two-stage cutting mill and pneumatically fed to a 60 m^3 silo for storage. Up to 500 kg/h air dry biomass (2 MW_{th}) can be removed from the silo and charged to the reactor via a bucket elevator and lock hopper system admitted with nitrogen as inert gas. Sand is added compensating the losses of heat carrier due to degradation. In a recent test the amount was found to be

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"Fast pyrolysis was chosen as a most promising process."

Fast Pyrolysis in the bioliq® process… continued

around 1 wt.% related to the biomass throughput.

In the twin screw mixer reactor, hot sand (550-600°C) is added in excess of the biomass (factor 5-10). At a reaction temperature of 500°C biomass is rapidly decomposed (gas retention time ca. 3 sec.). Hot vapours and char (plus inorganic fines, e.g. sand dust) leave the reactor top entering the hot gas cyclone closely connected to the quench. Here, after particle separation, a temperature of around 110°C is adjusted by recirculation warm tar condensate from the condenser's bottom.

The aqueous condensate is obtained in the second condenser; aerosol entrainment from the first condensation step is prevented by an electro filter. The remaining combustible pyrolysis gas can be used to fire a burner, which at present is operated with natural gas for simplicity. The hot flue gas generated in the burner drives the heat carrier cycle. In the lift pipe, the sand discharged at the reactor bottom is reheated and pneumatically conveyed to the heat carrier storage.

Char contained in the heat carrier flow may be partly combusted by control of the oxygen excess in the lift pipe for additional heat supply. Fines, including residual char, are removed from the flue gas stream by another cyclone and a hot gas filter. Afterwards, the flue gas containing up to several hundreds ppm CO is combusted in the flare, together with the pyrolysis gas. Char and condensate fractions are collected separately for detailed investigation, which are later used for preparation of biosyncrudes. These are characterized according to their fuel properties, rheological behaviour, and other properties related to safe handling, transport, and storage.

Figure 3: Process building of the fast pyrolysis plant.

So far, four test campaigns, with typically one week full shift operation included, have been conducted - mainly testing the functionality and to establish operation procedures and protocols. Operation targets for the future are:

- to achieve full operation of the plant with straw as feed material;
- to create a closed mass and energy balance;
- to produce relevant amounts of representative pyrolysis products and biosyncrudes.

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Ensyn Technologies

Stefan Müller provides an overview of Ensyn Technologies' past and current activities in North America

Ensyn first began developing Rapid Thermal Processing (RTP™), its fast pyrolysis process, in 1984 and built its first commercial plant in 1989. The company has been operating on a commercial basis since then. To date, its technology and equipment has been deployed—either by Ensyn or under license—in seven biomass plants across North America. The largest is the Ensyn owned facility in Renfrew, Ontario, Canada, with a capacity to process 100 bone dry tonnes of feedstock per day.

In 2008, the company announced a joint venture with UOP/Honeywell, a global supplier and licensor of fuel technologies, to improve its global capabilities to deploy RTP plants and to develop and deploy technology that allows the pyrolysis oil to be upgraded into a blend stock that can be fed into the existing fossil fuel refining infrastructure to produce green gasoline, green diesel, and green jet fuel.

"Ensyn first began developing its fast pyrolysis process in 1984."

Innovative reactor design

Ensyn utilizes a circulating fluidized bed design for its reactor, characterized by the movement of heated sand around the reactor vessels. In this process, a gas (not air) enters the bottom of the reactor, and hot sand is introduced, creating a whirlwind of sand with a temperature of 500 to 525°C. Upon contact with the whirlwind, feedstock particles are flash vaporized, leaving a gas and some remaining solids. Upon leaving the reactor, gases are combined with a spray of previously made pyrolysis oil; this condenses the gas into new pyrolysis oil.

The solids that remain are a combination of sand and char, which are redirected to a second vessel. In here, the char parts of the mixture are ignited by the introduction of air. This provides the necessary combustion to heat up the sand mixture to the temperatures required for the flash vaporization in the

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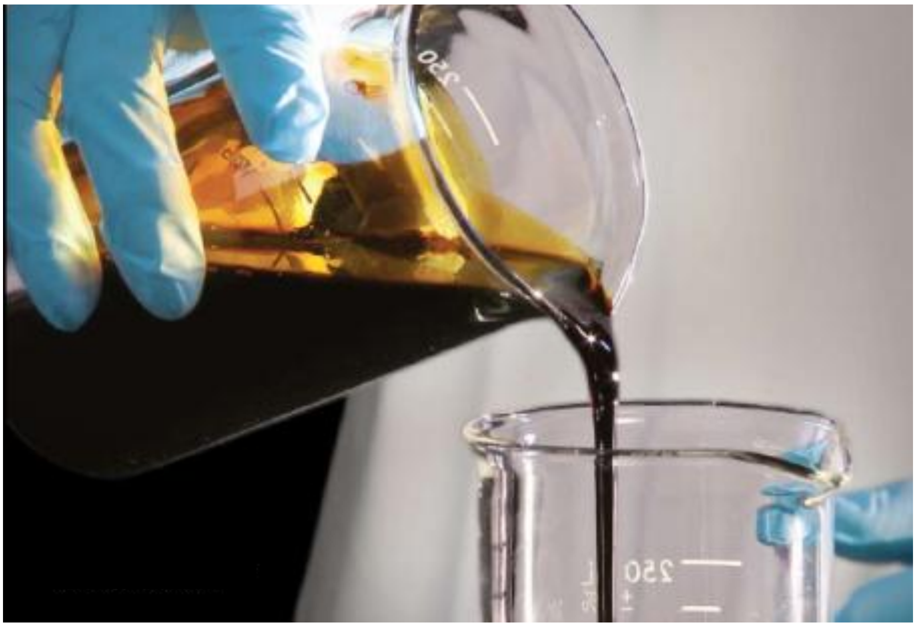
Ensyn Technologies...continued



reactor vessel. This is a key factor in increasing the net energy balance, and consequently the greenhouse gas (GHG) reduction, of the end product.

Some of the gases are non-condensable, but they can be used in other ways. Some are used as the carrier gas, which is introduced into the bottom of the fast pyrolysis reactor, and can be used as fuel in a dryer to reduce the moisture in the biomass (from around 45 percent for green biomass to the 6 to 8 percent moisture level necessary for the flash vaporization process).

The product of fast pyrolysis is pyrolysis oil; this pyrolysis oil is currently used in the manufacturing of specialty chemicals, as a fuel in thermal applications and in turbines to produce electricity, also the use of pyrolysis oil in medium speed diesels to produce electricity is advancing rapidly and will soon be ready for deployment.

The Joint Venture: Envergent

Envergent, Ensyn's joint venture with UOP/Honeywell, is engineering and deploying fast pyrolysis plant sizes of 200 to 1,000 dry tonnes per day. The joint venture brings UOP's plant building expertise, and the mode of deploying the technology has changed from an on-site piece-by-piece construction, to a modular assembly process used by UOP when building fossil refineries. This entails constructing modules offsite, and then delivering them to a site where they are connected together.

With this approach, the elapsed time from planning to plant commissioning is approximately 12 to 18 months. Since the Rapid Thermal Processing (RTP) unit is not dissimilar to a fluidized catalytic cracker they developed for the oil refining business, UOP can leverage some pre-existing knowledge in the plant design. This has reduced capital costs, and the capital expenditure investment for a 400 tonnes per day plant is significantly less than is required for an equivalently sized gasification or cellulosic ethanol plant. Plants currently being deployed carry a UOP/Honeywell guarantee of performance, which mitigates risk for those seeking financing to build plants.

The second objective of the joint venture is to scale up and offer pyrolysis-specific hydro-treating technology for sale. Hydro-treating, a process that converts the pyrolysis oil to a bio-crude, has been developed by UOP and has been demonstrated at bench-scale to work on pyrolysis oil. This bio-crude can then be upgraded in a normal petroleum refinery into a range of fuels, including green gasoline, green diesel and green jet fuel. The hydro-treating process could be located either at the pyrolysis plant (if there are sufficient feedstock volumes present), or more likely at the refinery.

UOP currently offers hydro-treating technology for fossil fuel refining and is well-placed to adapt it for pyrolysis. This is the crucial step in unlocking the potential of the pyrolysis oil—expanding its use from a fuel used to generate heat and electricity, to being the basis for mass-market premium transportation fuels.

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ENSYN

Pyrovac Process

Christian Roy, co-founder of Vaperma Inc reviews the biomass vacuum pyrolysis process developed by Pyrovac Institute in Canada

Project Status
The biomass vacuum pyrolysis process has been developed from scratch by Dr Christian Roy at Pyrovac Institute Inc between 1988 and 2002. Early R&D work was performed by Professor Roy at the Université de Sherbrooke (1981-85) and Université Laval (1985-88), both in Canada.

The process includes a combination of slow and fast pyrolysis conditions. Shredded solids are heated to 475°C within approximately 12 minutes, and the noncondensable gas is removed from the hot temperature zone relatively quickly by applying a reduced total pressure of 20 kPa. A 3.0 t/h industrial demonstration pyrolysis plant fed with softwood bark residues was designed, constructed and operated by Pyrovac in the City of Saguenay, Quebec, Canada, between 1999 and 2002.

Figure 1: The Pyrocycling™ process operates under low pressure with a water ring vacuum pump.

Crumb rubber was also successfully tested in 2002. The system proved to be functional except for a limitation encountered at one of the two condensing packed towers which somehow impaired the heavy oil condensation performance. That first condensing tower was on its way to be modified when the joint partner of Pyrovac Group, UNA BV (now NUON BV) was acquired by Reliant Energy Inc from Houston, TX. Because the pyrolysis project did not fit into the core business of the new owner, Reliant Energy withdrew from the joint venture and Pyrovac was subsequently brought to an end in June 2002.

The process equipment and the building housing the equipment were purchased by a third party from the bankruptcy in 2003 and the assets have kept in pretty good shape till today.

General Process Description
Biomass material is conveyed over two horizontal heating plates, which are heated indirectly by a mixture of molten salts composed of potassium nitrate, sodium nitrite and sodium nitrate. The salt itself was heated by a gas burner fed with the noncondensable gases produced by the pyrolysis process. In order to overcome the internal heat transfer limitations, the reactor was equipped with a patented internal agitation raking mechanism which resulted in efficient heat transfer towards

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Pyrovac Process...continued

the moving bed of wood particles.

A distinct feature of the process appeared to be the capacity to easily separate water and low molecular weight acidic compounds from the heavier bio-oil compounds. As a result, bio-oils containing as low as 5% water can be recovered in the first condensing tower. The pyroligneous aqueous phase concentrates most of the water and a few valuable oxygenated water soluble chemicals in the second condensing tower.

Between 2003 and today, Dr Roy through Vaperma (www.vaperma.com) contributed at the development of a permeation membrane technology which may be the missing tool to further separate the water from the light soluble organics.

Another interesting feature of the process is to allow increased production of biochar at the expense of bio-oils. This can become an advantage in the future upon definite demonstration of the benefit of biochar for soil amendment and for carbon permanent sequestration.

Reactor Performance

The system was fed during approximately 1000 hours with softwood bark residues dried to 10% moisture. Tests were performed at flow rates of between 1,000 and 3,500 kg/h. The yield of biochar was 29% and the oil yield (16% water content) was 31%. The non condensable gas product represented 20% of the products and the pyroligneous liquor phase also reached 20% on an anhydrous feedstock basis.

Figure 2: Pyrocycling™ Reactor.

It can generally be said that the industrial demonstration program was successful. The system was scaled-up by a factor of 60 when compared with the pilot plant of 50 kg/h. The moving and stirred bed reactor reached its nominal design capacity after a commissioning period which lasted approximately six months. Three innovations were tested at once: i) the moving and stirred bed concept which involved a raking internal system installed on top of the heating plates; ii) a molten salt heat carrier circulating inside two superimposed heating plates and; iii) operating a reactor under a vacuum of about 20 kPa absolute. This type of reactor is also easily scalable.

Product Collection Difficulties and their Solutions

The process enabled smooth and efficient phase separation of all pyrolysis products, which appears to be advantageous:

- A low-water-and-acid content heavy oil in the first condensing packed tower;
- A pyroligneous, acidic liquor at the bottom of the second condensing tower;
- Biochar; A noncondensable and burnable gas phase.

However the heavy oil condensing tower was not tall enough to achieve efficient heat exchange when the system was running at full capacity. As a result the packed tower # 1 was the limiting step of the entire system. Modification of the packed tower was easily achievable but the solution was not implemented at the time Pyrovac had to stop its activities. A cyclone was also missing between the reactor outlet and the first condensing tower.

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Pyrovac Process...continued

A further contemplated improvement of the collection system is the installation of permeation membrane modules to the front end of the second condensing tower in order to achieve vapour phase separation of the water on the retentate side, and lighter organic compounds on the retentate side. Such a recovery method is a wise way to separate water and should avoid costly treatment of the pyroligneous liquor.

Figure 3: Oil Recovery System consisting of two condensing columns.

What's up in the Near Future?

Time has come for a possible return of Dr Roy and his team in the pyrolysis world in the near future. New venture opportunities are currently being discussed with business partners principally located in the US.

Figure 4: Charcoal recovery system—here charcoal is cooled down to ambient temperature.

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Mississippi State University Follows Multiple Routes to Biofuels from Bio-oil

Update from Professor Philip Steele, Department of Forest Products and Thrust Leader of the Bio-oil Research Group in the Sustainable Energy Research Center, Mississippi State University

The Sustainable Energy Research Center (SERC) at Mississippi State University (MSU) was founded in 2006. The SERC selected production and conversion of bio-oils to liquid fuels as one of the three fuel types on which to focus university research efforts. The SERC Bio-oil Research Group has developed its own proprietary pyrolysis reactor design and is currently pursuing production of liquid biofuels from bio-oil conversion by three routes.

The SERC Bio-oil Research Group is comprised of eight faculty members from the departments of Agricultural and Biological Engineering, Chemical Engineering, Chemistry, Forest Products, Mechanical Engineering, and the Institute for Clean Energy Technology.

The three bio-oil conversion technologies pursued by the Bio-oil Research Group are hydroprocessing, catalyzed esterification and production of ethanol from increased anhydrosugars production. The hydroprocessing route entails application of catalysts under hydrogen pressure and heat.

This approach follows previous research practitioners in that a two-stage catalytic treatment is applied in which the first stage applies a hydrotreating catalyst under mild conditions and the second a hydrocracking catalyst under more severe conditions.

However, the MSU-developed catalysts are unique in the characteristics of the hydrocarbon mixture produced. This mixture contains zero oxygen which will allow this hydrocarbon mixture to be introduced directly into current petroleum refineries after the hydrotreating step and prior to distillation. The hydrocarbon mixture produced by application of the MSU catalyst was analyzed by gas chromatographic simulated distillation to provide the results shown in figure 1. The distribution of fuel weights corresponding to those produced in current petroleum refining were comprised of gasoline weight compounds at 37%, jet fuel compounds at 27%, diesel compounds at 25% and heavy fuel oil compounds at 11%.

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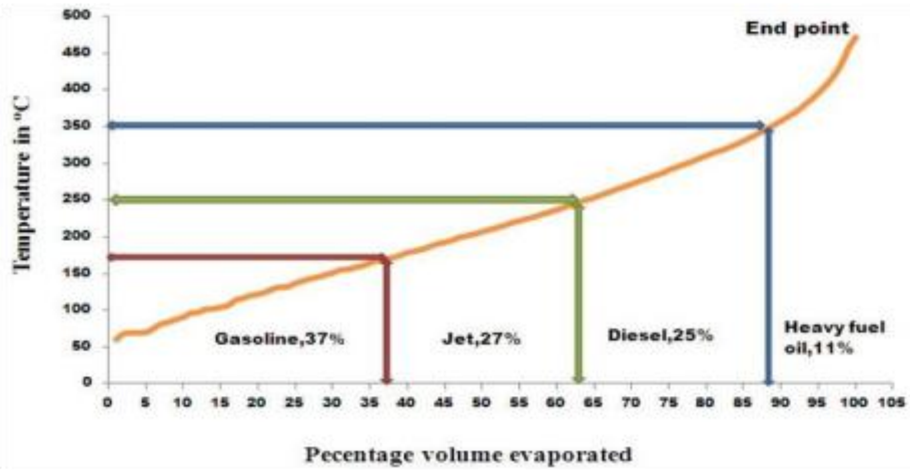

Figure 1: Simulated distillation curve of HDO hydrocarbon mix for boiling range distribution of petroleum fractions by gas chromatography (ASTM D2887).

MSU has also pursued esterification of bio-oil to produce a mildly upgraded boiler fuel. Researchers have pursued development of a fuel by this means for decades but no commercial venture has emerged. Previous research has concentrated on utilization of relatively large proportions of alcohol addition to achieve the esterification results and the cost of this high volume renders this approach uneconomic. MSU uses only 20% of alcohol but catalyst application is novel and achieves the desired esterification. Both acid value and viscosity of this product are both approximately 50% of the raw bio-oil values; energy value is 30% higher than for raw bio-oil. Aging of the esterified bio-oil is greatly reduced but not eliminated.

Additional methods to reduce aging are being pursued. Flashpoint of esterified bio-oil is not significantly higher than that of raw bio-oil. Initial boiler trials demonstrated difficulty in ignition and uncombusted residue build up in the fire box was a problem. Minor modifications of the boiler engineering were developed to allow both immediate ignition and prevention of residue buildup.

Figure 2: High-aeration boiler injector unit demonstrating the yard-long flame produced by combustion of esterified bio-oil during MSU boiler testing.

MSU has developed and filed a patent on a method to increase anhydrosugars content, mainly levoglucosan, in bio-oil. The method involves typical mild acid pretreatment followed by a secondary treatment. The combined effect of these treatments is to increase levoglucosan production from the usual 3% without treatments to 47% with treatment as showed in figure 3. Previous researchers attained yields of 35% based on acid pretreatment. Therefore, our secondary treatment beyond acid pretreatment resulted in a 34% increased yield of levoglucosan.

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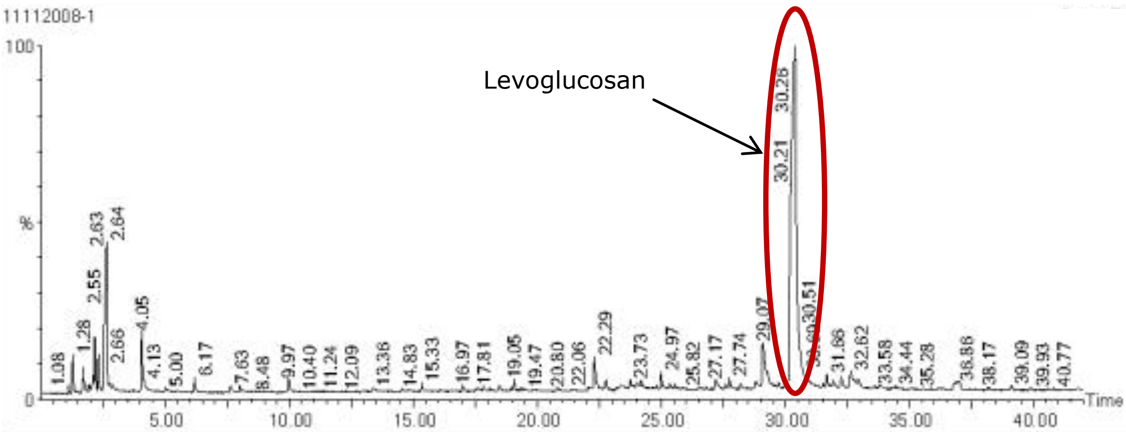
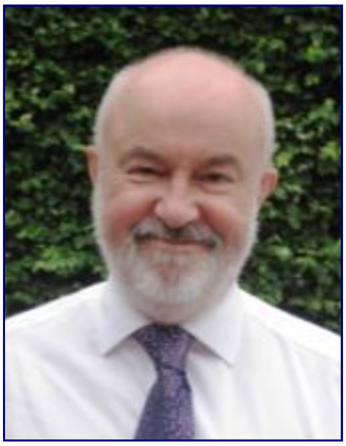


Figure 3: GC/MS spectra of pretreated bio-oil aqueous fraction showing high levoglucosan percentage.

Fast Pyrolysis Reactors Worldwide



Tony Bridgwater of Aston University, UK provides an insight into current activities in fast pyrolysis around the globe

At the heart of a fast pyrolysis process is the reactor. Although it probably represents only about 10–15% of the total capital cost of an integrated system, most research and development has focused on developing and testing different reactor configurations on a variety of feedstocks, although increasing attention is now being paid to control and improvement of liquid quality, as well as an improvement of liquid collection systems. The rest of the fast pyrolysis process consists of biomass reception, storage and handling, biomass drying and grinding, product collection, storage and, when relevant, upgrading.

Table 1 on the following two pages lists the known recent and current activities in fast pyrolysis arranged by reactor type and maximum known throughput. There has been considerable growth and expansion of activities over the last few years with more innovation in the types of reactor explored by academic institutions. It is disappointing to see in recent literature so much re-invention and poor appreciation of the underlying fundamental requirements of fast pyrolysis as well as a reluctance to carry out basic reviews of past research publications.

There is some increase in activities on fixed bed and related systems that are claimed to be fast pyrolysis. These are unlikely to give high liquid yields and will tend to give phase separated liquids. These may be desirable in some applications where fractionation is required, but it would seem preferable to control such separation rather than rely on poor design and process control.

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Bioenergy Research Group

Professor Tony Bridgwater is the founder of Aston University's Bioenergy Research Group (BERG), one of the world's biggest academic research groups in this field. Tony and his current team of over 20 researchers are developing innovative processes and products whereby fast growing wood, energy crops, agricultural wastes and other biogenic materials can be thermally converted into liquids, gases and solids for production of electricity, heat, transport fuels and a wide variety of chemicals.

Fast Pyrolysis Reactors Worldwide ...continued

Table 1: Summary of fast pyrolysis reaction systems for liquids, recently and currently operational. (Excludes analytical pyrolysis).

Fast pyrolysis	Industrial	Units built	Max size kg/h	Research	Max size kg/h
Fluid bed	Agritherm, Canada Biomass Engineering Ltd, UK Dynamotive, Canada RTI, Canada	2 1 4 5	200 200 8,000 20	Adelaide U, Australia Aston U., UK Cirad, France Curtin U, Australia ECN, Netherlands East China U. Science and Technology, Shanghai, China Gent U., Belgium Guangzou Inst, China Harbin Institute of Technology, China Iowa State U., USA Monash U. Australia NREL, USA PNNL, USA Shandong U. Technology, China Shanghai JiaoTong U, China Shenyang U., China South East U., China Texas A&M U., USA TNO, Netherlands U. Basque Country, Spain U. Campinas, Brazil U. Leeds, UK U. Maine, USA U. Melbourne, Australia U. Naples, Italy U. Science and Technology of China U. Seoul, Korea U. Twente, Netherlands U. Western Ontario, Canada U. Zaragoza, Spain USDA, ARS, ERRC, USA Virginia Tech. U., USA VTT, Finland vTI, Germany Zhejiang U., China Zhengzhou U., China	1 7 2 2 1 nk 0.3 10 nk 6 1 10 1 nk 1 1 1 42 10 nk 100 1 0.1 0.1 1 650 nk 1 nk nk 1 0.1 1 6 3 2
Spouted fluid bed	Ikerlan, Spain	1	10	Anhui U. Science & Technology, China U. Basque Country, Spain	5 nk
Transported bed & CFB	Ensyn, Canada Metso/UPM, Finland	8 1	4,000 400	CPERI, Greece Guangzhou Inst. Energy Conversion, China U. Birmingham, UK U. Nottingham, UK VTT, Finland	1 nk nk nk 20
Rotating cone	BTG, Netherlands	4	2,000	BTG, Netherlands	10
Integral catalytic pyrolysis	BioEcon, Netherlands + Kior USA	nk	nk	Battelle Columbus, USA PNNL, USA Technical U. of Munich, Germany U. Massachusetts-Amhurst, USA Virginia Tech. U., USA	1 1 nk nk 3?
Vortex				TNO, Netherlands	30

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Fast Pyrolysis Reactors Worldwide ...continued

Table 1...continued.

Fast pyrolysis	Industrial	Units built	Max size kg/h	Research	Max size kg/h
Centrifuge				Technical U. Denmark	nk
Ablative	PyTec, Germany	2	250	Aston U., UK Institute of Engineering Thermophysics, Ukraine Latvian State Institute, Latvia Technical U. Denmark	20 15 0.15 1.5
Auger or Screw	Abritech, Canada Lurgi LR, Germany Renewable Oil Intl, USA	4 1 4	2083 500 200	Auburn U. USA KIT (FZK), Germany Mississippi State U., USA Michigan State U. USA Texas A&M U., USA	1.0 500 2 0.5 30
Radiative-Convective				CNRS – Nancy U., France	nk
Entrained flow				Dalian U. of Technology, China Institute for Wood Chemistry, Latvia Shandong University of Technology, China	nk nk 0.05
Microwave	Carbonscape New Zealand & UK Bioenergy 2020+ gmbh, Austria	nk 1	nk nk	Chinese Academy of Sciences, Dalian 116023, China National Inst. Advanced Industrial Sci. & Technol., Japan Shandong U. China Technical U. Vienna, Austria U. Malaysia Sarawak U. Minnesota, USA U. Mississippi, USA U. Nottingham, UK and China U. York, UK Washington State U.-Tricities, USA	nk <0.1 <0.1 nk <0.1 10 nk nk nk <1
Moving bed and fixed bed	Anhui Yineng Bio-energy Ltd., China	3	600	Anadolu University, Turkey U. Autònoma de Barcelona, Spain U. Science & Technology of China	nk nk ~0.5
Ceramic ball downflow				Shandong University of Technology, China	110
Unspecified				U. Kentucky, USA U. Texas, USA Technical U. Compiegne, France	nk nk nk
Vacuum	Pyrovac, Canada	1	3500	None known	
KEY				U. = University	

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Ghent University update

Wolter Prins of Ghent University Belgium outlines current pyrolysis projects and collaborations

Figure 1: Ghent University's mini-plant for catalytic fast pyrolysis was designed and constructed by Daan Assink of BTG (pictured above).

Introduction
Ghent University was founded in 1817 by William, Prince of Oranje Nassau. Today it attracts over 30,000 students and employs almost 900 teaching staff members plus a significant number of research assistants. The University forms an integral part of the network for European Universities and is active in many EU funded projects concerning both research and education. It has 11 faculties, amongst them the Bioscience Engineering Faculty. The faculty plays a leading role in the exchange of students within the EU (Erasmus program) and with the US.

A 25 million US$ biomass project ("Bio Base Europe") funded by the EU, Flanders and the Netherlands is being executed in the framework of a public-industrial collaboration called Ghent Bio-Energy Valley (see www.gbev.be). Recently, the University Board granted the faculty one of their five new spearhead projects (5.5 million US$), on the basis of evaluation by an international panel of experts. It includes biomass pyrolysis for the production of biochar, amongst others from residues of biological processes.

After a long career at the University of Twente and BTG Biomass Technology Group in Enschede, the Netherlands, Wolter Prins was appointed as of May 2008 in the Biosystems Engineering Group of UGent's Bioscience Engineering Faculty, to cover the field of Bioresources Processing. He is a chemical engineer with a long track record in process technology research in general, and biomass conversion technology in particular. The development of the new Laboratory for Thermochemical Biomass Conversion (LTBC) is now well underway with a total

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Ghent University update...continued

Topic	Parties	Contract value (x 10^3 US dollars)
Catalytic pyrolysis: mini-plant operation	Albemarle Catalyst Company, Amsterdam, NL BTG, Enschede, NL University of Ghent, BE	Confidential
Catalytic micro-pyrolysis plus GC-FID analysis	ConocoPhilips Company, Houston, USA Iowa State University, Ames, USA University of Ghent, BE	300
Biochar production and analysis	Evonik Degussa GmbH, DE Interreg North Sea Region Programme, EU University of Ghent, BE	1000
Reactor and process development for torrefaction	Flemish biomaterials manufacturer, BE IWT, Brussels, BE University of Ghent, BE	Project under development

investment of almost 2 million US$ in infrastructure, equipment and personnel.

Projects and collaborations
Since May 2008 the activities have focused on:
1. acquiring funds;
2. constructing a laboratory suitable for high temperature research;
3. recruiting good research students.

Meanwhile there is a 100 square meter laboratory containing the usual furniture, plus four separate boxes allowing for safe mini-plant operations. Funds are available now to purchase equipment for KF titration, elemental analysis, micropyrolysis, TGA and GC-MS analysis. The projects on catalytic pyrolysis and biochar production (see table above), were started and publishable results are expected to become available soon. There are two vacancies, one for a tenure track position in thermochemical conversion of biomass (intended laboratory supervisor), and one for a PhD position in biochar research. Another vacancy (torrefaction PhD) is expected to become available by the end of this year.

Catalytic fast pyrolysis
When, in catalytic pyrolysis, the catalyst particles are mixed into the reactor together with the inert heat carrier (often sand), there is an immediate contact between the catalyst and pyrolysis products. Besides, in pyrolysis processes with a separate char combustor, the catalyst can be regenerated continuously (by coke burn off). Requirements are then that the particle properties of the catalyst should match those of the inert heat carrier while its activity should be maximal at the optimal fast pyrolysis temperature.

More flexibility regarding the design of the catalyst and the conditions of the catalytic treatment, is created when a separate reactor is installed in the pyrolysis vapour stream before the condenser. The latter procedure is mostly applied in research projects. In the project with Albemarle and BTG, a new experimental set-up (see figure 1 on page 21) will be used which allows:
1. the application of catalysis by partial replacement of the inert heat carrier (in various ratios) inside the pyrolysis reactor;
2. the catalytic treatment of the produced vapours prior to condensation.

This mini-plant for catalytic fast pyrolysis (up to 500 g/hr) has been designed and constructed by BTG who will also further provide support in the operation and maintenance. Catalysts screened by Albemarle will be used in continuous experiments to produce liquid samples large enough for adequate chemical analysis of all possible fractions.

The collaboration with ConocoPhillips Company and Iowa State University (Robert Brown's group) is focusing on the fundamentals of biomass decomposition, and how that is affected by naturally occurring catalysts. A new type of micro-pyrolyzer of CDS (supplier) will be used in combination with a GC-FID for rapid screening of multiple samples in a single run. Research assistants are

Continued on page 23

exchanged by the universities during the period of collaboration.

Biochar production and analysis

Despite the promises of biochar as a means of carbon sequestration and soil improvement, and the significant attention paid to the subject these days, little is known with respect to the optimal production conditions. In the process of determining the relationships between pyrolysis process conditions, biochar properties and soil amendment results, the research in Ghent makes a first step by characterizing biochar produced at both, conditions of slow and fast pyrolysis.

A small set up donated by the University of Twente, consists of a steel tube of 2.6cm internal diameter that can be inserted in a tightly fitting electric furnace. In case of slow pyrolysis, the tube is filled with a batch (typically 100g) of cylindrical biomass particles of about 3mm diameter. While heating the bed to the adjusted final temperature at approximately 15°C/min, a nitrogen flow of 1 L/min is passed through the fixed bed to remove the produced vapors. Variables are the final temperature, the residence time at this final temperature, and the biomass type. Generally the biomass particles (pine wood, green municipal waste, wheat straw, algae) were made by pelletizing pulverized material.

The characterization of biochar is meant to quickly predict its behaviour in soil conditions without actually conducting soil/plant studies. For an initial evaluation, the elemental and proximate analysis will be carried out, as well as an ash-content study and the determination of the BET surface area. Further analysis methods accelerating real-world soil and plant studies are conceivable.

Pending industrial permission, part of this work will be presented at the TCS 2010 Symposium in Ames - September 21st to 23rd, 2010. In May 2010, the available funds for biochar research increased significantly due to the approval of the University spearhead project and joining the EU-sponsored Interreg North Sea Region Programme.

Torrefaction technology

Torrefaction is the partial carbonization of biomass with the objective to get a charred product suitable for co-feeding coal fired combustion and gasification installations. The potential application is large due to the huge size of the coal based energy sector. In Belgium and the Netherlands, companies like Stramproy, Topell and 4Energy are planning to erect first installations up to 100,000 tons per year in collaboration with the power producers RWE/Essent and Electrabel.

A large biomaterials manufacturer in Flanders, is collecting a million tons of wood per year and looking for alternative applications in the bioenergy sector. Agreement has been achieved on a joint project with the University of Ghent concerning the development of torrefaction reactor and process technology. If approved by the Flemish government, the project will be started in January 2011.

Acknowledgements by the author

The challenge to start a new research group from scratch in an environment of agricultural and biological sciences is exciting. I am impressed by the support of my colleagues in the UGent faculty of Bioscience Engineering, and grateful for the financial assistance from the industries that took the risk of collaborating with me in such an early situation. Very practical assistance is provided continuously by the former colleagues at the University of Twente and BTG. The collaboration I was invited to take part in by Robert Brown of Iowa State University, is a very nice example of how I would like to work with my friends in the international biomass community.

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Hydrous Thermolysis of Biomass Production of Hodge Carbonyls and Oligomeric Lignin

A synopsis from Jan Piskorz and Piotr Majerski of Resource Transforms International in Canada

Introduction
Continuous, bench scale fast pyrolysis investigation was carried out to evaluate thermal behaviour of a variety of biomass feeds with an emphasis on obtaining realistic material balances. Yields of

- water of pyrolysis,
- oligomeric lignin,
- water-soluble chemicals,
- chars

were targeted.

Uniqueness of approach with thermal cracking of nature's main bio-polymers with a minimal molecular rearrangement as "explosive" release of those 'fragments' in a form of condensable smoke/ aerosol.

Experimental mode with fluid bed pyrolysis in the presence of steam i.e. hydrous conditions: ~500°C/, 1-2 second vapour residence time, ~0.5mm particle size, feed rate - 100g/h.

Target:

⇒Maximize yields of carbonyls and oligomeric lignin fragments

⇒Minimize dehydration reaction, suppressing soot and PAH's formation.

⇒Explore steam processing of lignocellulosics considering engineering advantages/ disadvantages.

⇒Obtain two distinct, stable liquid condensate fractions as main products.

Results
1. Carbohydrates Pyrolysis
The proof of the hydrous concept realized first by processing selected carbohydrates as glucose and sucrose-in-water solutions and cellulosic softwood pulp.

It is known that the thermal degradation of carbohydrates can lead to a variety of fission products, mostly carbonyls, bi-carbonyls and hydroxy-carbonyls (Hodge, 1953). These were quantified in this work.

Also found and/or detected: traces of furfurals, levoglucosan, glyceraldehyde (?), and as expected/ predicted:

Benzo(a)pyrene
<1 ppb for glucose degradation condensates.

- Microbiological testing done by Industrial Laboratories of Canada, 2001 on Hodge carbonyl solutions show no growth or negative growth for: yeast, mould, coliform, E. Coli, Staph. aureus, Clostridium perfringens PC, Listeria monocytogenes, Salmonella, Campylobacter, Streptococcus faecalis.
- Glucose pyrolysis was selected for commercial production of Hodge carbonyls in 2000. The bench scale results were fully confirmed on the 30kg/ h unit.

Figure 1: Semi Commercial Plant.

Hydroxyacetaldehyde
The key component of

Continued on page 25

Table 1: Hodge Carbonyls.

Yields wt% dry feed	Feed		
	Sucrose	Glucose	Bleached pulp, Tembec Cellulosics
Hydroxyacetaldehyde	34	57 - 62	18
Glyoxal	3.5	4.4	4.1
Methylglyoxal/glyceraldehyde	>1	3.3	>1
Acetol	2.5	2.3	2
Formaldehyde	11.5	8	5.1

Hydrous Thermolysis of Biomass Production of Hodge Carbonyls and Oligomeric Lignin...continued

carbohydrate thermal degradation and:

- The most reactive carbonyl participating in the formation of brown nitrogenous co-polymer - melanoidin (Maillard reaction, food chemistry);
- The key component of RNA;
- Pre-biotic, primordial soup component, detected in space, considered as the simplest sugar;
- Bi-functional, potential platform chemical (high temperature polymers, Fraunhofer Institute).

2. Lignocellulosics Pyrolysis
Also, acetic acid, levoglucosan, furfurals.

The experimentation switched to a 2kg/h unit (2009) to obtain bigger samples for analytical confirmations and for testing in some selective applications.

- Oligomeric lignin (water-insolubles), mostly lignin degradation products - molecular fragments of lignin polymer, 200 - 2000 Daltons, with most chemical functional groups like methoxy, carbonyl, hydroxyl preserved (Nicolaides, 1984) Oligomeric lignin could be considered as a humic acid precursor/analog.
- Humic matter – it is, arguably, the most important component of fertile soils. It forms in soils (over months, years) by microbial assisted degradation of native lignin.

The exact chemical structures of oligomeric lignin and humic acids have not been established due to macro-molecular complexities and varieties possible.

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Table 2: Key Components of Wood Pyrolysis Condensates.

Yields, wt% dry feed	Softwood mix: - fir-spruce from British Columbia	Hardwood, beech from Eastern Europe
Water soluble fraction:		
Hydroxyacetaldehyde	15	9.5
Glyoxal	1.4	2
Formaldehyde	2.4	2.5
Water insoluble fraction:		
Oligomeric lignin	22	22

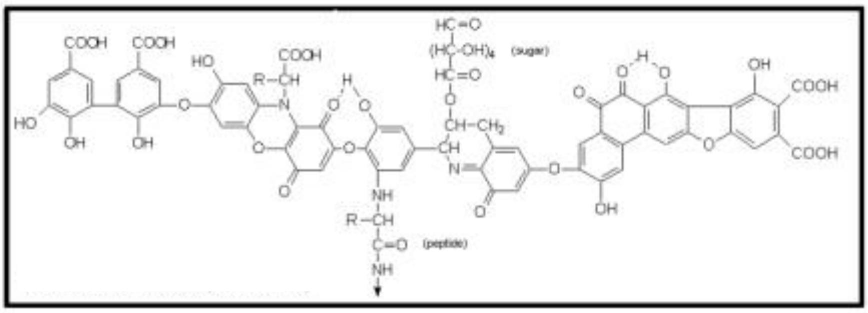

Figure 2: Model structure of humic acid (Stevenson 1982).

Figure 3: 2kg/h Pyrolyzer.

Table 3: Other Typical Results.

Biomass, feed	Corn Hulls	Sugar Cane Bagasse	Giant Reed	Willow Copice	Flax Straw	Oats Hulls	Switch Grass	Miscanthus	Corn Stover	Distiller's Grain	Flax Shives
Oligomeric Lignin	12	13.5	14	17	15	18	16	19	20	20	16
Char	11	12	14	12	15	13	14	13	15	17	16

Hydrous Thermolysis of Biomass Production of Hodge Carbonyls and Oligomeric Lignin...continued

The Concept of 4-letter Fertilizer
Combining oligomeric lignin - biochar matrix with commercially available mineral N, P, K fertilizers.

Variety of such N, P, K, C carbon containing compositions (under investigation) should sequester atmospheric carbon, prevent asphyxia of waterways, improve soil productivity.

Soils with depleted organic carbon (SOC): tropical, semi-arid, bad lands are in need of carbon component improvement.

As stated during the United Nations Convention to Combat Desertification, (UNCCD), "Poznan, Dec. 10, 2008":

The world's soils (although already much depleted by agricultural practises, - J.P.) hold more organic carbon than that held by the atmosphere as CO2 and vegetation".

As formulated by A. Laird, Agronomy J. Vol. 100, Issue 1, (2008):

"An integrated agricultural biomass-bioenergy system could make a significant contribution to both problems (competition of food and bio-energy production, J.P.) and have the added benefits of enhancing soil and water quality".

There is a need for a paradigm shift: how to design integrated agricultural biomass-bioenergy systems that build soil quality and increase productivity so that both food and bio-energy crops can be sustainably harvested.

The N, P, K, C fertilizer concept could have a positive feed back loop scenario: more SOC, more biomass for food and energy, and more SOC.

Engineering conclusions
Much improved overall simplicity of the whole processing system.

- No gas blowers/compressors required - elimination of the main troublesome parts of the whole operation.
- No poisonous/explosive gas in recirculation.
- Drastic reduction in size of condensing/recovery/ quenching vessels.
- No filters and no electrostatic precipitator required.
- No plugging and no pressure fluctuations.

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Table 4: Fast pyrolysis:- proposed, potential applications and main product streams.

	Energy	Agriculture	Green Chemistry
Water soluble, Hodge' carbonyls Typical yield: 35 - 45wt%	Hydrogen (S. Czernik, 2002)	Water-soluble polymeric fertilizers - melanoidins (after neutralization with ammonia, ureas...) Micro-nutrients carriers (Bio-Pirol, Brazil)	Chelating/complexing agents
	Synthesis gas (methane co-reforming)		Co-polymers based on hydroxyacetaldehyde dimer
	Gasoline Water-based catalysis (Huber, Dumesic, 2006)	Pesticides, anti-fungal and pathogen destruction agents (UWO)	Food aromas/browners Synthetic self-replicators
	Steam reforming towards synthesis gas (Arauzo, 2009)	Fumigation of tomato/strawberry pads	H_2S capture Cosmetics/embalmers
Oligomeric lignin Typical yield: 15 - 25wt%	Gasoline boosters Cyclo-paraffins (Piskorz, 1989) and UOP hydrogenation (2009)	SOC containing humus precursor N.P.K-C fertilizers	Resin modifiers/fillers
		Germination accelerators Seed coating	Anti-oxidants (ala pycnogenol, resveratrol, betulin...)
Bio-char Typical yield: 10 - 20wt%	Boilers, kilns,	Permanent fertilizer USDA ARS - reduced leaching of N and P (2008)	Absorbers
	metallurgy	Reduction of soil erosion. Loss of agrochemicals minimized (Laird, 2008)	Catalysts carriers

Country Update — Finland

VTT (Technical Research Centre of Finland)
In the new triennium, Anja Oasmaa of VTT is serving as the national team lead for Finland. At VTT, the biomass pyrolysis research is focused on three areas:

1. The industrial project supports the consortium of Metso Power, UPM Kymmene and Fortum in their effort to demonstrate pyrolysis oil production and long-term use.

2. The national Tekes project aims to create the basic tools for commercialization of pyrolysis oil production and use, for example the creation of standards and norms for pyrolysis oil production and use. This involves the work on REACH, co-operation with PNNL and Ensyn in their effort of establishing the ASTM standard, initialization of standardization in Europe under CEN, testing and modifying the standard fuel oil analyses developed for mineral oils, and validity of analytical methods for specifying fuel oil quality of pyrolysis oils.

3. In the EU BIOCOUP project, the focus is on the quality improvement of pyrolysis oil in order to upgrade pyrolysis oil into products which could be fed into the oil refinery.

Experiments are conducted in Metso's pilot plant, VTT's entrained bed pyrolyzer (20 kg/h), and VTT's 1 kg/h fluid bed unit.

Country Update — USA

Pacific Northwest National Laboratory (PNNL)
In the new triennium, Doug Elliott of PNNL is serving as both the Task 34 leader and the national team lead for the US. At PNNL, the biomass pyrolysis research is centered on the Pyrolysis Core R&D project funded by the Department of Energy (DOE). The project includes several task areas:

1. Bench-scale reactor studies involving both the 1 kg/h bubbling fluid-bed fast pyrolysis reactor and the fixed-bed catalytic hydrotreater. Bench-scale fast pyrolysis studies include both conventional and catalyzed fast pyrolysis. Of particular interest is an effort to study the particles in the product vapor to assess the particle composition and form (solid or liquid).

2. Supporting the effort to establish standards for bio-oil

3. Participating in the experimental work within the Task 34 collaborations.

4. Leading the effort in technoeconomic assessments for DOE related to pyrolysis.

In separate projects PNNL participates in the UOP-led effort in bio-oil stabilization. The PNNL contribution is in transfer hydrogenation and hydrothermal treatment. It is also a partner in UOP's Integrated Biorefinery project which will scale-up the hydroprocessing of bio-oil in conjunction with a 1 ton/day pyrolysis plant situated on the refinery site that Tesoro has in Hawaii. PNNL also co-leads the newly funded National Advanced Biofuels Consortium in which it plays a technical role in the topics of catalytic pyrolysis, hydropyrolysis and hydrothermal liquefaction.

Country Update — Germany

vTI-HTB (Chemistry)
The Johann Heinrich von Thünen Institute (vTI) is one of four German federal research institutes under the auspices of the German Federal Ministry of Food, Agriculture and Consumer Protection (BMELV). The vTI was created in 2008 from the German Federal Research Centre for Fisheries, the German Federal Research Centre for Forestry and Forest Products and part of the German Federal Agricultural Research Centre.

The vTI scientific work assists policymakers of the German federal government, and this combined with its application oriented and practice related research helps influence the development of tomorrow's society.

The Institute of Wood Technology and Wood Biology (HTB) is involved in several national and EU funded research projects related to the pyrolysis of wood and wood components. Research work focuses on analytical pyrolysis of biomass, lab-scale fast pyrolysis in a fluidized-bed reactor, upgrading of bio-oils by hydrotreatment in autoclaves and a small continuous catalyst test unit, and pyrolysis of lignins from biorefineries.

Furthermore, HTB has been developing methods for characterization and quantification of bio-oil components using wet chemical, spectroscopic and chromatographic methods. HTB helps in analysis of products from current German pyrolysis processes under development such as "bioliq" (KIT), "BTO" (PYTEC), and "SunDiesel" (CHOREN).

Country Update — UK

Aston University Bioenergy Research Group
In the new triennium, Tony Bridgwater of Aston University is serving as national team lead for the UK. He also leads one of the best established bioenergy research groups in Europe, the Aston University Bioenergy Research Group (BERG), which investigates all aspects of thermal processing of biomass and waste by fast pyrolysis and gasification. New research activities include:

1. "DIBANET"—an international project between the EU and Latin America. Its aim is to improve the state of art in the biorefining and pyrolysis of biomass in order to create sustainable second generation biofuels from wastes and residues that can be mixed with fossil diesel and used in a regular diesel engine.
2. "Bioliquids–CHP". This project includes partners from the EU and Russia and focuses on engine and turbine combustion for combined heat and power production. It aims to adapt engine and turbines to enable operation on a variety of bioliquids, including pyrolysis liquids.
3. "The Bio-oil Refinery project" aims to develop technology for bio-oil production and fractionation of bio-oil components for future establishment of a biorefinery producing green chemicals, transportation fuels and energy based on fast pyrolysis technology. The project consortium consists of partners from Norway and the UK.

Events

JUNE 2010

30th June - 1st July
AEBIOM European Bioenergy Conference at RENEXPO Bioenergy EUROPE
Brussels, Belgium

JULY 2010

12th - 15th
Pyrolysis 2010: 19th International Symposium on Analytical and Applied Pyrolysis
Montreal, Quebec, Canada

20th - 21st
Biomass '10 Renewable Power, Fuels and Chemicals Workshop
North Dakota, USA

AUGUST 2010

22th - 26th
American Chemical Society Fall 2010 National Meeting & Exposition
Boston, USA

28th Aug - 1st Sept
19th International Congress of Chemical and Process Engineering CHISA 2010 and the 7th European Congress of Chemical Engineering ECCE-7
Prague, Czech Republic

31st Aug - 4th Sept
Forest Bioenergy 2010
Tampere and Jämsä, Finland

SEPTEMBER 2010

13th
Training Course Biorefinery
De Zilveren Toren, Amsterdam, The Netherlands

13th - 15th
International Biomass Valorisation Congress
Regardz Zilveren Toren, Amsterdam, the Netherlands

13th - 14th
FAME 2010 - Premier Event For The Sustainable Fuel Industry
Intercontinental Hotel, Berlin, Germany

15th - 19th
14th International Biotechnology Symposium and Exhibition - Biotechnology for the Sustainability of Human Society
Palacongressi, Rimini – Italy

21st - 23rd
Bioten – Biomass, Bioenergy, Biofuels and Biorefineries
Birmingham, UK

21st - 23rd
TCS 2010 - Symposium on Thermal and Catalytic Sciences for Biofuels and Biobased Products
Iowa State University, USA

OCTOBER 2010

6th - 7th
European Bioenergy Expo and Conference
Stoneleigh Park, UK

7th – 10th
RENEXPO® 11th International Trade Fair for Renewable Energy & Energy Efficient Building and Renovation Messe
Augsburg, Germany

10th - 13th
10th International Workshop on Polymer Reaction Engineering
Hamburg, Germany

NOVEMBER 2010

10th - 11th
Innovation Towards Sustainable Materials
London, United Kingdom

DECEMBER 2010

13th - 15th
International Conference on Environment 2010
Malaysia

MARCH 2011

22nd - 24th
Nordic Wood Biorefinery Conference (NWBC)
Stockholm, Sweden

JUNE 2011

8th - 10th
RRB7 - International Conference on Renewable Resources and Biorefineries
Bruges, Belgium

21 - 23 September 2010

Birmingham city centre, UK

Biomass . Bioenergy . Biofuels . Biorefineries

This three day conference will bring together national and international experts on biomass, bioenergy, biofuels and biorefineries to engage the UK's bioenergy focused research community with stakeholders, policy makers and decision makers as well as promoting interaction between researchers.

The conference is sponsored by SUPERGEN Bioenergy which is funded by the Engineering and Physical Sciences Research Council; and the Energy Conversion Technology Subject Group of the Institution of Chemical Engineers UK.

Scope

Topics include but are not restricted to:

- **Biomass production**
- **Biomass pretreatment and preparation**
- **Biological conversion**
- **Biological products**
- **Thermal conversion**
- **Thermal conversion products**
- **Environment**
- **Socioeconomics**
- **System studies**
- **Policy**

Organiser

Tony Bridgwater - Technical Director SUPERGEN Bioenergy

Catherine Manhood & Rob Fenton — Event secretariat.

Location

The conference will be held at the Holiday Inn, Birmingham city centre, UK.

Registration and hotel booking

Visit **www.bioten.co.uk** or contact:

Catherine Manhood or Rob Fenton
Bioenergy Research Group,
Aston University,
Birmingham,
B4 7ET, UK.

Tel: +44 121 204 3420
+44 121 204 3071
Fax: +44 121 204 3680
Email: c.a.manhood@aston.ac.uk
r.fenton@aston.ac.uk

Please note: Early Bird booking rate available until 15th July 2010

www.bioten.co.uk

TCS 2010

Symposium on Thermal and Catalytic Sciences for Biofuels and Biobased Products

September 21–23, 2010

Iowa State University, United States

TCS2010 brings together leading scientists and engineers to share the latest advances in thermal and catalytic science for biofuels and biobased products.

This symposium, the year's largest gathering of researchers to discuss thermochemical biofuels, will offer a mix of informative plenary sessions with experts in the field, interactive breakout sessions, facility tours, and networking opportunities.

The Bioeconomy Institute of Iowa State University in the United States is lead sponsor, organizer, and host for the conference.

IOWA STATE UNIVERSITY

Symposium Topics:

- Feedstocks and pre-treatments for thermal and catalytic processing
- Science of fast pyrolysis, catalytic pyrolysis, and hydropyrolysis
- Bio-oil stabilization
- Non-fuel products from thermochemical processes
- Advances in gasification
- Advances in gas cleaning
- Catalysis for upgrading to liquid fuels
- Thermochemical process modeling, design and economics

Visit www.biorenew.iastate.edu/events for further information

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13 - 15 September 2010

Regardz Zilveren Toren
Amsterdam, the Netherlands

International Biomass Valorisation Congress

This edition of the International Biomass Valorisation congress will highlight the following themes:

13 September 2010:	**Training Course Biorefinery**
14 September 2010:	**Workshop Cellulose Ethanol**
	Workshop Regional Biomass Processing
	Workshop Biohydrogen
15 September 2010:	**Workshop Dimethyl Ether (DME)**
	Workshop Pyrolysis
	Workshop Co-fermentation

For more information about the training course or the International Biomass Valorisation Congress please contact: Ms. Mariëlle Brons on +31 348 484001 or email marielle.brons@dlg-benelux.com

www.biomass-valorisation.com

Further Information

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

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Past editions of PyNe newsletters are available on the website

www.pyne.co.uk

IEA Bioenergy

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