PyNe

SEPTEMBER 2001 ISSUE 12

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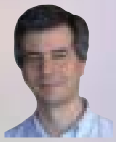

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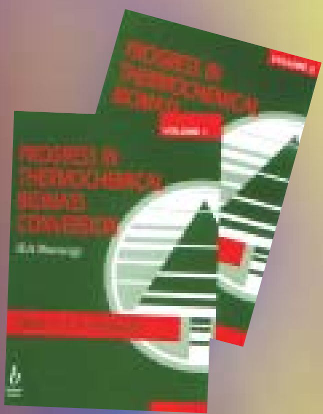
PyNe + GasNet = ThermoNet

ThermoNet comprising PyNe (for biomass pyrolysis) and GasNet (for biomass gasification) had its kick-off meeting in Helsinki at the end of June 2001. PyNe continues to be sponsored by the EC through DG TREN and the Energie programme and by IEA Bioenergy. GasNet will provide an analogous network through Harrie Knoef of BTG in the Netherlands.

The photograph shows Harrie Knoef (leader of GasNet), Kyriakos Maniatis, the EC Project Officer and IEA Bioenergy Executive Committee Vice Chairman, and Tony Bridgwater (leader of PyNe). The focus of PyNe will be based on Technical Topics that are described on pages 7, 8 and 9.



Proceedings from the PITBC Conference now available.

For details of the contents and how to order contact Claire Humphreys or Julie Ellen. For contact details see inside cover.

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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

Co-ordinator
Tony Bridgwater

Newsletter & Website Administrator
Claire Humphreys

Events Organiser
Julie Ellen

Bio-Energy Research Group,
Aston University, Birmingham B4 7ET.
UNITED KINGDOM.
Tel +44 121 359 3611
Fax +44 121 359 6814

Email a.v.bridgwater@aston.ac.uk
c.l.humphreys@aston.ac.uk
j.ellen@aston.ac.uk

Website http://www.pyne.co.uk

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In memory of Professor Antonie Adrianus Cornelis Maria (Ton) Beenackers

It is with great sadness and regret that we have to report the death of Ton Beenackers who passed away on 19th April 2001 after a very short illness.

Ton was known to the whole bio-energy community as an enthusiastic and highly competent chemical engineer with a particular interest in thermal gasification. He was closely associated with the EC RD&D programmes for over 20 years and actively contributed to their evolution through both evaluation and definition of new programmes, as well as through active participation in projects. His most recent major contribution was as Chairman of the Technical Programme Committee for the First World Biomass Conference in Sevilla in June 2000, during which he was awarded the Linneborn Prize for his contribution to bio-energy. More recently he acted as Conference Rapporteur for the Progress in Thermochemical Biomass Conversion Conference in Tyrol, September 2000 and had been actively working on the next European Energy from Biomass Conference to be held in Amsterdam in 2002.

Between these commitments he was a dedicated professor at the University of Groningen, where he led a substantial team working on a wide range of projects which included some on aspects of biomass gasification. He encouraged students to follow bio-energy, particularly in developing countries where he actively promoted scientific and technical collaboration with a focus on chemical engineering. He had a particular affinity with Indonesia and was looking forward to implementing a number of collaboration activities between the Institute of Technology in Bandung and the Universities of Groningen and Twente.

He was never reticent and everyone will remember his warm, incisive and positive contributions to discussions and debates including his impeccable attention at a personal level.

The scientific community has lost a personable and highly valued colleague who can never be replaced.


Low-temperature pyrolysis of CCA treated wood waste

By Lieve Helsen and Eric Van den Bulck, Katholieke Universiteit Leuven, Belgium

Summary

Low-temperature pyrolysis of CCA (copper, chrome, arsenic) treated wood waste at between 300 and 450ºC, enables the CCA to be concentrated in the char and hence disposed of more effectively. The evaluation of this technique, focused on metal and arsenic behaviour during the pyrolysis process, in order to understand the behaviour of the contaminants and hence derive models and hypotheses, that describe the influence of CCA on the thermal decomposition chemistry and the release of arsenic.

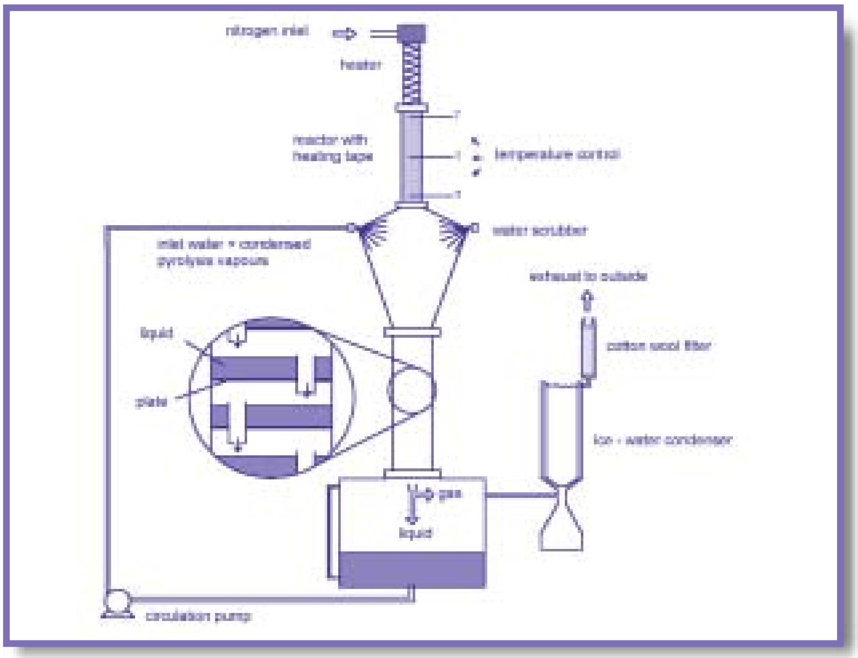

Figure 1: Experimental facility for the pyrloysis of wood chips: downdraft fixed bed reactor with extended gas cleaning system.

Outline of the work

The influence of temperature and residence time of wood particles on the release of Cr, Cu and As and the resulting mass reduction has been studied experimentally (see Figure 1). The influence of CCA has been studied in the kinetically-controlled regime through thermo-gravimetric studies. Mathematical models have been developed that describe the low-temperature pyrolysis of wood waste:

- A complete macro-particle model (combining heat, mass and momentum transfer with chemical kinetics) for the low-temperature pyrolysis of a single dried, untreated wood particle was implemented and validated.
- A kinetic model for the low-temperature pyrolysis of CCA treated wood was derived from the TG results.
- Finally, physical and chemical models for the release of arsenic during low-temperature pyrolysis were validated.

Conclusions

Low-temperature pyrolysis is a promising and valuable technique to dispose CCA treated wood waste, provided that temperature and residence time are precisely controlled. The conversion, as well as the metal volatilisation, can be calculated by incorporating the actual temperature profile in the kinetic schemes derived for the pyrolysis of CCA treated wood on one hand and for the release of As during pyrolysis of CCA treated wood on the other hand. CCA promotes charcoal production.

Chromium and copper do not pose any problems of metal volatilisation at these low temperatures. Arsenic, on the other hand, is the problematic compound. The mechanism responsible for the As release is identified as the reduction of As(V) to As(III), followed by the volatilisation of As(III). Arsenic is probably released as arsenic trioxide (As_4O_6), which is toxic and very difficult to capture. Limiting As release implies minimising this reduction reaction, which means that the As has to remain in pentavalent form and thus the temperature has to be kept low.

The leaching behaviour of As and Cu restricts deposition of char residue in landfill, whereas the presence of Cr poses no problems from leaching. The recombination and agglomeration of metals during the pyrolysis process (metal agglomerates are indicated in Figure 2) allows a dry separation of the metal-containing char residue, which allows complete metal recycling. In the near future an installation for the total recycling process will be built, tested and evaluated.

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For further information, please contact:

Dr. ir. Lieve Helsen
Katholieke Universiteit Leuven
Department of Mechanical Engineering
Division of Applied Mechanics and
Energy Conversion
Celestijnenlaan 300A
B-3001 Leuven (Heverlee)
Belgium
Tel.: +32-1632.2505 or 2509
Fax: +32-1632.2985
Email: lieve.helsen@mech.kuleuven.ac.be
Website: http://www.tme.mech.kuleuven.ac.be/~lieve

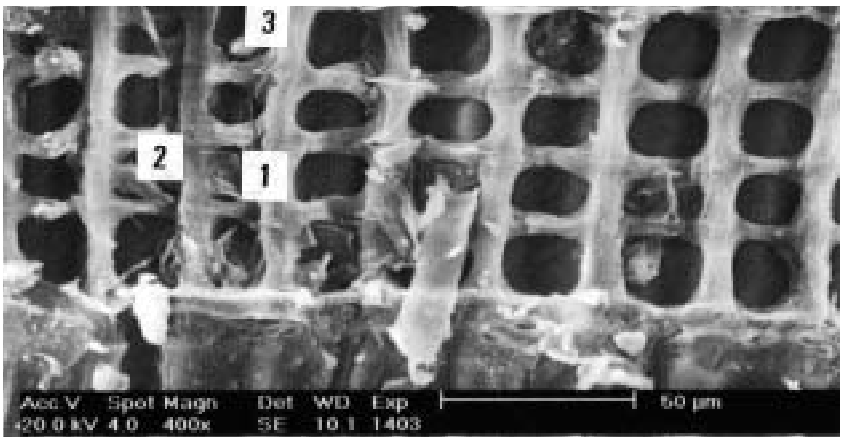


Figure 2: Longitudinal radial sectional view of ray cells in the pyrolysis residue of CCA treated Pinus sylvestris sapwood (400x) with metal agglomerates on the locations 1, 2 and 3.

Finnish Consortium Fortum and Vapo Announce Construction of Pyrolysis Pilot Plant

By Steven Gust, Fortum, Finland

Figure 1: Location of Pilot Plant.

Fortum together with it's partner Vapo Oy of Finland have announced they will begin pilot production of a liquefied wood fuel, utilizing a proprietary technology.

The approximately 3.2 million euro pilot plant with a capacity of 350 kilograms fuel per hour is currently under construction and is scheduled to begin production in the fall of 2001. The process and products will then be further developed and improved with commercialization planned to begin 2003-2004.

This process interests both Fortum and Vapo Oy because it can convert renewable feedstocks such as forestry residues and other industrial waste wood to a liquid fuel, which can be used to replace fossil fuels. "These fuels will have increasing demand in the future as countries look to reduce their net CO_2 emissions," Tapio Alvesalo, Vice President of Corporate Technology emphasizes.

The fuel will be used initially, for heating applications by large customers of light fuel oil, such as schools, retirement homes, office complexes and community buildings etc. Power applications are also being developed. The announcement of pilot plant construction is the conclusion of extensive development work by both companies and their partners in the 1990s in the areas of feedstock selection, processing concepts, pyrolysis fuel properties and use.

Competitiveness of the partnership

Vapo's R&D Director Timo Nyrönen further emphasises the importance of feedstock logistics to the overall success of the project. This includes proper selection of feed materials, collection and natural drying, chipping and transport to the production plant.

"It is the unique combination of Fortum Oil and Gas, as a refinery and chemical process developer and Fortum Power and Heat as a multifuel customer, utilising a wide variety of different boilers that has given the partners the added confidence required to launch a project of this magnitude" adds Tapio Alvesalo.

Commercial size planned for 2004

The size of the pilot plant was carefully selected to ensure easy scale up to commercial sizes based on past experiences of Fortum. This capacity is suitable for the development of applications and further fuel property improvements, but is too small for commercial production which will be roughly ten times this size. The pilot plant which is currently under construction, is situated in an existing building (Figure 1) at the Technology Centre of the Porvoo Refinery, in order to take advantage of the local infrastructure and development staff. Figure 2 shows a portion of the biomass preparation equipment under construction.

"If the test production plant operates according to our expectations and we do not encounter major difficulties in the development work, we will be in a position to start the planning for a commercial-size production plant towards the end of 2002, which would be completed in 2004," says Jukka-Pekka Nieminen, Fortum's Project Development Manager.

Figure 2: feedstock preparation under construction.

For further information, contact:-

Mr Steven Gust
Fortum Oil and Gas
Technology Centre
PO Box 310
Porvoo
Fin-06101
Finland

Tel: +358 20 450 3738
Fax: +358 20 450 6691
Email: steven.gust@fortum.com

Biomass Pyrolysis at NREL

By Stefan Czernik, NREL, USA

In the recent years, the priorities of the NREL research in thermochemical conversion biomass have changed from developing/improving the process for generating liquid product, bio-oil, to converting biomass into gaseous fuel and its use in energy generators (engines, micro-turbines, fuel cells).

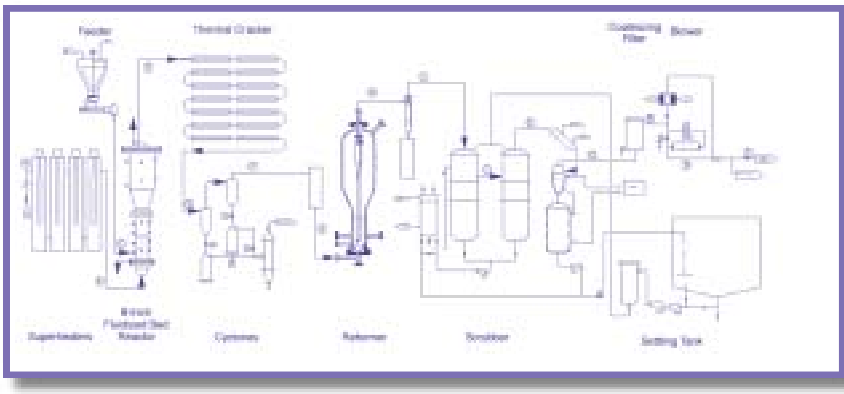


Figure 1: 8" Fluidised bed reactor reformer flowsheet.

Figure 2: Fluidised bed reactor at NREL.

For over 15 years, NREL has used the vortex (cyclonic) reactor as its primary reactor for thermoconversion of biomass and related feedstocks. Last year, a fluidized bed reactor was added to the NREL Thermochemical Users Facility (TCUF). The reactor is a 1.8 m high cylindrical vessel of 20 cm diameter in the lower (fluidization) zone, expanded to 36 cm diameter in the freeboard section. It is equipped with a perforated gas distribution plate and an internal cyclone to retain entrained bed media (typically sand).
The reactor is heated electrically and can operate at temperatures up to 700°C at a throughput of 15-20 kg/h of biomass.
The unit usually operates at similar conditions to those optimized for liquid production. However, superheated steam is used as the carrier gas and pyrolysis vapors, before condensation, are thermally cracked in the secondary tubular reactor at 800-850°C.
The char particles are then separated from the gas/vapor stream using two cyclones and, occasionally, hot baghouse filter. The tars and steam are removed in a scrubber system.
The unit is equipped with on-line monitors of the gas composition (CO, CO_2, CH_4, H_2, O_2), gas chromatographs, and molecular-beam mass spectrometer. Typically, 1-1.1 kg of gas is produced from 1 kg of biomass.

Clean, dry gas of HHV in the range of 17-19 MJ/kg is used as a fuel for a 15 kW commercial engine devised for combustion of natural gas. At the gas flow of 11 kg/h, the engine efficiency was 27% based on HHV and 29% on LHV. With λ (air to fuel ratio) of 1.2 the emissions included 2.5-3 g CO, 0.20-0.25g THC, and 5-10 g NOx for every kWh of the engine output.

Recently, a catalytic steam reformer was coupled to the pyrolysis/gasification system. Similarly to the pyrolyzer, the reformer is also an externally heated fluidized bed reactor that will be used to produce hydrogen from pyrolysis gas and vapors generated in the first stage of the process and to clean the gas from tars.

For further information contact:

Stefan Czernik
NREL
1617 Cole Boulevard
Golden
Colorado
80401
USA

Tel: +1 303 384 7703
Fax: +1 303 384 6363
Email: Stefan_Czernik@NREL.Gov

NREL
National Renewable Energy Laboratory

Implementation of Biomass Pyrolysis in Austria – Investigation of Possibilities

By Maximilian Lauer, Joanneum Research, Austria

An Austrian national project investigated and evaluated the possibilities to produce and to use pyrolysis oil as a fuel. The technical and economical aspects and the status of the technology development were reviewed and recommendations for the implementation in Austria were given.

Production of pyrolysis oil, technology, state of development, cost

Several processes for the production of pyrolysis oil are under development. Concerning the use (shipping, storage, use in burners etc.) it can be compared with a mixture of LFO and HFO. In Europe five demonstration plants will be operating in 2002. In Austria the cost for producing pyrolysis oil will range from 24 to 37 EUR/MWh, this is between prices for fossil fuel oils (light fuel oil, heavy fuel oil) in average from May 2000 to May 2001.
A sufficient availability of wood as feedstock for pyrolysis is assured in Austria.

Use of pyrolysis oil, technologies, state of development, economics

Pyrolysis oil can be used as a fuel for heating boilers (> 200 kW), low speed Diesel engines and gas turbines. Up to now, no appropriate burner technology is available for small heating boilers. The use in intermediate and big boilers are proven by experimental work in Finland and Sweden; no major problems are expected for the development to the state of the art. Experiments on the use in low speed Diesel engines with CHP were quite successful. In 2002 a demonstration plant will be put into operation in the UK. The use in gas turbines is in the experimental phase; there are plans to start a demonstration plant in the UK in 2002.

The economics for the use of pyrolysis oil in heating boilers are quite good compared to the use of fossil fuel oils. Also the competitiveness of using pyrolysis oil in Diesel engines is good. The use in gas turbines is only competitive under specific conditions. In Table 1 the competitiveness as an indicator for the economic situation is given, comparing the use of pyrolysis oil with the use of wood chips both in boilers and in CHP plants. Wood chip boilers are more competitive than pyrolysis oil boilers.
But practically the use of wood chip boilers is restricted to the wood processing industry. Pyrolysis oil boilers can be used in all branches of industry. Competition between pyrolysis oil and wood chip boilers has to be considered only in the wood processing industry.

Pyrolysis Oil	Power	cf	Wood chips	Power	cf
Boilers	0.5 MW	0.98–1.36	Boilers	0.5 MW	1.62
	2 MW	1.03–1.46		2 MW	1.88
	5 MW	1.04–1.48		5 MW	2.01
CHP-plants			CHP-plants		
Diesel	2.4 MWe	0.92–1.22	FB – Gasifier CHP	0.5 MWe	1.08
Gas Turbine *)	20 MWe		Biomass IGCC *)	45 MWe	1.3

Table 1: Competitiveness of the use of pyrolysis oil compared to the use of wood chips (Austria 2001).

cf: Indicator of the competitiveness (cost relation to conventional energy supply) cf < 1: not competitive cf increases with competitiveness

*) basis for cost estimation rather unsure

Environment, Health and Safety

Standards for the pyrolysis oil as a product and for shipping and handling do not exist, although in preparation. Compared to the use of fossil fuels a reduction between 59% and 84% of the greenhouse gas emission (depending on the specific application) can be achieved.

Recommendations for the Implementation in Austria

Based on the project results, recommendations for further activities aiming on implementation of pyrolysis technology in Austria are given:

- Realisation of a pilot pyrolysis plant (in the case of positive results of the demonstration plants in Europe).
- Realisation of experimental and demonstration plants for heating boilers and Diesel engine CHP.
- Technical development of small scale heating boilers.

For further information contact:

Dr Maximilian Lauer
Institute of Energy Research
Joanneum Research
Elisabethstrasse 5
A-8010 Graz
AUSTRIA

Tel: +43 316 876 1336
Fax: +43 316 876 1320
Email: max.lauer@joanneum.ac.at

PyNe TECHNICAL TOPICS

A number of Topics have been agreed to form the focus of the technical contributions of PyNe over the next three years. Some are being carried out in co-operation with the associated Network in ThermoNet – GasNet and these are indicated as Joint Topics. In addition, other aspects will be routinely covered such as technology developments and in associated projects such as economic and financial aspects. A summary list is shown below and further details of the PyNe and Joint topics are also provided.

PyNE Topics and Leaders	
Applications for bio-oil	S. Czernik
Characterisation, analysis, norms & standards	D. Meier and A. Oasmaa
Environment, health and safety aspects of bio-oil	P. Girard
Slow pyrolysis for charcoal	M. Gronli
Technical and non technical barriers	W. Prins
Technology review	
Economics and finance	To be covered in an associated ALTENER Project
Joint Topics and Leaders	
Education, training, information and PR	J. Arauzo (PyNe) + G. Neri (GasNet)
Environment, health & safety – general aspects	R. Buehler (GasNet) + P. Girard (PyNe)
Gas processing and tar reactivity	I. Gulyurtlu (GasNet) + K. Pedersen (PyNe)
Country reports	All members

PyNe TOPICS

Applications for bio-oil Leader: Stefan Czernik

Objectives
- Review current applications for fast pyrolysis liquids
- Define research needs to enhance and develop the use of bio-oil

Scope
- Application of bio-oil as liquid fuel for boilers, engines and turbines – e.g. performance, emissions
- Potential of bio-oil as a transport fuel – e.g. upgrading, blending
- Bio-oil as a source of chemicals – e.g. liquid smoke, adhesives, fertilizers, bio-lime, fine chemicals

Work Plan
- Review of literature on combustion of bio-oil – list of references
- Analysis of advantages and deficiencies of bio-oil as fuel – Upgrading methods
- Emissions from bio-oil combustion – Can they meet standards?
- Identify new potential applications – Co-firing, blend, slurries
- Research needs to enhance use

Deliverables
- Reports on fuel and chemicals
- Publications, presentations

Norms, Standards, Characterisation & Analysis Leaders: Dietrich Meier and Anja Oasmaa

Objectives
- Review and update physical and chemical methods
- Review and update properties of oils from demonstration plants
- Formulate recommendations for specifications and classification of bio-oils

Scope
- Methods for testing and analysis

Work Plan
- Review and update methods for analysis and characterisation
- Identify on-line methods
- Identify methods for physical upgrading
- Assess correlation between oil quality and composition
- Recommend handling and analytical procedures
- Propose classification system
- Distribute instructions and standards for analyses

Deliverables
- Report on recommended handling and analytical methods for pyrolysis liquids
- Proposed list of specifications

Environment, Health and Safety Leader: Philippe Girard

Objectives
- Improve knowledge on E.H.S. concerns at 3 levels:
  – Regulations
  – Process emissions
  – Bio oil toxicity

Scope
- Collect and review data and information
- Carry out toxicity test

Work programme
- Collection and review of existing regulations (in collaboration with GasNet)
  – Develop and circulate a questionnaire
  – Collation of information
  – Reporting
- Collect existing emission data (in collaboration with GasNet)
- Develop a proposal to fund a bio-toxicity study

Deliverables
- Set of European/US regulations information data
- Process environmental impact data
- Set of necessary, toxicological and eco-toxicological data for substance notification (ELINCS)
- Data for process optimisation
- Recommendations for safety procedures

Slow Pyrolysis for Charcoal Leader: Morten Grønli

Objectives
- Provide industry, researchers and decision makers a state of the art review of technologies for slow pyrolysis
- To identify the need for technology development and new exploitation of charcoal

Scope
- Feedstock:
  – native wood
  – agro residues
  – solid-recovered biofuels
- Production:
  – pre-processing (size reduction, drying and handling)
  – carbonization processes
  – emissions
- Utilization:
  – energy (cooking, co-firing, etc.)
  – industry (metal reduction, filtration, activated carbon, etc.)

Work Plan
- Prepare a questionnaire and compile information on available industrial carbonization processes. Process the information and make a state of the art review
- Prepare a questionnaire and compile information from each member country collate the information and prepare a report
- Arrange a seminar/workshop
- Distribute information on PyNe Web-site

Deliverables
- Report on available industrial carbonization processes including feedstock pre-processing and emission control systems
- Report on:
  – charcoal production and processes in each member country
  – import/export figures in each member country
  – charcoal utilization in each member country (metallurgical/cooking/etc.)
- Report on:
  – future (potential) utilization of charcoal
  – technology improvements and research needed

Technical/Non-Technical Barriers Leader: Wolter Prins

Objectives
- Identify and monitor barriers
- Assess routes for solution
- Remove the barriers, where possible

Scope
- Technical, such as:
  – Pyrolysis plant and environment interaction
  – Phase stability
  – Solids in oil – application related
  – Water, mineral content
  – Acidity
  – Odour
  – Noise
  – Emissions
- Non-technical such as:
  – Capitalization
  – Requirement for standards
  – Requirement for EHS data
  – Alternatives, wind, solar, ethanol, fossil
  – Feedstock cost and scarcity
  – Public perception
  – National/local legislation

Work Plan
- On a bi-annual basis circulation by mail of a list of barriers and solution. PyNe members can add barriers and routes of solution to the list. This list will be re-circulated amongst the PyNe members and parts of it published in the PyNe newsletter. If desired experts can be contracted to provide some of the most pressing solutions. Dissemination of information by means of a PyNe workshop and through the newsletter and website.

Deliverables
- Bi-annual updated list of technical and non-technical barriers and their status
- Identification of routes for solution
- Publication and dissemination of results

JOINT TOPICS WITH GasNet

Education, Training, Information & PR **Leaders:** Jesus Arauzo and Giuseppe Neri (GasNet)

Objectives
- To promote the use of thermochemical processes, pyrolysis and gasification as a source of energy
- To deliver clear and comprehensive information about processes and installations
- To promote courses and exchange of students

Work Plan
- Information
  – Standard basic information sheets on processes and installations
  – Review of existing thermochemical course
  – List of host institutions
  – Events
- Education
  – Targeted courses on specific topics
  – Summer courses
  – Student exchanges – school – school and school – industry
- Training
  – Courses for technical and non-technical people

Deliverables
- List of courses (programmes)
- List of institutions
- Summer courses programme
- Video/CD ROM

Gas processing & tar reactivity **Leaders:** Karsten Pedersen and Ibrahim Gulyurtlu (GasNet)

Objectives
- Collect information about gas upgrading regarding
  – Particle separation
  – Aerosols
  – Tar characteristics and reactivity
  – Process requirements
  – Contaminants from waste

Scope
- Different gasification and Pyrolysis processes
- Identification of particles tars and emissions of pollutants with different processes

Work programme
- Review existing information
- Collect new information
- Organize a workshop/seminar on this particular topic
- Identify needs for further R&D
- Coordinate information with IEA Activities

Deliverables
- Provide information for a database for ThermoNet

Environmental Health and Safety (General) **Leaders:** Philippe Girard and Ruedi Buehler (GasNet)

Objective
- To review all aspects of environment, health and safety that impact on thermal biomass conversion processes

Scope
- Collect and review data and legislation pertaining to gasification and pyrolysis processes and products

Work Programme
- Collect data on gasification and pyrolysis processes in terms of emissions from members of both Networks and any other relevant sources
- Collect data on gasification and pyrolysis products as made and as used from members of both Networks and any other relevant sources
- Compile information on current and proposed legislation that may impact on commercial implementation of thermal conversion processes
- Collate members experiences on EHS aspects of implementation at research development and commercial stages of development

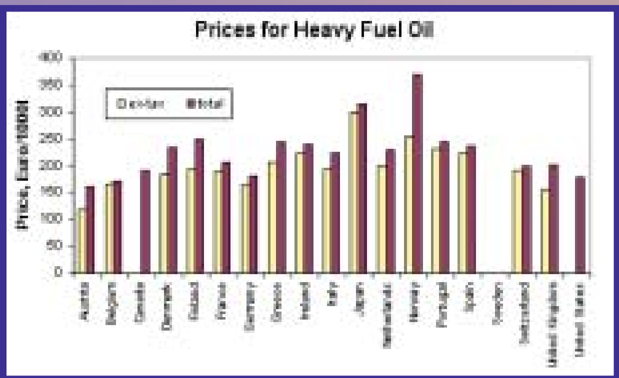
Deliverables
- Report on thermal conversion process emissions
- Report on emission from products as made and in use
- Report on current and planned legislation and its impact on implementation
- Report on practical experiences of plant operation in terms of EHS

Energy

By John Brammer, Bio-Energy Research Group, Aston University, UK

Fuel Oils

Country	*Heavy Fuel Oil*			*Light Fuel Oil (Industry)*			*Light Fuel Oil (Domestic)*		
	ex-tax	tax	total	ex-tax	tax	total	ex-tax	tax	total
Austria	119.3**	41.4**	160.7**	157.4**	39.4**	196.8**	297.3	150.3	447.6
Belgium	165.4	6.0	171.4	276.1	13.6	289.6	276.1	74.4	350.5
Canada			190.5			262.6			
Denmark	184.5	50.1	234.6	377.5	32.5	410.0	330.1	416.5	746.6
Finland	193.7	55.1	248.7	286.2	67.3	353.5	286.2	145.1	431.3
France	187.6	17.9	205.4	279.1	80.2	359.3	320.0	145.1	465.1
Germany	163.9	17.2	181.1	289.9	61.1	351.1	289.9	117.3	407.3
Greece	207.2	37.3	244.5	301.1	114.8	415.9	301.1	189.6	490.8
Ireland	224.7	13.1	237.8	296.5	47.2	343.6	361.4	98.2	459.7
Italy	193.0	30.2	223.2	337.2	376.8	714.0	337.2	519.6	856.8
Japan	300.1	15.0	315.1	295.1	14.8	309.9	450.8	22.5	473.4
Netherlands	198.9	29.6	228.5				334.2	227.6	561.8
Norway	254.6	116.2	370.9	446.2	57.8	504.0	456.5	176.1	632.6
Portugal	231.7	12.0	243.7						
Spain	224.4	12.9	237.4	286.8	78.4	365.2	286.8	136.8	423.6
Sweden				269.8	62.5	332.3	300.0	341.0	641.0
Switzerland	192.0	7.6	199.6	269.3	8.7	278.0	293.9	31.4	325.3
United Kingdom	156.7	43.4	200.1	215.1†	50.7†	265.8†	284.3	67.5	351.8
United States			178.7			251.5			389.0



Average prices over full year, except † part year only, * 1999, ** 1998

All liquid fuel prices in Euro/1000l

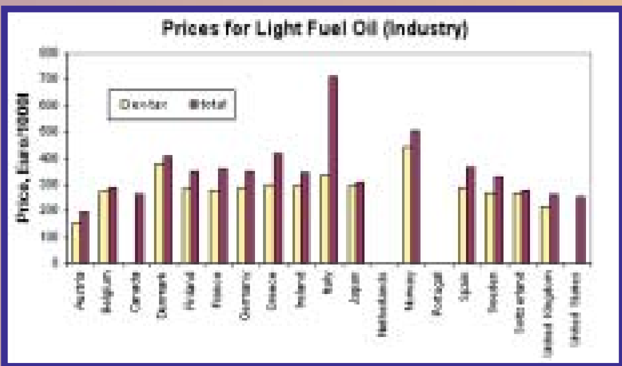
All gas and electricity prices in Euro/100kWh (or c/kWh), gas on GCV basis

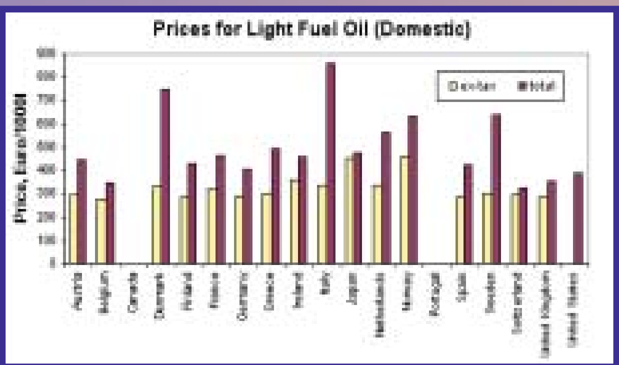
All currency conversions based on exchange rates only

1 Euro = 0.925 US$, 1.955 DM

Principal source: IEA Energy Prices and Taxes, 1st Quarter 2001 (ISBN 92-64-19069-4)

Brazil omitted as no data available

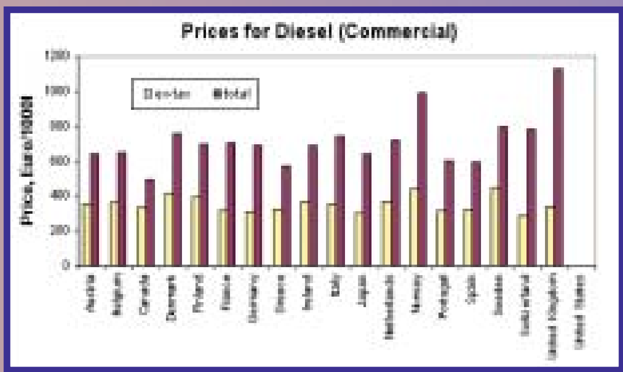


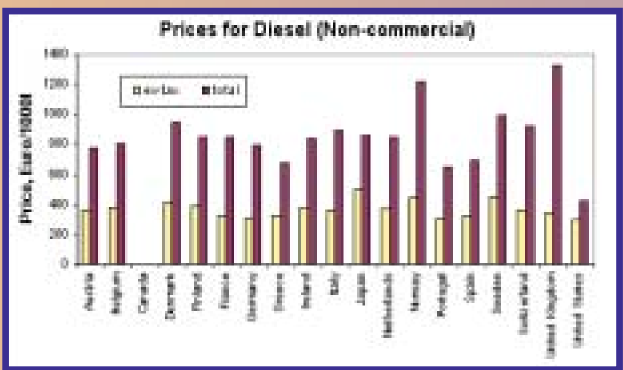


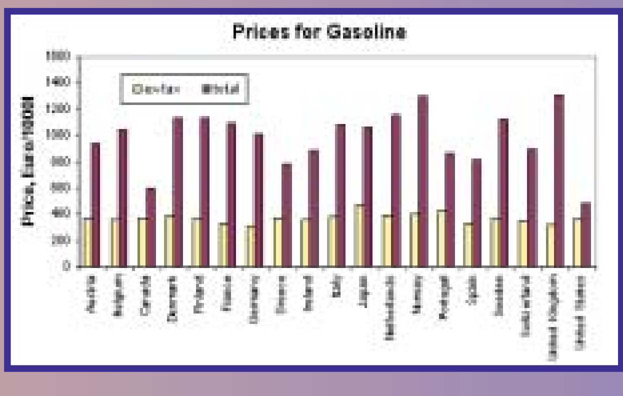
Prices & Taxes 2000

Transport Oils

Country	Diesel (Commercial)			Diesel (Non-commercial)			Gasoline		
	ex-tax	tax	total	ex-tax	tax	total	ex-tax	tax	total
Austria	357.7	288.6	646.3	357.8	417.8	775.6	369.0	569.2	938.2
Belgium	362.6	289.0	651.6	378.5	429.1	807.7	358.0	686.7	1044.7
Canada	333.4	162.3	495.8				367.6	229.3	597.0
Denmark	415.1	343.4	758.5	414.7	532.9	947.6	391.4	744.3	1135.7
Finland	391.4	302.9	694.4	391.4	455.8	847.2	369.5	761.0	1130.5
France	320.8	384.1	704.9	321.5	524.4	846.0	332.2	762.3	1094.4
Germany	311.3	377.0	688.3	311.3	487.0	798.3	311.3	700.0	1011.3
Greece	326.3	245.4	571.7	325.3	349.4	674.7	370.1	410.9	781.0
Ireland	367.9	317.4	685.3	375.5	462.8	838.3	385.4	524.7	880.2
Italy	359.2	382.3	741.5	359.2	530.5	889.7	380.3	700.3	1080.6
Japan	299.8	341.0	640.8	488.4	353.0	841.5	477.4	590.7	1068.0
Netherlands	369.0	350.4	719.4	369.0	476.1	845.1	392.0	767.3	1159.3
Norway	440.8	548.1	988.9	440.8	775.6	1216.4	406.8	891.7	1298.5
Portugal	314.0	292.4	606.4	311.5	339.7	651.1	437.7	427.2	864.9
Spain	326.8	268.9	595.7	326.8	364.2	691.0	333.7	483.1	816.8
Sweden	452.8	345.6	798.4	452.8	545.2	998.0	370.9	753.1	1124.0
Switzerland	286.9	493.1	780.1	358.7	561.7	920.3	356.1	540.5	896.6
United Kingdom	340.2	791.6	1131.8	340.2	989.5	1329.7	320.6	986.2	1306.8
United States				296.2	126.5	422.7	373.0	110.3	483.2

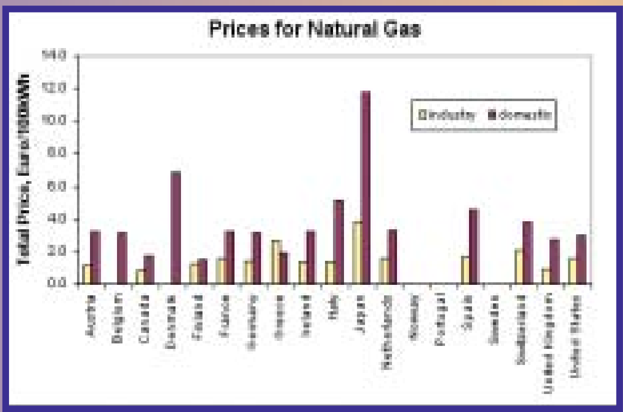






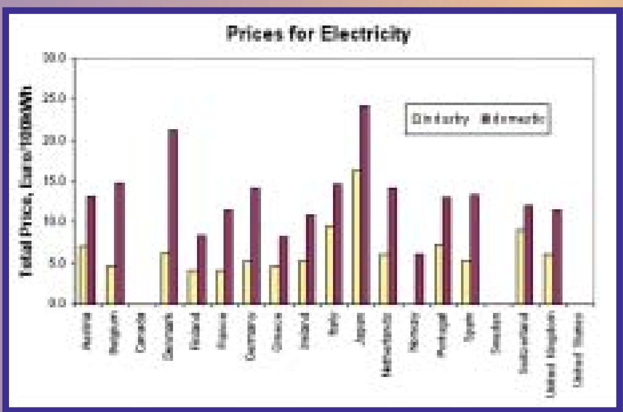
Gas

Country	Natural Gas (Industry)			Natural Gas (Domestic)		
	ex-tax	tax	total	ex-tax	tax	total
Austria	1.19**		1.19**	2.35	0.89	3.24
Belgium				2.49**	0.67**	3.16**
Canada			0.80†			1.76†
Denmark				3.38	3.46	6.84
Finland	1.06	0.16	1.22	1.05	0.43	1.48
France			1.56	2.75	0.48	3.23
Germany	1.19**	0.18**	1.37**	2.52**	0.60**	3.12**
Greece	2.47*	0.20*	2.67*	1.77†	0.14†	1.91†
Ireland	1.35		1.35	2.88	0.33	3.21
Italy	1.19**	0.13**	1.32**	2.75*	2.39*	5.14*
Japan	3.61*	0.18*	3.79*	11.20*	0.56*	11.76*
Netherlands	1.46	0.09	1.55	2.16	1.18	3.34
Norway						
Portugal						
Spain	1.63		1.63	3.88	0.69	4.57
Sweden						
Switzerland	2.05	0.02	2.07	3.54	0.29	3.83
United Kingdom	0.90†		0.90†	2.59	0.13	2.72
United States	1.58		1.58			2.86



Electricity

Country	Electricity (Industry)			Electricity (Domestic)		
	ex-tax	tax	total	ex-tax	tax	total
Austria	7.03**		7.03**	9.46	3.66	13.12
Belgium	4.68**		4.68**	12.09**	2.70**	14.79**
Canada						
Denmark	5.18	1.06	6.24	8.55	12.79	21.34
Finland	3.74	0.43	4.17	6.19	2.22	8.41
France	4.18**		4.18**	8.84**	2.71**	11.55**
Germany	5.32*		5.32*	12.24*	1.94*	14.17*
Greece	4.60†		4.60†	7.65†	0.61†	8.26†
Ireland	5.29		5.29	9.74	1.21	10.95
Italy	8.15	1.47	9.62	11.29	3.35	14.64
Japan	15.08*	1.22*	16.29*	22.67*	1.60*	24.28*
Netherlands	5.94	0.24	6.17	9.83	4.34	14.17
Norway				3.98	2.20	6.17
Portugal	7.25		7.25	12.46	0.62	13.08
Spain	4.96*	0.25*	5.21*	10.98*	2.41*	13.39*
Sweden						
Switzerland	8.99		8.99	11.20	0.84	12.03
United Kingdom	6.07†		6.07†	10.97	0.56	11.53
United States						



Pyrolysis Research at Advanced Fuel Research, Inc. (AFR)

By Michael A. Serio, AFR, East Hartford, CT USA

AFR has been involved for several years in R&D on the pyrolysis-based conversion of biomass into fuels, chemicals and materials. Much of this work has been sponsored by the U.S. Government, in particular the Department of Energy (DOE), the National Science Foundation (NSF), the Environmental Protection Agency (EPA), the U.S. Department of Agriculture (USDA) and the National Aeronautics and Space Administration (NASA). In addition, significant biomass R&D work has been carried out for private companies and institutions.

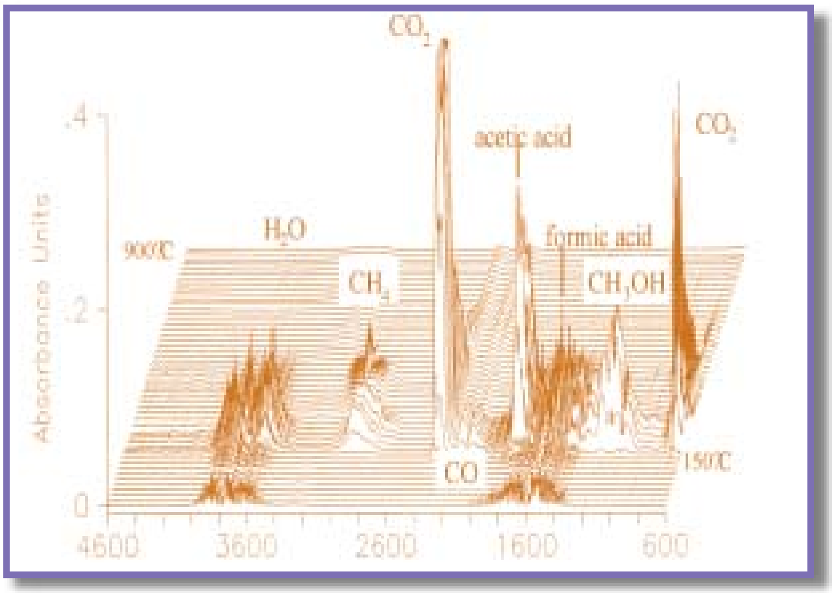


Figure 1: Sequential FT-IR spectra of xylan sample from TG-FTIR analysis at 30°C/min.

A primary investigative tool is a thermogravimetric analyzer equipped with FT-IR analysis of evolved gases (TG-FTIR). While TG-FTIR systems are available from several manufacturers, the system used at AFR was developed in-house with the collaboration of Bomem, Inc., an FT-IR spectrometer company. It is designed to permit analysis of the heavy tars (liquids) that form from the pyrolysis of biomass materials, in addition to the light gases [1]. A stack plot of FT-IR spectra collected from pyrolysis of a sample of xylan in the TG-FTIR apparatus is shown in Figure 1.

Figure 2 (see page 14) shows a comparison of quantitative evolution rate data for major pyrolysis species from the TG-FTIR for samples of cellulose, xylan and an organsolv lignin. These types of data are usually collected at multiple heating rates and used to build pyrolysis models based on the methodology used in AFR's Functional-Group. Depolymerization, Vaporization, Crosslinking (FG-DVC) model [2]. The data in Figure 2 clearly show the differences in the pyrolysis behavior of the different feedstocks. For typical biomass samples, quantitative data are routinely obtained on nearly 20 volatile species, including tars, H_2O, CO,CO_2, COS, SO_2, CH_4, C_2H_4, HCN, NH_3, acetic acid, acetaldehyde, formic acid, formaldehyde, methanol, phenol, acetone, and levoglucosan.

Many different types of biomass materials and waste products have been studied. These include the pyrolysis of lignin to produce chemicals [3], pyrolysis of waste tires to produce activated carbon and carbon black [4], and pyrolysis of plant biomass materials to produce fuel gases, chemicals and materials (activated carbon) [2].
A current NASA sponsored study is developing a prototype pyrolyzer for recycling of mixed solid waste streams in space [5].
The equipment is shown in Figure 3 (see page 14).

AFR is constantly expanding its biomass pyrolysis database with the purpose of providing kinetic and composition inputs to the biomass pyrolysis model. The kinetic data collected at low heating rates, where product resolution and quantification are relatively easy, is used in the model to obtain predictions for high heating rate pyrolysis.

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5. Serio, M.A., Kroo, E., Bassilakis, R., Wójtowicz, M.A., and Suuberg, E.M., "A Prototype Pyrolyzer for Solid Waste Resource Recovery in Space," Proceedings of the 31st International Conference on Environmental Systems, Orlando, FL, USA, July 9-12, 2001, SAE, Paper No. 200-01-2349.

For further information, please contact:

Dr. Michael A. Serio
President
Advanced Fuel Research, Inc.
87 Church Street
East Hartford,
CT 06108-3728
Tel: +1 860-528-9806, ext. 105
Fax: +1 860-528-0648
Email: mserio@AFRInc.com

Dr. Marek A. Wójtowicz
Manager, Hydrocarbons Group
Advanced Fuel Research, Inc.
87 Church Street
East Hartford, CT 06108-3728
Tel: +1 860-528-9806, ext. 142
Fax: +1 860-528-0648
Email: marek@AFRInc.com

Mr. Kenneth A. Wexler
Director, Business Development
Advanced Fuel Research, Inc.
87 Church Street
East Hartford, CT 06108-3728
Tel: +1 860-528-9806, ext. 126
Fax: +1 860-528-0648
Email: kwexler@AFRInc.com

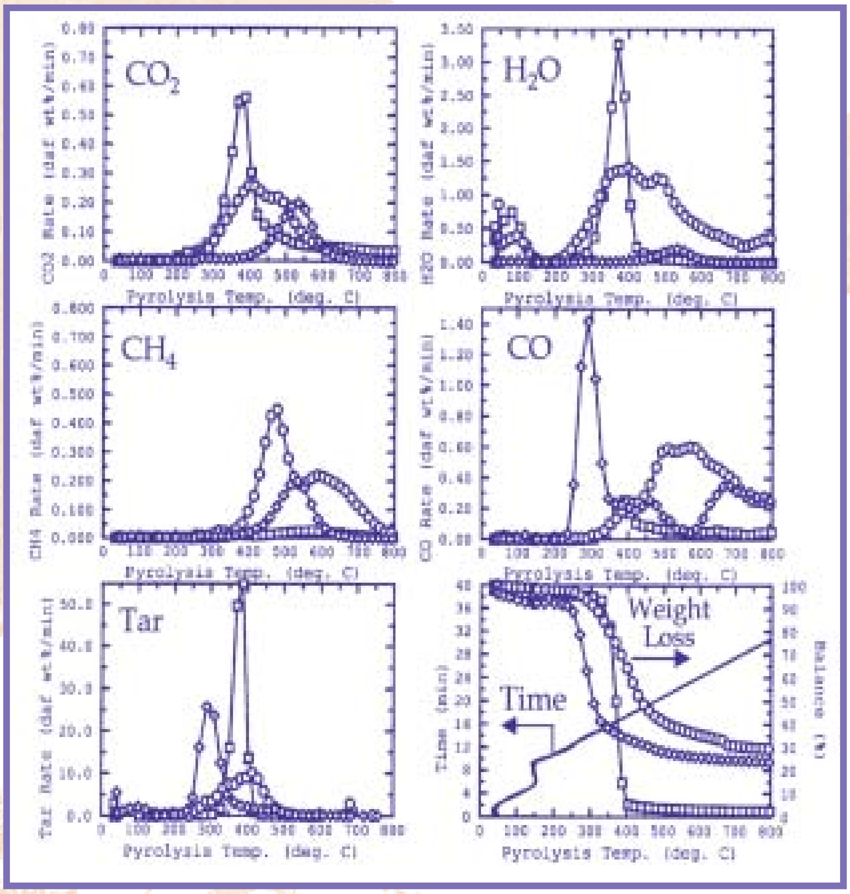

Figure 2: Comparision of TG-FTIR pyrolysis data for cellulose (squares), hemicellulose (xylan, diamonds), and ALC lignin (circles) at 30°C/min.

Figure 3: Picture of inlet side of NASA prototype pyrolyser.

Diary of Events

Information compiled by Claire Humphreys, Aston University, UK

Energie Aus Holz 2001

Venue: Straubing, Germany
Date: 4-7 October 2001 Contact:
Christian Schröter or
Walter Wallrapp
C.A.R.M.E.N.
Technologiepark 13
D-97222 RIMOAR, Germany
Tel: +49 9365 8069 32
Fax: +49 9365 8069 55
Email: contact@carmen-ev.de
Website: www.carmen-ev.de

18th World Energy Congress: Energy Markets: The Challenges of the New Millennium

Venue: Buenos Aires, Argentina
Date: 21-25 October 2001
Contact: 18th WEC
c/o Congresos Internationales SA
Moreno 584 – Piso 9
1091 Buenos Aires, Argentina
Tel: +54 1 4342 3216/4342 3283
Fax: +54 1 331 0223/334 38111
Email: 18th-wec@congresosint.com.ar

Renewable Energy Indonesia 2001

Venue: Jakarta's International Exhibition Centre, Kemayoran
Date: 7-10 November 2001
Contact: Stephen Luff
Overseas Exhibition Services Ltd
11 Manchester Square
London
W1U 3PL, UK
Tel: +44 207 862 2090
Fax: +44 207 862 2098
Email: indonesia@montnet.com
Website: www.montnet.com

2nd Annual European Renewables 2001 Summit

Venue: Brussels, Belgium
Date: 20-21 November 2001
Contact: Inbal Osmo
Tel: +44 (0)207 704 6161
Fax: +44 (0)207 354 9590
Email: iosmo@thecwcgroup.com
Website: www.thecwcgroup.com

Conferencia Cientifica internaacional MEDIO AMBIENTE SIGLO XXI

Venue: Santa Clara, Cub
Date: 20-24 November 2001
Contact: Ing. Pedro Casanova Treto
Universidad Central
'Marta Abreu' de las villas
CETA
Carretera a Camajuaní km 5_
Santa Clara, CP 54830
Villa Clara, Cuba
Tel: +53 422 281194 / 281630
Fax: +53 422 281608
Email: pcasanova@fim.uclu.edu.cu
Website: pcasanova2000@yahoo.com

International Conference on Energy and Quality of Life Policy Directions in the New Millennium and Symposium on Lighting

Venue: Baroda, India
Date: 29-30 November and
1 December 2001
Contact: Professor Rachel George or
Ms Z Marina
Conference Secretariat
Technical Backup Support Unit
NPIC
Home Management Dept,
Faculty of ome Science
The Maharaja Sayajirao
University of Baroda
Vadodara 390 002 India
Tel: +91 265 794864; 795060; 786429
Fax: +91 265 794864
Email: rachel_george1@rediffmail.com

6th European Conference on Industrial Furnaces and Boilers

Venue: Estoril, Lisbon, Portugal
Date: 2-5 April 2002
Contact: Professor Albino Reis
Rua Gago Coutinho, 185-187
4435-034 Rio Tinto
Portugal
Tel: +351 22 973 4624; 0747
Fax: +351 22 973 0746
Email: conference@infub.pt
Website: www.infub.pt

BIOS ENERGIE 2002

Venue: Lons le Saunier, France
Date: 4-7 April 2002
Contact: Francçis Bornschein or
Cécile Pierron
BP 149
28 Boulevard Gambetta
F-39004
LONS LE SAUNIER cedex, France
Tel: +33 384 47 8100
Fax: +33 384 47 8119
Email: salons@itebe.org
Website: www.itebe.org

Technibois Energie 2002

Venue: Québec, Canada
Date: 2-4 May 2002
Contact: Rolande Gauvin
GESTION TB Inc
C.P. 1010
CAN-G6P 8Y1
Victoria (Québec), Canada
Tel: +1 418 845 8247
Fax: +1 418 845 8576
Email: gesttb@videotron.ca
Website: www.technibois.com

Sustainable Development of Energy, Water and Environment Systems

Venue: Dubrovnik, Croatia
Date: 2-7 June 2002
Contact: 2002 Dubrovnik Conference
Energetika Marketing
Sokolska 25
HR-10000 Zagreb, Croatia
Tel: +358 1 3771 256
Fax: +358 1 3772 429
Email: dubrovnik2002@ege.hr

12th European conference and Technology Exhibition on Biomass for Energy, Industry and Climate Protection

Venue: Amsterdam, Netherlands
Date: 17-21 June 2002
Contact: ETA-Florence
Piazza Savonarola, 10,
I-50132 Florence
Tel: +39 055 500 2174
Fax: +39 055 57 3425
Email: eta.fi@etaflorence.it
Website: www.etaflorence.it
OR
Contact: WIP-Munich
Sylvensteinstr., 2
D-81369 Munich
Tel: +49 89 720 1235
Fax: +49 89 720 1291
Email: wip@wip-munich.de
Website: www.wip-munich.de

ISREE-8 Conference

Venue: Orlando, Florida
Date: 4-8 August 2002
Website: www.fsec.ucf.edu/ed/iasee

Waste Management 2002

Venue: Cadiz, Spain
Date: 4-6 September 2002
Contact: Gabriella Cossutta
Conference Secretariat
Waste Management 2002
Wessex Institute of Technology
Ashurst Lodge, Ashurst
Southampton, SO40 7AA, UK
Tel: +44 (0) 238 029 3223
Fax: +44 (0) 238 029 2853
Email: enquiries@wessex.ac.uk
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PyNe Membership

Please contact your country representative for further information.

Co-ordinator

Tony Bridgwater
Bio Energy Research Group
Aston University
Birmingham
B4 7ET
UNITED KINGDOM
Tel: +44 121 359 3611
Fax: +44 121 359 6814/4094
Email: a.v.bridgwater@aston.ac.uk

Austria

Maximilian Lauer
Institute of Energy Research
Joanneum Research
Elisabethstrasse 5
A-8010 Graz
AUSTRIA
Tel: +43 316 876 1336
Fax: +43 316 876 1320
Email: max.lauer@joanneum.ac.at

Belgium

Yves Schenkel
Centre for Agricultural Research (CRA)
Chaussée de Namur, 146
Gembloux
B–5030
BELGIUM
Tel: +32 81 612501
Fax: +32 81 615847
Email: schenkel@cragx.fgov.be

Denmark

Karsten Pedersen
Danish Technological Institute
Teknologiparken
DK8000 Aarhus C
DENMARK
Tel: +45 7220 1000
Fax: +45 89 43 8673
Email: karsten.pedersen@dti.dk

Finland

Anja Oasmaa
VTT Energy
New Energy Technologies
PO Box 1601
Espoo, FIN-02044 VTT
FINLAND
Tel: +358 9 456 5594
Fax: +358 9 460 493
Email: Anja.Oasmaa@vtt.fi

France

Philippe Girard
Cirad Forêt
Maison de la Technologie
73 rue J.Breton
TA 10/16
34398 Montpellier Cedex 5
FRANCE
Tel: +33 467 61 44 90
Fax: +33 467 61 65 15
Email: philippe.girard@cirad.fr

Germany

Dietrich Meier
BFH-Institute for Wood Chemistry
Leuschnerstrasse 91
D-21031 Hamburg
GERMANY
Tel: +49 40 739 62 517
Fax: +49 40 739 62 502
Email: d.meier@holz.uni-hamburg.de

Greece

Elma Gyftopoulou
C.R.E.S. – Biomass Department
19th km Athinon Marathonos Ave
GR 190 09
Pikermi – Attikis
GREECE
Tel: +30 1 60 39 900 Ext 416
Fax: +30 1 60 39 904/905
Email: elma@cres.gr

Ireland

Pearse Buckley
United Waste Ireland Limited
33 Elm Road
Donnycarney
Dublin 9
IRELAND
Tel: +353 1 805 8222
Fax: +353 1 805 8223
Email: pearseb@iol.ie

Italy

Colomba Di Blasi
Universitá degli Studi di Napoli
'Federico II'
Dipartimento di Ingegneria Chimica
P. le V. Tecchio
80125 Napoli
ITALY
Tel: +39 081 768 2232
Fax: +39 081 239 1800
Email: diblasi@unina.it

Netherlands

Wolter Prins
BTG
Business & Science Park
Pantheon 12
PS Enschede
7521
NETHERLANDS
Tel: +31 53 486 2282
Fax: +31 53 432 5399
Email: w.prins@ct.utwente.nl

Norway

Morten Gronli
SINTEF Energy Research
Thermal Energy and Hydropower
7034 Trondheim
NORWAY
Tel: +47 73 59 37 25
Fax: +47 73 59 28 89
Email: Morten.Gronli@energy.sintef.no

Portugal

Filomena Pinto
INETI-ITE-DTC
Edificio J
Azinhaga dos Lameiro
Estrada do Paço do Lumiar
1699 Lisboa Codex
PORTUGAL
Tel: +351 1 716 52 99
Fax: +351 1 716 65 69
Email: Filomena.Pinto@ineti.pt

Spain

Jesus Arauzo
Universidad de Zaragoza
Chemical & Environmental Engineering
Department
Centro Politecnico Superior
María de Luna 3
E 50015 Zaragoza
SPAIN
Tel: +34 97 676 1878
Fax: +34 97 676 1879
Email: qtarauzo@posta.unizar.es

Sweden

Erik Rensfelt
TPS Termiska Processer AB
Studsvik
S-611 82 Nykoping
SWEDEN
Tel: +46 155 221385
Fax: +46 155 263052
Email: erik.rensfelt@tps.se

USA

Stefan Czernik
NREL
1617 Cole Boulevard
Golden, Colorado,
80401, USA
Tel: +1 303 384 7703
Fax: +1 303 384 6363
Email: Stefan_Czernik@NREL.Gov

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