



Newsletter

NUMBER 1, MAY 2001

TASK MEMORANDA

Don Stevens

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FROM THE TASK LEADER

Welcome to the new IEA Bioenergy Task 39. Biofuels are becoming a significant part of the motor fuels mix in many countries. These renewable fuels address global and regional environmental concerns, provide opportunities for economic development, and help ensure national energy security.

IEA Bioenergy initiated Task 39 in 2001 to assist participants with biofuels implementation. The Task provides a framework to examine a range of biofuels issues in a consistent manner. These include:

- Policies and regulations that assist biofuels implementation in the shorter term
- Technical issues that support development of ethanol from lignocellulosic resources and provide for longer-term reduction of fuel prices
- Specialized topics and issues related to biodiesel

The integrated Task 39 builds on the successes of previous IEA Bioenergy tasks in each of those areas.

We welcome all the participants to the new Task, and we actively solicit your opinions and input regarding the Task in general or the Newsletter. Please feel free to contact me or any of management team with your suggestions. The Task organization and a list of participants is provided later in this document. Additional information on IEA Bioenergy can be found at www.ieabioenergy.com. ♦

EDITORS NOTES

D. J. Gregg

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I want to welcome all of you to the first issue of the Task 39 newsletter. Although this issue is somewhat late I hope to get the next newsletter out by the end of June.

Those of you that were receiving the Task 26 newsletter will likely already recognize my name particularly in the role of editor. Welcome back!

For all those people not involved with my previous efforts I want to welcome and encourage you to provide both content and feedback for the newsletter. Our past experience has shown that the newsletter provides tremendous possibilities for both information transmittal as well as a starting point for meaningful dialog.

A new Task has instilled a feeling of renewal into my efforts as the newsletter editor. I have modified slightly the look of the newsletter as well as moved closer to an e-book design using more pdf format capabilities. The newsletter is now fully searchable, contains hot links within the document via the bookmarked Table of Contents and hot-links to the outside world through e-mail addresses and websites.

In my other role as the webmaster for Task 39 I have been busily developing webpages incorporating elements of the past Tasks 26 and 27 as well as implementing some of my own ideas and wishes. I am currently trying to get the website on the Internet by the end of May, 2001. The website will initially be just a source of information. However, I have also been actively researching the possibility of hosting a list server or web forum to provide the opportunity for commentary and response on news items. This idea of providing a community chat line or bulletin board is not new. Past experience has suggested that there is a real need for this type of forum, particularly for students and young researchers. However, the administration and monitoring of the sessions can become extremely time consuming. I have expressed an interest in trying a web fo-

rum and will be setting one up later in the year. Please send any words of wisdom my way on this issue.

This first issue of the Task 39 newsletter contains primarily information on the concluding activities of the past two Tasks (26 & 27) which have combined their efforts in the new Liquid Biofuels Task. The newsletter will be organized to provide sections for each of the three subtask leaders to report on their individual areas of interest i.e., policy/regulatory issues to deployment of the liquid biofuels, technical issues associated with biodiesel, and technical issues with fuel ethanol.

The newsletter and website will, in large part, only be as good as the information that it contains. Please feel free to send me any relevant information, weblinks or other comments. Active participation is encouraged! ♦

RECENT ACTIVITIES

Task 39 held its initial kick-off meeting in Paris on April 2, 2001. Participants reviewed the status of the IEA Bioenergy work and focused the Programme of Work so the new efforts can begin.

Task 39 was also well represented at the 1st World Biofuels Conference in Paris on April 3-4, 2001. Members of the management team made presentations on policy/regulatory issues, the status of lignocellulosic research for ethanol production, and on biodiesel.

Task 39 also organized a technical session at the 23rd Symposium On Biotechnology For Fuels And Chemicals that was held in Breckenridge, Colorado on 8 May 2001. More information is provided on page 7. ♦

POLICY/REGULATORY ISSUES SUBTASK

Don Stevens

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TASK 27 – SUMMARY REPORTING

Task 27 completed a 3-year programme of work to examine the policy, regulatory, and other non-technical issues influencing biofuels. The primary objective of this effort was to determine why implementation of biofuels has been more successful in some countries than in others.

The task gathered detailed information on a variety of fac-

tors influencing biofuels including policies and regulations, business issues, public support for biofuels, and others. Work focused on biofuels implementation in North America and Europe. Part of this information is summarized below for specific countries and regions.

Based on the data gathered, several basic conclusions can be drawn:

- With present policies and regulations, the prices of biofuels exceed their petroleum-based counterparts. Countries with successful biofuels programs recognize the value of biofuels and have uniformly adopted policies that allow them to compete economically.
- The largest single driving force behind the establishment of policies and regulations to assist biofuels has been agricultural interests.
- Public support for biofuels exists, but it has been a less important factor. Consumers are typically unwilling to pay more than 2-3 ¢/liter at the pump as a “green premium”.
- Taxation mechanisms are one effective method to implement biofuels. Relatively small tax incentives can be effective, but the must deal specifically with biofuels. High motor fuel taxes alone and high pump prices for motor fuels do not, by themselves, favor biofuels.
- “Renewable fuels mandates” may also be an effective means of implementing biofuels. Legislation of this type establishes requirements that motor fuels contain certain percentages of biofuels. Regulations in both Europe and North America are currently increasing the use of biodiesel through this type of mechanism, and this approach could also be used with ethanol.
- Biofuels policies must be considered on a regional basis. The price of ethanol in Europe, for example is nearly double that in North America. The primary reason for this difference is feedstock cost. Cost differences will require differences in biofuels policies.

Task 27 also examined two biofuels growth scenarios to estimate the likelihood of modest or rapid growth of biofuels over the next few years. Moderate growth was defined as increasing biofuels use by ~10% over current levels in about 5 years in countries with existing biofuels programs, or achieving modest implementation in countries currently without them. Dramatic growth was defined as increasing biofuels to ~10% of a country’s total motor fuels mix in about 10 years. General conclusions from this analysis are as follows:

Moderate expansion in the use of biofuels is likely throughout both Europe and North America over the next few years even if current regulations and policies remain unchanged. Concerns about carbon dioxide emissions and the potential phase-out of MTBE is placing increasing emphasis on biofuels. Current and anticipated legislation that mandates minimum percentages of biofuels in motor fuels is also expected to increase demand. This type of legislation has recently been implemented or is being considered in several regions. As a result of these and other factors, the use of biofuels is expected to increase in most countries over the next five years.

More information about Task 27 is available from Don Stevens, the Task Leader. Contact information is provided later in this Newsletter. ●

BIODIESEL SUBTASK

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More information on the biodiesel activities will be coming in the next issue. Stay tuned! ●

ETHANOL SUBTASK

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TASK 26 – SUMMARY REPORTING

Task 26 finished off a very busy and successful triennium with a technical meeting in Honolulu, Hawaii.

*PACIFICHEM 2000
HONOLULU, HAWAII, USA
DECEMBER, 2000*

The Hawaii meeting was composed of two sessions of the PACIFICHEM American Chemical Society conference. This was a technical meeting with 12 presentations. Although we did not have as good a turnout as our previous PACIFICHEM meeting, due in part to tighter travel budgets and stormy weather in eastern North America, there was an enthusiastic response by those individuals that did make the conference. The abstracts for the presentations follow:

Synergies for Production of Ethanol and Chemical Co-

products from Biomass.

*Dr. Charles E. Wyman.
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When used to produce commodity fuels and chemicals, inexpensive sources of cellulosic biomass such as agricultural and forestry residues, substantial fractions of urban wastes, and dedicated crops promise to reduce greenhouse gas emissions, dispose of problematic solid wastes, improve energy security, reduce trade deficits, and improve air quality. Biological processes are particularly favorable routes to producing fuels and chemicals from biomass due to the dramatic cost reductions realized to date, the potential to achieve even lower costs in the longer term, and the benign conditions employed. Although more attention has been focused on producing ethanol from biomass, a wide range of chemicals could also be derived from such low cost materials, expanding the impact of the technology. Furthermore, coproduction of biofuels and biochemicals can improve the economics of both products and provide operational flexibility important to long term viability. However, technical, marketing, scale-up, and other challenges must also be considered in the development of such a modern biorefinery.

Fuel Ethanol from Softwood - Process Development Using a PDU.

*Professor Guido Zacchi, Dr. Mats Galbe, Dr. Kerstin Stenberg, Dr. Johanna Soderstrom
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We have performed a comprehensive study on the development of the enzymatic process for production of fuel ethanol using softwood as raw material. The study was performed using a Process Development Unit (PDU) comprising: pretreatment, enzymatic hydrolysis, fermentation, distillation and evaporation. The pretreatment step was evaluated using steam-pretreatment and impregnation with SO₂. The enzymatic hydrolysis and fermentation was performed using simultaneous saccharification and fermentation (SSF). The effect of the substrate and cellulase concentrations was investigated. More complex process integration, in the form of recirculation of process streams, which is desirable in an industrial process, was also investigated using the PDU. The experimental data was used to perform a techno-economic evaluation of the ethanol production from softwood using the SSF technology. The re-

duction in ethanol production cost from process integration, which reduces the energy and water requirements in the process, showed that the production cost could be reduced with up to 25%.

Conversion of Cotton Gin Waste to Ethanol by E. coli KO11.

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Disposal of cotton gin waste is increasingly becoming a major problem in the resurging cotton industry in Virginia. We have investigated the conversion of cotton gin waste to fuel ethanol as an alternative disposal method. The cotton gin waste contained 57% fermentable sugars, 8% ethanol extractives and 10% ash on dry biomass basis. Cotton gin waste was pretreated by steam explosion at various severities (2 to 4.9) and enzymatically hydrolyzed to monomeric sugars. Recovery of material after steam explosion was influenced by the steam explosion severity. At low steam explosion severities (2-3), almost all the material was recovered (97-100%) while at high severities (3.5-4.9) material recovery ranged from 82-97%. Steam explosion pretreatment improved both sugar and ethanol production. Low severity materials were more difficult to hydrolyze, while the high severity material hydrolyzed readily. For material pretreated at 4.68 severity, 24 h enzyme hydrolysis converted 67% of the cellulose to glucose. About 84% of the fermentable sugars were converted into ethanol using genetically modified *Escherichia coli* KO11.

Ethanol Production from Rice Straw Hydrolysate by Immobilized Recombinant Zymomonas mobilis in a Fluidized-bed Reactor.

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Rice straw is an agricultural waste product, which is available in large quantities in the United States. Arkenol's patented concentrated sulfuric acid process was used to hydrolyze this lignocellulosic waste to a solution of glucose and xylose. The mass ratio of glucose:xylose in the hydro-

lysate was 4:1. Immobilized cells of the recombinant strain *Zymomonas mobilis* ATCC 31821(pZB5) with capability of metabolizing both five- and six-carbon sugars were used to ferment the hydrolysate to ethanol. Comparison of results obtained in batch experiments using synthetic sugar solutions and the hydrolysate indicated that the hydrolysate was not inhibitory to ethanol production. Continuous experiments using this hydrolysate then were performed in a fluidized-bed reactor. The experiments were performed at 30°C and pH 5.5. The effects of sugar concentrations and residence time on ethanol yield and productivity were studied. The results of these continuous experiments will be discussed.

A comparison between hot liquid water and steam pretreatment of biomass.

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Agricultural residues (sugar-cane bagasse and corn fiber) were pretreated with either hot liquid water at low solids loadings (1 to 10 %), or steam at high solids loadings (greater than 50 %) at 200 to 230 °C for 1 to 10 minutes, using the same novel process equipment. Pentosan recovery and inhibition of yeast fermentation were evaluated and compared. In addition, the reactivity of pretreated fiber with respect to enzymatic hydrolysis was evaluated using a simultaneous saccharification and fermentation (SSF) system consisting of -glucosidase-supplemented *T. reesei* cellulase together with fermentation by *Saccharomyces cerevisiae*. In general, high reactivity (greater than 80 %) was possible with both hot liquid water and steam pretreatment. Reactivity was directly related to pentosan solubilization while pentosan recovery was inversely related to pentosan solubilization. A range of favorable reaction temperature and times exist, however, for hot liquid water pretreatment.

Greater than 80 % conversion to ethanol was achieved with pentosan recoveries of at least 80 % as well.

Metabolic engineering technologies for improved production of ethanol and lactic acid

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Development of suitable biocatalysts for the biomass to fuels and chemicals industry remains a significant technical challenge. We have developed a series of stable *E. coli* strains that convert biomass sugars to either L-lactate or ethanol by transforming nonfermentative strains with plasmids carrying either the lactate dehydrogenase (ldh) gene from *Streptococcus bovis* or alcohol dehydrogenase and pyruvate decarboxylase genes from *Zymomonas mobilis*. Under anaerobic conditions, these plasmids were retained in the absence of antibiotics by over 95% of the cells and the modified strains produced L-lactate or ethanol at 90-93% of theoretical. We have also cloned a ldh gene from the fungus, *Rhizopus oryzae*, and developed genetic transformation methods for stable chromosomal integration. Recombinant *R. oryzae* strains had increased ldh activity and produced 30% more lactic acid than the parental wild-type with a concomitant decrease in both ethanol and fumarate byproducts.

Fermentation of sugar beet pulp for enzyme production.

Dr. Lisbeth Olsson, Dr. Eva Palmqvist, Dr. Kim Poulin Hansen, Dr. Tove Christensen. Technical University of Denmark, Building 223, Sotofts plads, Center for Process Biotechnology, Department of Biotechnology, Kongens Lyngby, Denmark, +45 4588 4148, LO@ibt.dtu.dk.

Sugar beet pulp is a waste product from sugar production consisting of cellulose, hemicellulose, lignin and pectin and this could be an interesting substrate for enzyme production. The enzyme profile resulting after the cultivation is important for the application of the enzyme mixture. By cultivation of *Trichoderma reesei* RUT-30 on different substrates; sugar beet pulp, alkaline hydrolysed sugar beet pulp (pectin and part of the hemicellulose was hydrolysed) and cellulose, or by different combinations of these substrates, the relation between cultivation substrate and the resulting enzyme profile were investigated. The enzyme activities (endoglucanase, xylanase, α -arabinase and polygalacturanase) were followed during the course of the batch cultivation. The common features during the cultivations were an early production of endoglucanase and endoxylanase, whereas a late induction of α -arabinase production (after the first signs of sporulation was seen) resulted. The four enzymes determined were produced in all cultivations, but the amount depended on the cultivation substrate used.

Production of substrate specific enzyme complexes by solid substrate fermentation for hydrolysis of cellulose and hemicellulose-containing materials.

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Lignocellulolytic enzymes may be produced economically and efficiently by solid substrate fermentation (SSF). The advantage of SSF is operational simplicity and economy in a water restricted environment and possibility for use of the product with little or no downstream processing. Crude SSF enzymes may be used directly in agrobiotechnological applications such as ensiling, feed additives, retting, soil additives, and in biotechnological industries such as paper industry and biofuel industry. In situ SSF enzyme production may be incorporated into such biotechnologies with great saving in process cost. SSF laboratory experiments were carried out with *Trichoderma reesei* Rut C30, *Trichoderma hamatum* TUB F-105 and *Gliocladium sp.* TUB F-498 strains on corn fiber (corn seed hull), spent brewing grain and wheat straw/wheat bran 9:1 mixture substrates. The crude SSF enzymes were successfully used for enzymatic hydrolysis of cellulose-containing materials prior to bioalcohol production.

Effect of oxygen delignification on cellulase absorption and hydrolysis of lignocellulosic material

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Waste lignocellulosic materials represent a significant and presently underutilized energy feedstock. The environmental advantages of biomass-derived fuels has continued to drive advancements in technologies for the production of ethanol from lignocellulosic materials. However, several factors have hindered economic exploitation, including: (1) abundant, low priced fossil fuels, (2) uncertainty surrounding the cost of a sustained supply of feedstock, (3) inadequate or inconsistent tax incentives for wood-derived alternative fuels, and (4) costly multistage processing required for conversion of lignocellulosics to ethanol. To address the latter constraint, new technologies must be developed or applied which can improve overall process economics.

The pulp and paper industry has a wealth of expertise in

the processing of lignocellulosic materials. Many studies have shown that residual lignin has a strong negative impact on enzymatic hydrolysis of cellulose, and in this study we examined the effect of oxygen delignification (commercially used in pulp bleaching) on the hydrolysis of a model substrate (pulp) and on waste lignocellulosic material.

The influence of oxygen delignification on a model substrate (pulp) and on two waste lignocellulosic materials (sludge from a pulp mill primary clarifier, and steam exploded Douglas fir) was evaluated. For pulp, oxygen delignification removed up to 59% of the lignin (average 34%) and improved the rate of, and yield from hydrolysis by up to 111% (average 63%) and 174% (average 101%), respectively. The equilibrium concentration of cellulase enzyme protein in the liquid phase was higher for delignified substrate than for non-delignified substrate. For primary clarifier sludge, hydrolysis yield improvements of up to 90% were observed in batch reactors.

Novel Chromogenic Substrates for Glycosidase-Coupled Assays of a α -Glucuronidase and Feruloyl esterase.

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Dr. Daniel C. La Grange, Professor Willem H. Van Zyl,
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-Glucuronidase and feruloyl esterase belong to plant cell wall-degrading enzymes which are difficult to assay due to lack of their activity on the corresponding aryl glycosides and esters. In their substrates the released group has to be attached to a sugar residue. 4-Nitrophenyl 2-O-(methyl 4-O-methyl- β -D-glucopyranosyluronate)- β -D-xylopyranoside was found to be an excellent substrate for the measurement of α -glucuronidase activity. A new precise α -glucuronidase assay was elaborated coupling the α -glucuronidase-catalyzed formation of 4-nitrophenyl β -D-xylopyranoside with its efficient hydrolysis by β -xylosidase. Analogous effort was devoted to the development of principally similar assay of feruloyl esterase. 4-Nitrophenyl 5-O-trans-feruloyl- β -L-arabinofuranoside has been synthesized as a chromogenic substrate of feruloyl esterase in an β -L-arabinofuranosidase-coupled assay.

Continuous conversion of phenolic compounds with immobilized fungal laccases

Dr. Georg Guebitz, Dr. Elias Abadulla, Dr. Artur

Cavaco-Paulo, Dr. Karl-Heinz Robra
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Laccases can be used for the removal of phenolic substances released during bioconversion of lignocellulosics, which can e.g. inhibit yeast fermentation in the biomass-to-ethanol-process and reduce the nutritional value of feedstock. The properties of purified laccases from the white rot basidiomycete *Trametes hirsuta* and from the plant pathogen basidiomycete *Sclerotium rolfsii* produced under different physiological conditions were studied and the enzymes were immobilized on alumina. The effectiveness of immobilization varied between 75 to 95 % of the protein immobilized and 70 to 90 % of activity recovery. Immobilization of the laccases increased both thermal and pH stabilities by up to 40 %. Similarly, the immobilized enzymes were less vulnerable by inhibitors such as EDTA, diethyldithiocarbamate and thioglycolic acid. Among various halides, F⁻ was the strongest inhibitor for all laccases followed by Cl⁻ and Br⁻. Continuous detoxification of phenolics using the immobilized laccases and the influence of new mediators such as polyoxometalates was investigated using model compound.

*Influence of carbon catabolite repression and redox balance in xylose fermenting *Saccharomyces cerevisiae* strains.*

Mr. Christophe Roca, Professor Jens Nielsen, Professor
Lisbeth Olsson
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Saccharomyces cerevisiae is commonly used in the production of food and alcoholic beverages. Classified as a GRAS microorganism, it is widely used in production of baker's yeast and in the production of ethanol in brewery. Besides, high level of ethanol can be obtained by fermentation of the hexoses (glucose, galactose and mannose) present in lignocellulosic hydrolysates. Nevertheless, pentoses such as xylose and arabinose present in a large proportion in lignocellulosic hydrolysates remain unused. By insertion of the XYL-genes into the genome, the *Saccharomyces cerevisiae* strain TMB3001 able to use xylose has been obtained (Eliasson et al., 2000). However, the ethanol yield and productivity on xylose remain low which make the strain inappropriate to an industrial process. In order to achieve an efficient ethanol production from lignocellulosic hydrolysates, we have focused on two areas of difficulties, glucose repression and redox imbalance. Lignocellulosic

hydrolysates are composed of a mixture of sugars and glucose as well as other fast assimilable sugars are known to repress the utilisation of other sugars, increasing the fermentation time. By deleting the MIG1 gene, one can expect to alleviate the glucose repression and have a simultaneous consumption of all the sugars. As a result, the specific productivity of the strain can be improved. Another important aspect is the use of NADPH by xylose reductase (XR) during xylose fermentation, resulting in a redox imbalance. This could be a reason of the poor efficiency of the strain containing the XYL genes. Deletion of GDH1 gene coding for a NADPH glutamate dehydrogenase might avoid superfluous NADPH consumption, redirect it towards XR to facilitate xylose fermentation and restore the redox balance in the cell. Furthermore, *gdh1* deletion has been shown to improve the ethanol production in a mutant strain (Nissen et al., 2000). A *gdh1* mutant and a *mig1* mutant both containing the XYL-genes were cultivated on different mixtures of lignocellulosic sugars and their respective performances were studied in relevance to ethanol production and industrial application. Sugar uptake rates, specific growth rates and production of ethanol and by-products were determined. In this presentation, the influence of glucose repression and redox imbalance on the physiology of the xylose fermenting *S. cerevisiae* will be discussed.

Nissen, T.B., Kielland-Brandt, M.C., Nielsen, J., Villadsen, J. (2000): Optimization of Ethanol production by Metabolic Engineering of the Ammonium Assimilation. *Metabolic Engineering*, 2,69-77.

Eliasson, A., Christensson, C., Wahlbom, C.F., Hahn-Hagerdal, B. (2000): Anaerobic xylose fermentation by recombinant *Saccharomyces cerevisiae* harbouring XYL1, XYL2, XKS1 in mineral media chemostat cultivations. *Appl. Env. Microbiol.* In press.

ETHANOL SUBTASK CURRENT ACTIVITIES

IEA BIOENERGY TASK 39 SESSION AT 23RD SYMPOSIUM ON BIOTECHNOLOGY FOR FUELS AND CHEMICALS

As we are at the start of the three year Task we wanted to hear about the current programs and directions of the eight countries. Each country representative(s) discussed current directions in policy and utilization as well as on-going research &/or research groups for collaboration.

Location: Breckinridge, Colorado
Date: Tuesday, May 8, 2001
Time: 2-6 PM

The format was 15 minutes for each country followed by a 5 minute question period and a 20-30 minute general question session at the end. This represented roughly a three hour session.

The speakers were:

Austria
Herbert Danner
IFA - Tulln

Canada
Bill Cruickshank
Natural Resources Canada

Denmark
Brigitte Ahring
Technical University of Denmark

European Union
Kyriakos Maniatis - regrets

Finland
Liisa Viikari
VTT Biotechnology

The Netherlands
Eric van den Heuvel
Novem

Sweden
Bärbel Hahn-Hägerdal
University of Lund

USA
Bob Wooley
National Renewable Energy Laboratory

Materials presented at the workshop will be made available in subsequent IEA Bioenergy Task 39 newsletters and the website. ●

WORLD EVENTS

ETHANOL BC/NATURAL RESOURCES CANADA BIOFUELS WORKSHOP

Date: Friday May 4, 2001
Location: Centre for Advanced Wood Products (CAWP) at UBC in Vancouver, Canada

The workshop had 30 minute presentations with ample opportunity for discussion with the main topic areas being:

Biomass Residue Opportunities & Utilization Strategies

- Ethanol BC - Brian McCloy
- Canadian Forest Products - Michael Jordan
- Weyerhaeuser – Ray Norgren

Status of Commercialization of Utilization Technologies

- DynaMotive – Jan Barynin - Pyrolysis BioOil technology
- Ethopower – Ken Davison/Ivan Kawulka - Gasification to Ethanol using microbes
- Lignol Innovations - Paul Chisholm/Kendall Pye - Alcell process for Ethanol & Lignin production

Fuel Ethanol Marketing Potential & Strategies

- (S&T)² Consultants Inc. - Don O'Connor - Ethanol Marketing Opportunities in North America

Regional, Policy and Environmental Considerations

- Natural Resources Canada - Bill Cruickshank

International Perspective

- International Energy Agency – Jack Saddler

A CD of the presentations has been produced and will be made available to interested parties through Brian McCloy of Ethanol BC mailto:bmcclloy@dccnet.com. The presentations may also be made available in pdf format in the near future on the Task 39 website. ●

FUTURE WORKSHOPS/SYMPOSIA

5th Biomass Conference of the Americas
Bioenergy and Biobased Products:
Technologies, Markets and Policies
September, 17-21, 2001
The Rosen Centre Hotel
Orlando, Florida, USA ●

CONTACT INFORMATION

Please find information below for both the IEA Bioenergy contacts and IEA Bioenergy Task 39 contacts. Additional information is available at <http://www.iea.org> and <http://www.ieabioenergy.com>.

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