Welcome to ThermalNet

Introduction

We are pleased to present the first newsletter of ThermalNet – the latest network to provide a pan-European forum for thermal biomass conversion. This began with PyNe in 1995, followed by PyNe jointly with IEA Bioenergy in 1998, was extended to include gasification and GasNet in 2001 and extended once more to include combustion in 2005. This new network provides a forum to review and help resolve all the technical and non-technical barriers that may be encountered in implementing these three important biomass conversion technologies. The structure also provides a high level of interaction between the technologies and barriers so that all the technology areas can benefit from the experience and knowledge of the others.

Combustion is co-ordinated by Sjaak van Loo who also leads the IEA Bioenergy Combustion Task, gasification is coordinated by Herman Hofbauer and pyrolysis continues to be co-ordinated by Tony Bridgwater who also leads the IEA Bioenergy Pyrolysis Task.

As well as providing interactions with IEA Bioenergy, there are formal links with Eubionet2 and Bioenergy Network of Excellence to provide maximum benefits to the European bioenergy industry.

This new newsletter is a biannual joint publication for the whole Network to minimise duplication and costs and provide more comprehensive coverage of thermal conversion. The new website – www.thermalnet.co.uk – provides links to the individual technology websites and provides information on new events, activities, outputs from the Network and information on forthcoming ThermalNet events. We hope you like the new format and if you would like to contribute news or information, please contact Emily Wakefield at Aston University or any of the technology coordinators.

Comments and contributions are most welcome on any aspect of the contents. Please contact Emily Wakefield for further details or to send material.
Introduction
In co-operation with the Malaysian based Genting Sanyen Bhd, BTG Biomass Technology Group BV has completed the first pyrolysis plant based on rotating cone pyrolysis technology, in which Empty Fruit Bunches (EFB) are converted into pyrolysis oil (see Figure 1).

Usually, the wet EFB (moisture content of approximately 65 wt%) are combusted on-site yielding only ash which can be recycled to the oil palm plantations. The palm-mill produces about 6 t/hr of this wet EFB, and as a new alternative to combustion, the EFB can be converted into fast pyrolysis oil. Prior to feeding it into the pyrolysis plant, the EFB is comminuted and dried to a moisture content of about 5-10%. In this way, all the wet EFB from the palm is converted into approximately 1.2 t/hr pyrolysis oil.

Figure 1: Empty Fruit Bunches (EFB).

Figure 2: The conversion unit.
The pyrolysis plant was designed and built within 9 months in The Netherlands by BTG and Zeton. In January 2005 the plant was shipped to Malaysia and re-assembled. From April 2005 onwards the pyrolysis plant has been extensively tested, modified and optimised. The main achievements were:

- Significant improvement in overall plant reliability, including pretreatment section.
- Production of first batches of good quality pyrolysis oil from the dry EFB.
- Significant improvement in pyrolysis oil quality, with respect to water content and ash content. A consistent oil is produced with a typical water content of about 25 wt%.

The project has now entered the final stage of commissioning.

Indications of pyrolysis investment costs range from 2 to 3 M€ for a 2 t/hr installation. This broad range of costs is a consequence of uncertainties in location, means of control, type of feedstock, etc. The highly automated plant can be operated by two (trained) persons. The electrical consumption is below 150 kWe, and principally, all this electricity can be generated by the pyrolysis gas in an appropriate gas engine. Charcoal is used to supply the heat required by the plant. Additionally, it is expected that most of the heat for the drier can also be taken from the excess heat generated in the pyrolysis system.

Any party interested in green oil are welcome to talk with either BTG or Genting Bio-oil Sdn Bhd www.genting.com about their specific requirements. Deliveries of varying amounts can be made, from small amounts of 10 litres up to 20 to 100 tons or more.

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New Developments in Ablative Fast Pyrolysis at PYTEC, Germany

By Dietrich Meier, BFH-Institute for Wood Chemistry, Germany; Stefan Schoell and Hannes Klaubert, PYTEC, Germany

Introduction
PYTEC Thermochemische Anlagen GmbH, Lüneburg, Germany, has installed the first fast pyrolysis plant in Germany operating with an ablative pyrolyser. Inauguration of the plant was on 4th August 2005, with the Minister for Environment of Lower Saxony; Hannover in attendance, as his office is strongly supporting the pyrolysis project. Commissioning of the plant is envisaged for October 2005. Figure 1 shows an overall view of the new PYTEC site.

The plant is designed for 6 tonnes per day throughput of normal wood chips without prior grinding. Figure 2 shows the feed bin (blue container) and below the drum dryer. The chips fall from the top bin into the dryer and are then transported via a conveyor to the top of the pyrolyser where they enter the compactor unit. From here the chips are hydraulically pressed against a heated rotating disk which forms the heart of the plant. Figure 3 shows the insulated disc compartment. After collection and storage of the bio-oil it is burnt in the CHP plant (see Figure 4).

The special feature of the plant is that all system components are placed in standard containers in order to facilitate authorisation, transportation and assembly. The pyrolysis plant is erected at a saw mill site in Bülkau (near Cuxhaven, North Germany) which is producing roughly 100 tonnes per day of untreated waste wood chips.

An important milestone was reached by PYTEC in December 2004, when they continuously operated a modified 12 cylinder Mercedes-Benz CHP diesel engine on bio-oil for 12 hours (Figure 5). Only 4 vol.% of fossil diesel fuel was added. The bio-oil was delivered by FORTUM, Finland, and produced in their Forestera® plant. During the smooth engine operation, ca. 3 MW electricity (300-320 kWel/h) were produced and fed into the grid. No fouling of the motor parts could be observed. These results encouraged PYTEC to install the same CHP-type system at their ablative pyrolyser plant in Bülkau.

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Project Summary:
Utilizing the expertise developed in the earlier work, the research in this area since 2003 has involved testing innovative metal catalysts designed for use with the high-moisture environment of bio-oil. The combination of these catalysts with processing conditions better suited to bio-oil has led to new product slates through upgrading both whole bio-oil (from different biomasses and biorefinery residue, i.e. bagasse) and bio-oil fractions, such as pyrolytic lignin. Specifically, the project involves the process development of enabling technology for catalytic hydrogenation for converting bio-oil to value-added products. Basic chemistry studies are underway in bench-scale reactor systems to better understand catalytic effects on chemical mechanisms and kinetics for upgrading. Initial results have identified product fractions, which have value as chemical products, e.g. cyclohexanols and phenolics. In some cases, the product slates have properties more applicable to conventional petroleum refining operations. Specifically, such products were tested and found to be useful feedstock in conventional hydrocracking technology for production of hydrocarbon product streams.

Project Strategy:
The scope of work includes optimising processing conditions and demonstrating catalyst lifetime for catalyst formulations that are readily scaleable to commercial operations. We use a bench-scale, continuous-flow, packed-bed, catalytic, tubular reactor, which can be operated in the range of 100-400 mL/hr., from 50-400ºC and up to 20MPa (see Figure 1). With this unit we produce upgraded bio-oil from whole bio-oil or useful bio-oil fractions, specifically pyrolytic lignin. The product oils are fractionated, for example by distillation, for recovery of chemical product streams. Other products from our tests have been used in further testing in petroleum refining technology at UOP and fractionation for product recovery in our own lab. Further scale-up of the technology is envisioned and we will carry out or support process design efforts with industrial partners, such as UOP.

Recent Accomplishments:
A better understanding has been developed of the properties of current bio-oil products as produced with various catalyst metals over a range of processing conditions. Earlier process chemistry modelling carried out in batch reactor demonstrated some of that chemistry. The experiments in the continuous-flow catalytic reactor system have since verified those results. The products are being analysed by gas chromatography with mass spectrometric detector (GC-MS) and a flame ionisation detector (GC-FID), as well as carbon-13 nuclear magnetic resonance (NMR) analysis.

Future Plans:
In line with the support of the U.S. Department of Energy for the bio-refinery concept, evaluations will be carried out of new catalyst formulations and processing conditions for efficient conversion of bio-oil to value-added products. Catalyst lifetime issues will also be investigated. Sufficient hydrogenated product is generated so that product tests can be performed, including any required separation and purification.

Important reactions identified include:
- hydroxylacetalddehyde $\rightarrow$ ethylene glycol
- acetal $\rightarrow$ propylene glycol
- acetic acid $\rightarrow$ ethanol
- furfural $\rightarrow$ tetrahydrofuran-methanol
- methyl-hydroxycyclopentenone $\rightarrow$ methyl-cyclopentanone $\rightarrow$ methyl-cyclopentane
- isoeugenol and eugenol $\rightarrow$ 4-propyl-guaiacol
- acetovanillone $\rightarrow$ ethyl-guaiacol
- alkyl-(propyl, methyl, and ethyl) guaiacols $\rightarrow$ alkyl-methoxy-cyclohexanols $\rightarrow$ alkyl-cyclohexanols or to alkyl-phenols $\rightarrow$ alkyl-cyclohexanes
- oleic acid $\rightarrow$ stearic acid $\rightarrow$ heptadecane

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The third volume in the PyNe series is now available. This handbook provides a companion volume to the first and second handbooks and contains the following chapters:

1. The Pyrolysis Network PyNe.
2. Determination of Norms and Standards for Bio-oil as an alternative renewable fuel for electricity and heat production.
5. Biodegradability of Fast Pyrolysis Oil.
7. Applications of Biomass Fast Pyrolysis Oil.
9. The Science and Technology of Charcoal Production.

The first two volumes are also still available:

Published by CPL Press, Liberty House, The Enterprise Centre, New Greenham Park, Newbury, Berks, RG19 6HW.
Tel: +44 (0)1635 817408
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Web: www.cplpress.com

The book can be bought online at: http://www.cplbookshop.com/contents/C1836.htm
Iowa State University is leading a research consortium to develop a pyrolysis-based system that employs Cornstover for production of a nitrogen-rich, biologically active char that both enriches the soil and sequesters carbon from the atmosphere.

Cornstover - the part of a corn crop remaining in the field after harvest - is one of the largest biomass resources in the United States that could be marshalled into early service as feedstock for the production of bio-based products. The potential supply of this fibrous biomass in the United States is between 75 million and 230 million dry tons per year, depending on the intensity of crop production. Opinion is divided on exploiting this resource since corn tillage requires intensive use of inorganic fertilisers and some fraction of uncollected stover contributes to soil carbon.

The proposed fibre-to-fertiliser system would address these concerns by providing a renewable source of energy for production of nitrogen fertiliser while building soil carbon.

In this system concept, illustrated in Figure 1. Cornstover, or other fibred-rich agricultural residues, is collected and pyrolysed to yield fine, porous char (Figure 2) and energy-rich bio-oil (Figure 3). The bio-oil, which can be thought of as densified biomass, is transported by tanker truck to a central facility for steam reforming to hydrogen; followed by some part of it being converted to anhydrous ammonia (the process yields excess hydrogen for other applications). Using existing infrastructure of the agricultural fertiliser industry, anhydrous ammonia is transported back to the distributed pre-processing facilities where it is reacted with carbon dioxide, water, and char, which are byproducts from pyrolysis of biomass, to yield ammonia bicarbonate (NH$_4$HCO$_3$) precipitated within the pores of the char. The nitrogen-rich char is injected into the soil where it serves three purposes: nitrogen fertiliser, biologically-active soil amendment, and a means for sequestering carbon from the atmosphere.

Continued overleaf...
Background

The idea of using char to enrich soils originates from studies of Terra Preta soils in the Amazon Basin of South America. These anthropogenic soils were created by the gradual addition of charcoal to the soil by pre-Columbian indigenous people. A number of investigations show these soils to have remarkably enhanced fertility compared to untreated soils in the same locations, which is thought to arise from increased biological activity within the porous char. Furthermore, this carbon appears to have been stably sequestered as soil organic matter (SOM) for hundreds of years.

In this system, the farmer provides the energy to manufacture the fertiliser required for his own farm, with substantial benefits to both farmer and the environment. A 250 ha farm in corn production would save 1,000 GJ of natural gas annually by using stover to manufacture ammonia and would avoid releasing 57 t of CO₂ into the atmosphere. For supplying stover to the fertiliser manufacturer, the farmer would also receive a fuel credit equal to about 50% of the cost of anhydrous ammonia.

While switching from conventional tillage to no-till would sequester only about 280 t of carbon dioxide per year, the charcoal produced by this farm would effectively sequester 1,630 t of carbon dioxide—the annual tailpipe emissions from 330 automobiles. Although their value in the U.S. is only speculative at this time, the value of carbon credits in international markets averages about $3.50/t, or about $6,650 for a 250 ha farm.

Project

The team assembled for this investigation includes Iowa State University, National Renewable Energy Laboratory, Oak Ridge National Laboratory, the USDA ARS North Central Soil Conservation Research Laboratory, Cargill Corporation, and Epri. The goals of this project include controlling pyrolysis conditions to achieve optimum mass fractions of bio-oil, char, and gas for production of fertiliser; improving steam reforming of bio-oil to obtain hydrogen for synthesis of anhydrous ammonia; synthesising ammonium bicarbonate-impregnated char with desirable agronomic properties; establishing the carbon sequestration potential of the proposed N-rich char fertiliser; evaluating the corn yield response to the application of different amounts of nitrogen-char fertiliser to soils; and evaluating the economic performance of the proposed fertiliser system.

The U.S. Department of Agriculture recently announced its intent to support this work as a three year project (http://www.usda.gov/wps/portal/ut/p/_s.7_0_A/7_0_1OB?contentidonly=true&contentid=2005/10/0426.xml). Additional support comes from the Iowa Energy Center and Iowa State University.

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References

Biotox – Bio-oil Toxicity Assessment

By Joel Blin & Philippe Girard, Cirad, France

Objectives
The project has screened a total of 21 bio-oils from a wide variety of technologies, feedstocks and production conditions for their impact on the environment and on humans. A representative oil was then subjected to a comprehensive assessment of the toxicity and eco-toxicity in order to compile a dossier for formal notification and an authoritative MSDS.

Samples screened
Samples were produced from different pyrolysis reactors (fluid bed, rotating cone, circulating fluid bed, ablative pyrolysis, vacuum pyrolysis, slow pyrolysis), under different temperature conditions (450 to 600°C), and from different biomass types (forest residues, wood chips, energy crops). These bio-oils were then chemically and physically characterised and their biodegradability and evaluation of toxicity were assessed in screening tests.

Based on the screening tests results, a suitable bio-oil sample was selected for a complete set of toxicological and eco-toxicological analysis, which is still ongoing. Results of these mandatory tests, required by the EU legal authorities, were used to draw up the MSDS safety procedure and guidelines for bio-oils usage and transport preparation, as well as recommendations on the best operating conditions to be used to obtain environmentally friendly products.

Screening tests
Details of all analytical tests performed on the fourteen bio-oils are summarised in Table 1.

Table 1 – Analytical tests carried out on bio-oils.

<table>
<thead>
<tr>
<th>Type of study</th>
<th>Detailed analysis</th>
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<tbody>
<tr>
<td>Physico chemical</td>
<td>Chemical composition</td>
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<tr>
<td></td>
<td>Viscosity (at 20 &amp; 50°C)</td>
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<td>pH</td>
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<td>Density</td>
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<td>Stability</td>
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<td>Solids content</td>
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<td>Water insoluble content</td>
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<td>TOXOCological</td>
<td>PAH</td>
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<tr>
<td>Eco-toxicological</td>
<td>Elemental Analysis C,H,N &amp; O</td>
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<tr>
<td>Biodegradability study</td>
<td>Bacterial reverse mutation test</td>
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<td></td>
<td>Algal growth inhibition test</td>
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<tr>
<td></td>
<td>Acute toxicity in Daphnia Magna</td>
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<td></td>
<td>Modified Sturm test</td>
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Results of the physicochemical tests
Most of the oils showed typical characteristics of fast pyrolysis liquids: the water contents were in the range of 22 to 30%; density was around the normal value of 1.2 g cm⁻³; the solid content varied between 0.03 to 2.5%.

The gas chromatographic results show that a maximum of 28.7 wt% of the whole bio-oil could be identified by GC corresponding to 70-80% of the total GC-peak area. The identified single components were clustered into different chemical groups (see Figure 1 overleaf), of which acids, phenols, and sugars dominated. The variation of these groups within the oils is quite substantial and reflects the different processing parameters such as pyrolysis techniques and condensation modes.

The oils produced with the longest vapour residence times, exhibit the highest PAH values. The same is true for fractionated vacuum pyrolysis oil. The latter has the highest PAH content of 104 ppm. The other PAH levels vary between 23 and 3 ppm. The reason for the large variation is not yet clear, but it appears that temperatures higher and lower than 500°C tend to give high PAH concentration.

Continued overleaf...
Results of the Toxicological tests

All toxicological and eco-toxicological were carried out on the water soluble components of the samples provided.

An Ames test for mutagenicity was carried out for all the bio-oils using five strains of bacteria. In all cases, there was at least one test for a Salmonella typhimurium strain where the increase in number of revertants reached the level specified in international regulations to be considered as a positive mutagenic result. Based on these results all bio-oils must be considered to be mutagenic.

Results of the Eco-toxicological screening tests

The toxicity of bio-oil to daphnia magna was studied, and showed that bio-oils have a weak or nil eco-toxicological effect. The Algal growth inhibition study demonstrated a very rare effect of fast pyrolysis oils on the unicellular green algal: low concentrations of bio-oils in the medium had a fertiliser effect, increasing algal growth, and high concentrations of bio-oils induced an inhibition of algal growth. The Acute toxicity in daphnia magna study demonstrates that bio-oils have no toxicological effect on small animals.

Complete set of toxicological and eco-toxicological tests

Based on the screening tests results and the experience of the partners, the following parameters were selected to produce the representative sample for the full toxicological and eco-toxicological tests:

- A temperature of 500°C: based on the results of the chemical analysis which determined the best pyrolysis temperature around 500°C to minimise the PAH level
- Spruce feedstock: soft wood is a typical European biomass
- Fluidised bed process: this is the common industrial process used for bio-oil production.

The necessary full toxicological and eco-toxicological tests for notification are currently being finalised by CIT and are listed in Table 2 (on next page).
Table 2 – Full toxicological and eco-toxicological tests.

<table>
<thead>
<tr>
<th>Study title</th>
<th>Physico-chemical properties</th>
<th>Toxicological studies</th>
<th>Eco-toxicological study</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A6 / Water solubility</td>
<td>B1 tris / Oral route - rat</td>
<td>C2 / Acute toxicity in daphnia magna</td>
</tr>
<tr>
<td></td>
<td>A8 / Estimation of the partition coefficient</td>
<td>B3 / Cutaneous - rat</td>
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<td></td>
<td>A14 / Explosive properties</td>
<td>B4 / Cutaneous - rabbit</td>
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<td>B5 / Eye irritation - rabbit</td>
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<td>B6 / LLNA</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>TSR / 7-day study oral route in rats</td>
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<td></td>
<td></td>
<td>MAS / Micronucleus test in vivo</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>MNV / Micronucleus test in vitro</td>
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Outcomes

- The results of the full characterisation of the bio-oil are to be used to establish a definitive Materials Safety Data Sheet (MSDS) and to set up the dossier which could be used to complete a dossier for a future full notification under REACH.
- This MSDS sheet will be published on the PyNe website (www.pyne.co.uk)
- Fast pyrolysis bio-oils appear to offer no eco-toxicological effects
- Fast pyrolysis oils appear to have a slight mutagenic effect, but appear overall to be less harmful than conventional diesel fuel.
- The detailed biodegradability results will be published in the next issue of PyNe.
- Protocols used for these tests, full results, and the dossier for notification will be available shortly on the PyNe Website
- This project has been conducted with the EU support and through support from all bio-oil producers.

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Advances in Dry Distillation Technology

By Peter Fransham, Advanced Biorefinery Inc., Canada

Background

Advanced BioRefinery Inc. (ABRI) is the new name for the former Encon Enterprises Inc. In the late 1980’s and early 90’s Encon experimented with fluidised bed pyrolysis systems. A 200 kg/hr mobile pyrolysis unit was constructed on a standard drop deck trailer with the intention of converting Newfoundland peat moss to liquid fuels. The system was tested extensively until 1994 when it became evident that design limitations precluded the scale-up to a commercial size. In 1994, Encon started working with heated augers to drive off wood preservatives from salvaged utility poles. A bench scale unit was built and tested with positive results. While it is possible to drive off volatile matter with a hot shell auger, scale-up becomes impractical on account of heat transfer limitations through the auger shell. Perhaps the most impressive outcome of the experiments was the potential recovery of upards of 60% by weight of quality bio-liquid at reactor temperatures around 400°C.

Continued overleaf...
Process development
To overcome energy transfer limitations through the auger shell, a hot, high-density heat carrier is mixed with the biomass in the mixing auger. The volatile matter is rapidly driven off and immediately condensed. The system is therefore inherently different from sand transport bed and fluid bed reactors in that the hot vapours are rapidly removed from the char. Bench scale testing has shown that all of the volatile matter can be efficiently driven off from the biomass at approximately 380°C. The lower reactor temperature also limits secondary reactions prior to condensation. No sweep gas is required thereby eliminating the need for large blowers to move the sand heat carrier. The system has wide turndown capabilities and can operate over a range of temperature and residence time. The overall system is greatly simplified and overall capital costs are significantly reduced.

Current status
ABRI has evolved since the early days of fluid bed technology. A 5 dry tonne per day (dtpd) mobile system has been constructed and is operational at a large chicken farm in Alabama. A 15 dtpd plant is waiting for permission to be completed and will be set up at a saw mill in Massachusetts. ABRI has departed from conventional thinking that big is better and is presently commissioning its 1 dtpd system for on-farm use. Figure 1 shows the system complete with a chain flail dryer and pyrolysis system. The option to burn char in a furnace has been included. Currently the process gas is flared, but ultimately ABRI plans to use to gas to provide the necessary electricity to run the plant. The char provides the necessary heat for drying and conversion. More char is produced than is required for the process and work is underway to concentrate nitrogen in the char and provide a viable fertiliser. Poultry feed contains fat and therefore the liquid produced has a higher calorific value than woody biomass. A boiler is presently being designed and constructed to burn the bio-liquids and provide heat for the poultry barns. Natural Resources Canada and Agriculture Canada are providing funding for this project.

ABRI is also constructing a transportable 50 dtpd plant for onsite management of logging wastes. The plant is made up of seven skids and can be transported to the biomass. The 50 dtpd plant is slated for shakedown testing during the second quarter of 2006 and will likely see service in the field sometime later in the summer. The bio-liquids will be shipped to a pulp and paper mill and will be used to offset combustion of expensive natural gas. Ontario Ministry of Natural Resources and Industrial partners are funding this three year pilot study as part of an overall effort by the Ontario Government to increase the utilisation of forest resources.

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Figure 1: One tonne per day mobile pyrolysis unit.
The Renewgen process is the miniaturisation, optimisation and computer control of a wood charcoal based biorefinery. This low temperature pyrolysis of wood (such as slash, SDU (Small Diameter Underutilised) and pine beetle infested) is a continuous process. It can yield up to 33% of wood charcoal for fuel and activated carbon. Much more importantly, the process can yield significant amounts of methanol, acetic acid and tars.

Up to now, most wood charcoal manufacturing processes in forestry clear cuts have either utilised the product gas stream as fuel for the carbonisation process or flared it. Only large and centralised wood charcoal process plants are designed to utilise the product gas stream for further processing.

The innovation of the Renewgen process is the utilisation of the product gas to dry incoming feed as well as to collect and store the gas from several skid-based portable processes in a typical forestry clearcut. The gas can be delivered to a central processing plant for conversion and/or recovery to yield methanol, acetic acid and other fractions.

In a typical forestry clear cut, the slash and other undesirable biomass, such as SDU or pine beetle infested timber is left to dry and then burnt in piles.

This slashburning process is a pre-requisite step to silviculture and regulatory forest fire prevention measures. Silviculture is itself a pre-requisite step to forestry road de-commissioning and stream and wetland rehabilitation. The field based portable wood charcoal bio-refinery not only speeds up several stages in forest harvesting practices, but also yields valuable products.

Renewgen has initiated evaluation of the Lurgi methanol to propylene process (a building block with 6% annual increase in demand). In addition, Renewgen is currently evaluating the Lambotte & Cie SA processes that develop a set of products from methanol to formaldehyde which leads to a family of acetal solvents and eventually aerosols, cosmetics and resins.
Biomass gasification is a promising technology, which has the potential to make a significant contribution to the development of tomorrow’s energy systems. To this end, however, renewability and conversion efficiency must be supplemented by operational safety as well as environmental compliance, in order to attract investors and bring biomass gasification to the stage of broad commercialisation. Today, health, safety and environmental (HSE) issues are recognised as a major barrier in the deployment of the technology, since dealing with HSE risks currently lacks adequate understanding by virtually all actors involved. The judgement of risk along with precautionary measures and effective counteraction in cases of emergency must therefore be systematically analysed.

For these reasons, both task 33 of IEA Bioenergy (Thermal Gasification of Biomass) and GasNet health, safety and environmental aspects of biomass gasification have received growing attention. In a joint effort, IEA Bioenergy and GasNet aim to create awareness of HSE issues, with the goal of eventually establishing a “state of the art procedure” to assess and improve operational safety and long-term reliability of gasification plants. To this end, it was decided to organise a joint workshop, which would review the status quo of HSE and interrelated aspects in biomass gasification, collect and organise existing information, as well as enhance mutual understanding of manufacturers, permitting authorities, engineers and scientists.

Concerning the scope of discussion, the investigation of biomass gasification plants up to a thermal power of up to 5 MW was chosen.

The workshop was held at the Hilton Innsbruck on September 28, 2005 to coincide with the last ThermalNet meeting. Contributions from various European countries addressed topics ranging from the impact of gaseous emissions, liquid waste formation, treatment and avoidance, as well as risk assessments to aspects concerning the legal basis and required documentation for permitting procedures. The workshop was split into three sessions, including presentations and panel discussions.
Especially within these panel discussions, much insight into the actual problems of producers and operators of gasification facilities was gained and future activities were addressed. Specifically in relation to gaseous emissions such as CO and NO\textsubscript{2} regulations differ within Europe. While strict limits certainly prevent environmental harm, they severely restrict the commercialisation of gasification plants, as cleaning requirements may have negative effects on profitability. Moreover, the discussion showed that complete knowledge of the exact damage gaseous emissions cause to the environment is scarce and that analytical methods currently in use may need revision in the future.

Similarly, there was consensus on the expediency of concise and clear standards concerning risk management of gasification plants. In addition, adequate documentation on permitting requirements which could be utilised by operators and producers and thus facilitate commissioning, is not currently easily available or accessible. Since risk is difficult to standardise, documentation is typically either incomplete or voluminous and therefore hard to use. However, as more gasification plants enter large-scale operation, authorities will become more familiar with the technology and knowledge of both risk assessment as well as permission requirements, which will therefore become more easily available, giving further impetus to the commercialisation of this promising technology.

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I/S Skive Fjernvarme - Skive district heating company
I/S Skive Fjernvarme is a non-profit energy company owned by Skive municipality in Denmark, supplying more than 2,600 consumers in the Skive area with district heat and electricity. The yearly amount of heat sold is 114 GWh and electricity 58 GWh.

I/S Skive Fjernvarme is installing a new biomass fuelled CHP plant producing 5.5 MW electricity and 11.5 MW district heat. The new biomass fueled CHP plant is a Biomass Gasification Gas Engine (BGGE) plant based on Carbona low-pressure fluidised bed gasification and gas-engine. One Gasification Plant supplies three gas-engines with biomass derived fuel gas.

Project Basis
The heat production from the new biomass CHP plant will amount to 70% of the annual heating production of I/S Skive Fjernvarme and in addition, it will produce 40 GWh “green” electricity per year based on CO₂ neutral renewable energy.

The incentive to build BGGE plant in Skive is to increase heat and electricity production from renewable sources. In small scale, the electrical efficiency has to be maximised to make the generation feasible, therefore a novel process concept was selected by Skive. The ultimate goal for this technology with the help of this project is to be competitive on the liberalised electricity market.

Project Participants
I/S Skive Fjernvarme acts as the main contractor in the project having the responsibility to integrate the various parts of the plant to act as an entire CHP-plant (Combined Heat and Power plant).

Carboma Inc. will provide the Gasification Plant for the project. The Gasification Plant includes fuel feeding, gasification, gas cleaning (tar reforming catalyst and filter), gas cooling and distribution.

The Technical Research Center of Finland (VTT) acting as the subcontractor of Carbona Inc. will participate in the tar reformer design and testing of the Gasification Plant.

Other main subcontractors of Skive Fjernvarme are GE Jenbacher GmbH to provide the gas engines, Bruun & Sorensen A/S for district heat and power generation and Rambøll Group for the building and plant erection and Aaen Consulting Engineers as owner’s engineer.

Project Financing
The project is financed on commercial basis. However, since the plant will be the first of its kind, a demonstration-plant, subsidies are available from the European Union, from the Department of Energy (DOE/USA) and the Danish Energy Agency (DEA).
Process Description
The Gasification Plant includes fuel feeding and gasification and gas treatment (gas cooling, cleaning and distribution) sub-processes.

Fuel, which is wood pellets, is supplied from the existing indoor wood pellet storage next to the gasification plant and is fed by feeding screws into the gasifier, to the lower section of the fluidized bed. Air is used as gasification medium. The product gas generated in the gasifier contains carbon monoxide (CO), hydrogen (H₂) and methane (CH₄) as main combustible components. The gas also contains a small amount of heavy hydrocarbons – tar – which has to be removed by a novel tar cracking/reforming system. This has been developed and tested together with VTT in pilot plants and at a commercial biomass gasification plant in Finland.

After tar reforming, the product gas is partly cooled in a gas cooler. The cooling medium is district heating water. The gas cooler is followed by a bag filter unit, which separates the remaining fine dust passing through the cyclone of the gasifier. In normal operation, the filtered product gas is directed after further conditioning to the gas engines. Gas can also be combusted in two gas boilers or in the flare.

The gas engines drive the generators producing electricity. The heat of gas engine cooling (lubrication oil and jacket cooling) and the gas engine exhaust gas is recovered, producing district heat in separate heat exchangers.

Process Performance
The nominal capacity of the CHP plant is 11.5 MW district heat and 5.5 MW electrical capacity but the plant can be operated at a wide turndown area. The daily capacity of the CHP plant is determined by the heat demand of the district heating network.

The overall plant performance with nominal capacity is as follows:

<table>
<thead>
<tr>
<th>Fuel consumption</th>
<th>t/h</th>
<th>4.13</th>
</tr>
</thead>
<tbody>
<tr>
<td>Net Power generation</td>
<td>kW</td>
<td>5400</td>
</tr>
<tr>
<td>Net District Heating (50/94°C)</td>
<td>kJ/s</td>
<td>11393</td>
</tr>
</tbody>
</table>

Project status
The environmental and other permits were completed by the end of March 2005. The groundbreaking ceremony took place on the site on April 11, 2005. The plant construction was started by building the 4000 m³ hot water accumulator tank. The gasification equipment installation started in October 2005 and will continue into spring 2006. The plant is scheduled to start operation in mid 2006.

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An extensive economic evaluation of biomass gasification was carried out, by calculating the electricity production costs for different gasification technologies at a scale of 20 MWel, gas cleaning concepts and gas conversion technologies. An evaluation basis has been defined to obtain comparable results.

**Evaluation basis**

To evaluate different concepts economically, the interest rate was calculated on a cash-flow basis, assuming an utilisation period for the plants of 13 years. The rate of interest was chosen in conformity with other techno-economic assessments at 6%. The evaluation was based on the net electric efficiency of the plants. The inflation rate was fixed at 2%. Commissioning of the plant is assumed in the year 2006, with the same interest rate (6%) during the construction. For plants operating in CHP-mode, 6000 full load operation hours/a are assumed for electricity production, whereas only 4000 hours/a are assumed for heat production. The district heat feed in tariffs are fixed at 20€/MWh. As fuel forest wood with a price of 14€/MWh was chosen as fuel.

The maintenance costs are assumed to be 2% of the investment costs, insurance costs to be 1% and additional costs (tax, inspection, etc.) to be 0.75% of the investment costs per year. The final investment costs are increased by the percentage of unexpected costs, which accounts for possible risks during the construction of the plant. This percentage is chosen as 8% of the final investment costs.

The economic evaluation of the gasification concepts for power production indicate that electricity production costs of 70 – 110€/MWh can be achieved by gasification based biomass conversion technologies, compared to 75 – 100€/MWh using a conventional combustion based steam cycle. In general gasification concepts based on a gas engine showed lower electricity production costs than gas turbine based concepts. Of major influence on the economy of the evaluated concepts are the costs for the applied feedstock.

To give an impression of the competitiveness of the gasification concepts the calculated electricity production costs are compared to other renewable technologies using literature values in Figure 1. The light greyblue bars on the top represent thereby the range of the electricity production costs.

Power generation by photovoltaic (350 – 440€/MWh) represents the most expensive form of energy production followed by the geothermic power production (160 – 220€/MWh) and wind power (48 – 84€/MWh). Both generation methods have higher electricity production costs than the biomass based technologies. The lowest production costs can be achieved by hydropower (49 – 73€/MWh) and wind power (48 – 84€/MWh). The evaluated biomass technologies, based on a steam cycle and gasification, achieve electricity production costs, which are on average 25€/MWh more expensive than wind or hydro based generation technologies.

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Green Electricity from Biomass Fuelled Producer Gas Engine

P J Paul, S Dasappa, Bangalore, India

Open top re-burn downdraft biomass gasification technology developed at the Indian Institute of Science (IISc), Bangalore has entered the era of commercial operations. This is established by the fact that more than 35 plants are successfully operating in India for heat and power applications. In the field of power generation, there has been substantial effort in the development of producer gas engine; systematic experimental and modelling studies followed by long duration field monitoring. As part of this effort, a gas carburettor has been designed for producer gas fuel and forms a part of the power package. Currently there are more than a dozen operational gas engines.

The plant is operated by Bagavathi Biopower Private Limited and was supplied and installed by Energreen Power Limited, Chennai. The power plant is configured with a 150 kg/hr gasifier coupled with a GTA855G (Cummins) gas engine. The plant is also provided with an effluent treatment plant and an engine-waste-heat based biomass drier. The plant, commissioned in September 2003, has successfully completed over 7200 hours of operation (up until April 2005) of operation. It took about three months to stabilise the plant operations; subsequently the plant has been operating 24 hours per day, 6 days a week at an average load of 110 – 125 kWe, with a peak load of 134 kWe.

Continued overleaf...
The woody biomass is Julifora Prosopsis. The specific consumption is 1.1 to 1.2 kg/kWh. In addition to electricity, partially activated carbon is also produced at 6-8% of biomass fed. The carbon has a typical iodine number of 500 – 550 and is understood to have a market value of 0.5 USD/kg. With additional processing, this product has the potential to provide additional revenue to the operator and thereby lower the unit cost of electricity generation.

The gas engine is being jointly monitored by IISc and Cummins India and periodically inspected once every 1000 hours of operation. These inspections have shown the engine components (throttle valve, compressor of turbo-charger, after-cooler, intake manifold, intake valves and spark plug) to be clean and intact. Similarly the lubricating oil quality has been found to be satisfactory from the reports of the engine manufacturer.

The tar and particulate matter amount to less than 50-60 microgram/Nm$^3$. Measurement of the engine exhaust has shown the CO and NO$_x$ levels to be much lower than most of the emission norms of various countries. More details on the technical performance can be obtained from the website (address as below).

The current operating cost (fuel + manpower + maintenance) is about 5 US cents per kWh with return on investment at about 15 to 20%. The plant has received financial assistance under the subsidy programme of the Ministry for Non-Conventional Energy Sources (MNES), Government of India. The research and development effort at IISc, which is the backbone of commercial activities, has been substantially supported by MNES.

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Performance of a flexible CHP Gasification Plant

By Dr. Kasper Lundtorp, Babcock & Wilcox Vølund ApS, Denmark

Since 1988 Babcock & Wilcox Vølund ApS has been active in the field of gasification, focusing on updraft gasification of biomass, and has recently licensed its gasification technology to the Japanese company JFE Engineering Corporation. Figure 1 shows the 1 MWth CHP plant in the village Harboøre.

The Harboøre plant can be divided into the following main components:

- 4 MWth updraft gasifier with fuel feed, ash system, and air humidifier.
- Gas cooling and cleaning system.
- Two Jenbacher gas engines with generators and exhaust boilers.
- Tarwatc system (tar water cleaning system).
- Heavy tar fired boiler with storage tank for heavy tar.

The Harboøre plant has been in operation with heat production since 1996, and it has been operating with power production since the year 2000. The gasifier has now been operating for more than 80,000 hours and the engines have more than 20,000 hours of operation. In 2003 a comprehensive performance test was made on the plant indicating the great flexibility of the Harboøre plant.

During the performance test, the load of the system was set to 1.0 MWe, which corresponds to a fuel input of 3.52 MW. The load and other operating parameters were set to equal an usual operation of the plant (summer months excluded).

During the test the composition of the product gas, the flow of the product gas, the exhaust gas from the gas engines, and the flue gas from the Tarwatc system were continuously registered. The flows of liquids from the gas cooler and cleaning system and Tarwatc system have been registered, sampled, and analysed. The performance test on the heavy tar fired boiler included sampling of the heavy tar, feed flow of heavy tar, flue gas composition and flue gas flow.

Continued overleaf...
Table 1. Specification of the wood chips used as fuel during the performance test.

<table>
<thead>
<tr>
<th>Unit</th>
<th>Wood chips</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuel flow</td>
<td>kg/h</td>
</tr>
<tr>
<td>Heating value (as received)</td>
<td>MJ/kg</td>
</tr>
<tr>
<td>Ash</td>
<td>% w/w(dry)</td>
</tr>
<tr>
<td>Water</td>
<td>% w/w</td>
</tr>
</tbody>
</table>

Table 2 shows the emissions from one of the gas engines, the Tarwatc system, and the heavy tar fired boiler. The figures are averages for the test period as mg/Nm$^3_{dry}$ at 10% O$_2$. A small proportion of the exhaust gas is lead through a catalyst to reduce CO emission. This has proven to reduce the CO emission from the prior level of 2200–2500 to 1488 mg/Nm$^3_{dry}$ at 10% O$_2$. The heavy tar has a water content of 7.6% (w/w) and a heating value of 29.9 MJ/kg.

Table 2. Emission data. The figures are averages for the test period as mg/Nm$^3_{dry}$ at 10% O$_2$.

<table>
<thead>
<tr>
<th></th>
<th>Gas engine</th>
<th>Tarwatc system</th>
<th>Heavy tar</th>
</tr>
</thead>
<tbody>
<tr>
<td>CH$_4$ – C</td>
<td>53.1</td>
<td>17.4</td>
<td>5.4</td>
</tr>
<tr>
<td>CO</td>
<td>1488</td>
<td>1023</td>
<td>492</td>
</tr>
<tr>
<td>NO$_x$ - NO</td>
<td>229</td>
<td>149</td>
<td>6.6</td>
</tr>
<tr>
<td>Dust</td>
<td>0.5</td>
<td>15.4</td>
<td></td>
</tr>
</tbody>
</table>

*pH is measured on-site with spot checks throughout the test period. COD: Chemical Oxygen Demand.*
Based on a fictive situation in which the heavy tar is combusted in the boiler with an efficiency of 91.5% and it is produced at the same rate in the gas cooling system. Table 3 shows the analysis results of the condensate from the Tarwatc system. The results are averages of 5 analysed samples. After neutralisation (just in case the condensate has a pH below 6) the condensate can be discharged to the sewer.

This results in a total net heat efficiency of 69.5%. 52.2% of this heat is produced from the product gas cooler, gas engines, Tarwatc, accumulated in the buffer tank in the Tarwatc system, and the heat used for heating the gasification air system. Additional 17.3% heat is produced from utilising the heavy tar in a boiler. The gross electricity produced was 1005 kW resulting into an electric efficiency of 28.6% for the engines.

The ash was analysed and had a content of TOC of 7g/kgdry, PAH of 0.43 mg/kgdry (mainly phenanthrene 0.14 mg/kgdry, and dioxin below detection limit (0.3 ng/kgdry for 1,2,3,7,8 PCDD).

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit</th>
<th>Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flow</td>
<td>m³/h</td>
<td>0.2</td>
</tr>
<tr>
<td>pH</td>
<td></td>
<td>4.9-7.1</td>
</tr>
<tr>
<td>COD</td>
<td>mg O₂/l</td>
<td>47</td>
</tr>
<tr>
<td>Acetic acid</td>
<td>mg/l</td>
<td>10</td>
</tr>
<tr>
<td>Formic acid</td>
<td>mg/l</td>
<td>2.3</td>
</tr>
<tr>
<td>Phenol</td>
<td>mg/l</td>
<td>39</td>
</tr>
<tr>
<td>Total N</td>
<td>mg/l</td>
<td>50</td>
</tr>
</tbody>
</table>

Advantages
As it can be seen from Table 4 the gasifier system offers flexibility with regard to heat and power production due to the possibility of storing or exporting approx. 17% of the energy output as heavy tar. Compared to a traditional combustion based boiler, the gasifier, in connection with gas engines, can operate down from almost zero load to 100% load in minutes. In its present operation the plant is running 100% load on the gas engines during the winter and using the heavy tar in cold periods. In the summer time the heat uptake in the village is very low, and the plant is running with heat production of 600-700kW and operating with a little less than 50% load at one of the gas engines. Hereby, the system’s ability to offer a flexible energy supply is illustrated with relatively high power efficiency even at e.g. 25% load and in compliance with the Kyoto protocol.

Table 4. Heat production of the Harboøre plant divided into individual components.

<table>
<thead>
<tr>
<th>Gas engines</th>
<th>Tarwatc</th>
<th>Heavy tar fired boiler*</th>
<th>Product gas cooler</th>
<th>Accumulated in Tarwatc buffers</th>
<th>Plants own consumption</th>
<th>Used to the gasification air</th>
<th>Produced in net total</th>
</tr>
</thead>
<tbody>
<tr>
<td>971 kW</td>
<td>725 kW</td>
<td>610 kW</td>
<td>373 kW</td>
<td>- 112 kW</td>
<td>22 kW</td>
<td>119 kW</td>
<td>2426 kW</td>
</tr>
</tbody>
</table>

Future improvements foreseen include:
- Automatisation and service planning.
- Condensing operation on the gas engine exhaust and heavy tar fired boiler.
- Optimisation of plants own consumption of electricity.
- Full size catalyst system on the gas engines.
- Gasification of the heavy tar, which potentially will raise the power efficiency of the total system to 31 - 32%.

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Summary

No suitable gasification process is available to convert biomass as such into synthesis gas. Moreover this would involve the uneconomical transport of biomass over large distances. Flash pyrolysis produces bio-oil that can be readily transported and converted in commercially proven units into synthesis gas for chemicals and fuel production.

Biomass is often considered as having the potential to supply a large part of the energy in a renewable world. It is unlikely this can be accomplished in an environmentally friendly manner, especially in view of biodiversity. However, it is certain that biomass is our only readily available source of carbon in any non-fossil fuel scenario.

Although some synthesis gas can be obtained by recycling organic chemicals, a substantial amount will have to come from biomass. Fortunately there is more than sufficient waste biomass to supply all the synthesis gas required for the production of all organic chemicals and a fair amount of liquid fuel.

Currently there is not one successful process available for the direct conversion of biomass into synthesis gas. This is not surprising because biomass as such can only be economically gasified in fluid bed gasifiers that operate at temperatures of about 900°C. Thermodynamically it is impossible to produce synthesis gas with a reasonable purity from biomass at such low temperatures. Entrained flow gasification implying slugging conditions is a no-go for biomass because pulverising and pressurising biomass is difficult and the ash is extremely aggressive towards refractories. Last but not least gasifiers for the production of synthesis gas require large throughputs that involve the transportation of biomass over large distances, which is uneconomical in the absence of cheap fossil fuel and/or subsidies. (See Figure 1).

The way out of this problem is to first produce bio-oil from biomass. This can be carried out economically in small capacity flash pyrolysis plants where the low energy dense biomass waste is converted into an energy dense transportable liquid: bio-oil. This virtually ash free liquid can be economically transported over large distances and gasified in industrially proven gasifiers from Texaco, Shell and Lurgi. These processes operate at temperatures of about 1350°C and at pressures of up to 80 bar and produce synthesis gas that after CO-shift conversion and acid gas removal can be used for the production of ammonia, methanol, Fischer-Tropsch liquids, etc.

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Figure 1: Gasifier configurations for bio-oil gasification.
Thermal processing of biomass has the potential to offer a major contribution in meeting the increasing demands of the bio-energy and renewable energy sectors, as well as meeting the targets set by the EC and member countries for CO₂ mitigation. Biomass gasification is considered one of the most promising routes for syngas production and combined heat and power production, because of the potential for higher efficiency cycles. Good technical progress has been made in the field of biomass gasification, but at a commercial level, good achievements still have to be attained.

International Networks like IEA Bioenergy and the Gasification Network, GasNet, have been established to provide a forum for the discussion, exchange and dissemination of information on new scientific and technological developments regarding biomass gasification and related technologies. Demonstration projects are reviewed to identify technical and non-technical issues that inhibit rapid and widespread implementation of gasification technologies. Results are disseminated through newsletters and websites.

Besides these instruments, a handbook has been published on biomass gasification, which is a compilation of topics and discussions within the GasNet network. International experts contributed with chapters on specific subjects. The hardback Handbook comprises a historical overview of gasification, practical aspects and status of gasification including gas cleaning, feeding and gas utilisation, health, safety and environmental aspects, and non-technical issues such as public perception, policies, standardisation and economics.

The handbook is intended to be a useful guideline both to newcomers and to those already involved in research, technology development, industry, policy development, investments and end-users. GasNet was clustered with the Pyrolysis Network, PyNe, in the ThermoNet project and both Networks will be continued for a second term, now also associated with the Combustion Network, CombNet. The three networks are collaborating in “ThermalNet” to maximise the benefits of integration. This may result in a second volume of the Handbook.

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Web: www.btgworld.com
“The inclusion of combustion into the well established PyNe and GasNet networks is a welcome and valuable addition.”

IEA Bioenergy Task 32 - Biomass Combustion and Cofiring

By Sjaak van Loo, Procede, Netherlands

Introduction

Of all thermochemical conversion technologies available for biomass, combustion can be regarded as the most widely applied option, with a global market share exceeding 90%. Commercial availability is high and there is a multitude of options for integration with existing infrastructure, varying from domestic woodstoves to cofiring at large coal fired power stations.

Task 32 aims to stimulate the expansion of the use of Biomass Combustion and Cofiring for the production of heat and power to a wider scale. Over the past years, a strong global network of industrial and university combustion experts has been formed, leading to successful collection and dissemination of knowledge and experiences.

With 11 member countries, Task 32 is currently one of the largest tasks within the Bioenergy Agreement. In addition to the European Commission, country participation includes Australia, Austria, Belgium, Canada, Denmark, Finland, Netherlands, Norway, New Zealand, Sweden, Switzerland, United Kingdom and USA. Task 32 regularly interacts in joint meetings with EU projects (including ThermalNet), other IEA Bioenergy activities (especially Task 33 and 36) and other IEA Implementing Agreements (IEA Fluid Bed Conversion, IEA Coal Combustion Science and IEA Coal Research).

During the past years, Task 32 has generated a wealth of knowledge that contributes to further development and implementation of biomass combustion and cofiring systems in its member countries. This includes workshops on certain technical and non-technical combustion related topics such as aerosols emissions and cofiring, specific studies and a Handbook of Biomass Combustion and Cofiring.

Increasing interest in biomass/coal cofiring

During the last 5-10 years, cofiring biomass with coal has received increased attention globally as it capitalises on the large investment and infrastructure associated with the existing fossil-fuel-based power systems, while requiring only a relatively modest investment to include a fraction of biomass in the fuel. When proper choices of biomass, coal, boiler design, and boiler operation are made, traditional pollutants (SO\textsubscript{x}, NO\textsubscript{x}, etc.) and net greenhouse gas (CO\textsubscript{2}, CH\textsubscript{4}, etc.) emissions decrease. Ancillary benefits include increased use of local resources for power, decreased demand for disposal of residues, and more effective use of resources. These advantages can be realised in the near future with relatively low technical risk. However, improper choices of fuels, boiler design, or operating conditions could minimise or even negate many of the advantages of burning biomass with coal and may, in some cases, lead to significant damage to equipment. Task 32 focuses a significant part of its activities on addressing the fireside risk factors related to co-combustion of biomass or producer gas, pyrolysis oil or charcoal (not to the gasification, pyrolysis or carbonisation itself).
Task initiated actions

The work programme of Task 32 is based on a prioritisation of national activities, performed at the start of each triennium. The task reserves part of its budget to carry out targeted studies to address these issues. Examples of such strategic actions are:

1. Two seminars on aerosol emissions from biomass combustion.
3. An internet database on experiences with cofiring biomass with coal.
6. A detailed techno-economic assessment of innovative concepts for biomass combustion based CHP installations.
8. Development of a new methodology for determination of Efficiency for Automatic Biomass Combustion Plants and Comparison of Efficiency and Emissions for Different Operation Modes, which can be used to simplify fuel accounting procedures for automatic wood chip fired systems.

Task meetings and workshops

Task 32 meets twice a year to discuss actual developments in its member countries and progress in its activities. Each of these meetings is held in combination with a task organised workshop on a specific combustion related topic. An overview of recent and upcoming meetings and workshops is given below.

All reports of events, studies as well as databases of cofiring initiatives and fuel/ash compositions can be downloaded from the Tasks website www.ieabcc.nl.

<table>
<thead>
<tr>
<th>Topic</th>
<th>Planning</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recent developments in biomass co-firing</td>
<td>Rome, May 2004</td>
</tr>
<tr>
<td>Public perception of biomass cofiring</td>
<td>Victoria, August 2004</td>
</tr>
<tr>
<td>Aerosols from biomass combustion</td>
<td>Graz, March 2005</td>
</tr>
<tr>
<td>Optimisation of small scale combustion systems</td>
<td>Paris, October 2005</td>
</tr>
<tr>
<td>Fuel flexibility / availability</td>
<td>Spring 2006 (place to be determined)</td>
</tr>
<tr>
<td>Corrosion and deposit formation</td>
<td>Autumn 2006, Glasgow</td>
</tr>
<tr>
<td></td>
<td>(in connection with an EC-ThermalNet meeting)</td>
</tr>
</tbody>
</table>

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Task 32 visiting Cuijk Power Plant.

Task 32 participants.
This article presents an example of the combustion of wood chips and olive residues in a CFB boiler, which has been in operation since autumn 2002 in Strongoli, Southern Italy.

**Biomass combustion in a Circulating Fluidised Bed Boiler**

The CFB technology is well suited for combustion of high calorific fuels in large quantities. As relatively small particle fuels and high gas velocities (5-6 m/s) are used, particles in the fluidised bed burning chamber get entrained in the gas flow, and end up in the cyclone, from where they are fed back into the burning chamber. This circle explains the name: circulating fluid bed.

The combination of intense mixing of gas and solids, and the high slip velocity occurring between solids and gases results in excellent heat exchange, a relatively constant temperature profile, good burnout of the fuel and consequently, relatively small reactor design. As low excess air ratios are required, combustion efficiency is high and NO\textsubscript{x} formation low. If necessary, SO\textsubscript{2} can be reduced easily by adding limestone to the bed.

Fuel enters the combustion chamber from the side and burns at a temperature of 850-950°C. Depending on the situation, heat can be extracted either from the membrane walls in the combustion chamber, from a heat exchanger inside the cyclone or from a heat exchanger placed in the return from cyclone to the combustion chamber. In the latter option, ash that is delivered in controlled quantities back into the burning chamber is cooled down before it re-enters the burning chamber. This provides a controllable option for heat exchange, enabling accurate control of the combustion temperature for a wide variety of fuels and thermal loads.

In principle there are several thermal and biological technologies available to convert biomass into electricity. The combustion of e.g. wood chips can be done in different combustion systems, the choice of which basically depends on system size. The most important options are listed below:

### Table 1: Combustion systems for wood chips.

<table>
<thead>
<tr>
<th>Combustion system</th>
<th>Heat output (MW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grate furnaces</td>
<td>5-20</td>
</tr>
<tr>
<td>Bubbling fluidised bed furnaces</td>
<td>20-100</td>
</tr>
<tr>
<td>Circulating fluidised bed furnaces</td>
<td>Above 50</td>
</tr>
</tbody>
</table>

The combination of intense mixing of gas and solids, and the high slip velocity occurring between solids and gases results in excellent heat exchange, a relatively constant temperature profile, good burnout of the fuel and consequently, relatively small reactor design. As low excess air ratios are required, combustion efficiency is high and NO\textsubscript{x} formation low. If necessary, SO\textsubscript{2} can be reduced easily by adding limestone to the bed.

This article presents an example of the combustion of wood chips and olive residues in a CFB boiler, which has been in operation since autumn 2002 in Strongoli, Southern Italy.

### Table 2: Fuel specifications for the Strongoli CFB Plant.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lower Heating Value</td>
<td>MJ/kgwet</td>
<td>8-13</td>
</tr>
<tr>
<td>Ash content</td>
<td>%w</td>
<td>3-8</td>
</tr>
<tr>
<td>Moisture content</td>
<td>%w</td>
<td>25-50</td>
</tr>
<tr>
<td>Sulphur</td>
<td>%w</td>
<td>0.05</td>
</tr>
<tr>
<td>Chlorine</td>
<td>%w</td>
<td>0.01-0.1</td>
</tr>
<tr>
<td>Alkali metals</td>
<td>%w</td>
<td>0.05</td>
</tr>
</tbody>
</table>

In Strongoli (Italy), Lurgi Lentjes AG has built a CFB combustion unit for combustion of wood chips as a main fuel. As secondary fuels, olive residues, hazelnut shells and meat-and-bone meal can be used. The composition of the fuel is shown in Table 2.
Two identical CFB combustion lines were established, equipped with options for heat extraction from the bed, in the cyclone, the convection zone as well as the return from cyclone to bed. The flue gas cleaning system consists of an absorber, followed by a cloth filter. The fuel preparation and storage is organised jointly for both combustion lines. Waste heat from the turbine is used for steam production as well as preheating of boiler feed water and combustion air. A principle diagram is shown in Figure 1.

An overview of key plant data is shown in Table 3. Both combustion lines together generate 2 x 79 t/h of steam, resulting in a total net electricity production in the turbine of approx. 40 MWe.

Important features of the CFB plant are its compact design and the integrated heat exchangers in the boiler top and cyclone return. Because of the extensive tubing of the boiler in different boiler sections, minimum use needs to be made of thermal mass and compensators that are normally placed in the hot ash stream. The compactness of the installation also made it possible to design it as a relatively inexpensive and lightweight standing construction instead of a hanging construction normally used. The precise control of both the amount and temperature of the ash that is returned to the combustion chamber through a needle valve also makes it possible to also control the combustion temperature precisely for different fuels and partial loads.

Continued overleaf...

Table 3: Overview of key plant data.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wood fuel flow</td>
<td>2 x 21 t/h</td>
</tr>
<tr>
<td>Flue gas flow</td>
<td>2 x 94000 Nm3/h</td>
</tr>
<tr>
<td>Live steam production (95 Bar(a), 515°C)</td>
<td>2 x 79 t/h</td>
</tr>
<tr>
<td>Heat production from boilers</td>
<td>2 x 60 MWth</td>
</tr>
<tr>
<td>Electrical power production</td>
<td>40 MWe, net</td>
</tr>
<tr>
<td>Cyclones</td>
<td>2 of 11.5 m height</td>
</tr>
<tr>
<td>Top cross sectional area of combustors</td>
<td>2 of 21.6 m²</td>
</tr>
<tr>
<td>Total height of combustors</td>
<td>26 m</td>
</tr>
</tbody>
</table>
Plant Operation and Test Results

After plant commissioning and establishment of stable operating conditions, the performance and reliability tests have been carried out. The test period ended successfully in July 2003, achieving all guaranteed values required for the plant take over.

The flue gas cleaning has been designed to meet the emission limits listed in Table 3.

During the test periods a boiler efficiency of 91.7% (acc. to DIN 1942) was measured, resulting in an overall net electrical efficiency of 31%.

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Email: claus_greil@lentjes.de
Web: http://www.lurgi-lentjes.de

Table 3: Emission limits imposed on the Strongoli biomass power plant.

<table>
<thead>
<tr>
<th>Emission limits</th>
<th>mg/m³ (STP at 11 % O₂, dry)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dust</td>
<td>10</td>
</tr>
<tr>
<td>CO</td>
<td>50</td>
</tr>
<tr>
<td>HCl</td>
<td>10</td>
</tr>
<tr>
<td>SO₃</td>
<td>50</td>
</tr>
<tr>
<td>NOₓ</td>
<td>200</td>
</tr>
<tr>
<td>TOC</td>
<td>10</td>
</tr>
</tbody>
</table>
TNO has developed and demonstrated a software sensor for online determination of the net heating value (NHV) of solid (bio) fuels and waste, used in combustion processes. The soft sensor can be of value both for operator support and improved control of the combustion process.

**Background and principle**

The very inhomogeneous character of some biomass fuels and especially municipal solid waste can lead to widely varying compositions and net heating values of the material. For combustion plants, this implies that it is difficult to achieve constant process operation in terms of steam production, temperature distribution over the furnace etc. Since it is not currently possible to measure the NHV of the fuel being burned online, control is typically based on derived process quantities, such as oven temperature and amount of steam produced. Due to the delay between fluctuations in actual combustion on the grate and fluctuations in steam production, it is difficult to sufficiently prevent process fluctuations. Municipal solid waste incinerators therefore, cannot be constantly operated at maximum load, which causes production losses in the range of 200,000 to 500,000 per year for an average 20 t/h plant in the Netherlands. In addition to that, continuous fluctuations in flue gas temperatures in the furnace may lead to unwanted corrosion and ash melting effects. For biomass combustion plants the fuel fluctuations cause a limitation in fuel flexibility. A better control system based upon an early detection of the NHV of the fuel would increase the fuel flexibility, and also result in the possibility of combusting cheaper fuels, which are often less constant in quality.

TNO has developed a sensor that can determine the instantaneous net heating value of waste being combusted in a furnace, based upon a number of signals received from the plant. Since the sensor uses only process quantities that, without appreciable delay, are related to the NHV of the fuel being incinerated at that particular moment, the NHV can be determined online. Figure 1 presents the working principle of the sensor.

---

**Figure 1: Principle of the software sensor for NHV.**
Use of the sensor

In addition to measuring the NHV, the sensor can also determine moisture content and composition of the fuel. As it can predict steam production some 5 to 10 minutes in advance, it can help the control system and/or operator to adjust the combustion process and stabilise steam production. Where volumetric fuel feeding systems are applied, as is often the case for biomass combustion systems, it is also possible to determine the density of the waste to be incinerated.

In addition to its application as part of a strongly improved combustion control system, the NHV sensor makes new developments in operating combustion installations possible, such as:

- The ability to continuously establish energy balances over a plant;
- The installation of new supervisory systems for continuous verification of balances and for monitoring of the correct operation of measuring equipment;
- Online operator support;
- Accurate characterisation of the incinerated fuels, for example, for creating databases that provide insight into the effect that various circumstances (such as seasonal effects) have on fuel composition and heating value.

Field tests

Over a number of years, the software sensor has proved its reliability in tests at various Dutch MSW incinerators. The evidence shows that the values predicted by the sensor are accurately in line with measured values obtained through accurate sampling and testing procedures.

Commercially available

The principle of the NHV sensor is patented by TNO. The product is commercially available and supplied together with a PC and extra measuring equipment for gas concentration determination. The precise configuration of the product to be supplied is typically established in consultation with the customer.

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Figure 2: In addition to the Net Heating Value (above), the software sensor calculates, for example, the moisture content of the fuel.

Figure 3: The amount of steam produced by an incinerator for MSW, calculated in advance (red line) and actually measured (blue line).
Comparison of Health Relevance and Size Distribution of Diesel Soot and Particles from Wood Combustion

By T. Nussbaumer, Verenum, Switzerland

Airborne particles smaller than 10 microns (PM 10) are respirable, and can cause severe health effects. Combustion particles are of specific interest with respect to health issues, as they can consist of carbonaceous compounds or act as a carrier of toxic substances such as polycyclic aromatic hydrocarbons (PAH). Among combustion processes, Diesel engines and biomass combustion are the dominant sources of particle emissions. While particles from Diesel engines consist almost exclusively of soot, biomass combustion leads to two types of particles. Under optimised conditions, biomass particles consist mainly of salts formed from ash constituents, while under poor combustion conditions, organic particulate matter is also emitted. Particles from incomplete biomass combustion are expected to contain both, salts and carbonaceous matter. The aim of an ongoing research project in Switzerland is to compare indicators for health effects from Diesel soot and wood combustion particles.

Continued overleaf...

Automatic wood combustion with almost complete combustion of wood and without filter.

Euro 3 Diesel car without particle filter.
For this purpose, particles from an EURO 3 Diesel engine without a particle filter and from different wood combustion processes have been sampled. Different biological tests with the particles are planned. So far, the cytotoxicity of these particles has been investigated during in-vitro tests of V79 lung cells of the Chinese hamster. The results reveal a significantly higher cytotoxicity for Diesel soot than for wood particles from optimised combustion. The concentration of wood particles needs to be more than five times higher than for Diesel particles to cause a similar cytotoxicity as e.g., a destruction rate of 70%. Tests on additional indicators for health effects than cytotoxicity are in progress.

In additional tests on wood stoves, the influence of combustion design and operation conditions on the particle size distribution is currently being investigated. Three types of combustion designs are compared:

1. A simple wood stove.
2. A properly designed conventional wood stove, and;
3. A prototype wood stove with two-stage combustion.

The tests reveal significant differences in particle and particle size distribution as a function of the combustion type and the combustion phase, i.e., start-up, stationary combustion, and char burnout. Under good conditions in the two-stage combustion stove, particle emissions below 20 mg/m³ at 13% O₂ can be achieved. During such conditions, particles greater than 1 micron are almost negligible. However, during start-up or under poor combustion conditions due to wet wood or simple combustion design, the particle mass concentration can increase by more than a factor of 10. During such conditions, particles greater than 1 micron are emitted in relevant concentrations as a result of incomplete burnout. The toxicity of such particles will be investigated in additional cell tests.

Acknowledgments:
Swiss Federal Office of Energy (BFE) and Swiss Agency for the Environment, Forests and Landscape (BUWAL).

Reference:

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Figure 1: Filters after particle sampling, left from Diesel engine (filter loaded with 0.6 g particles), right from almost complete wood combustion (filter loaded with 1g particles).

Figure 2: Cell survival as a function of particle concentration for Diesel and wood particles. The back-ground toxicity level, which is caused by residual filter fibres, is indicated as dashed line.
A World First –
Supercritical CFB

Kalle Nuortimo, Foster Wheeler Energia Oy, Peter Herring

The history of circulating fluidised bed (CFB) technology has been one of steady, cumulative development, as the technology has been scaled up, proven at utility scale and adopted by a wider number of customers. CFB is now set to take a major step forward with the world’s first supercritical CFB unit at PKE’s Lagisza power plant in Poland. Rated at 460 MWe, the boiler plant will also be the world’s largest CFB to date and will offer world-leading levels of operational and fuel efficiency.

CFB technology has evolved a great deal from its starting point as an industrial application for challenging fuels. The technology is capable of delivering high levels of efficiency and availability with low emissions when co-fired with biomass or refuse-derived fuel in ever larger unit sizes. Supercritical CFB technology is ideally suited to the requirements of the current business environment, where CO$_2$ trading sets stricter requirements for power plant efficiency and where high fuel prices are making the combustion of opportunity fuels such as biomass even more attractive.

The Lagisza Project

On December 30, 2002, the company PKE, one of Poland’s largest utility companies, selected Foster Wheeler as the boiler supplier for a 460 MWe once-through supercritical, coal-fired boiler plant for their Elekrownia Lagisza power plant. The final selection of the technology was made on February 28, 2003, when CFB was selected over PC technology. The project is currently waiting for Notice to Proceed (NTP).

“We saw CFB as being the most cost-effective alternative for our new power plant,” says Jan Kurp, CEO of PKE. “CFB was clearly the lower capital cost solution, and the most efficient. As we have 10 coalmines as potential suppliers of fuel, we can select any coal we like to burn in the new CFB, and Foster Wheeler’s design also includes an option to burn coal slurry.”
The PKE Lagisza CFB Design

The fuel data is shown in Table 1. In addition to the design fuel, there is also a provision to burn dried washery rejects 50% and biomass up to 10%.

The gaseous emissions from the plant will meet the requirements of the new European Union Large Combustion Plant Directive (LCP).

Table 1: Fuel Data (as received).

<table>
<thead>
<tr>
<th>Unit</th>
<th>Performance Coal</th>
<th>Coal Range</th>
<th>Coal Slurry Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sulphur</td>
<td>%</td>
<td>1.2</td>
<td>0.6-1.4</td>
</tr>
<tr>
<td>Ash</td>
<td>%</td>
<td>23</td>
<td>10-25</td>
</tr>
<tr>
<td>Moisture</td>
<td>%</td>
<td>12</td>
<td>6-23</td>
</tr>
<tr>
<td>LHV</td>
<td>%</td>
<td>20</td>
<td>18-23</td>
</tr>
</tbody>
</table>

The plant’s steam parameters are shown in Table 2. The efficiency increase will be significant, and total efficiency will now be in excess of 43%. The furnace acts as the evaporator, and the tubes are vertical. This Benson Vertical technology is developed by Siemens, and is offered by Foster Wheeler under license.

A single upflow evaporative pass is used as the base design. The low mass flow rates result in low steam/water pressure losses and low auxiliary power consumption. With vertical tubing, the furnace enclosure tubes are self-supporting and do not require special support straps to counteract thermal growth, as in spirally wound once-through boilers.

Table 2: Steam Parameters.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum continuous steam flow</td>
<td>kg/s 359.8</td>
</tr>
<tr>
<td>Minimum continuous steam flow</td>
<td>kg/s 143.9</td>
</tr>
<tr>
<td>HP steam pressure at turbine inlet</td>
<td>MPa 27.50</td>
</tr>
<tr>
<td>HP steam temperature at turbine inlet</td>
<td>°C 560</td>
</tr>
<tr>
<td>Cold reheated steam flow</td>
<td>kg/s 306.9</td>
</tr>
<tr>
<td>Cold reheated steam pressure</td>
<td>MPa 5.46</td>
</tr>
<tr>
<td>Cold reheated steam temperature</td>
<td>°C 314.3</td>
</tr>
<tr>
<td>RH steam temperature at IP turbine inlet</td>
<td>°C 580</td>
</tr>
<tr>
<td>Feed water temperature</td>
<td>°C 289.7</td>
</tr>
</tbody>
</table>

The superheaters and reheaters are located in the backpass, while the final superheater and reheater are INTREX™ units. Like all boilers of this size, the unit will be equipped with a regenerative air preheater. The cross-section of the boiler is shown in Figure 2.

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Figure 2: Cross-section of the PKE Lagisza boiler.
Current EC Projects in Bioenergy

Compiled by E Wakefield, Aston University, UK

AUSTRIA
BIOASH (502679)
Ash and aerosol related problems in biomass combustion and co-firing.

Co-ordinator
Ingwald Obernberger, Technical University of Graz
obernberger@tugraz.at

Summary
The project focuses on R&D concerning ash related problems in biomass combustion and co-firing of biomass in coal fired plants. The main objectives of the project will be: to investigate the release of ash forming compounds from biomass fuels in fixed-bed and pulverised fuel combustion systems, to determine presently not available thermodynamic data concerning the melting behaviour of Na, Zn and Pb-rich ashes, to further develop simulation tools for aerosol and deposit formation and to develop and test a new technology (an aerosol condenser) for efficient and cost effective aerosol precipitation in small-scale biomass combustion units.

BELGIUM
PREMIA (AMF2/503081/2003)
R&D, demonstration and incentive programmes effectiveness to facilitate and secure market introduction of alternative motor fuels.

Co-ordinator
Leen Govaerts, Flemish Institute for Technological Research
leen.govaerts@vito.be

Summary
The project aims to investigate cost effectiveness of measures to support the large-scale introduction of alternative motor fuels and alternatively fuelled vehicles in the EU15 and the partner countries, in relation to the market maturity of the technology and the country dependent situation. Current and past initiatives to facilitate and secure market introduction will be evaluated for their role in the process towards market introduction of alternative motor fuels.

FINLAND
Bioenergy NoE
See separate article on page 43.

Eubionet II
See separate article on page 40.

Continued overleaf...
**GERMANY**

**RENEW (502705)**

Renewable fuels for advanced powertrains.

Co-ordinator
Frank Seyfried, Volkswagen AG
frank.seyfried@volkswagen.de

Summary
The project aims to develop new combustion technologies for bio-residues. Innovative combustion technologies like flameless oxidation (FLOX) and continuous air staging (COSTAIR) will be enhanced to develop two basic types of BIO-PRO burners: A burner capable of burning gases as well as liquids; A burner for solid fuels applying a pre-gasification step.

**RECOFUEL**

(Bioma/503184/2003)

Demonstration of direct Solid Recovered Fuel (SRF) co-combustion in pulverised fuel plants and implementation of a sustainable waste-to-energy technology in large-scale energy production.

Co-ordinator
Thomas Glorius, RWE Umwelt AG
thomas.glorius@rwe.com

Summary
The demand for alternative waste treatment is addressed by production and direct co-combustion of SRF in pulverised fuel fired power plants as an environmentally friendly, energy efficient, short-term available and cost effective technical solution. Large scale demonstration of SRF co-combustion at a 450 MWth brown coal lignite boiler of RWE Rheinbraun AG in a continuous period of at least 12 months with the scope of permanent and reliable operation is proposed.

**HUNGARY**

**PRO-BIOBALKAN (510680)**

Promotion of Cost Competitive Biomass Technologies in the Western Balkan Countries.

Co-ordinator
Kristzian Edoecs, Innoterm Energetikai es info@innoterm.hu

Summary
The aim of the project is to organise conferences in order to describe, compare and evaluate new and innovative technologies, which promote the use of sustainable energy with a potential to maximise regional productivity. Two 2-day conferences have been organised, which are expected to have a major impact on the enhancement of regional productivity and/or to initiate trans-border co-operation through the promotion of biomass.

**ITALY**

**BIOMASS USE IN BRIANZA**

(Bioma/503177/2003)

Thermal utilisation of virgin and residual biomass in Brianza (Italy) for district heating and electric co-generation.

Co-ordinator
Giovanni Riva, Comitato Termotecnico Italiano
riva@cti2000.it

Summary
The study aims to reduce the barriers relevant to knowledge of the biomass market, diffusion of new technologies and identification of effective investment opportunities. Brianza offers elements for a positive outcome such as large availability of residual and virgin biomass, technological know-how and experience in new technologies, intense industrialisation and high population density (therefore strong energy demand) and favourable conditions for the installation of district heating systems.

**GREECE**

**RES INTEGRATION (509204)**

Rural Sustainable Development through Integration of Renewable Energy Technologies in Poor European Regions.

Co-ordinator
Spyros Kyritsis, Agricultural University of Athens
ppap@auadec.aua.ariadne-t.gr

Summary
The aim is to study the implementation of innovative low cost renewable energy and energy saving technologies at selected poor regions of the participating countries. The final goal will be regional sustainable socio-economic development, eventually based mainly on renewable energy sources. This will be a combination of modern wind and solar energy production as well as production of energy from biomass.

**NETHERLANDS**

**NATURALHY (502661)**

Preparing for the hydrogen economy by using the existing natural gas system as a catalyst.

Co-ordinator
Onno Florisson, N.V. Nederlandse Gasunie
get@gasunie.nl

Summary
The new process technology is based on steam gasification of low rank, high moisture brown coal, which includes the high temperature removal of CO₂ by using high temperature efficient sorbet materials. The combination of both the gasification and the in situ CO₂ capture initiates a shift reaction in product gas composition towards H₂.

**SWEDEN**

**CHRISGAS (502587)**

Clean hydrogen-rich synthesis gas.

Co-ordinator
Mehri Sanati, Vaxjo University
Mehri.Sanati@itp.vxu.se

Summary
This project will develop and optimise an energy-efficient and cost-efficient method to produce hydrogen-rich gases from biomass, including residues. This gas can then be upgraded to commercial quality hydrogen or to synthesis gas for further upgrading to liquid fuels such as DME and methanol or Fischer-Tropsch diesel. The hub of the project will be the Varnamo Biomass Gasification Centre in Sweden and the use of the existing and unique biomass-fuelled pressurised IGCC (integrated gasification combined-cycle) CHP (combined heat and power) plant in Varnamo (presently owned by one of the participants in this proposal) as a pilot facility. By building this Centre around this plant, gasification research and demonstration activities can be conducted at a much lower cost than if new equipment were to be built.
**UK**

**CROPGEN (502824)**

Renewable energy from crops and agrowastes.

Co-ordinator
Charles Banks, University of Southampton
C.J.Banks@soton.ac.uk

Summary
The overall aim of the research is to produce from biomass a sustainable fuel source that can be integrated into the existing energy infrastructure in the medium term, and in the longer term will also provide a safe and economical means of supplying the developing hydrogen fuel economy. The results will add to EU databases on bioenergy crops; give engineers the necessary tools to develop the technology; provide the farming community with evidence of profitable energy production without subsidy and within the EU's target cost for renewable energy.

**MICROCHEAP (LSInt/503138/2003)**

The Integration of Micro-CHP and Renewable Energy Systems.

Co-ordinator
Giles Cooper Smith, Chalex Research Ltd
giles@chalex.com

Summary
This co-ordination action intends to bring together industrial specialists and research experts to focus entirely on renewable micro-CHP technology. It will co-ordinate and steer research in this field and highlight the most promising technologies with the highest potential for market penetration in existing and future market conditions.

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**Intelligent Energy for Europe**

**Biomass & Bioenergy Projects Agreed for 2005**

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Title</th>
<th>Acronym</th>
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</thead>
<tbody>
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<td>EUBIONETII</td>
<td>Efficient trading of biomass fuels and analysis of fuel supply chains and business models for market actors by networking</td>
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<td>Boosting Bio</td>
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<td>An integrated network on thermal biomass conversion for power, heat and transport fuels</td>
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<td>BIO-SOUTH</td>
<td>Techno-economical assessment of the production and use of biofuels for heating and cooling applications in South Europe</td>
<td><a href="http://www.bio-south.com">http://www.bio-south.com</a></td>
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</table>
European bioenergy network, EUBIONET 2 concentrates on biofuel markets and fuel supply chains in Europe. The project will be carried out during 2005 - 2007.

**Aims**

- To give a clear outlook of current and future biomass fuel market trends in Europe.
- To give feedback on the suitability of CEN 335 biofuel standards for trading of biofuels.
- To give well-analysed estimation on techno-economic potential of the biomass fuel volumes to the year 2010 based on the existing studies and experts’ opinions. As regards forest biomass co-operation will be done also with forest industry stakeholders to find a proper balance between forest industry raw material and bioenergy use.
- To enhance biomass fuel trade and technology transfer by networking of different actors.
- To analyse, select and describe the most suitable trading and business models for small and large scale biofuel supply chains for heat and power production by taking into account the environmental aspects and sustainability.
- To enhance biomass use by co-operation and information dissemination with different market actors in the fuel-utilisation chain.

**Fuel production methods and business models for 30 supply chains**

30 different fuel production methods and business models will be analysed by using a systematic approach. Different methods will be selected and described. Analysis includes raw material, technology, social and economic aspects, production costs, organisation models, marketing, contracting, information on fuel quality and fuel quality control. Recommendations on suitability of the method for other countries or sectors will be made. Most suitable methods will be described.

**Biomass in national and EU wide legislation**

Policies, definitions, classifications and prices for biomass and waste differ from country to country. These differences impact on the implementations of the various EU directives in the member states. Compatibilities between EU and national legislations will be evaluated regarding terminology, emission levels, supporting schemes etc.

*Figure 1: Forest biomass harvesting.*
Biomass trade in Europe

The project will evaluate the current situation and future trends in biomass fuel trade in Europe. The aim is to assess the economically and technically viable volumes of solid biomass fuels – wood residues from forest operations and industry, agro-biomasses and energy crops, used wood, using the classification and specification of CEN TC 335 on solid biofuels (CEN/TS 14961).

Training, events and study tours

Several actions will support the efficient information dissemination of the project. International and national events will take place. This task is co-ordinated by the European Bioenergy association - AEBIOM and its 28 members are key organisations in information dissemination.

Co-operation is done also with IEA Task 40 in biomass trade (www.fairbiotrade.org) and with ThermaNet project (www.thermalnet.co.uk) in biomass conversion technologies and standardisation.

Expected results

• European review of market and policy analysis of the European biofuel trade and potential estimation for future trading.
• Establishment of continuous fuel prices collecting systems in several countries.
• Basics for future development of biofuel standards based on the experiences collected from biofuel traders.
• Recommendations and guidelines for efficient business models for different fuels and user groups in both small and large scale.
• Summarised effects and driving forces for the implementation of new EU Directives.
• Co-operation and broad dissemination of the results by means of publications, seminars, workshops and web-page and by using associations with several thousands of members.

Project Partners

• VTT, Finland
• ADEME, France
• AEBIOM and its 28 national bioenergy associations
• BLT, Austria
• CBE, Portugal
• CEPI Brussels
• CRES, Greece
• CRA, Belgium
• DTI, Denmark
• FNR, Germany
• NCP, Finland
• Senter Novem, Netherlands
• SODEAN, Spain
• SLU, Sweden
• SWS, Ireland
• University of Manchester, UK.

For further details contact:

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Email: eija.alakangas@vtt.fi
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Fax: +358 20 772 2598

Information on events and publications will be available at www.eubionet.net
Introduction
ERA-NET Bioenergy is a European project devoted to developing a structured cooperation of Member State national agencies and Ministries responsible for coordinating and funding national research efforts in bioenergy. It started in October 2004 with a life of just over 4 years. Collaborative research efforts not only lead to higher quality, but also to more cost-effective results, contributing to a greener and more secure energy infrastructure, thus preserving valuable fossil fuels for generations to come.
An important challenge of ERA-NET Bioenergy is to create joint work packages based on a solid review of national bioenergy research programmes.
ERA-NET is a new tool in the FP6 programme, to realise the collaboration between national research programs in the EU. This project identifies and develops this collaboration specifically for bioenergy.

Goal
The goal of this network is to strengthen national bioenergy research programmes, through enhancing cooperation and coordination between the national agencies and governments. Through collaboration, the individual national programmes will produce higher quality results, while through coordination they will seek to complement each other, avoiding duplication.

Objectives
• Create a structure for cooperation.
• Information exchange.
• Identify areas of collaboration by networking of RTD programmes.
• Prepare cooperation models.
• Set up pilots of joint work packages and learn from these pilots.
• Create national support and expand the collaboration.

Mission
ERA-NET Bioenergy’s mission is to enhance the quality and cost-effectiveness of European bioenergy research programmes, through coordination and cooperation between EU Member States.

How you can participate
The ERA-NET Bioenergy consortium initially seeks internal collaboration, with the goal of strengthening national bioenergy research programmes. In the course of time it will open up to other countries’ governments and agencies to allow for a wider European outreach.

As programmes of the participating countries are adjusted and joint work packages are formulated, this will also have a structuring effect on the research community in industry, research institutes and universities in the participating countries.

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Catharijnesingel 59
PO Box 8242
Utrecht NL-3503 RE
Netherlands
Tel: +31 30 239 34 58
Fax: +31 30 231 64 91
Email: k.kwant@novem.nl

Table 1: Partners in ERA-NET Bioenergy

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<tr>
<th>SenterNovem (coordinator)</th>
<th>The Netherlands</th>
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<tr>
<td>Ministry of Economic Affairs</td>
<td>Finland</td>
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<td>National Technology Agency of Finland Tekes</td>
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<td>Swedish Energy Agency</td>
<td>United Kingdom</td>
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<td>Department of Trade and Industry</td>
<td>Austria</td>
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<tr>
<td>Federal Ministry of Transport, Innovation and Technology</td>
<td>Austria</td>
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<tr>
<td>The Industrial Research Promotion Fund</td>
<td>Austria</td>
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<td>Energie Verwertungs Agentur</td>
<td>Germany</td>
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<tr>
<td>Fachagentur Nachwachsende Rohstoffe</td>
<td>United Kingdom</td>
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<tr>
<td>Engineering and Physical Sciences Research Council</td>
<td>Germany</td>
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<tr>
<td>Federal Ministry of Consumer Protection, Food and Agriculture</td>
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Please check our website to find out the latest developments: www.eranetbioenergy.net
Introduction

Europe has a sound reputation for innovation in bioenergy research and development, but in order to compete in the global market, European RTD capacity in this sector needs to be built into a dynamic and resourceful force. Networks of Excellence were one of the new instruments in the EC 6th Framework Programme to achieve this transition.

The Bioenergy Network of Excellence (Bioenergy NoE) was launched in January 2004. Its 140 core researchers are already making a significant contribution to the European RTD skills base.

At this year’s European Bioenergy Conference in Paris in October, Bioenergy NoE researchers presented 40 posters, gave 25 oral presentations and chaired seven sessions. The challenge of the NoE is to integrate these activities into a powerful resource base.

Bioenergy NoE’s basic mission is integration. Rather than directly funding traditional RTD projects, this NoE funding aims to reinforce the complementary strengths of the eight partner institutes to build a much stronger base for bioenergy research in Europe.

“Integration in the Bioenergy NoE goes beyond what was successfully practiced in preceding FPs, in which “networking” was to establish contacts, develop ideas and exchange RTD results,” says Bioenergy NoE Board Member Josef Spitzer.

The first 18 months work has been fruitful in sharing best practices, mapping capabilities, investigating key barriers to bioenergy and building new relationships and activities.

“We are now at a crucial point in the NoE’s work as we begin to build a solid base for the future,” reports Bioenergy NoE Coordinator Kai Sipilä.

Integration is being achieved through a wide range of cooperative measures such as joint research projects, researcher exchanges and workshops. In a recent survey 89% of NoE researchers felt that the NoE encourages them to cooperate more, signalling that these practical steps are working.

“Bioenergy NoE offers an exciting opportunity to meet the education and training needs of the professional engineers and scientists who will form the core of tomorrow’s European Bioenergy companies,” explains Tony Bridgwater, leader of the education and training task and NoE Board Member.

At the end of the 5 years of funding, the Bioenergy NoE plans to have built a Virtual RTD Centre that can provide a unique resource for the European bioenergy sector of the future and thus provide the security of energy supplies and contribution to environmental issues that we expect.

Sponsored by EC DG RTD, Bioenergy NoE is coordinated by VTT, Finland. The partners are EC Baltic Renewable Energy Centre in Poland (ECBREC), the Bio-Energy Research Group at Aston University in the UK, the Energy Research Centre in the Netherlands (ECN), Forschungzentrum Karlsruhe in Germany (FZK), the International Institute for Industrial Environmental Economics at Lund University in Sweden (IIIEE), Institut National de la Recherche Agronomique in France (INRA), and Joanneum Research in Austria.

For more information please visit the website:

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7th Framework Programme

Compiled by E Wakefield, Aston University, UK

Introduction

The Framework Programme (FP) is the European Union’s main instrument for funding research and development. The FP is proposed by the European Commission and adopted by Council and the European Parliament following a co-decision procedure. FPs have been implemented since 1984 and cover a period of five years. The current FP is FP6, which will be running up to the end of 2006. It has been proposed for FP7, however, to run for seven years. It should be fully operational as of 1 January 2007. It is designed to build on the achievements of its predecessor towards the creation of the European Research Area, and carry it further towards the development of the knowledge economy and society in Europe.

The proposed Seventh Framework Programme will be organised in four areas known as “Specific Programmes” corresponding to four major objectives of European research policy:

- **Cooperation**
  Support will be given to the whole range of research activities carried out in trans-national cooperation, from collaborative projects and networks to the coordination of national research programmes. International cooperation between the EU and third countries is an integral part of this action. Transnational cooperation will be implemented through four actions:
  - **Collaborative research** will constitute the bulk and the core of EU research funding.
  - **Joint Technology Initiatives** will mainly be created on the basis of the work undertaken by the European Technology Platforms.
  - **Coordination of non-Community research programmes.**
  - **International Co-operation.**

- **Ideas**
  This programme will enhance the dynamism, creativity and excellence of European research at the frontier of knowledge in all scientific and technological fields, including engineering, socio-economic sciences and the humanities. This action will be overseen by a European Research Council.

- **People**
  Strengthening, quantitatively and qualitatively, the human potential in research and technology in Europe by putting into place a coherent set of Marie Curie actions.

- **Capacities**
  The objective of this action is to support research infrastructures, research for the benefit of SMEs and the research potential of European regions (Regions of Knowledge) as well as stimulate the realisation of the full research potential (Convergence Regions) of the enlarged Union and build an effective and democratic European Knowledge society.

FP7 presents strong elements of continuity with its predecessor, for instance regarding the themes which are covered in the Cooperation programme. The themes identified for this programme correspond to major fields in the progress of knowledge and technology, where research must be supported and strengthened to address European social, economic, environmental and industrial challenges. The overarching aim is to contribute to sustainable development.

Nine high level themes are proposed:

2. Food, Agriculture and Biotechnology.
3. Information and Communication Technologies.
5. Energy.
6. Environment (including Climate Change).
7. Transport (including Aeronautics).
8. Socio-economic Sciences and the Humanities.

The European Technology Platforms will provide a major input to those aspects of FP7 that involve and concern industry.

The new elements in FP7 include the following:

- Emphasis on research themes rather than “instruments.”
- Significant simplification of its operation.
- Focus on developing research that meets the needs of European industry, through the work of Technology Platforms and the new Joint Technology Initiatives.
- Establishment of a European Research Council, funding the best of European science.
- Integration of International co-operation in all four Programmes.
- Development of regions of knowledge.
- A Risk-Sharing Finance Facility aimed at fostering private investment in research.

For further information please visit http://www.cordis.lu/fp7/
(Source used for this article)
Biorefinery planned in Ontario, Canada

Source: Biocap Canada website – www.biocap.ca

The Ontario government has announced it will spend $771,000 to build a transportable bio-refinery plant to promote alternative energy and help northern communities in the province. The plant will convert forest waste into bio-oil, a biofuel that can be used to generate heat and electricity, as well as to produce plastics, glue and other products. According to Natural Resources Minister David Ramsay, the province has a sustainable supply of forest waste, including residues from logging operations and trees damaged by insects, disease and fire. The project is part of the government’s plan to ensure that renewable energy provides five percent of the province’s electricity by 2007.

First steps towards a European Biofuels Technology Platform

The establishment of a European Biofuels Technology Platform is high on the European agenda for the development, promotion and implementation of biofuels. It is intended to provide and implement a common European vision and strategy for the production of biofuels, in particular for transport applications, and to be compatible with the present-day infrastructure.

To prepare the Technology Platform, a high-level Advisory Council has been established. The Biofuels Research Advisory Council (BIOFRAC) consists of members who represent a balance of the major European biofuels stakeholders, including the agricultural and forestry sectors, food industry, biofuels industry, oil companies and fuel distributors, car manufacturers and research institutes.

The mission of BIOFRAC, in the initial phase of the work, is to develop a vision report which should address all the issues that are relevant to ensure a breakthrough of biofuels and increase their deployment in the EU, with an emphasis on research, development and demonstration. The vision report is intended to become a guidance tool for all stakeholders including policy makers and could also be supportive in the development and implementation of the 7th framework programme for research (FP7).

Public documents related to the work of BIOFRAC are available on CIRCA at http://forum.europa.eu.int/Public/irc/rtd/biofrac/home.

STC CBC Proceedings now available

The proceedings from the STCBC (Science in Thermal and Chemical Biomass Conversion) conference held in Victoria, Canada, on 30th August – 2nd September 2004 are now available. This two-volume publication contains a total of 156 papers. Each volume contains papers organised into areas of interest, which are detailed below.

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Intelligent Energy – Europe: 2005

By Peter Löffler, Intelligent Energy Executive Agency (IEEA), Brussels

Introduction

The 2005 Call for Proposals of the ‘Intelligent Energy – Europe’ (IEE) Programme of the European Union was published in September 2005, opening a 4-month period during which applications for IEE co-funding can be submitted. The closing date will be 31st January 2006 for Type 1 proposals SAVE, ALTENER and STEER projects and the 28th February 2006 for COOPENER projects. Type 2 proposals (Energy Agencies) have a deadline of 31 January 2006 and Type 3 projects (Events) either 30th November 2005 or 28th April 2006.

In total, approximately 50 million Euros of financial support will be made available to support international projects, events, and the start-up of local or regional agencies with a thematic focus on 4 main areas: energy efficiency, renewable energy sources, energy aspects of transport, and co-operation with developing countries. The biggest share of this budget will be used to support collaborative projects (about 45 million Euros), followed by start-ups of local/regional energy agencies (5 million Euros), and the organisation of international events (0.8 million Euros). Successful applications can expect to receive financial support covering up to 50 per cent of the total costs.

It is important to understand that IEE does not fund technology development, construction of installations, or research and demonstration projects. Rather, the programme seeks to enhance our social and institutional capacity for the more intelligent use of energy and the wider use of renewables. This includes activities which give input into European policy development, create certification and labelling systems for energy efficiency and renewables, monitor market conditions, promote sustainable energy, or spread of best practice.

More information on the IEE Programme, the 2005 Call for Proposals and the Info Days is available at: http://europa.eu.int/comm/energy/intelligent/index_en.html.

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Integrated Biorefineries US DOE Announces Notice of Public Interest (NOPI)

The Office of the Biomass Program (OBP) of the United States Department of Energy intends to offer a Funding Opportunity Announcement (FOA) in FY2006 with the objective of demonstrating integrated biorefineries at an industrial scale that will lead to their replication at a commercial scale within the United States. These demonstrations will enable a validation of the integrated technologies and the economics at a scale and length of operation that the business risk is sufficiently quantified to permit a decision to commercialise these technologies.

Successful completion of these demonstrations is expected to support the OBP’s strategic goals of reducing dependence on imported oil and enabling of a domestic biolndustry. The OBP has two objectives in making an FOA in FY2006. First, the program anticipates supporting efforts that can validate the pretreatment and conversion of lignocellulosic feedstocks to biofuels and biobased products on a systems basis and at a scale large enough to foster the replication of the technology at the commercial scale. This includes validating the economics associated with a multi-product biorefinery. Second, in FY2006 the program is interested in efforts that evaluate biomass feedstocks comprised of residues from existing wet or dry mills, corn fiber, and corn stover.

The program intends to issue a FOA in January of 2006 and make awards no later than March of 2007. The overall funding availability for the FOA is anticipated to be $160-$180 MM over three years. The FOA will require cost sharing. The estimated number of DOE-funded awards under the FY2006 FOA will be contingent upon merit review and available funding. It is anticipated that one to three awards could be made. See the website for the full announcement:
http://e-center.doe.gov/iips/foopor.nsf/o62beb2f6e6159a852566c60075270a
Diary of Events

Information compiled by Emily Wakefield, Aston University, UK

10th International Symposium on Catalyst Deactivation
Venue: Berlin, Germany
Date: 5th - 8th February 2006
Contact: Ms. Claudia Martz
Tel: +49 (0) 69-7564 129
Email: martz@dechema.de
Website: http://events.dechema.de/CatDeact

Energy Use from Biomass
Venue: Velen, Westfalen, Germany
Date: 24th-26th April 2006
Contact: Frau Christa Jenke
Kapstading 2
22297 Hamburg
Germany
Tel: +49 (0)40 63900412
Fax: +49 (0)40 6300736
Email: jenke@dgmk.de
Website: www.dgmk.de/kohle

Biofuels Markets
Venue: Brussels
Date: 16th - 17th February 2006
Website: http://www.greenpowerconferences.com/events/biofuelsmarkets.htm

EWEC (European Wind Energy Conference) 2006
Venue: Megaron, Athens, Greece
Date: 27th - 2nd March 2006
Contact: Anne Lannoy
Tel: +32 2 776 09 96
Email: registration@ewec.info
Website: http://www.ewea.org/06b_events/events_2006EWEC.htm

World Sustainable Energy Days 2006
Venue: Wels/Austria
Date: 1st - 3rd March 2006
Tel: +43-732-7720-1486
Email: office@esv.or.at
Website: http://www.ewea.org/06b_events/events_2006EWEC.htm

Central Biofuels II
Venue: Panama Marriot Hotel, Panama City, Panama
Date: 21st March 2006 - 23rd March 2006
Contact: Pam Frazee
Operations Manager
TSG Conferences
Tel: +01.605.323.0119
Email: pam@biofuelsconferences.com
Website: http://www.centralbiofuels.com

Power/Gen Renewable Energy 2006
Venue: Mandalay Bay, Las Vegas
Date: 10th - 12th April 2006
Website: http://www.acore.org/download/2005-PGRE-3_15_05.pdf

WindEnergy
Venue: International Trade Fair, Hamburg, Germany
Date: 16th - 19th May 2006
Website: http://www.hamburg-messe.de/windenergy/jumppage/index.html

17th International Symposium on Analytical and Applied Pyrolysis
Venue: Budapest, Hungary
Date: 21st - 26th May 2006
Email: py2006@chemres.hu
Website: http://www.chemres.hu/py2006

World Bioenergy 2006
Venue: Jonkoping, Sweden
Date: 30th - 1st June 2006
Website: www.svebio.se

Eastern Biofuels Conference and Expo II
Venue: Intercontinental Budapest, Budapest, Hungary
Date: 30th - 1st June 2006
Email: wendy@biofuelsconferences.com

BioEnergy Conference & Exhibition 2006
Venue: University of Northern British Columbia, British Columbia, Canada
Date: 31st - 1st June 2006
Contact: Cam McAlpine
Website: http://www.bioenergyconference.org/index.php

Biofuels Markets Asia
Venue: Bangkok
Date: 5th June 2006 - 6th June 2006
Email: info@greenpowerconferences.com
Website: http://www.biofuelsmarkets.com

WASTE 2006, 5th Annual Symposium on Waste Treatment Technologies
Venue: Paiington, UK
Date: 12th - 16th June 2006
Email: events@ciwm.co.uk
Website: http://www.eiforum.org.uk/home.asp?pageID=885

8th International Conference on Greenhouse Gas Control Technologies
Venue: Trondheim, Norway
Date: 19th - 23rd June 2006
Email: info@ghgt-8.no
Website: http://www.leagreen.org.uk/ghgt8.html

BBI International’s 22nd Annual International Fuel Ethanol Workshop & Expo
Venue: Milwaukee, Wisconsin
Date: 20th - 23rd June 2006
Website: http://www.fuelethanolworkshop.com/

5th European Motor Biofuels Forum
Venue: Hilton Newcastle Gateshead, UK
Date: 11th - 13th September 2006
Contact: Ms. Marieke Bouman
Tel: +31 (0)30 6933489
Email: mbouman@europoint-bv.com
Website: www.europoint-bv.com/biofuels2006

2006 Renewable Energy Policy Conference
Venue: European Quarter, Brussels
Date: 12th September 2006 - 14th September 2006
Email: erec@erec-renewables.org

Bois Energie 2006
Venue: Luraparc, Lons le Saunier, France
Date: 6th - 9th October 2006
Website: http://www.ademe.fr/htdocs/publications/publipdf/BOIS.PDF

Asia Biofuels IV
Venue: The Great Wall Seraton Hotel, Beijing, China
Date: 10th - 12th October 2006
Contact: Wendy Vincent
Tel: +01 605 338 6829
Website: wendy@biofuelsconferences.com

Workshop on Biomass Gasification Success Stories and Lessons Learnt
Venue: Gas Technology Institute, Des Plaines, Illinois, USA
Date: 16th - 18th October 2006
Website: http://www.gastechnology.org/webroot/app/xn/id.xhtml?it=enweb&x=d=iea/taskmeetings.xml
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