PyNe

**Boocock**
a role for pyrolysis in vegetable oil biodiesel formation
on page 4

part 2

**Mass Transfer**
Measuring the vapour pressures of cellulose pyrolysis tars
on page 10

**Boukis**
Recent EC sponsored projects on fast pyrolysis
on page 12

# Advancing Pyrolysis Technology

**Dedicated Subject Groups will form the main mechanism by which PyNe will contribute to the technical development and advancement of fast pyrolysis. Five groups have been formed as follows:**

- **Analysis and characterisation headed by Dietrich Meier and Anja Oasmaa**
- **Environment, health and safety headed by Philippe Girard**
- **Implementation headed by Maximilian Lauer**
- **Science and fundamentals headed by Jan Piskorz**
- **Stabilisation and upgrading headed by Stefan Czernik and Rosanna Maggi**

**Each Subject Group will follow activities and progress in their respective areas and actively contribute to their development through specialist meetings and workshops, scientist exchange and technical support of agreed objectives.**


## Science and Fundamentals of Fast Pyrolysis

The first of the Subject Group Workshops was held in Stratford-upon-Avon, UK, from 22nd to 24th July this year when the subject of Science and Fundamentals was discussed by an eminent and international group of scientists from all over Europe and North America.

The workshop was well attended with 32 enthusiastic participants. The papers presented will be published by PyNe.

*PyNe Science and Fundamentals Subject Group, Stratford-upon-Avon, July 1998.*

SEPT. 1998 ISSUE 6

# Pyrolysis Network.

ASTON UNIVERSITY

Comments and contributions are most welcome on any aspect of the contents.
Please contact your country representative for further details or send material to Claire Humphreys.

# Contents




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# Conference & Meeting Reports

*Compiled by Mr Pearse Buckley, University of Dublin, Ireland*

10th

## Biomass for Energy and Industry
## 10th European Conference
## Wurzburg, Germany,
## 8-11 June 1998

The 10th European Conference and Technology Exhibition on Biomass for Energy and Industry took place in Wurzburg from the 8th to 11th June 1998. The conference was well attended with over 900 participants.

During the Oral Sessions in the section on 'Advanced Thermo-chemical Processes and Novel Applications,' two papers on pyrolysis were presented. The first paper by Tony Bridgwater gave an overview of the status of fast pyrolysis of biomass in Europe. This was followed later by a report on electricity production from pyrolysis gas in Denmark.

In the related poster sessions of the Thermo-chemical Conversion Section some 20% of the 100 posters dealt with pyrolysis. The main focus was on the pyrolysis process itself with more than 50% of the posters covering this aspect. However, upgrading also figured prominently indicating the importance of this aspect to the evolution of pyrolysis as an important technology in the conversion of biomass to useful products. Our PyNe network was presented in one of the posters to increase awareness of its activities among industrialists and researchers in the field of biomass.

The Conference Proceedings are included in one volume of over 1800 pages.

**Title:** 'Biomass for Energy and Industry – 10th European Conference and Exhibition'

**Editors:** H. Kopetz, T. Weber, W. Palz, P. Chartier and G.L. Ferrero

**Year:** 1998

Copies are available from:-

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10th

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# PyNe Subject Groups

## Environment, Health and Safety

*Convenor: P Girard*

Producers and users of bio-oil require reassurance and guidelines on its handling and utilisation. Selected issues will be addressed through review, consultation with experts and where appropriate, commissioning of new information.

*Bio-oil*

*Oil refinery*

## Implementation

*Convenor: M Lauer*

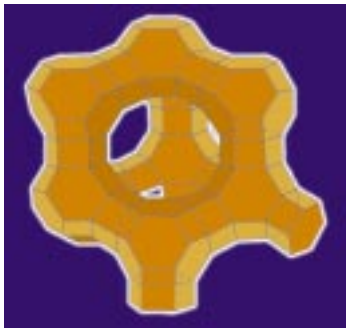
The opportunities and problems influencing the successful commercialisation of fast pyrolysis and applications for bio-oil will be reviewed with recommendations made to improve the rate and success of commercialisation.

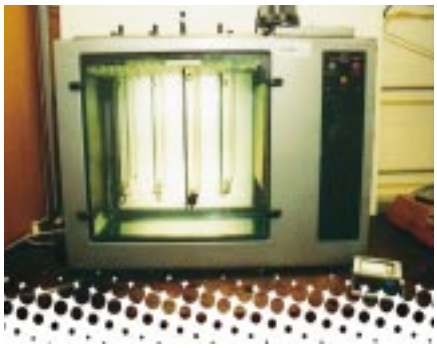
## Stabilisation and Upgrading

*Convenors: S Czernik, R Maggi*

Bio-oil exhibits some peculiar properties that may restrict its more widespread use. There is a range of possible methods to improve the properties of bio-oil and these will be monitored and reviewed with recommendations for an RD&D programme.

*Zeolite catalyst*





*Capillary viscometer*

## Analysis, Characterisation & Test Methods

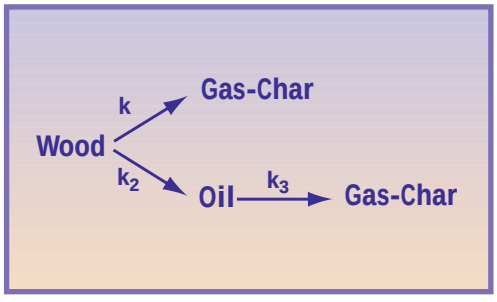
*Convenors: D Meier, A Oasmaa*

Successful utilisation of bio-oil requires that its properties be appropriately measured and that quality and consistency are defined. A review of test methods and quality criteria will identify where further work is required and small work programmes may be established to derive new test methods.

## Science and Fundamentals

*Convenor: J Piskorz*

Science and fundamentals are essential features of successful process development, which improve the understanding of the underlying basic phenomena and hence permit process optimisation.
Information and views on ongoing work will be maintained and recommendations made for a more co-ordinated and interactive programme to resolve the major uncertainties.




*Liden reaction mechanism*

# A Role for Pyrolysis in Vegetable Oil Biodiesel Formation

*By Professor David Boocock, Department of Chemical Engineering and Applied Chemistry, University of Toronto, Canada*

In 1878 the School of Practical Science was set up in Toronto, and offered for the first time a three-year diploma course in Analytical and Applied Chemistry. The present Department of Chemical Engineering and Applied Chemistry at the University of Toronto is the direct descendant of this program.

Currently, the Department has 29 tenure stream Faculty, 350 undergraduate students and 150 graduate students. Research is focused in Biomedical Engineering, Environmental Engineering, Process Engineering and Pulp and Paper.

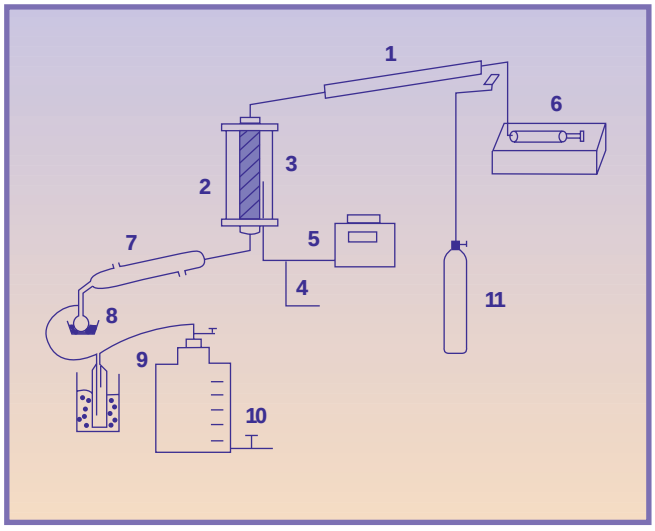



*Figure 1: Pyrolysis unit*

1. *316 stainless steel feed preheater tube (1.3 cm i.d. x 46 cm length);*
2. *block heater containing a 316 stainless steel fixed bed reactor tube (2.5 cm i.d. x 46 cm length);*
3. *catalyst bed;*
4. *chromel-alumel thermocouple probe;*
5. *temperature controller;*
6. *syringe pump;*
7. *condenser;*
8. *receiving flask;*
9. *gas trap;*
10. *gas collection vessel;*
11. *nitrogen cylinder.*

## Improvement of Bio-diesel Production

At the University of Toronto pyrolysis is being used to solve some problems associated with bio-diesel fuel production from vegetable oils. The normal process for making such fuel is to split the vegetable oil molecules into three methyl ester molecules. The splitting reaction solves the problem that the vegetable oils are too viscous to be used as diesel fuels themselves. The methyl esters have viscosities closer to regular diesel fuel.

However, there is a second potential problem with bio-diesel. The methyl esters of saturated fatty acids tend to precipitate when the fuel is cooled. Rape seed methyl ester (RME) contains only 6% saturated acids and has a cold filter plugging point (CFPP) as low as -8°C, which may still be too high for some climates. Soybean methyl ester, which is favoured in the USA, contains more saturates and has CFPP's considerably above 0°C. Blending with fossil diesel can solve some of these problems but biodegradability of the bio-diesel is inhibited. Also, the customer does not identify the bio-diesel as being any different from fossil diesel.

We have shown that the pyrolysis of the methyl esters over alumina in a trickle-bed reactor (see Figure 1) at 450°C yields linear liquid mono-olefins in high yield. These olefins can be used directly as diesel fuel. This offers the choice of either converting these total methyl esters to mono-olefins or only converting those solid methyl esters removed by cold filtration. In the latter case, the mono-olefins could be blended back with the methyl esters, thereby lowering the CFPP even further. Vegetable oils themselves had been previously used in the same pyrolysis process. Although mono-olefins were also formed in high yield, the catalyst deteriorated prematurely because of the formation of fatty acids intermediates. Fatty acids do not form in the pyrolysis of the methyl esters, and at this time we have not been able to deactivate the catalyst up to 14 hours of use.

## Other Research – Methyl Ester Formation

At the present time the commercial production of methyl esters takes one to eight hours at a temperature close to 60°C. The reaction is initially slow because of the two-phase nature of the methanol/oil system, and slows even further because of polarity problems. We have addressed the first problem by the use of an inert co-solvent which causes a one-phase reaction. The polarity problem has also been solved with the result that the reaction is complete in one to seven minutes at ambient temperature depending on whether 2 wt.% or 1 wt.% sodium hydroxide is used. Product containing over 99.4 wt.% methyl ester is easily achieved.

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# Pyrolysis of Polymers

*By Professor Walter Kaminsky, University of Hamburg, Germany*

Pyrolysis research has been carried out in the Institute of Technical and Macromolecular Chemistry of the University of Hamburg since 1976. There are extensive laboratory and pilot plant units with throughputs of 100 g/h, 500 g/h, 2-3 kg/h and 20-50 kg/h for the pyrolysis of plastics, rubber, bio-polymers, sewage sludge and oil shale. The pyrolysis of waste polymers is of increasing importance as land filling and combustion become more expensive and the acceptability of these methods is decreasing.

*Figure 1: Pyrolysis reactor capacity 20kg/h small pilot plant.*

## Pyrolysis Units

In the Institute only indirectly heated fluidised beds are used (known as the Hamburg Process). Figure 1 shows the small pilot plant, which has just been fitted with a process control system. The core of the plant is a quartz sand bed reactor with an inner diameter of 450 mm. The polymers are fed into the reactor through a double flap gate or screw and are depolymerised at temperatures between 450 and 900ºC. Recycled pyrolysis gas preheated to 300ºC, or steam or nitrogen is used to create the swirl in the fluidised bed. The heat input takes place indirectly through heat radiation fire tubes inside the fluid bed which are heated by pyrolysis gas. Reactor residence times are short and in the range of a few seconds. The process flowsheet is shown in Figure 2.

## Products from Polymer Pyrolysis

The original aim of the Hamburg Process was to produce benzene, toluene and xylene (BTX) through pyrolysis of plastics at temperatures in excess of 700ºC. In recent years, research efforts have been widened to investigate feedstock and monomer recovery at lower temperatures of 450 to 600ºC. The products are hydrocarbons, gases, oil, and a solid residue containing fillers and impurities such as heavy metals. Olefins as ethylene, propene and dienes are the main product from mixed polyolefins if steam is used as the fluidising gas. At temperatures of 500ºC, polymethylmethacrylate is depolymerised to give more than 98% of the monomer and similar results are obtained with polystyrene.

The pyrolysis oil contains less than 10 ppm of chloro-organic compounds from pyrolysis of mixed plastic fractions from household waste separation with a low PVC content. In a collaborative effort with BP Chemicals and other European companies, the fluidised bed process is being developed to recycle mixed plastic wastes as refinery purified, waxy distillate hydrocarbon are obtained. The content of aromatics is low and lies between 0.1 and 0.3%. Research is continuing to optimise the amounts of monomers and oil from different polymers and to construct an industrial pilot plant.

Some work has also been carried out on higher temperature pyrolysis of biomass in the form of sewage sludge, lignins and bark which gives mainly gas and charcoal.

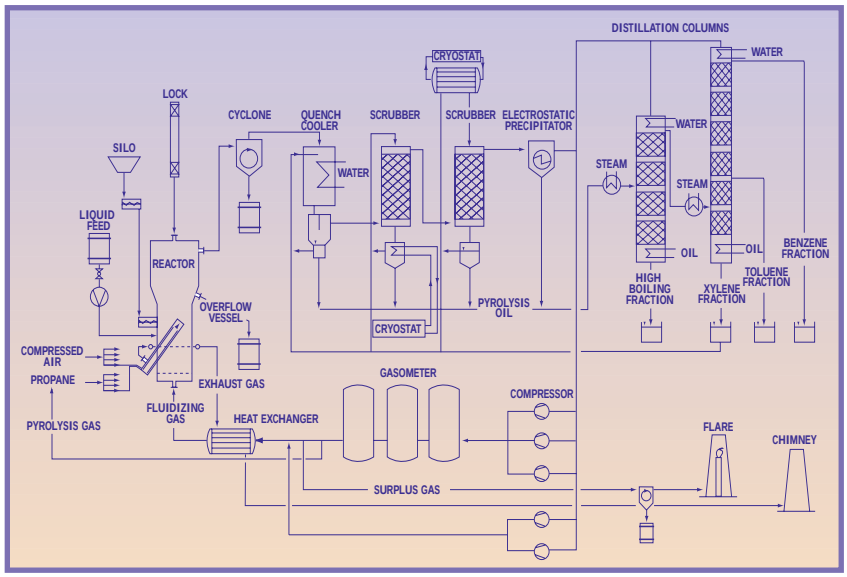


*Figure 2: Process flowsheet.*

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# Binders for the Wood Industry made with Pyrolysis Oil

*By Mr Panagiotis Nakos, Sapemus Chemie GmBH, Germany*

Sapemus Chemie GmBH, specialises in the production of adhesives and auxiliaries for the wood based industry. The adhesives are mainly amino resins (formaldehyde and urea or melamine) and phenolic resins (formaldehyde and phenols). The auxiliaries are catalysts and resin substitutes. As the phenolic resins are of higher commercial importance only this product is described here.

## Chemistry of Resin Production

The reaction of phenol with formaldehyde gives mainly o- and p-hydroxymethylated phenols as shown in Figure 1. This reaction is catalysed by alkali that converts the phenol to the phenol-anion which is highly activated for the electrophilic attack of the formaldehyde. It is obvious that +M and +I substitution in the m-position improve the reactivity of the aromatic ring.

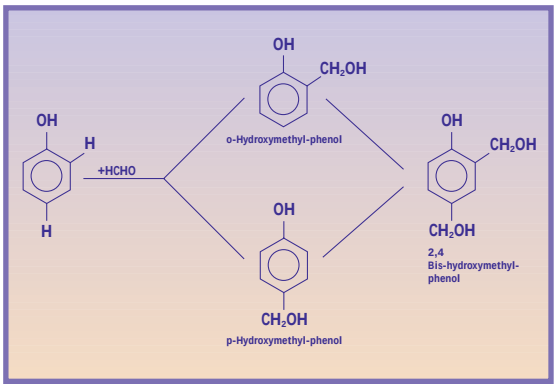


*Figure 1.*

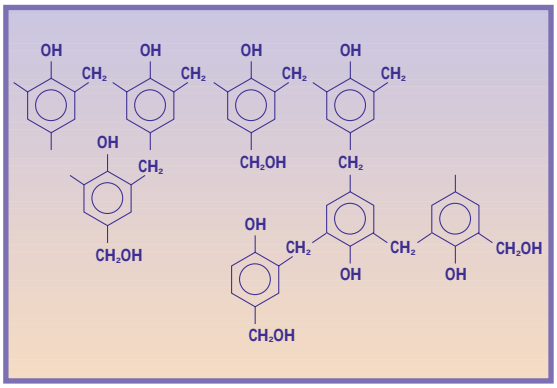


*Figure 2.*

The products depend mainly on the temperature, the reaction time, the alkali amount and the ratio of formaldehyde and phenol. On prolonged heating of the mixture of aqueous formaldehyde with phenol the hydroxymethyl groups start reacting with the free o- and p- positions of the hydroxymethylated phenols giving molecules like the one shown in Figure 2. The mechanism is quite complicated so will not be explained here.

These molecules, which can be linear or branched, are still soluble in the presence of alkali which reacts with the phenolic hydroxyls. This mixture is called resole. The resole can be converted to the absolutely insoluble resit by heating and excess formaldehyde which can be supplied externally in the form of paraformaldehyde. The insolubility of the cured resins makes them one of the most widely used adhesives in the manufacture of water resistant wood based products, mainly plywood and particleboard.

## Phenol Substitution

Phenolic resins are quite expensive due to the rising phenol prices. Additionally, phenol requires very special handling. A substitute for phenol would be welcome if it is:

1. Cheaper than conventional synthetic phenol,
2. Less toxic than phenol,
3. Does not affect the quality of the manufactured resin.

The first two requirements are fulfiled by fast pyrolysis oil. The scope of the current study is to find out whether the third requirement can also be fulfiled by fast pyrolysis oil. While bio-oil has been used in the manufacture of both amino and phenolic resins, only the results with phenolics are reported here.

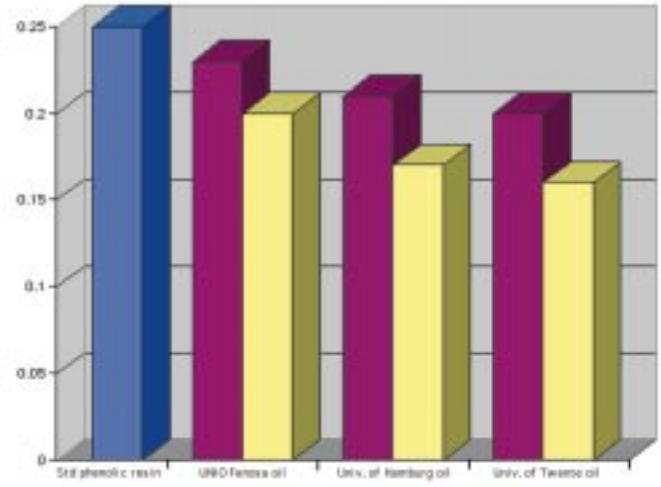


*Figure 3: Wet strength of boards in N/mm$^2$ at 15% and 30% substitution.*

## Results of Bio-Oil Substitution

The substitution of phenol by bio-oil using commercial know-how gives resins with totally different behaviour than conventional resols, with loss of mechanical strength and reactivity. In order to recover the strength and the water durability, major changes in resin preparation had to be made with very promising results.

Up to 30% of the phenol was replaced by bio-oil with no impact on the reactivity (curing time) of the resins. The mechanical properties of the resins were tested with the manufacture of laboratory scale boards. The water durability of the bonding was checked by testing the strength of board samples after 2 hours boiling in water (V100 test, where the strength of boards after boiling has to exceed 0.2 N/mm$^2$ in order to pass the test). This is also the most critical test as the strength of the boards prior to boiling far exceeds the European Norm in all cases. Therefore only the wet strength results at two substitution levels of 15 and 30%, and with three different oils from Union Fenosa, Institute of Wood Chemistry Hamburg, and University of Twente are reported. The results are shown in Figure 3.

Two points become clear from the results. First, the bio-oils provided from different suppliers have different impact and second the properties of the particle boards are in all cases negatively affected with increasing substitution level. However, what is most important is that in most of the cases the EU-Norm value is reached.

## Conclusions

Pyrolysis oil can be used in the manufacture of phenolic resins with very good results. With the oils provided so far, phenol substitutions up to 30% were possible. To provide significant savings for the resin manufacturer, the price of the pyrolysis oil should be not more than 50% of the synthetic phenol price. Its lower toxicity compared to phenol and its conformity with the EU directive for sustainable development – it is produced from renewable resources – make it attractive for further investigation.

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*Typical Wood Products*

# Unión Eléctrica Fenosa

*By Mr Andres Matas, Spain*

## The Company

Unión Eléctrica Fenosa, S.A. is an utility which produces and supplies electrical power to approximately 16% of the Spanish state, that is to say, an 80,000 km$^2$ area located in the central and north-western regions of the peninsula providing approximately 20,000 million kWh annually. There are about 5,000 employees distributed throughout the plants and other premises. The production capacity of 5,500 MW is divided among hydro-power plants (35%), coal, lignite and fuel oil thermal plants (50%) and nuclear power plants (15%).

*Figure 1: Pilot plant of 200kg/h of dry biomass. Meirama, Galicia (Spain).*

The company has been traditionally characterised by a market enterprising and innovative spirit, such that it can be considered the forerunner in the introduction of new technologies, relative to both the methods and sources of production to apply, as well as to the organisational structures and strategies necessary for its internal operation.

Unión Fenosa Ingeniera (UFISA) is part of the Unión Eléctrica Fenosa Group whose activity is centred on consulting and engineering services offering capabilities and experience in fields like architecture and urban planning, civil, electrical, hydraulic, industrial, energy, sanitary and environmental engineering. The scope of services goes from preliminary reports, feasibility studies, projects engineering, management and direction, assistance, control and management of manufacturing, supplies, mounting and start-up as well as turnkey installations, mainly, but not only, energy related plants.

More specifically, in the renewable energies and environmental fields it can provide and has carried out or participated in projects and works on waste management, audits, analysis of environmental impact of plants, recycling, treatment and disposal of MSW with energy recuperation, treatment and disposal of industrial wastes, environment control networks, as well as advanced applications of fossil fuels plants in open cycle, simple steam cycle or combined cycle, and the exploitation of renewable energy sources like biomass, wind, photovoltaic, MSW, marine and solar thermal.

## Pyrolysis

Related to fast pyrolysis of biomass, Unión Eléctrica Fenosa has developed, built and operate a pilot plant *(Figure 1)* of semi-industrial scale (200 kg/h of dry biomass) in Galicia (Spain). Within several European projects and inside the own R&D framework of the group, the bio-oil produced has been analysed and tested in order to evaluate the possibilities and opportunities, from an economic point of view, of this bio-oil as a fuel mainly for power generation.

## Background

In 1987, Unión Eléctrica Fenosa started its activities in the biomass field with a project of using forestry waste in Galicia (north-western Spain) for energy uses.
The first stage of the project was to carry out preliminary studies of feasibility where it was concluded that the fast pyrolysis technology was a suitable one according to the strategy of Unión Eléctrica Fenosa. In this selection it was remarked on the simplicity of the system and the possibility of using the obtained.
The second stage of the project consisted on the design, building and operation of a pilot plant with the aim of outlining the feasibility, efficiency and versatility of the selected technology. In 1992, the construction of the pilot plant was finished and it started to operate in the middle of 1993.

The bio-oil obtained during the operating time of the plant has been supplied to partners involved close to Unión Eléctrica Fenosa, in several European research projects (e.g. AIR, JOULE and RENA programs) inside its agreements.

## Current Activities

Unión Eléctrica Fenosa is involved in two European projects namely:

### JOR-CT95-0081 – Catalytic Pyrolysis of Biomass for Improved Liquid Fuel Quality

The objective of this proposal is to explore a variety of ways of catalytically and chemically modifying the fast pyrolysis process and the pyrolysis liquids to improve their properties and characteristics and thus make them more amenable to utilisation. Subsidiary objectives include minimising the cost of improvement modelling the pyrolysis process, recovering valuable components, and testing the more promising results on a large scale.

*Figure 2: Pyrolysis pilot plant pretreatment area.*

### JOR-CT95-0025 – Bio-Fuel Oil for Power Plants and Boilers

This European project is aimed at:

1. generating performance, emission and cost data for flash pyrolysis oil (bio-fuel oil) utilisation schemes focusing on the market quality of the oil,
2. developing downstream units of oil production, improving the oil quality, and establishing fundamental understanding of biomass pyrolysis,
3. establishing a network of potential oil producers and users.

Within these European projects, Unión Eléctrica Fenosa has operated the pilot plant producing bio-oil for testing and trials at different levels. Moreover and based on the experience acquired on operation, Unión Eléctrica Fenosa has developed techno-economic studies about the possibilities of this technology in the electricity market focused in Spain, taking into account internal factors (stability of the bio-oil, water content, solids, etc.) as well as external factors related to the electricity market (liberalisation, environmental laws, etc.).

## Future Work

As result of the experience of operation, Unión Eléctrica Fenosa started a period of maintenance and improvements of the pilot plant which were aimed at reaching more stable operation and better bio-oil quality, in order to improve the possibilities of the introduction of the product in the ever increasing competitive market of the electricity production. In this way, the trend of the market is to reduce the generation costs in order to be able to compete in the market with competitive prices. Nevertheless in the future electricity market, renewable energies will be subsidised taking into account the environmental benefits of each technology. So, the future activities in the pyrolysis of biomass will be firstly influenced from an internal point of view, by the behaviour of the modifications and improvements as well as the latest results of the projects where Unión Fenosa takes place. Secondly, the possible bonus that the government will set for schemes based on biomass within the liberalised market.

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# Mass Transfer

## may play a role in determining cellulose pyrolysis kinetics

*By Eric M. Suuberg, Brown University, USA*

part 2

### Measuring the vapour pressures of cellulose pyrolysis tars

Part 1 of this pair of articles presented evidence that there are apparently two different commonly reported sets of kinetic constants describing mass loss during the pyrolysis of cellulose[1]. On the one hand there are the results characterised by activation energies in excess of 200 kJ/mol, which come from careful work, normally performed in thermogravimetric (TGA) type systems. On the other hand, there are a number of reports of mass loss kinetics governed by activation energies of about 140 kJ/mol, seen in studies conducted at higher heating rates than are conveniently examined in the TGA. The evidence strongly suggests that a transport limitation is the explanation for this apparent discrepancy, but there are some inconsistencies associated with an explanation based on heat transfer limitations[1,2]. This has led to a search for other plausible sources of transport limitations.

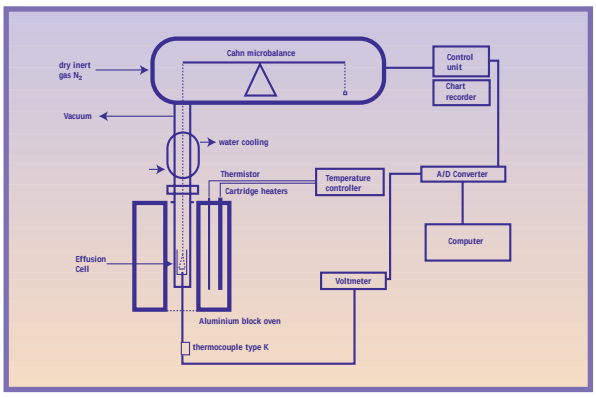


*Figure 1: The device used to perform molecular effusion determinations of the vapour pressures of cellulose tars and levoglucosan[3].*

### A Fortunate Coupling of Interests

At the time we had reached this apparent paradox, we were engaged in other unrelated experiments on the pyrolysis of coal. In those, we were specifically interested in the vapour pressures of coal tars.

The measurements were difficult because coal tars are quite thermally labile at temperatures at which their vapour pressures are conveniently measurable. This required development of a very sensitive vapour pressure technique, which could then be employed at low temperatures. The technique was based upon the classical Knudsen effusion method, in which the mass loss rate from a pinhole leak in a chamber containing the sample allows calculation of sample vapour pressure. Long used for pure materials, the classical method was unsuitable for mixtures, until we developed a modified method analogous to batch distillation[3]. A schematic of the device is shown in Figure 1.

### Measurements of Cellulose Tar Vapour Pressures

The availability of this technique in our laboratory permitted exploration of the nature of cellulose pyrolysis products in a manner similar to that which we were using for coal tars. Our liquid chromatographic and vapour phase osmometric techniques convinced us that most of the mass loss during our cellulose pyrolysis experiments was in the form of condensable products which had a molecular weight close to that of a single glucose residue, as would be expected from the high yields of products such as levoglucosan. It proved to be the case that the vapourisation behaviour of the cellulose pyrolysis tars (or oils) was similar to that of pure levoglucosan[4]. The vapour pressures of pure levoglucosan and our cellulose tar are as shown in Figure 2. The enthalpy of the tar vapourisation process can be calculated from the slope of the vapour pressure curve, and is 141 kJ/mol. This was quite similar to the apparent activation energy for pyrolysis under high heating rate conditions[4].

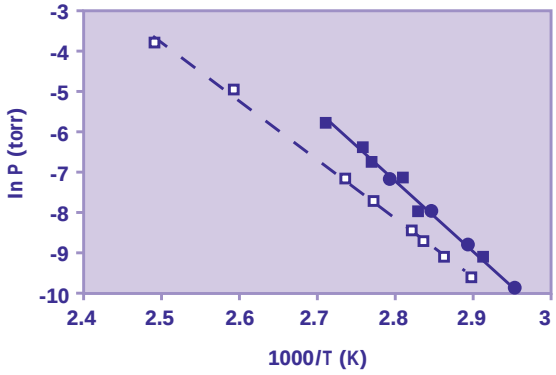


*Figure 2: The vapour pressures of levoglucosan (open points) and fresh cellulose pyrolysis tar (closed points) measured by a Knudsen effusion method [4].*

## Implications for Understanding the Kinetics of High Heating Rate, Mass Transport Limited Pyrolysis Kinetics

Based upon the accumulated evidence, we postulated that the transport limitation, which may govern many of the high heating rate kinetic results, could be mass transport, rather than heat transfer. There were several further pieces of experimental evidence supporting the influence of mass transfer limitations on the apparent kinetics of cellulose pyrolysis[4].

A somewhat simple model can be put forth that permits the role of mass transfer to give rise to the observed high heating rate activation energy. Such a scheme is shown in Figure 3. Cellulose can decompose via a typical unzipping type of process to yield a glucose-like residue, such as levoglucosan[5]. While typically the temperatures are high enough to assure that these decomposition products are somewhat volatile, their vapour pressures are still finite. If there exists within the sample a limitation to outward transport of vapour products, then saturation vapour pressure is achieved within the sample, and the apparent rate of product formation (i.e., mass loss) becomes limited by the rate of vapour transport out of the sample. It is believed that the temperature dependence of vapour pressure becomes a key aspect of the transport, since the pressure exerted by the tars becomes a significant factor in governing the net pressure gradient for convective transport out of the particle. If, on the other hand, the formation rate of (condensed phase) tar intermediates is slow, as it is at low temperatures and heating rates, the forward rate constant $k_1$ is what limits the evolution of products, and the lower apparent activation energy associated with $k_t$ is never observed; this is most likely to be the case in most of the usual low heating rate, small-sample thermogravimetric analysis (TGA) results. We are entirely in accord with the viewpoint that under true chemical kinetic control, a single-step mass loss model should be expected to yield an activation energy of over 200 kJ/mol, as advocated by Antal, Varhegyi and co-workers[6].

The rate constant $k_1$ is a chemical rate constant, corresponding to the pyrolytic breakdown of the cellulose structure. The tar intermediate remains in the condensed phase until it is able to evaporate, at a rate indicated by the constant $k_T$. The evaporation process is in competition with the exothermic chemical reactions which lead to char formation. This is why in situations involving slow mass transport rates, char formation is enhanced. If the rate $k_1 << k_T$, the usual case of chemical rate control is observed. The latter is typical under the low temperature conditions used to examine pyrolysis kinetics in the laboratory. On the other hand, rapid heating to high temperatures ensures a large pool of condensed phase tar intermediates in the sample.

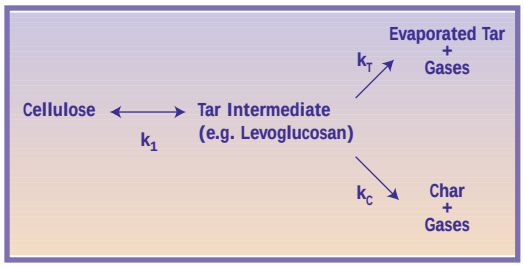


Figure 3: A schematic representation of the role of mass transport processes in determining cellulose pyrolysis kinetics.

## Mass Transfer or Heat Transfer Limitation? It Depends.....

The above is by no means intended to suggest that all of the results in the literature which involve low apparent activation energies for pyrolytic mass loss involve mass transport limitations. It is quite likely that in many cases heat transfer limitations played a role, just as in our own experiments with large blocks of cellulose. But in the cases in which heat transfer limitations do not seem to provide adequate explanation, there is now an alternative explanation. We look forward to continuing our research on the vapour pressures and enthalpies of vapourisation of condensable products of pyrolysis, and intend to extend the study to other biomass components.

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## References

1. Ivan Milosavljevic and Eric M. Suuberg, "Cellulose Thermal Decomposition Kinetics: Global Mass Loss Kinetics", Ind. Eng. Chem. Res., 1995, 34, 1081-1091.

2 Ivan Milosavljevic, Vahur Oja, and Eric M. Suuberg, "Thermal Effects in Cellulose Pyrolysis: Relationship to Char Formation Processes" , Ind. Eng. Chem. Res.,1996, 35, 653-662.

3. Vahur Oja and Eric M. Suuberg, "Development of a Nonisothermal Knudsen Effusion Method and Application to PAH and Cellulose Tar Vapor Pressure Measurement", Analytical Chemistry, 1997, 69, 4619-4626.

4. Eric M. Suuberg, Ivan Milosavljevic and Vahur Oja, "Two-Regime Global Kinetics of Cellulose Pyrolysis: The Role of Tar Evaporation", 26th Symposium (International) on Combustion, The Combustion Institute, Pittsburgh, PA, 1996, pp1515-1521.

5. Glenn R. Ponder, Geoffrey N. Richards and Thomas T. Stevenson, "Influence of Linkage Position and Orientation in Pyrolysis of Polysaccharides: A Study of Several Glucans" Journal of Analytical and Applied Pyrolysis, 1992, 22, 217-229.

6. Michael J. Antal, Jr. and Gabor Varhegyi, "Cellulose Pyrolysis Kinetics: The Current State of Knowledge" Ind. Eng. Chem. Res., 1995, 34, 703-717.

# Recent EC Sponsored Projects on Fast Pyrolysis

*Compiled by Dr Yannis Boukis, CRES, Greece*

## A novel approach for the integration of biomass pyrolytic conversion processes in existing markets of liquid fuels and chemicals: JOR3-CT96-0099

**Partners**
Agricultural University of Athens (AUA), Co-ordinator, Greece
CRES, Greece
University of Stuttgart, Germany
Joint Research Centre (ISPRA), Italy
Technical University of Vienna, Austria
Hellenic Aspropirgos Refinery, Greece

In previous R&D programmes supported by DG XII, a novel fast pyrolysis CFB reactor configuration has been conceived, designed, constructed and tested. The novelty lies in the recirculation of byproduct char to the lower portion of the CFB reactor where it is combusted to provide the process energy requirements.

Preliminary results have given liquid yields of 40-45% wt. on dry feed. However, improvements in the liquid product recovery system should raise the yields of pyrolysis liquids to at least 60-65%. The liquid products are to be analysed and upgrading techniques such as hydro-treatment or zeolite cracking will be thoroughly investigated prior to scaling up the process.

Scale-up to pilot plant and demonstration plant size needs to be based on robust results from extensive experimentation and from large-scale hydrodynamics study. Finally, market applications of the overall process require a detailed risk analysis as well as an assessment of procedures to accelerate pyrolysis products penetration in the existing fuels and chemicals infrastructure and overcome barriers at technical and institutional levels.

### Objectives

The project has the following objectives:

- select alternative feedstocks and evaluate their characteristics,
- assess feedstock suitability for pyrolytic conversion,
- integrate of conversion (flash pyrolysis) and post-treatment (upgrading) systems,
- identify and characterise both upgraded and non-upgraded products,
- produce guidelines to utilise byproducts either internally (energy self-sufficiency) or externally,
- derive scale-up rules for an demonstration flash pyrolysis plant of up to 1 t/h,
- establish requirements for risk analysis of integrated advanced pyrolysis systems,
- identify and make proposals to remove barriers to introduce pyrolysis products to refineries,
- a technoeconomic estimation of an integrated large scale system.

## Development of advanced fast pyrolysis processes for power and heat: JOR3-CT97-0197

**Partners**
Aston University (Co-ordinator), UK
IWC, Germany
BTG, Netherlands
KARA, Netherlands
Ormrod Diesels, UK
Wellman Process Engineering, UK

### Objectives

The primary objective is to design, construct, commission, automate and operate a novel advanced fast pyrolysis process to produce 150 kg/h pyrolysis liquids (bio-oil) for testing in an engine and a boiler. This activity will be supported with experimental work on a modified laboratory pyrolyser with similar feedstocks and operating conditions. This will result in a prediction and performance model of the process. The bio-oil will be characterised and bio-oil fuel specifications suggested. In addition, a rotating cone pyrolysis system will be automated and operated to also provide bio-oil for testing.

The bio-oil will be tested in a modified 250kWe 700 rpm dual fuel diesel engine with measurement of essential process parameters. The bio-oil will also be tested in a modified 100 kWth boiler. Techno-economic and market assessments will be carried out for plants from 1 to 20 t/h.

### Anticipated Achievements and Exploitation

- Design and operation of a 200 kg/h fast pyrolysis pilot plant, to gain sufficient experience to be able to proceed to a demonstration plant,
- Results from an analogous laboratory fast pyrolysis plant with performance models,
- Specifications and procedures for automation of fast pyrolysis systems,
- Chemical and physical analyses of bio-oils with suggested bio-oil standards,
- Operation of a dual fuel diesel engine on bio-oil with sufficient operational experience to be able to offer engines commercially,
- Operation of an industrial boiler on bio-oil with sufficient experience for system demonstration,
- Economic and market assessments of the opportunities for fast pyrolysis and heat and power production.

## Bio-Emulsion: Development of a Bio-Crude-Oil/ Diesel Oil Emulsion: JOR3-CT98-0307



**Partners**
University of Florence Consorzio interuniversitario per lo Sviluppo dei Sistemi a Grande Interfase, Italy
Pasquali Macchine Agricole, Italy
Ormrod Diesels, UK
University of Kassel
Institute für Elektrische Energietechnik, Germany

The aim of this research project is the development of a low-cost physical-chemical and mechanical process for improving the operational properties and performance of pyrolysis oil in small diesel engine units. This process is based on preliminary but very promising results recently obtained by CSGI by a process similar to that developed for particular types of crude oils. These results demonstrated the possibility of:

- Reducing the acidity of the pyrolysis oil,
- Producing binary emulsions with different ratios of pyrolysis oil and diesel from 30 to 75%
- Running small low-speed diesel engines and, for the first time, high speed engines,
- Reducing emissions, particularly in terms of dust and sulphur.

The use of a mixture of the pyrolysis oil and conventional diesel is therefore relevant in both economic and environmental terms.

### Objectives

The proposed research activity has the following main objectives:

- Characterisation of BCO provided by ENEL (Italy) and other suppliers such as Union Electrica Fenosa (Spain) and B.T.G. (Netherlands),
- Development of a low-cost physical/chemical and mechanical process for the BCO quality improvement based on the removal of low molecular weight organic substances and the reduction of inert minerals and other noxious fractions,
- Development and optimisation of stable emulsions ranging from 25% to 75% pyrolysis oil,
- Characterisation of emulsions in terms of physical, chemical, rheological, operational, and thermodynamic stability,
- Design, construction and commissioning of a complete specific feeding system for the engine,
- Experimental campaign to assess the combustion characteristics and performance of the emulsion in small diesel engines and measurement of emission levels,
- Assessment of the economic and market potential for electricity and Combined Heat and Power production,
- Assessment of the effect on rural activity, new job creation (contribution to rural development), and evaluation of the specific investment cost per job created (ECU/job),
- Assessment of the potential benefits on the environment ($CO_2$, CO, $SO_2$, $NO_X$ and dust noxious emissions, improved management of marginal land, forest fire control,etc.),
- Evaluation of the investment financial support needed to penetrate the EU and export markets.

## Small-scale Combined Heat and Power (CHP) from a Bio-Crude Oil (BCO) fuelled Stirling Engine: JOR3-CT97-0310



**Partners**
Centre for Renewable Energy Source (Co-ordinator), Greece
Agricultural University of Athens, Greece
Centre of Solar Energy and Hydrogen Research, Germany
SOLO-Kleinnmotoren, Germany
WS-Warmeprozetechnik, Germany
Hellenic Aspropyrgos Refinery, Greece
Joint Research Centre, Italy
Termiska Processer AB, Sweden

### Objectives

The main objectives of this project are:

- the development of feedstock supply logistics for BCO production via fast pyrolysis,
- evaluate the scale-up potential of biomass fast pyrolysis,
- produce BCO for fuelling a Stirling engine for CHP,
- develop a suitable burner for BCO for a Stirling engine,
- evaluate the techno-economics of the technology, perform Life Cycle Assessment, and carry out market studies for fast pyrolysis technology and end-use applications.

### Expected Achievements

It is expected that immediately after the end of this project, pilot plants can be safely designed for different suitable sites in Europe for demonstration and market introduction and the following industrial benefits are anticipated:

- optimisation of the production and logistics of suitable feedstocks,
- production of BCO will be technically proven,
- the scale-up potential of the fast pyrolysis technology will be investigated,
- the combustion of BCO in the burner of a Stirling engine will be established,
- emissions will be minimised in accordance with EU requirements,
- the economics of the entire system from energy crop to CHP will be evaluated,
- market studies on fast pyrolysis and end-use applications will be carried out.

# Biomass Pyrolysis at the Latvian State Institute of Wood Chemistry

*By Dr Galina Dobele, Latvian State Institute of Wood Chemistry, Riga, Latvia*

The Latvian State Institute of Wood Chemistry was established in 1946 as the Institute of Forestry Problems and Wood Chemistry, Latvian Academy of Sciences. The main research activities of the Institute are:

- Xylogenesis, the structure, chemistry and properties of wood and its components, and their transformation by chemical, thermal, enzymatic and radiation processes,
- Wood protection,
- Biotechnology and bioengineering,
- Processing of wood and its components, biomass and wastes to obtain materials and products with commercial prospects.

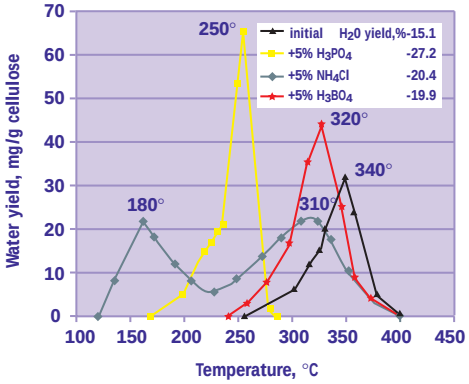


*Figure 1: Variation in water yields obtained by thermal degradation of cellulose in absence and presence of catalysts.*

## Thermal Processing

Thermal processing of wood has been one of the central research activities since the foundation of the Institute. Particularly significant contributions have been:

- the development of a method for production of levoglucosan by pyrolysis of lignocellulose,
- thermo-catalytic production of furfural,
- production of wax from peat,
- improved methods for production of charcoal.

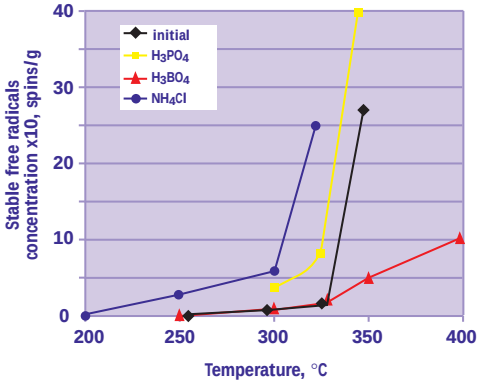


*Figure 2. Formation of polyconjugated systems in solid products of pyrolysis of cellulose in absence and presence of catalysts.*

Thermo-catalytic processing of lignocellulose is the study of materials to produce liquid products from pyrolysis that are suitable for organic synthesis as well as carbonized residues which are characterised by a high sorption activity, magnetizability and other valuable properties.

The research is based on the determination of the mechanism of reactions proceeding over a wide temperature range from 200 to 1000°C. The composition of volatile substances are analysed by GLC and MS, and the structure and properties of the carbonized residue are analysed by TGA, IR, ESR and X-ray photoelectronic spectroscopy. In order to elucidate the impact of separate components of biomass in the pyrolysis process, various model systems are used. Special attention is paid to dehydration reactions which are primary steps in the process of low-temperature destruction and are prerequisites for the formation of polyconjugated structures of carbonization products and interesting monomer products such as levoglucosenone.

A wide range of materials have been pyrolysed including hardwood and softwood, various types of cellulose, lignin-containing wood processing wastes, sewage sludge and agricultural wastes. A variety of chemicals and metals have been tested for their catalytic activity including acids and alkalis, boron, phosphorus and nitrogen compounds and variable valency metals such as iron, aluminium, copper and chromium. Some results are shown in Figures 1, 2 and 3.

## Collaboration

The work on catalytic pyrolysis of biomass to obtain monomer products, primarily levoglucosenone and levoglucosan, is being developed by Dr. G. Dobele, Dr. G. Rossinskaya, Dr. T. Dizhbite and Dr. G. Telysheva. Scientific collaboration with the Institute of Wood Chemistry in Hamburg (Dr. D. Meier and Prof. Dr. O. Faix) has opened up the possibilities for the development of novel pyrolysis technologies for manufacturing valuable monomeric products from biomass as illustrated in Figure 4. The objective of the current joint studies is the optimisation of the production process for 1,6-anhydro sugars.

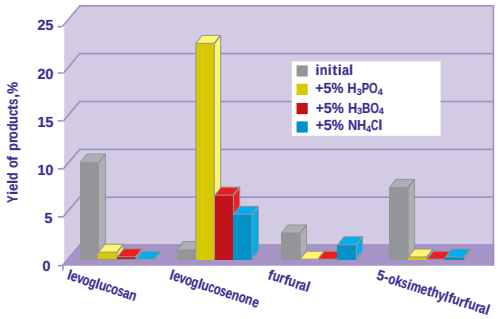


*Figure 3: Yields of the main volatile products obtained by pyrolysis (350°C) of cellulose in absence and presence of catalysts.*

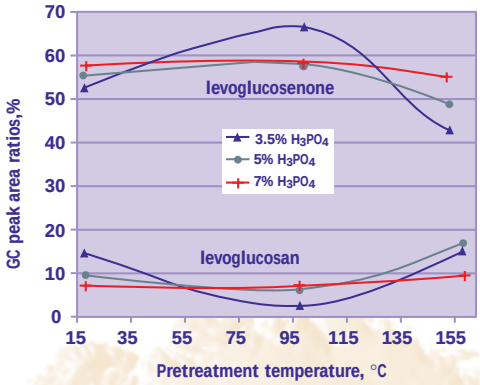


*Figure 4: Results of analytical pyrolysis of cellulose. Variation in levoglucosan and levoglucosenone yields depending on the phosphoric acid amount used for pretreatment.*

## Recent Publications

G. Dobele, T. Dizhbite, G. Rossinskaya, G. Telysheva. Thermocatalytic destruction of cellulose. – In: "Cellulose and Cellulose Derivatives: Physico-chemical aspects and industrial application", Woodhead Pub. Ltd, Cambridge, UK, pp. 125-130 (1995).

U. Viesturs, G. Telysheva, G. Dobele, T. Dizhbite. Energy production from biomass: world experience. Review Biotechnology – Proceedings of LAS, .g., 9/10, lpp. 97-112 (1995).

G. Dobele, N. Bogdanovich, G. Telysheva, U. Viesturs. Application of sorbent obtained by pyrolysis of sewage sludge for biological treatment of waste water. – Applied Biochemistry and Biotechnology, 57/58, pp. 857-876, (1996).

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# News from Canada

*By Ed Hogan, Natural Resources Canada, Canada*

There have been two recent announcements by Canadian pyrolysis companies, which indicate that biomass fast pyrolysis, is receiving increasing commercial interest in Canada.

Northwood Inc. recently announced that they intend to proceed with the construction of an Ensyn Technologies Rapid Thermal Processing (RTP) system at one of their pulp mills in the Prince George, British Columbia area. The Ensyn RTP plant will utilise wood waste currently being incinerated in a beehive burner. In the first phase of the project, 40,000 - 45,000 tonnes of wood waste will be converted into three products – a fuel oil, a high quality carbon and a natural resin product that could be used as a bonding agent in plywood manufacturing. This project is expected to be completed by the fall of 1999. A second phase project is intended to process the remaining 75,000 – 80,000 wood waste.

Pyrovac International, in partnership with Sodexfor and Rexfor in Quebec and Ecotechniek in the Netherlands announced the construction of a Pyrocyclage plant in Jonquiere, Quebec. The system will transform approximately 40,000 tonnes of bark waste into bio-oil and other co products. It is intended that the bio-oil will be fired in an Orenda Aerospace Corp. turbine to produce electricity for sale to the city of Jonquiere. As part of this project, the consortium will examine the commercial potential of producing a number of value added chemicals from the process.

# Universitá Di Napoli Federico II

*By Dr Colomba Di Blasi, University of Napoli "Federico II", Italy*

The University of Napoli dates back to the year 1224, when Federico II di Svevia, heir of both the Roman-German Empire and the Kingdom of Sicily, decided to give rise to an institution whose main aim was to build up a strong and skilful team of experts, in charge of ruling over his huge empire.

Napoli University is among the oldest in Europe: Salerno Medicine School dates back to the XI century, Bologna, Paris, Oxford and Napoli chronologically followed, during the XII century. The fact that Napoli University was laic and did not originate from a religious aggregation was the main difference with all the other middle age universities and, at the same time, it was the main reason for its being left apart in the following years. Napoli University, always pressed by the Church State and the Arabs, was often rearranged by the many conquerors ruling on the kingdom. During the XVI century it resisted the Inquisition showing how an institution founded for the government turned to react against it. During the XVIII, many teachers and students fought and died for ideals of thought independence and justice, keeping up the free spirit of culture. Before the union of Italy (1860), about half of the students in the whole country attended the Napoli University.

The University of Napoli "Federico II" now supports 98,500 students, of which 14,000 attend the Faculty of Engineering. This faculty includes Aeronautical, Building, Chemical, Civil, Computer Science, Electrical, Electronic, Environmental and Territorial Management, Management, Materials, Mechanical, Naval, Telecommunications Engineering and is one of 12 Faculties.

## Current Activities

The staff of the Department of Chemical Engineering consist of 13 faculty teachers, 9 researchers and 14 laboratory and administrative assistants. Eight courses in Chemical Engineering Fundamentals and fifteen courses on selected topics are provided to a typical student population of 150 per year.

The areas of research are:

- biotechnology,
- chemical reaction kinetics,
- combustion,
- environmental protection,
- rheology of polymers,
- thermochemical conversion of biomass and waste,
- transport phenomena.

*Figure 1: A bench scale system for the determination of the chemical kinetics of biomass reactions.*

*Figure 2: Detail of the reactor.*

The high-temperature response of wood and synthetic polymers has been investigated since 1983. Early work focused on applications in the fields of fire safety science and combustion fundamentals, while from 1989 attention moved to energy recovery from biomass and waste. Activities currently carried out by the research group lead by Dr.C.Di Blasi include detailed mathematical modelling and laboratory-scale experiments (single-particle systems, fixed- and fluid-bed reactors coupled with GC and GC-MS, and a fast heating system specifically developed for the analysis of chemical kinetics) of biomass and waste drying, pyrolysis and gasification. These were described in PyNe Newsletter 5.

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*The biomass team.*

# TPS Termiska Processer AB

*By Mr Michael Morris, TPS, Sweden*

TPS Termiska Processer AB is an independent Swedish company, established in 1992, working in the field of energy and environmental process research and technology development. The company employs a strong team of qualified and experienced scientists and engineers, specialising in the areas of combustion and gasification, and today, TPS employs fifty people.

## Activities

TPS's activities include basic and applied research, process and product development and process design, within the heat and power generation sector, with special emphasis on the environment. Services offered by the company include experiment-oriented research and development and technical-oriented consultancy related to the energy and environmental field. Typical of this work is that conducted for more than twenty Swedish energy producers to optimise the operation of their existing boilers by using state-of-the-art techniques including physical and numerical modelling.

Commercial exploitation of new techniques developed by TPS normally progress from test work at bench-scale and in pilot plants through large-scale demonstration plants to commercial operating plants. This type of exploitation has been achieved through both technology licensing and joint venture activities. Projects financed partly by the EU and/or the Swedish government are a significant part of TPS's turnover.

## Laboratory

The work at TPS is backed up by a well-equipped laboratory and a specialised group of laboratory and service technicians.
The equipment in TPS's laboratory includes flow rigs for two and three dimensional simulation of flows and combustion, burners and fluidised bed combustion pilot plants with 2 to 4 MW capacity, small-scale stoves and atmospheric and pressurised gasification plants up to 2 MW capacity. This is shown in Figure 1.

## Commercial Activities

The main thrust of TPS's commercial activities is the promotion of a combined-cycle concept for small to medium-scale electricity production plants, using biomass or RDF as feedstock. This concept includes an atmospheric-pressure gasifier, hot gas conditioning system, cold gas cleaning, gas turbine and steam turbine. This technology will be demonstrated in two IGCC plants, both due for start-up in the next two to three years.

TPS is to supply the gasification know-how to a United Nations Global Environment Facility sponsored project in Brazil. The goal of this project is to confirm the commercial viability of producing electricity from wood through the use of BIG-GT technology. To fulfil this goal, a 30 MWe demonstration power plant will be built in Brazil.

TPS is part of the joint venture company Arbre Energy Limited formed to build, own and operate an 8 MWe biomass-fuelled gasification combined-cycle plant in the UK. This project is sponsored by the EU Thermie programme. The plant will incorporate TPS's gasification technology. The EPC contractor is Schelde Engineers and Contractors, Netherlands. The plant is scheduled to start-up in late 1999 (see http://www.arbre.co.uk).

*Figure 1: 2 MW CFB gasification pilot plant.*

## Recent references


M. MORRIS and L. WALDHEIM, "Energy Recovery from Solid Waste Fuels Using Advanced Gasification Technology" The 1998 International Conference on Incineration and Thermal Treatment Technologies. Salt Lake City, Utah, USA (11-15 May 1998)

K. PITCHER and H. LUNDBERG, "Wood Energy: The Development of a Gasification Plant Utilising Short Rotation Coppice. Project ARBRE" Third International Wood Fuel Conference. Glasgow, Scotland (9-13 October 1995)

E. RENSFELT "Atmospheric CFB Gasification - The Grève Plant and Beyond" International Conference on Gasification and Pyrolysis of Biomass. Stuttgart, Germany (9-11 April 1977)

L. WALDHEIM and E. CARPENTIERI, "Update on the Progress of the Brazilian Wood BIG-GT Demonstration Project" Special Biomass Session, ASME Turbo Expo98. Stockholm, Sweden (2-5 June 1998)


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### Renewable Energy World

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# Energy Costs

By Wolfgang Baldauf, VEBA, Germany

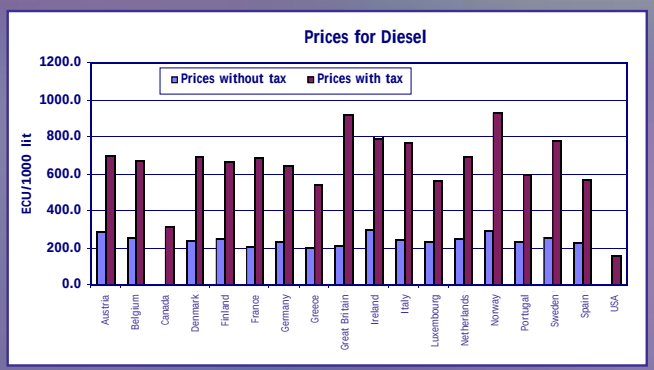
## Fuel Prices 1997

*Date: January - December 1997*

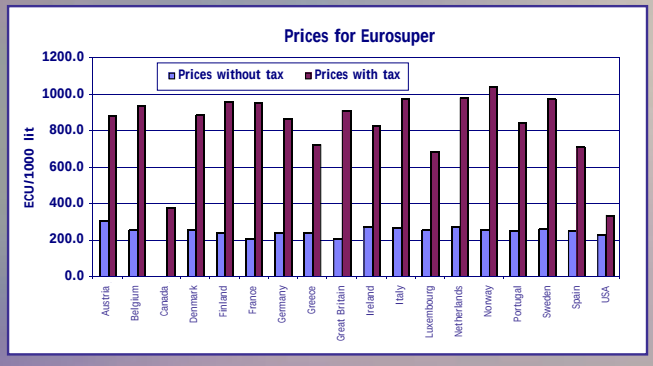
*Sources*
*1 Source: Erdöl-Informationsdienst*
*2 M Gronli*
*3 J Piskorz*
*4 S Czernik*

All liquid fuel prices in ECU/1000l.
Electricity prices in ECU/kWh.
Conversion 1 ECU = 1.100 US$ 1.500 Can$

| Country | Source | Diesel | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Prices without tax | | | Prices with tax | | | Tax |
| | | min. | **av.** | max | min. | **av.** | max. | **av.** |
| Austria | 1 | 277.0 | **286.2** | 298.0 | 688.1 | **699.4** | 713.7 | **413.2** |
| Belgium | 1 | 248.2 | **258.6** | 284.3 | 659.3 | **672.3** | 703.8 | **413.7** |
| Canada | 3 | | | | | **312.7** | | |
| Denmark | 1 | 226.2 | **240.6** | 267.1 | 676.5 | **694.3** | 727.3 | **453.7** |
| Finland | 1 | 238.8 | **254.7** | 299.5 | 646.7 | **665.3** | 721.6 | **410.6** |
| France | 1 | 192.2 | **206.7** | 231.5 | 670.8 | **690.3** | 718.4 | **483.6** |
| Germany | 1 | 222.5 | **236.1** | 258.7 | 628.9 | **645.0** | 670.8 | **408.9** |
| Greece | 1 | 186.4 | **200.4** | 221.0 | 526.3 | **540.7** | 561.9 | **340.3** |
| Great Britain | 1 | 209.5 | **214.4** | 222.5 | 858.8 | **921.7** | 1002.3 | **707.3** |
| Ireland | 1 | 282.2 | **301.0** | 332.0 | 764.5 | **795.0** | 825.8 | **494.0** |
| Italy | 1 | 239.3 | **245.7** | 269.7 | 754.0 | **768.7** | 800.7 | **523.0** |
| Luxembourg | 1 | 222.0 | **234.3** | 253.4 | 553.0 | **567.1** | 589.1 | **332.8** |
| Netherlands | 1 | 244.5 | **255.4** | 288.5 | 669.2 | **694.1** | 722.1 | **438.7** |
| Norway | 2 | | **294.6** | | | **929.8** | | **635.2** |
| Portugal | 1 | 227.3 | **236.6** | 243.0 | 589.6 | **596.5** | 604.3 | **360.0** |
| Sweden | 1 | 225.7 | **256.4** | 279.1 | 760.3 | **784.4** | 834.2 | **528.1** |
| Spain | 1 | 216.8 | **227.7** | 246.1 | 562.4 | **575.3** | 600.1 | **347.6** |
| USA | 4 | | | | | **162.7** | | |

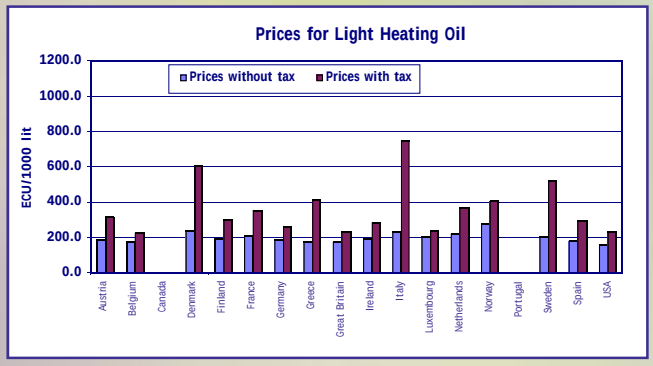



| Country | Source | Gasoline (Euro-super) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Prices without tax | | | Prices with tax | | | Tax |
| | | min. | **av.** | max | min. | **av.** | max. | **av.** |
| Austria | 1 | 299.5 | **307.6** | 325.2 | 868.7 | **878.2** | 899.6 | **570.7** |
| Belgium | 1 | 246.1 | **254.6** | 275.4 | 925.8 | **936.5** | 961.4 | **681.8** |
| Canada | 3 | | | | 326.7 | **384.0** | 400.0 | **204.0** |
| Denmark | 1 | 245.6 | **254.0** | 262.9 | 877.6 | **888.0** | 899.6 | **634.1** |
| Finland | 1 | 222.0 | **241.8** | 272.8 | 940.5 | **962.8** | 1003.8 | **720.9** |
| France | 1 | 195.3 | **206.1** | 219.4 | 943.6 | **959.3** | 976.6 | **753.2** |
| Germany | 1 | 234.6 | **240.8** | 254.5 | 859.8 | **867.1** | 882.9 | **626.3** |
| Greece | 1 | 233.0 | **243.1** | 258.7 | 703.8 | **722.2** | 730.0 | **479.0** |
| Great Britain | 1 | 196.4 | **206.9** | 222.0 | 843.1 | **913.0** | 991.8 | **706.1** |
| Ireland | 1 | 257.6 | **276.8** | 291.7 | 797.5 | **829.3** | 854.1 | **552.5** |
| Italy | 1 | 261.8 | **270.6** | 276.5 | 958.8 | **973.3** | 983.9 | **702.7** |
| Luxembourg | 1 | 247.2 | **256.3** | 276.5 | 675.0 | **685.2** | 707.4 | **428.9** |
| Netherlands | 1 | 265.0 | **273.3** | 292.7 | 944.7 | **981.1** | 1036.8 | **707.8** |
| Norway | 2 | | **255.5** | | | **1046.4** | | **790.9** |
| Portugal | 1 | 244.0 | **251.9** | 261.3 | 836.3 | **844.3** | 856.2 | **592.4** |
| Sweden | 1 | 257.6 | **264.3** | 288.5 | 941.5 | **977.2** | 1039.4 | **712.9** |
| Spain | 1 | 234.1 | **246.9** | 267.6 | 699.6 | **714.9** | 738.3 | **468.0** |
| USA | 4 | | **232.7** | | | **337.3** | | **104.5** |

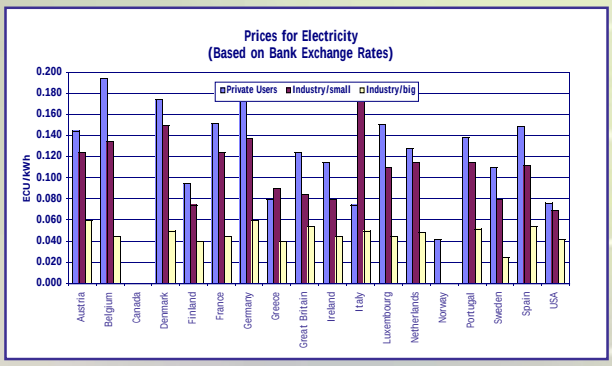


# & Prices

| Country | Source | Light Heating Oil | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Prices without tax | | | Prices with tax | | | Tax |
| | | min. | av. | max | min. | av. | max. | av. |
| Austria | 1 | 170.2 | **186.8** | 216.3 | 297.4 | **318.6** | 352.9 | **131.8** |
| Belgium | 1 | 161.8 | **172.3** | 201.6 | 212.6 | **225.6** | 260.8 | **53.2** |
| Canada | 3 | | | | | | | |
| Denmark | 1 | 230.9 | **241.2** | 258.2 | 591.2 | **604.0** | 625.2 | **362.8** |
| Finland | 1 | 183.8 | **195.6** | 226.7 | 291.7 | **306.4** | 345.1 | **110.8** |
| France | 1 | 201.6 | **216.0** | 241.9 | 339.8 | **357.8** | 389.6 | **141.7** |
| Germany | 1 | 175.9 | **188.8** | 232.0 | 250.8 | **265.4** | 315.2 | **76.6** |
| Greece | 1 | 164.9 | **175.2** | 191.1 | 325.2 | **410.9** | 511.6 | **235.6** |
| Great Britain | 1 | 161.8 | **176.3** | 193.7 | 216.3 | **229.6** | 246.6 | **53.3** |
| Ireland | 1 | 180.7 | **193.5** | 214.2 | 265.5 | **281.3** | 304.2 | **87.8** |
| Italy | 1 | 219.4 | **230.3** | 249.8 | 733.6 | **750.4** | 776.6 | **520.0** |
| Luxembourg | 1 | 194.3 | **205.9** | 228.3 | 223.1 | **236.6** | 261.8 | **30.7** |
| Netherlands | 1 | 203.2 | **218.0** | 255.0 | 347.7 | **365.2** | 409.0 | **147.3** |
| Norway | 2 | | **278.5** | | | **407.7** | | **129.2** |
| Portugal | 1 | | | | | | | |
| Sweden | 1 | 199.5 | **209.2** | 237.2 | 496.4 | **521.0** | 553.5 | **311.8** |
| Spain | 1 | 168.1 | **179.7** | 206.3 | 285.4 | **299.1** | 331.5 | **119.4** |
| USA | 4 | | **160.9** | | | **231.8** | | **70.9** |




| Country | Source | Electricity | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Private Users | | | Industry/Small Consumer 500kW | | | Industry/Big Consumer 10MW | | |
| | | min. | av. | max | min. | av. | max. | min. | av. | max. |
| Austria | 1 | | **0.145** | | | **0.125** | | | **0.060** | |
| Belgium | 1 | | **0.195** | | | **0.135** | | | **0.045** | |
| Canada | 3 | | | | | | | | | |
| Denmark | 1 | | **0.175** | | | **0.150** | | | **0.050** | |
| Finland | 1 | | **0.095** | | | **0.075** | | | **0.040** | |
| France | 1 | | **0.152** | | | **0.125** | | | **0.045** | |
| Germany | 1 | | **0.180** | | | **0.137** | | | **0.060** | |
| Greece | 1 | | **0.080** | | | **0.090** | | | **0.040** | |
| Great Britain | 1 | | **0.125** | | | **0.085** | | | **0.055** | |
| Ireland | 1 | | **0.115** | | | **0.080** | | | **0.045** | |
| Italy | 1 | | **0.075** | | | **0.180** | | | **0.050** | |
| Luxembourg | 1 | | **0.151** | | | **0.110** | | | **0.045** | |
| Netherlands | 1 | | **0.128** | | | **0.115** | | | **0.048** | |
| Norway | 2 | | **0.042** | | | | | | | |
| Portugal | 1 | | **0.138** | | | **0.115** | | | **0.052** | |
| Sweden | 1 | | **0.110** | | | **0.080** | | | **0.025** | |
| Spain | 1 | | **0.149** | | | **0.112** | | | **0.055** | |
| USA | 4 | | **0.076** | | | **0.069** | | | **0.042** | |




Energy

# The Fair–Programme Biomass Projects

*By Mrs Ann Segerborg-Fick, EC, Brussels, Belgium*

This specific programme FAIR concerns all the agriculture, horticulture, forestry, fishery, aquaculture and related food and non-food industries and is jointly managed by the commission services of DG12 (agro-industrial research) and DG6 (agricultural research) and DG14 (fisheries research).

The programme covers several aspects of forestry and agro-industrial work with main interest for the concept of the biomass-to-energy chain, so called integrated projects. This includes selection of raw material for cultivation (short rotation forestry for example), harvesting, fuel production (one example is rape methyl ester to replace diesel) and energy production (small scale combustion for example).

A few demonstration plants have been supported within the programme. Twenty projects have been financed in the FAIR programme of which five were projects concerning pyrolysis. The budget for biomass within the FAIR programme has been 15 million ECU, half of which is contribution from EC. More than 50% of the total has been paid to it's projects. PyNe is supported by the FAIR programme.

# Diary of Events

### Gasification – The Gateway to a Cleaner Future

Venue: Dresden Hilton, Dresden, Germany
Date: 22-24 September 1998
Contact: Conference Section (Gasif3), IChemE, 165-189 Railway Terrace, Rugby, CV21 3HQ, UNITED KINGDOM
Tel: +44 1788 578214
Fax: +44 1788 577182

### International Biomass Ash Workshop

Venue: Technical University Graz, Austria
Date: 1-2 October 1998
Contact: Mrs Anita Schneider, Institute of Chemical Engineering, Technical University, Graz, Inffeldgasse 25, A-8010 Graz, AUSTRIA
Tel: +43 316 873 7461
Fax: +43 316 873 7469
Email: schneider@glvt.tu-graz.ac.at

### 8th Biennial Conference on Biomass

Venue: Madison, Wisconsin
Date: 4-8 October 1998
Contact: Fred Kuzel or Naureen Rana, Great Lakes Regional Biomass Energy Program, 35 East Wacker Drive, Suite 1850, Chicago, IL,60601, USA
Tel: +1 312 407 0177
Fax: +1 312 407 0038
Email: fkuzel@cglg.org OR nrana@cglg.org
Website: http://www.great-lakes.net/partners/cglg/projects/biomass/bioenergy98.html

### Crops for a Green Industry

Venue: Gmunden, Austria
Date: 7-9 October 1998
Contact: Ms Sonja Mayer or Ms Irene Baumann, CFI, Congress & Fair International, Wasagasse 6/12, a-1090, Vienna, AUSTRIA
Tel: +43 1 310 20 07
Fax: +43 1 310 20 09
Email: cfi@Eunet.at
Website: http://cfi.austrian.org

### Making Info Technology Work for Renewable Energy

Venue: Birmingham, UK
Date: 8-9 October 1998
Contact: Julie Belsten, The Franklin Company, 192 Fraklin Road, Birmingham, B30 2HE, UNITED KINGDOM
Tel: +44 121 459 4826
Fax: +44 121 459 8206
Email: ifs@tfc-bham.demon.co.uk

### Materials and Energy from Refuse

Venue: Oostende, Belgium
Date: 12-14 October 1998
Contact: Ms Rita Peys, c/o Technologisch Instituut vzw, Desguinlei 214,B-2018 Antwerpen, BELGIUM
Tel: +32 3 216 0996
Fax: +32 2 216 0689
Email: mer@ti.kviv.be
Website: http://www.kviv.be/ti/mer.htm

### REAP '98 Renewable Energy & Energy Efficiency Asia-Pacific Conference and Exhibition

Venue: Shanghai, China
Date: 14-16 October 1998
Contact: ADA, 1406 Leader Commercial Building, 54-56 Hillwood Road, TST, Kowloon, HONG KONG
Tel: +852 2574 9133
Fax: +852 2574 1997
Email: office@adal.com
Website: http://www.adal.com

### Boosting the Market for Bioenergy in Europe

Venue Herning Congress Centre, Denmark
Date: 19-21 October 1998
Contact: GREEN CITY DENMARK A/S, Merkurvej 910, DK-7400, Herning, DENMARK
Tel: +45 97 21 64 00
Fax: +45 97 21 74 21

### International Conference & Exhibition on Renewable Energy & Energy Conservation for Buildings

Venue: Shanghai, China
Date: 20-22 October 1998
Contact: Room 1322, Building 3, 1486 Nanjing Road. (W), Shanghai 200040, P.R. CHINA
Tel: +86 216 247 9796
Fax: +86 216 204 9481
Email: wjyao@online.sh.cn

# Diary of Events

### Workshop on Optimisation of Pyrolysis Processes for Fluid Fuel Production

Venue: Bergen, Norway
Date: 26-27 November 1998
Contact: Tanja Barth, University of Bergen, Department of Chemistry, Allegaten 41, N-5007 Bergen, NORWAY
Tel: +47 5558 3483
Fax: +47 5558 9490
Email: tanja.barth@kj.uib.no

### 2nd International Conference LCA in Agriculture, Agro-Industry and Forestry

Venue: Brussels, Belgium
Date: 3-4 December 1998
Contact: Mrs Mieke Engelen, Product and Process Assessment, VITO,Boeretang 200, B-2400 Mol, BELGIUM
Tel: +32 14 33 5853
Fax: +32 14 32 1185
Email: engelenm@vito.be

### R'99 – Recovery, Recycling, Re-integration 4th World Congress with Company Displays

Venue: Geneva, Switzerland
Date: 2-5 February 1999
Contact: Ms Maria Bühler,PEAK Ltd, R'99 Project Manager, Seefeldstrasse 224, CH-8008 Zurich GERMANY
Tel: +41 1 386 44 44
Fax: +41 1 386 44 45
Email: buehler@peak.ch

### World Renewable Energy Congress 1999

Venue: Murdoch University, Perth, Western Australia
Date: 10-13 February 1999
Contact: Dr Kuruvilla Mathew, Environmental Science, Murdoch, University, Murdoch, WA 6150, AUSTRALIA
Tel: +61 8 9360 2896
Fax: +61 8 9310 4997
Email: mathew@assun1.murdoch.edu.au
Website: http://www.phys.murdoch.edu.au/acre/

### Fourth European Symposium on Industrial Crops and Products

Venue: Bonn, Germany
Date: 23-25 March 1999
Contact: Sarah Wilkinson, Elsevier Science Ltd, The Boulevard, Langford Lane, Kidlington, Oxford, OX5 1GB, United Kingdom
Tel: +44 (0) 1865 843691
Fax: +44 (0) 1865 843958
Email: sm.wilkinson@elsevier.co.uk
Website: http://www.elsevier.nl/locate/icp99

### SUSTAIN '99 The World Sustainable Energy Trade Fair

Venue: Amsterdam RAI, NETHERLANDS
Date: 25-27 May 1999
Tel: +44 181 289 8989
Fax: +44 181 289 8484
Website: http://www.emml.com

### AgEnergy '99

Venue: Athens, Greece
Date: 2-5 June 1999
Contact: Professor G Papadokis, AgEnergy '99, Dept. of Agricultural Engineering, Agricultural University of Athens, 75 Iera Odos Street, GR 118 55, Athens, GREECE
Tel: +30 1 529 4002, 529409
Fax: +30 1 529 4023
Email: agenergy@auadec.aua.gr
Website: http://www.aua.gr/conferences/agenergy

### Fourth Biomass Conference of the Americas

Venue: Oakland Marriott City Centre
Date: 29 August to 2 September 1999
Website: http://www.nrel.gov/bioam

### REWAS'99 – Global Symposium on Recycling, Waste Treatment and Clean Technology

Venue: San Sebastian, Spain
Date: 5-9 September 1999
Contact: Dr Rodolfo Solozabal, General Secretary of REWAS'99, INASMET, Camino de Portuetxe, 12, B. de Igara, E-20.009, San Sebastian, SPAIN
Tel: +34 43 31 6144
Fax: +34 43 21 7560
Email: rsoloza@inasmet.es

### Progress in Thermochemical Biomass Conversion

Venue: Innsbruck, Austria
Date: 21-26 May 2000
Contact: Prof Tony Bridgwater or Nina Ahrendt Aston University Birmingham B4 7ET UNITED KINGDOM
Tel: +44 121 359 3611
Fax: +44 121 359 6414/4094
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