IEA Bioenergy

Biofuels & Bioenergy
A Changing Climate

August 23 – 26, 2009

UBC Forestry
University of British Columbia

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Thank you to our generous sponsors & exhibitors

IEA Bioenergy

IEA Bioenergy is an organisation set up in 1978 by the International Energy Agency (IEA) with the aim of improving cooperation and information exchange between countries that have national programmes in bioenergy research, development and deployment. Membership consists mainly of OECD countries and a few other non OECD countries

BC Bioenergy Network

The BC Bioenergy Network is a not-for-profit, non-governmental organization, that assists with the deployment of near-term bioenergy technologies and organizes mission-driven research for the development and demonstration of new environmentally sustainable technologies for the province of BC.

British Columbia Innovation Council

The British Columbia Innovation Council (BCIC) is the lead organization charged with driving the commercialization of innovation in British Columbia. BCIC is focused on accelerating the growth of our science and technology communities and competitively positioning British Columbia in the global science and technology economy. Visit www.bcic.ca for more information.

Canadian Renewable Fuels Association

The Canadian Renewable Fuels Association (CRFA) is a non-profit organization with a mission to promote the use of renewable fuels for transportation through consumer awareness and government liaison activities. The CRFA is hosting its 6th annual marketing and policy summit from November 30 – December 2nd in Vancouver, British Columbia. www.greenfuels.org.

Fink Machine Inc.

Fink Machine Inc. supplies modern wood chip boilers and pellet boilers to suit commercial, institutional and industrial heating requirements. Over the last decade Fink Machine Inc. has been supplying KOB boilers to schools, hospitals, industrial facilities and many other clients across North America. These fully automatic, high-end biomass boilers are able to achieve emission levels comparable to natural gas emission.

Forestry Innovation Investment

Forestry Innovation Investment (FII) is a provincial agency that promotes British Columbia's forest practices and products around the world. Learn more about FII and the forest economy at www.bcfii.ca, or link to information about B.C. forest products and companies, building green with wood, and B.C.'s sustainable forest practices.

Genome British Columbia

Genome British Columbia is a research organization that invests in and manages large-scale genomics and proteomics research projects and science and technology platforms focused on areas of strategic importance such as human health, forestry, fisheries, agriculture, bioenergy, mining, ethics, and the environment. By working collaboratively with all levels of government, universities and industry, Genome BC is the catalyst for a vibrant, genomics-driven life sciences cluster with far reaching social and economic benefits for the province and Canada.

LifeSciences British Columbia

LifeSciences British Columbia supports and represents the biopharmaceutical, medical device, bioproducts, bioenergy and greater life sciences community of British Columbia through leadership, advocacy and promotion of our world-class science and industry. Via active facilitation of partnering and investment into the life sciences sector, British Columbia is fast becoming a global life sciences leader. LifeSciences British Columbia is a not-for-profit, non-government, industry-funded association.

Lignol

Lignol is a Canadian company undertaking the development of biorefining technologies for the production of fuel-grade ethanol and other biochemical co-products from non-food cellulosic biomass feedstocks. For more information about Lignol, please visit our website at www.lignol.ca.

Natural Resources Canada

Natural Resources Canada (NRCan) seeks to enhance the responsible development and use of Canada's natural resources and the competitiveness of Canada's natural resources products. We are an established leader in science and technology in the fields of energy, www.nrcan-rncan.gc.ca/com/eneene/index-eng.php, forests, cfs.nrcan.gc.ca/?lang=en, and minerals and metals, www.nrcan-rncan.gc.ca/mms-smm/index-eng.htm, and use our expertise in earth sciences http://ess.nrcan.gc.ca/index_e.php, to build and maintain an up-to-date knowledge base of our landmass. NRCan develops policies and programs that enhance the contribution of the natural resources sector to the economy and improve the quality of life for all Canadians.

Natural Sciences and Engineering Research Council of Canada

NSERC is a federal agency whose vision is to help make Canada a country of discoverers and innovators for the benefit of all Canadians. Through its Research Partnerships Programs NSERC helps Canadian companies compete in today's economy by jointly funding collaborative R&D projects with scientists and engineers in universities and colleges across the country. Over 1,400 Canadian companies, including the top innovative firms in the country, are benefiting from NSERC's Partnership Programs. Our shared-cost programs are flexible and responsive, and they: stretch your company's research dollars; link you with skilled and knowledgeable people; deliver creative ideas and practical solutions; promote long-term partnerships; and provide access to specialized facilities and equipment.

Nexterra Systems Corp.

Nexterra is a leading supplier of biomass gasification solutions that generate renewable heat and power for institutional and industrial customers. Sales to date include projects at the University of South Carolina, Dockside Green, the US Department of Energy's Oak Ridge National Lab, Kruger Products and Tolko Industries. For more information: www.nexterra.ca

SBC Firemaster Ltd.

SBC Firemaster Ltd. is a leader in the bioenergy field and has been in business for over 25 years selling the simplest forms of bioenergy products. SBC Firemaster has engineered, manufactured and is operating the first modular pellet plant in North America. The 'Mod Mill' marks a new era for pellet manufacturing.

Sustainable Development Technology Canada

Sustainable Development Technology Canada is an arm's-length, not-for-profit corporation created by the Government of Canada to support innovative clean technology solutions through 2 funds. The $550 million SD Tech Fund supports projects that address climate change, air quality, clean water, and clean soil and the $500 million NextGen Biofuels Fund supports the establishment of first-of-kind large demonstration-scale facilities for the production of next-generation renewable fuels.

general information

Registration & Information Centre

On site registration and distribution of meeting packet

Sunday, August 23	4:30 pm – 7:00 pm
Monday, August 24	7:30 am – 6:00 pm
Tuesday, August 25	7:30 am – 7:00 pm
Wednesday, August 26	7:30 am – 1:30 pm

Programs will be distributed at the meeting to all attendees. (Extra copies of the meeting program are $50). Name badges must be worn for admittance to the sessions, exhibits, and special functions.

The Organizing Committee would like to ensure you enjoy your stay at the Conference. Please let us know if we can help at the Registration & Information Desk.

Exhibit Booths

Set-up	Sun, August 23	3:00 pm – 4:00 pm
Take down	Mon, August 24	3:40 pm – 4:10 pm

Posters

Set up	Mon, Aug 24	5:30 pm – 6:00 pm
Take down	Wed, Aug 26	10:10 am – 10:40 am

Internet Lounge

Internet connection through an Internet Lounge (Forest Sciences Centre - Room 1406) and UBC wireless are both available to all attendees.

Computer Access in Internet Lounge, Room 1406

Login name: ieabioen

Password: Bio9!energy

Sunday	4:30 pm –7:00 pm
Monday	7:30 am – 6:00 pm
Tuesday	7:30 am – 7:00 pm
Wednesday	7:30 am – 1:30 pm

Wireless Internet Access at UBC

Login name: ieabioen

Password: bioenergy2009

Meals at a Glance

Sunday, August 23

Welcome Reception and Exhibitor Event	4:30 pm – 7:00 pm

Monday, August 24

Continental Breakfast	7:30 am – 8:30 am
Coffee Break	10:30 am – 11:00 am
Lunch	12:20 pm – 1:30 pm
Coffee Break	3:10 pm – 3:40 pm
Salmon BBQ reception Cecil Green Park House 6251 Cecil Green Park Road, UBC	6:00 pm – 8:30 pm

Tuesday, August 25

Continental Breakfast	7:30 am – 8:30 am
Coffee Break	10:10 am – 10:40 am
Lunch	12:30 pm – 1:30 pm
Coffee Break	3:10 pm – 3:40 pm
Drinks & Snacks	5:30 pm – 7:00 pm
Evening on your own	7:00 pm

Wednesday, August 26

Continental Breakfast	7:30 am – 8:30 am
Coffee Break	10:10 am – 10:40 am
Boxed Lunch (& Bus Trip)	1:00 pm – 2:45 pm
Banquet at Malcolm Knapp	5:30 pm – 7:00 pm

social program

Sunday, August 23, 4:30pm to 7:00pm

Welcome Reception and Exhibitor Event

UBC, Forest Sciences Centre Atrium, 2424 Main Mall

Join us for an excellent opportunity to connect with conference delegates and meet some of the leading companies and organizations advancing bioenergy and biofuel development in Canada at a Welcome Reception and Exhibitor event. There will also be special live entertainment for your enjoyment. Spouse/guest of delegates are welcome to join this event.

Monday, August 24, 6:00pm to 8:30pm

Salmon BBQ Reception sponsored by Life Sciences BC and BCIC

Cecil Green Park House located beside Green College at UBC, 6251 Cecil Green Park Road and is a 25 minute walk from the Conference venue through the UBC campus *(see page 9 for a map).*

LifeSciences British Columbia and BC Innovation Council cordially invite you to a Salmon Barbeque at beautiful Cecil Green House on the University of British Columbia campus.

As sponsors of the IEA conference, LifeSciences British Columbia and BC Innovation Council are delighted to host this event with UBC where conference attendees can enjoy a great meal in a breathtaking setting while networking amongst peers.

Methanex CEO, Mr. Bruce Aitken, will provide comments on the importance of Clean Energy Research and Alternative Fuels.

Spouse/guests of delegates are welcome to join this event and can register during check-in for a nominal cost of $50. For conference delegates, the fee is waived.

Walk from Cecil Green Park House to UBC West Coast Suite or UBC North Bus Loop approx. 15 min.

Taxis are available (Approx. 20-30 min for $30-40 to Sheraton Van Wall Centre and Holiday Inn Broadway, Vancouver). Please see Page 7 for phone numbers.

Wednesday, August 26

Social Activity/Walk and Evening Banquet

Maple Ridge, Malcolm Knapp Research Forest, Loon Lake Research and Education Centre

1:00 pm (Departure time) to 9:00 pm (arrival back to Vancouver)

Only 1.5 hours away and east of Vancouver is the Loon Lake Research and Education Centre at the UBC Malcolm Knapp Research Forest in Maple Ridge, BC. Enjoy this beautiful lakeside setting and learn about BC's unique forest ecosystems through guided forest walks around the shores of Loon Lake that include informative stops at interesting sites and a short trip across the water on a cable ferry. Athletic clothing and footwear is recommended.

The evening will end with a dinner banquet at beautiful Loon Lake. Spouse /guests of delegates are welcome to join this event and can register during check-in for a nominal cost of $75. For conference delegates, the fee is waived.

Buses to and from Loon Lake will be provided with drop offs in the evening at the Sheraton Wall Center, Holiday Inn Broadway Vancouver and UBC. To enable us to arrange drop-offs at any of the 3 locations, please register with us in person at Registration Desk by Monday, August 24.

Post-conference events

Thursday, August 27 to Friday, August 28

An Hour's Flight from Vancouver to Prince George

Two-Day Tour of the Impacts of Mountain Pine Beetle Infestation hosted by Forest Innovation Investment (FII)

Prince George

Forestry Innovation Investment (FII) is an agency of the Government of British Columbia with a mandate to: actively maintain, build and diversify demand for BC forest products in Canada and in key world markets; help break down trade and market barriers to ensure opportunities for BC forest products; work with the forest industry to promote BC's forest products and forest management to the global marketplace; and help ensure that the forest sector, through product development and strong international sales, continues to be a leading contributor to the BC economy.

FII has arranged a two day forest management and supply chain tour for IEA Bioenergy Conference participants. The "by invitation" tour will allow conference participants to see the full extent of mountain pine beetle devastation, primarily attributed to climate change – in British Columbia's lodgepole pine forests. The two day "field trip" includes visits to: forest operations where the beetle impacted trees are being harvested, traditional wood processing units such as sawmills and pulp mills, as well as wood pellet and cogeneration facilities.

Thursday, August 27, 8:30 am to 11:45 am

Tour of UBC and FP Innovations Biorefinery/Bioenergy/Biomaterials facilities

UBC Vancouver Campus

Please join us for a walking tour of the University of British Columbia and FP Innovations biorefinery/ bioenergy / biomaterials research facilities on the morning of Thursday, August 27th. The tour will showcase the UBC campus' BIO-Cluster's expertise in biomass production, conversion and preprocessing. Included in the tour will be: the UBC Clean Energy Research Centre, with an emphasis on fluidized bed gasification and wood pellet improvement (torrefaction & steam explosion); the Forest Sciences Centre, focusing on the ethanol production from wood, biomaterials from lignin and cellulose, genetic improvement of biomass woody crops (poplar, spruce, pine); the Michael Smith Laboratories (one of UBC's Nobel Prize winners) which showcases a full spectrum of genomic, proteomics, engineering, etc, expertise, and FP Innovations– Canada's Innovation R&D group which works on a range of breakthrough technologies in the broad biorefinery area.

The tour is free of charge, but has limited capacity. If you have not pre-registered yet, please register with us in person at Registration Desk by Monday, August 24

Transportation and Directions

From Vancouver International Airport to Conference Venue (Forest Sciences Centre, 2424 Main Mall)

Taxi*	35 mins	$35 – 45
Public Bus**	65-70 mins	$2.50 (weekends), $3.75 (weekdays)
Bus #424, #98 and #99 West (2 transfers)	(including 15-20 min walking time from bus loop to venue)	

From Vancouver International Airport to Sheraton Van Wall Centre (1088 Burrard Street, Vancouver)

Taxi*	Approx. 20 mins	$30 – 40
Public Bus	40 mins	$2.50 (weekends), $3.75 (weekdays)
Bus #424 and #98 (1 transfer)	(including 10 min walking time)	

From Vancouver International Airport to Holiday Inn (711 West Broadway, Vancouver)

Taxi*	Approx. 30 mins	$30 – 40
Public Bus	Approx. 45 mins	$2.50 (weekends), $3.75 (weekdays)
Bus #424, #98 and #99 East (2 transfers)	(including 5-10 min walking time)	

From Vancouver International Airport to UBC West Coast Suite (5961 Student Union Boulevard, UBC)

Taxi*	Approx. 35 mins	$35 – 45
Public Bus	Approx. 45 mins	$2.50 (weekends), $3.75 (weekdays)
Bus #424, #98 and #99 West (2 transfers)	(including 5 min walking time)	

From Sheraton Van Wall Centre to Conference Venue (Forest Sciences Centre, 2424 Main Mall)

Taxi*	20 mins	$35 – 45
Public Bus**	50 mins	$2.50
Bus #04, #17, #44 (weekdays)	(including 15-20 min walking time	
Bus #04, #17 (weekends)	from bus loop to conference venue)	

From Holiday Inn to Conference Venue (Forest Sciences Centre, 2424 Main Mall)

Taxi*	15 mins	$20 – 30
Public Bus	50 mins	$2.50
*Bus #99, #84***	(including 15-20 min walking time	
	from bus loop to conference venue)	

From UBC West Coast Suite to Conference Venue (Forest Sciences Centre, 2424 Main Mall)

Walk Approx. 15-20 mins

*Some taxis available in Vancouver are listed, as follows.

Black Top Cabs	604-731-1111
MacLure's Cabs	604-731-9211
Vancouver taxi	604-255-5111
Yellow Cabs	604-681-1111

**If you choose to use public buses, give yourself approximately 15-20 min to walk from UBC North Bus Loop to Forest Sciences Centre. Forest Sciences Centre is located at 2424 Main Mall at the intersection of Agronomy Road and Main Mall, UBC.

For more assistance or information regarding public buses, go to www.translink.ca or phone Transit Information at 604-953-3333.

For transportation from Vancouver International Airport to other accommodations in downtown Vancouver, you may choose to use the airport bus service, called Vancouver Airporter. This is available 7 days a week for $22/adult (round trip) or $14/adult (1 way). Time for picking up passengers will vary by terminal. For more details, please visit www.yvrairporter.com.

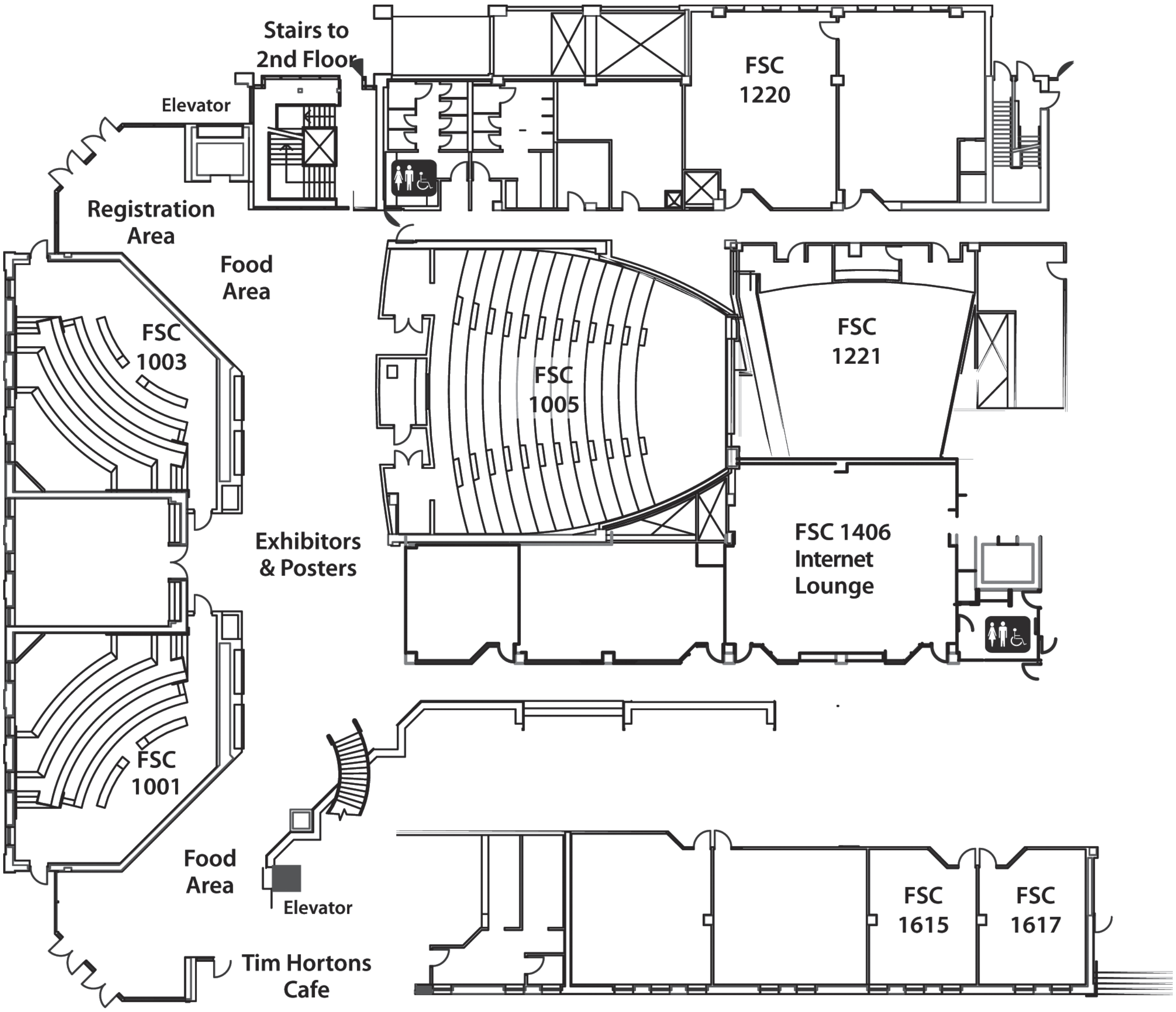
Exploring and Getting Around Vancouver:

Vancouver has many city attractions and tours. For more information, please visit Tourism Vancouver at www.tourismvancouver.com.

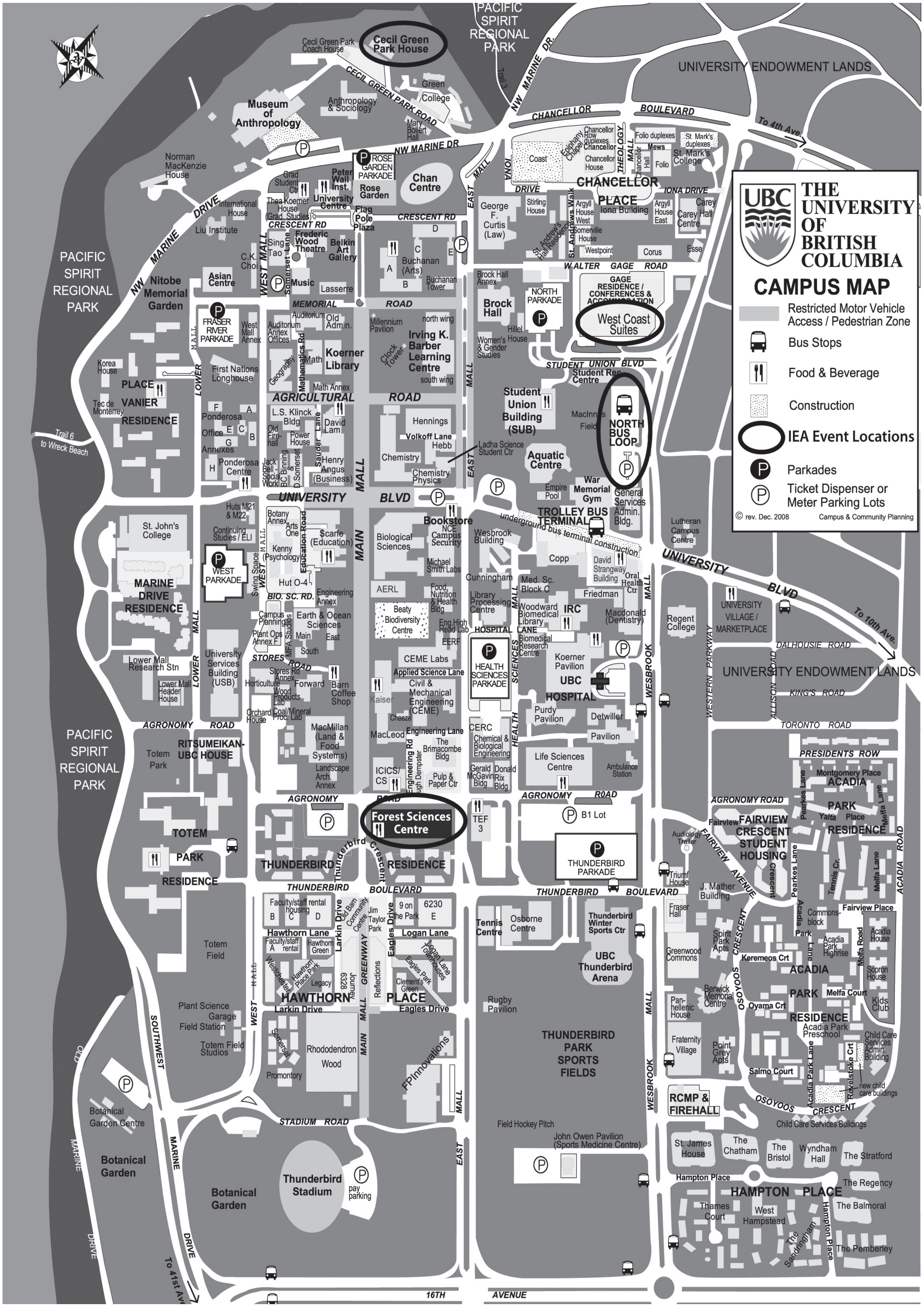
If you wish to explore Vancouver by public transportation, we recommend purchasing a DayPass, which provides you with unlimited transit on all buses, SkyTrain and Seabus for one day from the start of the first transit service. This will save you money and time over buying multiple single fares and crossing different zones in Vancouver. For more details, please go to www.translink.ca.

You may also hop on the Vancouver Trolley for City Attractions Loop Tour and/ evening tours. For more details, please go to www.vancouvertrolley.com.

forest sciences centre floor plan



UBC campus map



program at a glance

Sunday, August 23

3:00 pm – 4:00 pm	**Exhibit Setup** Forest Sciences Centre, Atrium
4:30 pm – 7:00 pm	**Welcome Reception and Exhibitor Event** FSC, Atrium

Monday, August 24

7:30 am - 8:30 am	**Exhibits** FSC, Atrium
8:30 am – 9:00 am	**Welcome Session** FSC, Rm. 1005
9:00 am – 10:30 am	**Plenary Sessions** – Overview Session FSC, Rm. 1005
10:30 am – 11:00 am	**Coffee Break/Exhibits** FSC, Atrium
11:00 am – 12:20 pm	**Plenary Sessions** – Government Strategies FSC, Rm. 1005
12:20 pm – 1:30 pm	**Lunch/Exhibits** FSC, Atrium
1:30 pm – 3:10 pm	**Concurrent Oral Sessions** Rm. 1001/ Rm. 1003 / Rm. 1221
3:10 pm – 3:40 pm	**Coffee Break/Exhibits** FSC, Atrium
3:40 pm – 5:40 pm	**Concurrent Oral Sessions** Rm. 1001/Rm. 1003/Rm. 1221
6:00 pm – 8:30 pm	**Salmon BBQ Reception** Cecil Green Park House, UBC

Tuesday, August 25

7:30 am – 8:30 am	**Poster Session** FSC, Atrium
8:30 am – 10:10 am	**Concurrent Oral Sessions** Rm. 1001/Rm. 1003/ Rm. 1221
10:10 am – 10:40 am	**Coffee Break/Poster Session** FSC, Atrium
10:40 am – 12:30 pm	**Concurrent Oral Sessions** Rm. 1001/Rm. 1003/ Rm. 1221
12:30 pm – 1:30 pm	**Lunch/Poster Session** FSC, Atrium
1:30 pm – 3:10 pm	**Concurrent Oral Sessions** Rm. 1001/Rm. 1003/ Rm. 1221
3:10 pm – 3:40 pm	**Coffee Break/Poster Session** FSC, Atrium
3:40 pm – 5:30 pm	**Concurrent Oral Sessions** Rm. 1001/Rm. 1003/ Rm. 1221
5:30 pm – 7:00pm	**Poster Session/Drinks & Snacks** FSC, Atrium
7:00 pm	**Evening on your own**

Wednesday, August 26

7:30 am - 8:30 am	**Poster Session** FSC, Atrium
8:30 am – 10:10 am	**Plenary Sessions – Industrial perspectives** FSC, Rm. 1005
10:10 am – 10:40 am	**Coffee Break** FSC, Atrium
10:10 am – 10:40 am	**Poster Takedown**
10:40 am – 12:40 pm	**Plenary Sessions – Global perspectives** FSC, Rm. 1005
1:00 pm – 2:45 pm	**Boxed Lunch and Board Bus to Malcolm Knapp Research Forest** Depart Vancouver; Arrive in Maple Ridge, BC
2:45 pm – 4:30 pm	**Social Activities/Walk** Malcolm Knapp Research Forest, Maple Ridge
4:30 pm – 5:30 pm	**Reception** Malcolm Knapp Research Forest, Maple Ridge
5:30 pm – 7:00 pm	**Evening Forest Banquet** Malcolm Knapp Research Forest, Maple Ridge
7:00 pm – 9:00 pm	**Board Bus for return to Vancouver** Drop-offs at Sheraton Van Wall Centre/ Holiday Inn /UBC

program

plenary session

Monday, 24 August 2009 (FSC Room 1005)

Welcome Session

Chair: Jack Saddler (IEA Bioenergy / UBC, Canada)

08:30	Welcome
08:40	Stephen Toope (President, UBC)
08:50	Minister Pat Bell (BC Minister of Forests & Range, Canada)

Overview Session

Chair: George Weyerhaeuser Jr. (Houghton Cascade, US)

09:00	Ralph Sims (Senior Analyst, IEA, France) *"Biomass - A saviour or a sin?"*
09:20	Viviana Coelho, Environmental Monitoring and Assessment Manager, Petrobras, Brazil) *"Petrobras' Strategy on Biofuels"*
09:40	Miles Drake (SVP, R&D, Chief Technology Officer, Weyerhaeuser, US) *"Challenges in Scale Bio Energy Production from Forest resources"*
10:00	Claus Fuglsang (Senior Director of BioEnergy R&D, Novozymes, Denmark/US) *"The Road to Commercial Lignocellulosic Ethanol"*
10:20	Pierre Meulien (Chief Scientific Officer, Genome BC, Canada) *"The Role of Genomics in Biofuels Innovation"*

Government Strategies

Chair: Josef Spitzer (IEA Bioenergy / Joanneum Research, Austria)

11:00	Cassie Doyle (Deputy Minister, NRCan, Canada) *"Bioenergy and Biofuels in Canada: Important Renewable Energy Options for the Future"*
11:20	Jacques Beaudry-Losique (Deputy Assistant Secretary, Office of Energy Efficiency and Renewable Energy, U.S. Department of Energy, U.S.) *"US DOE Bioenergy Program"*
11:40	Kees Kwant (Senior Expert, SenterNovem, Netherlands Agency for Innovation and Sustainability, Member of Exco of IEA Bioenergy) *"The Transition towards a Biobased Economy in the Netherlands"*
12:00	Jim Snetsinger (Chief Forester, BC Ministry of Forest and Range, Canada) *"Future Forest: Opportunities for Biofuels"*
12:20 – 1:30	Lunch/Exhibits

program

parallel session

Monday, 24 August 2009

Track 1 – Crops & Sustainable Forestry for Bioenergy (FSC Room 1001)

Co-Chairs: Brendan George & Tat Smith

1:30 pm	1-1 Brendan George (New South Wales Department of Primary Industries, Australia) *"Energy, agriculture, forestry and environmental policies for short rotation crop"*
1:50 pm	1-2 Peter Ralevic (University of Toronto, Canada) *"Cross-country comparison of drivers, challenges & opportunities for bioenergy"*
2:10 pm	1-3 Blas Mola-Yudego (University of Joensuu, Finland) *"The potential of short rotation willow coppice on agricultural land in Northern Europe based on empirical data"*
2:30 pm	1-4 Darren Allen (Natural Resources Canada, Canada) *"Feasibility of short rotation coppice and high yield afforestation for bioenergy in Canada"*
2:50 pm	1-5 Anthony Anyia (Alberta Research Council, Canada) *"Jerusalem artichoke as a platform for inulin, ethanol and feed production in Canada"*
3:10 – 3:40	Coffee break
3:40 pm	1-6 Jim Richardson (IEA Task 31) *"Biomass production for energy from sustainable forestry"*
3:50 pm	1-7 Tim Young (University of Tennessee, USA) *"A real-time, web-based optimal Biomass Site Assessment Tool (BIOSAT)/Module 2 An economic assessment of mill & logging residues for the Eastern US"*
4:10 pm	1-8 Jaconette Mirck (Queens University, Canada) *"The challenges of improving biomass inventory for southeastern Ontario Canada"*
4:30 pm	1-9 Timo Tahvanainen (Joensuu Science Park, Finland) *"Moisture management, energy density & fuel quality in forest fuel supply chains"*
4:50 pm	1-10 Brian Titus (Natural Resources Canada, Canada) *"Sustainable forest biomass harvesting research in the Canadian Forest service: An overview"*
5:10 pm	1-11 Shannon Berch (BC Ministry of Forests and Range, Canada) *"The framework for sustainable harvest of forest biomass in BC"*
5:30 pm	Co-chair wrap-up

Track 2 – Bioenergy Optons: Upgrading Biogas, SWM and District Heating (FSC Room 1003)

Co-Chairs: Arthur Wellinger & Richard Hallman

1:30 pm	2-1 Pat Howes (IEA Task 36) *"Energy from Solid Waste in IEA Countries: Policies and Trends"*
1:50 pm	2-2 Judith Bates (AEA Group, UK) *"Comparing the environmental parts of residual waste management options"*

2:10 pm 2-3 Timo Gerlagh (SenterNovem, the Netherlands)
"Energy recovery from MSW - one step further"

2:30 pm 2-4 Jürgen Vehlow (Institute for Technical Chemistry, Germany)
"Residential Waste - an often overlooked bioenergy source "

2:50 pm 2-5 Matt Babicki (G4 Insights Inc., Canada)
"Process for bionatural gas production from forestry residue"

3:10 – 3:40 Coffee break

3:40 pm 2-6 Arthur Wellinger (Nova Energie/IEA)
"Application of biomethane in private and public transport"

4:00 pm 2-7 Anneli Petersson (Swedish Gas Centre, Sweden)
"Modern technologies of biogas upgrading"

4:20 pm 2-8 Serge Guiot (National Research Council of Canada, Canada)
"Anaerobic digestion as a biofuel production technology from crops"

4:40 pm 2-9 Taraneh Sowlati (University of British Columbia, Canada)
"Ranking the renewable energy options for a district heating system in Vancouver using multi-criteria decision making"

5:20 pm 2-10 Warren Mabee (Queen's University, Canada)
"Biofuel sustainability: recent developments and way forward."

5:40 pm *Co-chair wrap up*

Track 3 – Policy Considerations on Liquid Biofuels (FSC Room 1221)

Co-Chairs: Warren Mabee & Les Edye

1:30 pm 3-1 John Benemann (MicroBio Engineering, Inc.)
"Microalgae biofuel economics"

1:50 pm 3-2 David Baxter (European Commission, Joint Research Centre, the Netherlands)
"European Union policy promoting bioenergy"

2:10 pm 3-3 W.H. (Emile) van Zyl (University of Stellenbosch, South Africa)
"From biomass to sustainable biofuels in southern Africa"

2:30 pm 3-4 Tom Granström (Helsinki University of Technology, Finland)
"Commodity chemicals from forest biomass (Bioforest)"

2:50 pm 3-5 Paul Grabowski (US DOE)
"The US biomass energy program: current effort and transition to the development and implementation of fungible fuel technologies"

3:10 – 3:40 Coffee break

3:40 pm 3-6 Johann Görgens (Stellenbosch University, South Africa)
"Developing opportunities for commercial production of second generation biofuels in Southern Africa"

4:00 pm 3-7 Axel Munack (Johann Heinrich von Thünen Institute, Germany)
"Political framework and tail pipe emissions for rapeseed oil based fuels"

4:20 pm 3-8 Kishari Sooriya Arachchilage (University of Saskatchewan, Canada)
"Opportunities and challenges for the production of ethanol from lignocellulosic biomass in Western Canada"

4:40 pm 3-9 Blaine Kennedy (Sustainable Development Technology Canada, Canada)
"Canadian progress on biotechnologies"

5:00 pm 3-10 Francisco Girio (LNEG – Laboratório Nacional de Energia e Geologia, Portugal)
"The potential for bioenergy in Portugal: Introducing the activities of the R& D programme of rthe transportation sector at the National Laboratory of Energy and Geology"

5:20 pm Co-chair wrap-up

Tuesday, 25 August 2009

Track 4 – Global Perspective – GHG Balance & Sustainable Trade (FSC Room 1001)

Co-Chairs: Don O'Connor & Kees Kwant

8:30 am 4-1 Mark Laser (Dartmouth College, USA)
"Global feasibility of large scale biofuel production"

8:50 am 4-2 Peter-Paul Schouwenberg (IEA Bioenergy Task 40)
"International sustainable bioenergy trade – an overview from IEA Bioenergy Task 40"

9:10 am 4-3 Bo Hektor (IEA Task 40, Sweden)
"Future structures of bioenergy markets"

9:30 am 4-4 Kees Kwant (SenterNovem, the Netherlands)
"Needs for certification of biomass"

9:50 am 4-5 Peter Flynn (University of Alberta, Canada)
"A criterion for selecting renewable energy processes"

10:10 – 10:40 Coffee break

10:40 am 4-6 Anand Tripathy (University of Saskatchewan, Canada)
"Life cycle analysis of multi-crop lignocellulosic material (Perennial grasses) for bioethanol production in Western Canada: A review"

11:00 am 4-7 Leif Gustavsson (Mid Sweden University, Sweden)
"Integrated biomaterial and bioenergy benefits of balanced forest fertilization in Sweden"

11:20 am 4-8 Jon McKechnie (University of Toronto, Canada)
"Harvesting standing trees for energy applications: Impact of harvest and pelletization emissions on overall greenhouse gas balance"

11:40 am 4-9 Douglas Bradley (Climate Change Solutions, Canada)
"Shipping study-international biomass supply and maritime trade routes"

12:00 pm 4-10 Margaret Gruber (Agriculture and Agri-Food Canada, Canada)
"Breaking agricultural barriers: The ABIP cellulosic biofuels network

12:20 pm Co-chair wrap-up

Track 5 – Direct Combustion & Thermochemical Conversion (FSC Room 1003)

Co-Chairs: Ed Hogan & Jaap Koppejan

8:30 am 5-1 Michael Jackson (Syntec Biofuel Inc, Canada)
"The thermochemical revolution: Biofuel production via gasification"

8:50 am 5-2 Stephanie Trottier (Alberta Research Council, Canada)
"Demonstration of small scale biomass gasification for combined heat & power production"

9:10 am 5-3 Dejan Sparica (Nexterra Energy Corp, Canada)
"Reducing greenhouse gas emissions from heat and power production by biomass gasification"

9:30 am 5-4" Martha Salcudean (University of British Columbia, Canada)
"Advantages of computer modeling in biofuel production and utilization processes

9:50 am 5-5 John Olver (Wessex Inc., USA)
"Combustion & heat transfer technologies for biomass combustion"

10:10 – 10:40 Coffee break

10:40 am 5-6 Jaap Koopejan (IEA Bioenergy - Task 32)
"Challenges in biomass combustion and cofiring: the work of IEA Bioenergy Task 32"

11:00 am 5-7 Kelly Cantwell (Nova Scotia Power Inc., Canada)
"The role of biomass at Nova Scotia Power"

11:20 am 5-8 Jane Todd (Ontario Power Generation, Canada)
"Biomass health and safety"

11:40 am 5-9 Larry Baxter (Brigham Young University, USA)
"Biomass particle reactions: experimental and model results"

12:00 pm 5-10 Sudhager Mani (University of Georgia, USA)
"Biomass torrefaction - a promising pretreatment method for thermochemical conversion technologies"

12:20 pm Co-chair wrap-up

Track 6 – Progress in Commercialization of Liquid Biofuels (FSC Room 1221)

Co-Chairs:Tony Sidwll & Manfred Wöergetter

8:30 am 6-1 Chris Somerville (University of California Berkeley, USA)
"The development of cellulosic biofuels"

8:50 am 6-2 Alex Berlin (Lignol Innovations, Canada)
"Key technical factors enabling today's biochemical biorefineries"

9:10 am 6-3 Niclas Bentsen (University of Copenhagen, Denmark)
"1st or 2nd generation bioethanol-impacts of technology integration & on feed production and land use"

9:30 am 6-4 Adam Gagnon (Climate Change Central, Canada)
"Alberta renewable diesel demonstration: An assessment of winter operability & infrastructure integration"

9:50 am 6-5 David Humbird (National Renewable Energy Laboratory, USA)
"2009 Update of the NREL biomass-to-ethanol biochemical process design report"

10:10 – 10:40 Coffee break

10:40 am 6-6 Lew Christopher (South Dakota School of Mines and Technology, USA)
"Biofuels and bioprocessing research and development in South Dakota"

11:00 am 6-7 Robert Jost (Alberta Research Council, Canada)
"Chemical conversion of hemicellulose coproducts from forest biorefineries to polymers & chemicals"

11:20 am 6-8 Erin Powell (University of Saskatchewan, Canada)
"Integrated biofuel facility w/ carbon dioxide consumption & power generation"

11:40 am 6-9 Barbara Illman (US Forest Service- Forest Products Lab, USA)
"Fermentation of biomass to fuel ethanol: adding value prior to pulping"

12:00 pm 6-10 Les Edye (Queensland University of Technology, Australia)
"Commercialisation of biofuels in Asia-Pacific"

12:20 pm Co-chair wrap-up

Track 7 – Socio-Economic Drivers in Bioenergy Systems (FSC Room 1001)

Co-Chairs: Bill White & Terry McIntyre

1:30 pm	7-1 Jyrki Raitila (VTT Technical Research Center of Finland, Finland) *"Business models in forest based bioenergy production – "Show me the money""*
1:50 pm	7-2 Bill White (IEA Task 29) *"Assessing drivers for bioenergy: An economics perspective"*
2:10 pm	7-3 Ivan Pržulj (North West Regional Energy Agency, Croatia) *"Progress in biomass utilization in the north-west Croatia"*
2:30 pm	7-4 Ian Thomson (Canadian Bioenergy Corporation, Canada) *"Renewable fuels policy development: Canada"*
2:50 am	7-5 Matt Carr (Biotechnology Industry Organization, USA) *"Indirect land use change, low carbon fuel standards, & cap & trade: The role of biofuels in greenhouse gas regulation"*
3:10 - 3:40 pm	Coffee break
3:40 pm	7-6 Terry McIntyre (Environment Canada, Canada) *"In search of the Holy Grail – Unequivocal environmental data to inform / support Canada's Biofuels Agenda"*
4:00 pm	7-7 Stephen Salter & Jim Savage (Farallon Consultants Ltd & Quesnel Community & EDC, Canada) *"Development of a community electricity & heating system in Quesnel, BC"*
4:20 pm	7-8 Paul Adams (SBC Firemaster, Canada) *"North America's first modular pellet plant"*
4:40 pm	7-9 Shahab Sokhansanj (University of British Columbia, Canada) *"Wood pellet optimization"*
5:00 pm	7-10 Elizabeth Cushion (The World Bank) *"Bioenergy development: Issues and impacts for poverty and natural resource management"*
5:20 pm	Co-chair wrap-up

Track 8 – Bioenergy Systems Analysis & Biorefineries (FSC Room 1003)

Co-Chairs: Henning Jørgensen & Bob Ingratta

1:30 pm	8-1 Gisle Johansen (Borregaard, Norway) *"Creating value from wood – The Borregaard biorefinery"*
1:50 pm	8-2 Gerfried Jungmeier (IEA Task 42) *"Comparing biorefinery systems to conventional processes - the methodological approach of IEA Bioenergy Task 42"*
2:10 pm	8-3 Mark Downing (Oak Ridge National Laboratory, USA) *"US Department of Energy investment in the integrated biorefinery: research, development, demonstration, & deployment"*
2:30 pm	8-4 Edmund Mupondwa (Agriculture & Agri-Food Canada, Canada) *"Sustainable biorefinery business models for rural development in Western Canada: A critical review"*
2:50 pm	8-5 Douglas Singbeil (FPInnovations, Canada) *"Materials selection for the biorefinery"*
3:10 - 3:40 pm	Coffee break

3:40 pm	8-6 Peter Lübeck (Copenhagen Institute of Technology, Denmark) *"Development of a biorefinery concept for integrated production of biomedicals, biochemicals, feed and fuels from selected plant materials "*
4:00 pm	8-7 Lauri Sikanen (University of Joensuu, Finland) **See addendum.** *"The great history and challenging future of forest based bioenergy in Finland"*
4:20 pm	8-8 Giuseppe Mazza (Agriculture and Agri-Food Canada, Canada) *"Green technologies for the conversion of crop residues to biochemicals"*
4:40 pm	8-9 Gurminder Minhas (Lignol Energy Corp, Canada) *"Biorefinery technology for renewable fuels and chemicals"*
5:00 pm	8-10 Gerry Kutney (Alterna Energy Inc, Canada) *"Biomass, biocarbon, bioenergy and bioproduct"*
5:20 pm	Co-chair wrap-up

Track 9 – Technological Advancements In Liquid Biofuels (FSC Room 1221)

Co-Chairs: Lisbeth Olsson & Emile van Zyl

1:30 pm	9-1 Lisbeth Olsson (Chalmers University of Technology, Sweden) *"Bioethanol production – From lab medium to large scale lignocellulosic fermentations"*
1:50 pm	9-2 Vince Martin (Concordia University, Canada) *"Genome shuffling of Saccharomyces cerevisiae through recursive population mating to evolve tolerance to inhibitors of spent sulfite liquor"*
2:10 pm	9-3 Rebecca Sydenham (Concordia University, Canada) *"A study in enzymology of xylan degradation"*
2:30 pm	9-4 Adrian Tsang (Concordia University, Canada) *"Genomic & proteomic approaches to identify & characterize fungal biomass-degrading enzymes"*
2:50 pm	9-5 Bernard Prior (Stellenbosch University, South Africa) *"Metabolic engineering of ethanol fermentation by Saccharomyces cerevisiae away from glycerol formation towards alternative products"*
3:10 – 3:40	Coffee break
3:40 pm	9-6 Michael Paice (FPInnovations, Paprican Division, Canada) *"Bioproducts from Kraft & sulfite dissolving pulp manufacturing"*
4:00 pm	9-7 John Ruffell (University of British Columbia, Canada) *"Pretreatment and hydrolysis of recovered fibre for ethanol production"*
4:20 pm	9-8 Kecheng Li (University of New Brunswick, Canada) *"Morphological alteration of wood fibres in the process of enzymatic hydrolysis of cellulose"*
4:40 pm	9-9 Emma Master (University of Toronto, Canada) *"Enzymatic valorization of hemicellulose & cellulose polymers"*
5:00 pm	9-10 David Levin (University of Manitoba, Canada) *"Biofuel production via cellulosic fermentation"*
5:20 pm	Co-chair wrap-up

program

plenary session

Wednesday, 26 August 2009

Industry Perspectives

Co-Chairs: Jim McMillan (NREL, US) and Janice Larson (BC EMPR, Canada)

08:30 am	Avrim Lazar (President & CEO, FPAC, Canada) *"The Dangers and Opportunities of Government Policy"*
08:50 am	George H. Weyerhaeuser Jr. (Former Senior Fellow, World Business Council for Sustainable Development, US) *"Bioenergy, Forest Sustainability and Climate Change"*
09:10 am	Claes-Inge Isacson (Chief Operating Officer, Mercer International, Canada) *"Bioenergy from the Perspective of a Forest Industry Company: An Innovation Approach"*
09:30 am	Hideo Kawabata (Chief Staff of R&D Planning, Nippon Oil Corporation, Japan) *"Movement for the Introduction of Cellulosic Bioethanol in Japan"*
09:50 am	Anthony Sidwell (New Opportunities Manager, British Sugar PLC, UK) *"Carbon and Sustainability Reporting is Good for Business"*
10:10 – 10:40 am	Coffee break

Global Perspectives

Co-Chairs: Hosny El-Lakany (UBC, Canada) and Adam Brown (IEA Bioenergy / Energy Insights, UK)

10:40 am	Werner Kurz (Senior Research Scientist, CFS, Canada) *"Forest Sector Mitigation Options to Reduce Climate Change"*
11:00 am	Stefan Bringezu (Director of Material Flows and Resource Management, Wuppertal Institute, Germany) *"Global Implications of Biofuels and Options for Sustainable Resource Management"*
11:20 am	Luis Antonio Carrillo (Principal Advisor, GTZ, Germany-West Africa) *"Biofuels: The African Experience"*
11:40 am	Anselm Eisentraut (Biofuels Analyst, IEA, France) *"Potential for Sustainable Production of Second Generation Biofuels"*
12:00 pm	Tiina Vähänen (Senior Officer, FAO, Italy) "Reduction of Emissions from Deforestation and Forest Degradation"
12:20 pm	Don O'Connor (President, (S&T) 2 Consultants, Canada) *"Bioenergy - Have We lost Sight of the Forest for the Trees?"*

program

poster session

1 **Mark Downing**
(Oak Ridge National Laboratory, USA)
"The US Department of Energy - Sun Grant initiative relationship: regional feedstock partnerships"

2 **Christine Stadnyk**
(University of Saskatchewan, Canada)
"Examining root dynamics of willow plantations in Saskatchewan"

3 **Ryan Hangs**
(University of Saskatchewan, Canada)
"Evaluating different techniques for estimating biomass in short rotation willow plantations"

4 **Richard Krygier**
(Natural Resources Canada, Canada)
"Production of short rotation willow biomass with & without irrigation using treated effluent water from a municipal sewage treatment plant"

5 **Lan Zhang**
(Beijing Forestry University, China)
"Biomass feedstock cost structure from forest residues: an analysis from Inner Mongolia, China"

6 **Sheala Konecsni**
(University of Saskatchewan, Canada)
"Nitrogen uptake by willow bioenergy cropping systems in Saskatchewan, Canada"

7 **Xiujin Zuo**
(Dalian University, China)
"The assembly of comprehensive unilization bio-gas obtained from swine manure by zymolysis in high consistency biomass at constant temperature for bio-gas power generation"

8 **Shahab Sokhansanj**
(Oak Ridge National Laboratory, USA)
"Integrated Biomass Supply Analysis & Logistics - Framework for model validation"

9 **Edmund Mupondwa**
(Agriculture and Agri-Food Canada, Canada)
"Lignocellulosic biomass logistics and rural farm value chain integration in rural Canada"

10 **Jerry Yuan**
(University of British Columbia, Canada)
"Numerical modelling of a biofuel gasification reactor"

11 **TJ Shankar**
(University of Saskatchewan, Canada)
"Studies on physical properties and grinding energy requirements for barley, wheat, oat, and canola straws"

12 **Kelly Maher**
(University of Alberta, Canada)
"Pyrolytic conversion of lipid feeds for bio-chemical & bio-fuel production "

13 **Phani Adapa**
(University of Saskatchewan, Canada)
"Pelleting characteristics of selected agricultural biomass-density & energy models"

14 **Serge Guiot**
(National Research Council of Canada, Canada)
"Bio-upgrading of synthetic gas into hydrogen"

15 **Ville Hankalin**
(Tampere University of Technology, Finland)
"Pyrolysis modeling with emphasis on thermal properties of wood"

16 **Yuqiu Song**
(University of Saskatchewan, Canada)
"Plant biomass briquetting – A review"

17 **Majid Soleimani**
(University of Saskatchewan, Canada)
"Quantification of the major carbohydrates, alcohols and toxic components in a bio-based medium by dual detection HPLC analysis"

18 **Ohene Akoto**
(Jatropha Africa, Ghana)
"Jatropha: A perfect feedstock for biodiesel"

19 **Junyong Zhu**
(US Forest Service, USA)
"Potential of sporl technology for commercial ethanol production from forest biomass"

20 **Humberto Tambor**
(Concordia University, Canada)
"Identification of fungal cellulases for efficient biomass conversion"

21 **Barbara Illman**
(US Forest Service, USA)
"Optimizing microbial conversion of biomass to liquid fuels"

22 Taraneh Sowlati
(University of British Columbia, Canada)
"Techno-economic analysis & optimization of wood biomass utilizationin the greenhouse heating systems in BC"

23 Anvar Buranov
(Agriculture and Agri-Food Canada, Canada)
"Extraction and purification of ferulic acid & vanillin from flax shives & other feedstocks"

24 Farah Hosseinian
(Agriculture and Agri-Food Canada, Canada)
"Triticale bran and straw are potential new sources of phenolic acids, proanthocyanins, lignans, & alkyl resorcinols"

25 Carl Pronyk
(Agriculture and Agri-Food Canada, Canada)
"Pressurized low polarity water fractionation of lignocellulosic biomass for the production of bioproducts"

26 Yasantha Athukorala
(Agriculture and Agri-Food Canada, Canada)
"Supercritical carbon dioxide and soxhlet extraction of waxes, polycosanols and phytosterols from flaxstraw"

27 Marc Duceppe
(Agriculture and Agri-Food Canada, Canada)
"Genetic diversity for fermentable carbohydrates production in alfafa "

28 Yukihiro Tamaki
(Agriculture and Agri-Food Canada, Canada)
"Structural carbohydrates, lignin, & microcomponents in straw of selected Canadian crops"

29 Gerfried Jungmeier
(Joanneum Research, Austria, IEA Bioenergy 42)
"Classifying biorefinery systems-the approach of IEA Bioenergy Task 42 "biorefineries""

30 Edmund Mupondwa
(Agriculture & Agri-Food Canada, Canada)
"Integrative investment analysis of lignocellulosic biomass to bioethanol biorefineries in Western Canada"

31 Scott Erickson
(Agriculture and Agri-Food Canada, Canada)
"Bayesian network model of regional biofuel supply chains"

32 Shiro Saka
(Kyoto University, Japan)
"Establishment to biorefinery by supercritical fluid technologies"

33 Amadeus Pribowo
(University of British Columbia, Canada)
"Differential adsorption and desorption of cellulase components may promote the development of an effective enzyme recycling strategy for cellulosic bioethanol production"

34 Eridan Pereira
(University of Western Ontario, Canada)
"Optimization of Ruminococcus albus endoglucanese Cel5-CBM6 production in plants by incorporating an ELP Tag and targeting to different subcellular compartments"

35 Igor Kolotilin
(University of Western Ontario, Canada)
"Assessment of multi-enzyme operon engineering of tobacco chloroplast genome for high-level simultaneous expression of cellulolytic enzymes"

36 Bhupinder Chadha
(Guru Nanak Dev University, India)
"Screening of natural Isolates & metagenomic libraries for novel cellulases/xylanases"

37 Jerald Lalman
(University of Windsor, Canada)
"Diverting electron fluxes to hydrogen in mixed anaerobic communities"

38 Shiro Saka
(Kyoto University, Japan)
"Bioethanol production from lignocellulosics with hot-compressed water treatment followed by acetic acid fermentation & hydrogenolysis"

39 Hung Lee
(University of Guelph, Canada)
"Genome shuffling of pentose-fermenting yeast Pichia stipitis for improved tolerance to hardwood spent sulphite liquor"

40 Xiang Li
(Agriculture and Agri-Food Canada, Canada)
"Seedling tolerance of Ethiopian mustard to metal salts"

41 Anil Hira
(Simon Fraser University, Canada)
Sugar rush: prospects for a global market in sugar cane ethanol"

Jacques Beaudry-Losique

(Deputy Assistant Secretary, Office of Energy Efficiency and Renewable Energy, U.S. Department of Energy, U.S.)

Jacques Beaudry-Losique was appointed in December 2008 as the Deputy Assistant Secretary (DAS) of Renewable Energy of DOE Office of Energy Efficiency and Renewable Energy (EERE). EERE works to strengthen the United States' energy security, environmental quality, and economic vitality in public-private partnerships. In this role, he oversees a portfolio of six major clean energy programs, including Wind, Water, Solar, Biomass, Geothermal and Hydrogen. Previously, Mr. Beaudry-Losique served as the Program Manager of the $200 million U.S. Department of Energy (DOE)'s Office of Biomass Program. Among numerous milestones, his office initiated major programs to launch a cellulosic biofuels industry, including an investment of up to $272 million in four major cellulosic ethanol projects in 2007 and another investment of up to $240 million in nine 10% cellulosic biofuels demonstration projects in 2008. Jacques' office has also played a leadership role in helping industry address environmental sustainability issues and supply chain bottlenecks such as the "ethanol blend wall." Mr. Beaudry-Losique holds a Bachelor of Science degree in chemical engineering from the University of Montreal and a Master of Science degree in Industrial Engineering and Engineering Management from Stanford University. As a recipient of a Canadian Science Foundation Fellowship, he attended the MIT Sloan School of Management, where he received a master's degree in management in 1992.

Stefan Bringezu

Director of Research Group on Material Flows and Resource Management, Wuppertal Instsitute, Germany

Dr. Stefan Bringezu is the Director of Research Group on Material Flows and Resource Management at the Wuppertal Institute and has chaired the working group on biofuels of the International Panel for Sustainable Resource Management (hosted by UNEP). He is a biologist by training with a Ph.D. in ecosystems analysis and has a Professorial degree at the Faculty of Environment and Society from the Technical University of Berlin. In prior affiliations he had worked in Chemical Assessment at the German Federal Environmental Agency, and Environmental Planning at Dortmund University. He initiated scientific networks (ConAccount, cofounder of ISIE), and pioneered methods such as MFA and derived indicators. His main area of work is in the analysis of socio-industrial metabolism and instruments to sustain resource supply, use and waste management.

Luis Antonio Carrillo

Principal Advisor, GTZ, West Africa

Luis Antonio Carrillo is currently the Principal Advisor of German Agency for Technical Cooperation (GTZ) in Forestry and Land Administration Programs in Guinée Conakry, Ghana, and Cameroun. He had been a Principal Advisor of GTZ in Forestry and Resources Conservation Programs in Venezuela and Guatemala in 1992 to 1998. He had also been a Principal Advisor of GTZ for a project for the coordination of Tropical Forestry relevant Programs while based in Eschborn, Germany in 1989 to 1991. Previous to this work at GTZ, he was a university instructor and research coordinator in Guatemala and Germany for 6 years where he specialized on social forestry, bioenergy, land administration and cadastre, and was also head of Economics at Centro Internacional de Agricultura Tropical, in Cali, Colombia for several years. Before these professions, he spent several years in remote sensing with National Forest Inventories in Central America, as Aerofoto Centroamericana Photogrammetric Pilot in 1975 to 1978.

Cassie Doyle

Deputy Minister, NRCan, Canada

Cassie Doyle was appointed Deputy Minister of Natural Resources Canada in June 2006. Ms. Doyle is an accomplished leader with 25 years of experience building successful public service organizations at the municipal, provincial and federal levels of government in Canada. Prior to joining NRCan, she served as Associate Deputy Minister, at Environment Canada. Ms. Doyle came to the Government of Canada from the British Columbia Assets and Land Corporation, where she was President and CEO. From 1992 to 1999, Ms. Doyle held senior positions in the Government of British Columbia, including Deputy Minister of Environment, Lands and Parks; Small Business, Tourism and Culture; and Housing and Consumer Services, as well as Assistant Deputy Minister of Municipal Affairs. Ms. Doyle holds a Master of Social Work degree in Public Policy and Administration and a Bachelor of Arts degree in Sociology.

Miles Drake

SVP, R&D, Chief Technology Officer, Weyerhaeuser, US

Miles P. Drake was appointed senior vice president, research and development and chief technology officer, October 8, 2006. He oversees a technology organization devoted to growing the core businesses, supporting Weyerhaeuser's customers and creating new technical-based options for growth for the corporation. Prior to joining Weyerhaeuser, Drake was with Air Products and Chemicals, Inc., where he had served as vice president, research and development and chief technology officer since 2001. Drake joined APCI in 1986 as a European technology manager based in London and held numerous other leadership positions. Drake holds a Ph.D. from Bristol University School of Surface Chemistry and a BA in Natural Science from Cambridge University UK. He served as a board member of the Da Vinci Discovery Center until his move from Pennslyania in 2006 and served for two years on the Board for Chemical Science & Technology for the National Academies. He was elected Chair of the Industrial Research Institute for the term 2005/2006. In 2007 he received the Maurice Holland Award for pertinence, significance and originality of new management concepts related to the field of R&D Technology & Innovation from Research & Technology Management. He received the AIChE American Institute for Chemical Engineering, Management Division Award in 2008. He is a Fellow of the Royal Society of Chemistry.

Anselm Eisentraut

Biofuels Analyst, IEA, France

Anselm Eisentraut is currently working as a Biofuels Analyst at the International Energy Agency in Paris. Prior to coming to the IEA, he was studying Landscape Ecology at the University of Münster, including nine months at the University of Joensuu in Finland, focusing on Forestry and Bioenergy. He spent time in the service sector of BKN Biostrom AG in Berlin, working on quality assurance in the production chain of biogas plants, along with experience in ecological planning and remote sensing from NLU Projektgesellschaft in Münster. At the IEA he is co-ordinator and lead-author of the forthcoming publication Potential for Sustainable Production of 2nd Generation Biofuels, in cooperation with the German Technical Cooperation (GTZ).

Claus Crone Fuglsang

Senior Director of BioEnergy R&D, Novozymes, Denmark/US

In January 1993, Claus Crone Fuglsang received his master degree in Biochemistry from University of Copenhagen, specializing in protein chemistry. In July 2000, he completed his MBA at Heriot-Watt University, Edinburgh Business School, in UK. Fuglsang have worked in Novo Nordisk, Enzyme Division (later Novozymes) since 1993 as a research scientist at first, and then, as a manager. Since 2002, Fuglsang worked as a Director/Senior Director, who was responsible for Novozymes Protein Chemistry area and Pharmaceutical Protein Development. Since the end of 2008, he transferred to US attaining global responsibility for Novozymes R&D efforts in BioEnergy with focus on cellulosic ethanol, a portfolio of projects with more than 100 employees. Fuglsang is also an author/co-author with around 20 publications, and an inventor/co-inventor on more than 20 patents and patent-applications.

Claes-Inge Isacson

Chief Operating Officer, Mercer International, Canada

Claes-Inge Isacson is the Chief Operating Officer at Mercer International in Canada. He holds a Master's of Science degree in Mechanical Engineering from Chalmers University of Technology and finished several management programs at INSEAD among others. He has a wealth of experience from various executive and management positions over the course of his career in different parts of the world including Europe ,North America and Asia. His areas of specialization are general management, pulp and paper, project management continuous improvement, and energy systems.

Hideo Kawabata

Chief Staff of R&D Planning, Nippon Oil Corporation, Japan

Hideo Kawabata is currently the Chief Staff of R&D Planning at Nippon Oil Corporation, Japan. He is one of the leading proponents of the cellulosic bioethanol movement in Japan. After completing a Master's degree in Polymer Technology from Tokyo Institute of Technology in 1983, and research work at Bristol University in UK, he concentrated his research and development on Flame Retardant properties of PE in wire and cables and adhesive resin for fuel tanks in several major companies in Japan. Since 2006, his work focused on research and development planning related to cellulosic bioethanol at Nippon Oil Corporation.

Werner A. Kurz

Senior Research Scientist, Canadian Forest Service – Natural Resources Canada, Canada

Dr. Kurz is a Senior Research Scientist at the Canadian Forest Service (Natural Resources Canada) in Victoria, BC. He holds a Ph.D. in Forest Ecology from the University of British Columbia. He is the lead scientist in charge of the development of Canada's National Forest Carbon Monitoring, Accounting and Reporting System and the development of the Carbon Budget Model of the Canadian Forest Sector (CBM-CFS3). His research focuses on the impacts of natural disturbances, forest management and land-use change on forest carbon budgets. Dr. Kurz was an author of five reports of the Intergovernmental Panel on Climate Change (IPCC) including the chapter on Forestry Mitigation Options in the IPCC Fourth Assessment Report (Working Group 3). He is appointed as adjunct professor at the University of British Columbia and at Simon Fraser University.

Kees W. Kwant

(Senior Expert at SenterNovem, Netherlands Agency for Innovation and Sustainability, Member of Exco of IEA Bioenergy)

Kees W. Kwant studied at the Technical University Twente; and graduated in: Applied Physics, Heat and Fluid dynamics; and Business: Technology Development for Developing Countries. At present, he is a linking pin on bioenergy between research (EOS) and implementation in the framework of the Renewable Energy Program in the Netherlands. He is a Member of the national Platform on Renewable Resources and was a member of Cramer Commission and chaired the working group on the GHG calculation methodology. He is Executive member of the IEA Bioenergy Implementing Agreement for the Netherlands; Project leader of the ERANET BIOENERGY project: 2004-2010 (www.eranetbioenergy.net) on bioenergy research cooperation in Europe; Project leader of Government to Government cooperation on bioenergy and biofuels between Netherlands and Poland in 2007, and Ukrain and Romania in 2009; Winner of the Dutch Bioenergy price 2009 of the Platform Bioenergy.

Avrim Lazar

President & CEO, FPAC, Canada

Avrim Lazar is President & CEO of the Forest Products Association of Canada since Jan. 1, 2002. He also chaired the National Business Association Roundtable and is the Past-President of the International Council of Forest and Paper Associations (ICFPA). He has held senior policy positions in the government of Canada in the Ministries of Justice, Agriculture, Environment and Human Resource Development. During this period he was responsible for national policy in areas as diverse as climate change, biodiversity, child poverty, employment insurance and labor force training. Mr. Lazar was Chair of the Committee of the Whole of the Second UN Conference of the Parties to the Convention on Biological Diversity in 1995. Mr. Lazar taught high school in Vancouver and Zambia from 1969 to 1973. Over the years, he has given many courses in the graduate studies programs at the University of Ottawa and Carleton University. Mr. Lazar holds degrees in science and education, including a B.Sc (1968) from McGill University, a B.Ed (1970) and a PhEd in Ed (1976) from the University of Ottawa. Mr. Lazar has four children.

Pierre Meulien

Chief Scientific Officer, Genome BC, Canada

Dr. Pierre Meulien is currently the Chief Scientific Officer of Genome British Columbia, a research organization that invests in and manages large-scale genomics and proteomics research projects and science and technology platforms focused on areas of strategic importance such as human health, forestry, fisheries, bioenergy, agriculture, mining and the environment. He has been in this position since May 2007. Previous to this he was the founding Chief Executive Officer of the Dublin Molecular Medicine Centre (DMMC) in Ireland. Established in 2002, the DMMC is a centre of excellence in life sciences, linking the scientific knowledge and translational research capabilities of three medical schools and five teaching hospitals. It is now a national initiative called Molecular Medicine Ireland. For over 20 years, Dr. Meulien has managed large research teams with a number of organizations, including Aventis Pasteur (now Sanofi-Pasteur) in Toronto (Senior Vice President of R&D), and in Lyon, France (Director of Research). Prior to this, he spent seven years with the French biotechnology company Transgene in Strasbourg, initially as a Research Scientist and then in several management positions. Dr. Meulien's academic credentials include a PhD from the University of Edinburgh and a post-doctoral appointment at the Institut Pasteur in Paris.

Don O'Connor

President of (S&T)2 Consultants, Canada

Mr. O'Connor is President of (S&T)2 Consultants Inc. He is a mechanical engineer with a broad background in energy and environmental consulting and in industry. Mr. O'Connor's background includes over 15 years of manufacturing and marketing experience with Western Canada's largest independent fuel retailer. He has successfully developed and commercialized environmentally sound transportation energy alternatives. Other aspects of Mr. O'Connor's background include: extensive experience with production of biofuels; development of NRCan's GHGenius lifecycle greenhouse gas model; detailed knowledge of fuels and the fuels industry; developing objectives, strategy and tactics in highly competitive manufacturing and retail industries; and managing and enhancing process operations in two distinct industries. Mr. O'Connor has recently provided strategic advice on fuels and transportation issues to a number of Provincial governments, several Federal Government departments and foreign governments. Mr. O'Connor has also consulted for a number of companies developing new technologies for alternative fuelled vehicles and companies developing new transportation fuel processes.

Viviana CBG Coelho

Environmental Monitoring and Assessment Manager, Petrobras, Brazil

Ms. Viviana Coelho is currently responsible for R&D in the environmental assessment field for all areas of the Corporation, including biofuels. The area is staffed with 60 researchers, who work in partnership with other areas to provide technologies for the superior social and environmental performance of Petrobras. Annual budget amounts approximately US$ 30 Million. She holds a MSc degree in Environmental Technology from the Imperial College, a Chemical Engineering Degree from the Federal University of Paraná and a Biology Degree from the Pontifical Catholic University of Paraná. She has been in Petrobras for 7 years and was previously the manager of the Downstream Environmental Corporate Department. Prior to Petrobras she worked in Consulting in Brazil, Portugal, USA, Argentina, Venezuela, Italy and Singapore to over 40 clients.

Anthony W. (Tony) Sidwell

New Opportunities Manager, British Sugar plc, UK

A. W. (Tony) Sidwell is currently the New Opportunities Manager at British Sugar plc, UK. He worked originally in operations, moved on to running the central analytical labs and then onto R&D for British Sugar, where he now works in Business Development. Sidwell had successful projects, which include a 5 hectare glasshouse utilising waste heat and CO_2 from the sugar process and the first fuel ethanol plant in the UK. Recently, he worked on designing systems for carbon and sustainability reporting for British Sugar's renewable fuels projects. Currently, Sidwell is running the ventures pipeline for the British Sugar Group to find new technologies and markets to move the group forward into new but adjacent areas of business. Ralph Sims.

Ralph Sims

Senior Analyst, IEA, France

Professor Ralph Sims is currently a Senior Analyst in Renewable Energy and Climate Change at the International Energy Agency, Paris whilst maintaining the position of Professor of Sustainable Energy at Massey University, New Zealand where he began his energy research career over three decades ago as an agricultural engineer. He was the Co-ordinating Lead Author of the "Energy Supply" chapter for the 4th Assessment Report of the Intergovernmental Panel on Climate Change, the 2007 Nobel Peace Prize recipient and is a Lead Author for the forthcoming IPCC Special Report on Renewable Energy. He has written two books on biomass including "The Brilliance of Bioenergy - in business and in practice" and has been a major contributor to several key publications at the IEA, including World Energy Outlook 2008, Renewable Energy Heating and Cooling, Energy Technology Perspectives 2008 and recently Transition from 1st to 2nd-Generation Biofuels jointly with IEA Bioenergy. He has acted as a consultant to many energy companies, is a Chartered Engineer and a Companion of the Royal Society of New Zealand.

Jim Snetsinger

Chief Forester, BC Ministry of Forests and Range, Canada

In November, 2004, Jim Snetsinger was appointed as BC's chief forester. As chief forester, Jim Snetsinger is the senior professional forestry executive of the ministry, responsible for developing plans and programs to manage provincial forest and range lands. He's the executive in charge of the Forest Science program and is responsible for determining timber harvest levels for each timber supply area and tree farm licence in the province. He also oversees the ongoing implementation of the new Forest and Range Practices Act and regulations. A professional forester since 1981, he's a graduate of the University of Toronto and worked as a forester for five years with BC Hydro before joining the Forest Service in 1986.

Chris Somerville

Director of Energy Biosciences Institute and Philomathia Professor, UC Berkeley, US

Chris Somerville is the Director of the Energy Biosciences Institute, a new research institute at UC Berkeley, Lawrence Berkeley National Lab and the University of Illinois Urbana-Champaign initiated with a $500M award from the energy company BP (www.energybiosciencesinstitute.org). He is the Philomathia Professor in Alternative Energy at UC Berkeley. He was a professor at Stanford University and director of the Carnegie Institution for Science from 1994-2007 and a professor at Michigan State University from 1982-1993. He has published more than 200 scientific papers and patents in plant and microbial genetics, genomics, biochemistry, and biotechnology. His current research is focused on the characterization of proteins, such as cellulose synthase, implicated in plant cell wall synthesis and modification. He is a member of the US National Academy of Sciences, The Royal Society of London and the Royal Society of Canada and has received numerous scientific awards including the Gibbs and Schull awards from the American Society of Plant Biologists, the Mendel Medal from the Genetics Society, the Hopkins medal from the Biochemical Society, the Khumo Award from the Plant Molecular Biology Society and most recently the Balzan Award which he shared with Elliot Meyerowitz (Caltech) for their role in helping to develop the current paradigm in plant molecular biology. He cofounded several biotechnology companies, Mendel Biotechnology, LS9 Inc and Poetic Genetics.

Tiina Vähänen

Senior Officer, FAO, Italy

Tiina Vähänen is currently Senior Officer at the Secretariat of the United Nations Collaborative Programme on Reduction of Emissions from Deforestation and Forest Degradation in Developing Countries (UN-REDD Programme), overseeing the global activities of the programme and representing the Food and Agriculture Organization of the United Nations (FAO) in the Secretariat. Previous to this she was coordinating international forest policy issues and FAO contributions to international agreements and the Collaborative Partnership on Forests, an interagency mechanism consisting of 14 major international organizations dealing with forests. Between 1998 and 2001, Ms Vähänen undertook an assignment at the United Nations Headquarters in New York, working on national reporting system and analyses for the UN Commission on Sustainable Development and the Secretariat of the UN Forum on Forests, playing a key role in creating the Collaborative Partnership on Forests and acting as its Secretary. Ms Vähänen has also worked in the Finnish forest industry and as Senior Adviser at the Ministry of Agriculture and Forestry of Finland. She graduated in 1994 from the University of Helsinki.

George H. Weyerhaeuser Jr.

Former Senior Fellow, World Business Council for Sustainable Development, US

George H. Weyerhaeuser Jr. is a partner at Houghton Cascade, a pulp and paper research partnership. Before working with Houghton Cascade, he was a Senior Fellow at the World Business Council for Sustainable Development. His work was focused on intellectual property, technology policy, energy and mobility. Prior to WBCSD, Weyerhaeuser was SVP, Technology at Weyerhaeuser. Previously he held various positions in pulp and paper manufacturing, wood products, research, and timberlands. He served as president of Weyerhaeuser Canada from 1993 to 1998. Weyerhaeuser received his bachelors in philosophy/mathematics from Yale University, and MSc from the Sloan School of Management, MIT. Weyerhaeuser has served as an Oklahoma State Regent for Higher Education, Chair of the Canada US Fulbright Foundation, Chair of the Institute of Paper & Science Technology (IPST) and Chair at Paprican. Weyerhaeuser currently serves as the Chair of Clearwater Investment Trust. He is also the Chair of the University of British Columbia Forestry Advisory Council, the Executive Board of the Sloan Center for Paper and Business Studies at Georgia Tech and the Institute of Forest Biotechnology.

PRESENTATION P1–1

Biomass – a saviour or a sin?

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The future potential of biomass in the global energy mix to provide heat, power and transport fuels is uncertain. Although providing around 10% of primary energy today, much of this resource is not produced or utilised sustainably. As a result almost all biomass use has become under close scrutiny. The food versus fibre versus fuel land use debate has caused many policy makers to become wary of encouraging the greater deployment of bioenergy projects. Such projects are also suffering from financial constraints, planning regulations, securing biomass supplies over the longer term, meeting emission regulations, reducing water demands, and often negative societal perceptions. In part this is due to misinformation in the media, but certainly some of the concerns about the present biomass industry are justified.

This paper provides an overview of what can be construed as "good biomass" and "bad biomass". It outlines the co-products and co-benefits that are not always fairly considered in the public debate but should be. It considers the technical, economic and socio-economic potentials for biomass and bioenergy based on IPCC and IEA analysis that are necessary to achieve atmospheric stabilisation at 450ppm CO_2 equivalent and thus give us a 50% chance of keeping global warming to below 2°C (although even at this level adaptation will be essential and biomass production may also be effected). Finally it aims to set the scene for other conference presentations by providing a vision for the role that biomass and bioenergy might play, including greenhouse gas mitigation opportunities, in the need to rapidly make the transition towards a future sustainable world.

PRESENTATION P1–2

Petrobras' strategy on biofuels

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This paper presents Petrobras strategy on biofuels. Committed to the sustainable development of its business, Petrobras has become an integrated energy company. This strategy made Petrobras increase significantly its investments in renewable sources of energy, especially in biofuels. The Company plans to establish a global presence in the biofuels segment, with a particular focus on biodiesel and ethanol. With this aim, Petrobras Biocombustível was created on July 29 2008 by Petrobras. It is the subsidiary in charge of developing the production and management of ethanol and biodiesel projects. In the ethanol segment, the company created a business model which policy is to seek for partnerships with international companies that hold markets for exports and with Brazilian ethanol producers who are already performing in the sector. Petrobras Biocombustível has two plants producing biodiesel: one in Candeias, in the state of Bahia, and the other in Quixadá, state of Ceará. A third unit will go online late this year in Montes Claros, state of Minas Gerais. Together, the three plants will be capable of producing 170 million liters of biodiesel per year. The Candeias and Quixadá plants have already been granted the Social Fuel Seal. The feedstock for these plants will come, prioritarily, from family farming, generating jobs and income in the farmland, always in search of economic, social and environmental sustainability. In terms of technology, the strategy is to develop competitive technologies to produce biofuels from residual biomass. These efforts confirm Petrobras' belief that investing in renewable energy is the path to achieve sustainable growth.

PRESENTATION P1–3

Challenges in scale bioenergy production from forest resources

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There are many opportunities to produce power and fuel intermediates like transportation fuels from forest resources. The production of energy on a scale that will have material impact at a national level requires a series of challenges to be overcome that span policy, logistics, chemical engineering and silviculture. This presentation will describe how Weyerhaeuser is tackling these challenges in collaboration with multiple partners.

PRESENTATION P1–4

The road to commerical lignocellulosic ethanol

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Novozymes A/S is, as an independent enzyme technology provider, focusing on enabling the industry in a wider context to commercialize lignocellulosic ethanol through the route of cost efficient bioconversion. By an unprecedented research effort with more than 100 scientists, Novozymes is breaking through the barriers for commercialization. Novozymes takes a holistic view on the process from feedstock to ethanol and develops both cost effective enzymes as well as overall process improvements to allow for cost efficient conversion. With leading ethanol producers in US, China, Brazil and in Europe, processes are developed and integrated leading to total cost scenarios that could make sustainable lignocellulosic ethanol production competitive with gasoline in the near term. Novozymes will be presenting examples on its work with respect to enzyme improvements as well as process developments and will in full cost modeling show how these developments help bring down the cost of lignocellulosic ethanol to a cost competitive level.

PRESENTATION P1–5

The role of genomics in biofuels innovation

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The increased production of economically viable liquid biofuels will require new and innovative technologies that can be scaled up. As a life science sector, many of these innovations can be enabled through genomics and related "-omics" sciences. The tools of genomics apply throughout the biofuels value chain, from enhancing biomass productivity to developing novel and ideal feedstock traits to increasing conversion efficiencies. British Columbia is rich in potential biomass opportunities and is positioned to be a leader in applying genomics to biofuel production as the province has: 1) world class research and platform facilities, 2) internationally recognized scientists with far-reaching collaborations, and 3) a strong funding environment, led by Genome BC's commitment to the biofuel, agriculture, and environment sectors.

PRESENTATION P2–1

Bioenergy and biofuels in Canada: Important renewable energy options for the future

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Canada is a world leader in the production and use of energy from renewable resources. Renewable energy sources currently provide about 16 percent of Canada's total primary energy supply and biomass is our second most important renewable energy source. The primary types of bioenergy include electricity and industrial heat from wood waste, space heating from firewood, and biofuels from agricultural crops.

Canada's cooperation in the International Energy Agency (IEA) helps provide the science and technology to support the success of its bioenergy and biofuels strategies over the long term. The IEA indicates that renewable energy and biofuels must play a role in achieving global greenhouse gas (GHG) reduction targets. The Government of Canada has committed to reducing GHG emissions by 20 percent over 2006 levels by the year 2020. We fully expect that bioenergy will be a significant part of the solution.

Canada has huge biomass resources, innovative technologies and the expertise to take advantage of these resources. We are leading in the sustainable development of next-generation biofuels. We are developing biorefineries that result in many useful industrial products. The Government of Canada is providing over $2 billion to support biofuels and the development of transformative technologies that use forestry residues, agricultural residues, and municipal waste to produce biofuels.

Many important initiatives are facilitating the sharing of scientific knowledge and the development of technologies to make bioenergy a reality: the IEA Bioenergy Implementing Agreement; the U.S.-Canada Clean Energy Dialogue; and the Canadian Biomass Innovation Network. International cooperation is essential and Canada expects to play a continuing role in the IEA's work.

PRESENTATION P2–2

US DOE Bioenergy Program

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**** Presenting Author***

Mr. Beaudry-Losique will discuss the U.S. Department of Energy's research, development and demonstration programs in the Office of Energy Efficiency and Renewable Energy. These are comprised of ongoing R&D programs (such as the Biomass Program), the newly initiated activities funded under the Recovery Act, and commercialization activities. Further included are cross-border (U.S.- Canada) Clean Energy Dialogue activities.

The U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy (EERE) develops renewable energy, and energy-use reduction technologies. The Department also has an active demonstration and commercialization strategy for those technologies. The President's interest in advancing our cross-border partnership and the current Clean Energy Dialogue (CED) provides a unique opportunity to make significant advances. Recently, the American Recovery and Reinvestment Act of 2009 (Recovery Act) provided more than $60 billion in clean energy investments, with nearly $800 million going to biomass research and development and demonstration alone. Because of Canada's national efforts and its excellent knowledge and capabilities in all of the EERE thrust areas, we are keenly interested in furthering our cross-border relationships. The United States and Canada have been participating in a Clean Energy Dialogue for biomass research and development in such areas as biomass pyrolysis, algal biomass and sustainable bioenergy production.

PRESENTATION P2–3

The transition towards a biobased economy in the Netherlands: An Innovation approach

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The Dutch governmental policy is based on the transition approach. A major transition is foreseen to secure an environmental sound supply of food, materials and energy in the future. Based on a vision and identification of transition paths an innovation agenda was developed to start the transition. Biomass is expected to play a major role in the sustainable energy supply but also in the biobased economy by the biorefinery approach. Limited local availability of biomass resources demands for a global supply of certified sustainable biomass. Opportunities exist, but need be assured to realise a win-win situation with the developing world. The innovation agenda supports projects in biorefinery, sustainable biomass import and improved production of biomass (e.g. algae). The paper will present the cooperative action of government and actors in the market to realise the transition.

PRESENTATION P2–4

Future forests: Opportunities for biofuels

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British Columbia's public forests, a source of quality forest products, are becoming increasing important as a source of fibre for bioenergy and for their role in ecosystem services such as carbon sequestration, biodiversity, energy and water. These new and emerging opportunities will have an impact on the province's silviculture, forest management, tenure and valuation, which have evolved from the assumption that sawlogs are the primary forest product.

British Columbia is reviewing its forest management and silviculture practices to ensure they encourage maximum productivity and value, and support forest resilience. The province is exploring ways to provide the flexibility needed to deliver sustainable forest management while addressing climate change, the timber supply impacts of the mountain pine beetle infestation, and the demand for new product and ecosystem service opportunities.

The British Columbia Ministry of Forests and Range is taking a strategic approach to climate change that consists broadly of three areas of work:

- predicting and monitoring climate change;
- adaptation to reduce impacts such as maladaptation and capture opportunities such as higher growth rates; and
- mitigation to reduce impacts such as deforestation and capture opportunities such as bioenergy.

Forest managers need to find ways to adapt forest practices to changing ecosystems and, as much as possible, maintain ecosystem resilience to stress and disturbance. They must manage forests for new values, such as carbon, bioenergy and specialty products. Society may have to change its expectations of what the forests can provide under new conditions, and decisions in approved land use plans may no longer reflect current realities and changing public values.

British Columbia is also taking steps to more fully integrate science, policy, and social issues – integrating work across agencies to deal holistically with the land base. This involves an adaptive, dynamic process with a feedback loop for continuous improvement, continuous learning.

PRESENTATION P3–1

The dangers and opportunities of government policy

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Government policy plays a significant role in driving the market for energy from forest products. When well designed, renewable energy and climate policies can drive the production and consumption of green energy and displace fossil use and thus result in a net benefit to the environment and social well being grounded in sustainability. When poorly designed these policies can actually increase greenhouse gas production and have negative effects on forest ecosystems and the sustainability of rural communities. This presentation will address the dangers and opportunities intrinsic to the policy enterprise in seeking forest based energy and suggest guidelines for good practices.

PRESENTATION P3–2

Bioenergy, forest sustainability and climate change

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The immediate commercial prospects of forest based bioenergy is very much dependant on the future climate change framework under negotiations at the United Nations Framework Convention on Climate Change. Will the framework have the elements to drive a rapid decarbonization of the world's economy? Will it stimulate private investment in research, development, and demonstration of new, clean energy technologies? Most critically, how will it treat the stocks and flows of carbon associated with the world's forests? Will the new mechanisms support international cooperation and deliver financial support to forest based energy?

It is too early to predict the outcomes of the political process. The tenor of negotiations changed dramatically in the last year. For the uninitiated energy scientist, even following the debate is difficult. The UNFCCC subsidiary body structure is Byzantine. The language is full of acronyms and arcane references to previous decisions. The protocols for negotiations are inscrutable.

The forest carbon discussions subsumed in the general climate negotiations have a different flavour. The battle lines about man's use of forest resources were drawn long ago. Since Kyoto, accounting for changing forest carbon stocks has confounded the emissions based methodology of the protocol. Harvested wood products are not dealt with easily in a framework designed for fossil fuel. The last minute compromises on the methodologies at Kyoto came after the CO_2 reduction targets were set. The mistrust generated by those circumstances poisoned the land use change conversations for the next decade. Today, accounting for bioenergy is caught in the same old controversies. Will the negotiators set the targets before the rules again?

In the months leading to Copenhagen, the UNFCCC subsidiary bodies are dealing with these mundane issues while the world's political leadership tackles the global challenges. Progress at both levels will signal the bioenergy investors that it is time to begin reinventing our energy sector.

PRESENTATION P3–3

Bioenergy from the perspective of a forest industry company

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Mercer International is an international forest industry company headquartered in Vancouver and we produce and sell 1, 45 million ton of northern bleached softwood kraft pulp and 430 GWh of power to the grids.

Mercer Internationals purpose is defined as: "Provider of fibres, renewable energy and chemicals, from sustainable sources, for essential human needs."

We are currently investing in more power production capacity in our Canadian mill to bring it up to the same standard as our German mills. Meanwhile we are investigating various alternatives to further develop bio mass residues from the process into either increased power production or alternative bio fuels and materials.

Our pulp mills annually handle large carbon streams, as we annually process 7, 5 million m^3 of solid wood. The amount of carbon in the raw material is about 1.6 million ton/yr, while the pulp has 0.6 million ton/yr carbon bound, which then is stored in paper products from our customers. The bark on the wood and in the process dissolved carbohydrates and lignin's are burned in high pressure boilers and the steam expanded in turbo generators to produce steam for the process and electrical power. By employing state of the art process technologies and equipment and effective management, substantial surplus of energy is produced for the market. Many opportunities exist to develop the biomass streams in and from the process further either as fuels or raw materials such as dried lignin, phenols, methanol, turpentine, tall oil etc. Technologies exist, or are being developed, that would further allow the production and sale of bio products. Many Chemical companies are today actively looking for alternate and sustainable feed stocks to their traditional fossil based raw materials.

Financially these alternatives have to be competitive with fossil based ones as there is little or no "green" premium to be gained from the market, as the case is with green power. Government policies are of high importance and set the frame within the development and commercialization will occur. To develop these various technological possibilities into commercialized products with market potentials requires research and development and close collaboration in clusters.

PRESENTATION P3–4

Movement for the introduction of cellulosic bioethanol in Japan

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Biofuels are an important tool in the fight against global warming. The Kyoto Protocol Target Achievement Plan adopted by the Japanese Cabinet in 2005 sets a target of an annual supply of transport-use Biofuel equivalent to 500,000 kiloliters of crude oil to be introduced by the end of March 2011.

However, to ensure a stable energy supply it is essential that the introduction of Biofuel ensures reliable raw-material procurement, lower costs and price stability. It is also important to explore means to overcome some of the shortcomings associated with Biofuel production, namely competition with food supplies and the destruction of forests and other ecosystems. Moreover, although the Kyoto Protocol treats biofuels as a carbon-neutral energy source, the need exists to conduct a life-cycle assessment LCA of the actual CO_2-reduction benefits of Biofuel use.

Depending on such situations, aiming to realize technology innovation in which Biofuel is effectively produced from Cellulosic raw-material economically and in large quantity, while maintaining compatibility with the "Schedule for expanding domestic Biofuel production (a report to the prime minister)" compiled by Biomass Nippon Strategy Promotion Council in February 2007, METI (Ministry of Economy, Trade and Industry) and MAFF (Ministry of Agriculture, Forestry and Fisheries) held "Biofuel Technology Innovation Conference", consisting of 16 major private companies in petroleum, automobile and other industries, research institutes of universities/colleges and independent administrative agencies, to formulate the "Biofuel Technology Innovation Plan" containing concrete targets, technology innovation, and roadmaps. The ultimate goal of this plan is to develop production-process technology by 2015 that will enable 200,000 kiloliters of bioethanol—priced at 40 Japanese yen per litter to compete with crude oil—to be produced annually.

To this end, the six companies including Nippon Oil Corp. have established a new association named Research Association of Innovative Bioethanol Technology to utilize their own elemental technologies for each stage of the production of non-food-source Cellulosic bioethanol. The association will aim to deliver production technologies allowing stable and economical mass-production of bioethanol. In order to develop the groundbreaking technology, the association has teamed up with the University of Tokyo—a base for cutting-edge research on biomass resources—and also cooperate with research institutions involved in the areas of agriculture, forestry and fisheries. This all-Japan cooperative framework is now intensively implementing R&D under the financial support of the New Energy and Industrial Technology Development Organization (NEDO).

PRESENTATION P3–5

Carbon and sustainability reporting is good for business

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The British Sugar Group (BSG) is one of the leading sugar producers in the world. It has 39 factories, in 8 countries, at the last count, processing sugar beet and cane to produce sugar, and a wide range of co-products, including bioethanol, furfural, betaine, animal feed and many others.

When the UK Government decided to encourage biofuel production it also insisted on carbon and sustainability reporting of all biofuel sold in the UK. Because of this, BSG designed and integrated their bioethanol plant into existing sugar process to minimise overall fuel consumption. BSG has also worked with its contracted farmers to optimise agricultural inputs and this has reduced fertiliser consumption and improved yields significantly over the years. Not only does this reduce green house gas emissions, it also means lower cost to the industry as a whole. Another area which has improved the cost base, improved profitability and reduced overall GHG emissions has been to diversify into other products from the same inputs to the existing process, like producing tomatoes from the waste heat and CO_2 from our power plant and to co-generate electricity for export to the local grid. It doesn't stop there.

We have recently done a piece of work to benchmark what we do with the worlds best, this has shown that there is great scope to improve in many areas, including crop yields, processing yields and energy consumption. It also shows, when you look at the world as a whole there is tremendous scope for us all to improve. If we all concentrate on these basics and add on satellite processes to make more from the raw material we already have, we will not only improve GHG balances, but also produce more from existing crop lands, and most importantly improve profitability for farmers and processors.

PRESENTATION P4–1

Forest sector mitigation options to reduce climate change

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Concerns about accelerating rates of atmospheric carbon dioxide concentration increases and the resulting impacts on global warming are motivating efforts to develop mitigation strategies. Climate change mitigation objectives are achieved when, relative to a baseline, emissions are reduced or removals from the atmosphere are increased. Mitigation options in the forest sector include the use of harvested wood products to substitute for more fossil-fuel intensive materials (such as steel and concrete) and for bioenergy. In Canada, high rates of natural disturbances, in some cases already affected by climate change, will result in millions of tons of forest biomass killed annually by fires, insect outbreaks, drought and other climate-related stresses. These dead trees will decompose and release carbon dioxide to the atmosphere. Some of the standing and downed dead trees could be salvage logged and used as feedstock for bioenergy. Salvage logging, however, can have a wide range of impacts on subsequent forest carbon dynamics. Quantification of these impacts is a prerequisite for assessing the magnitude and temporal dynamics of any mitigation benefits that may arise from salvage logging as a way to derive bioenergy feedstock. Such analyses of net greenhouse gas benefits can assist in the selection of stands for salvage logging that can make the largest contributions to mitigation objectives. Analyses of salvage options in stands with mortality from Mountain Pine Beetle demonstrate that the magnitude and timing of net greenhouse gas benefits from salvage logging depend on the stand conditions that are salvaged, the rate of recovery post salvage, and the type of fossil energy that is substituted. Moreover, because fossil fuels are more energy intensive than biofuels, a net mitigation benefit may not be achieved for several decades into the future. This emphasizes the need for comprehensive assessments of the net greenhouse gas benefits of proposed mitigation activities, if the objective of reducing atmospheric carbon dioxide concentrations is to be achieved.

PRESENTATION P4–2

Global implications of biofuels and options for sustainable resource management

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Recent scientific reviews of the IPSRM and SCOPE have underlined the multi-faceted implications of biofuels. On the one hand, they may provide benefits in particular when used for stationary applications, and to support local communities. On the other hand, the growing demand for transport biofuels may significantly contribute to land use change and subsequent losses of biodiversity and increased green house gas emissions. Considering global trends of agricultural yields, the global situation is characterised by the circumstance that cropland will be expanded only to feed the growing and more prosperous world population. Any additional demand for non-food biomass will come on top of this. Regions importing biofuels tend to enlarge their global net consumption of crop (and forestry) land, and contribute to land use change, i.e. the conversion of grasslands, savannahs and natural forests especially in the tropics. Various options exist to foster a more efficient and sustainable resource management. These comprise the optimization of agricultural production and the use of degraded land; the use of bioenergy in stationary applications, the preferred use of waste and residues and the cascading use of non-food biomass; mineral based systems might be more resource efficient than biomass, and policies to foster a more efficient use of materials and fuels in industry and households may be more rewarding than the subsidization of transport biofuels. Altogether, biofuel and biomass policies need to be integrated into a broader perspective of sustainable resource management.

PRESENTATION P4–3

Biofuels: The African experience

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The situation concerning biofuels in Africa shows that some countries are in an advanced stage of planning their introduction, others are already producing biofuels, and others have already set mandatory mixing of ethanol into gasoline. Below is a review of information found in the literature and on internet and from own observations and reports.

Also recently (July 2006) thirteen of the Africa's poorest nations have joined forces to become global suppliers of biofuels. In a meeting in Senegal, they formed the African Non-Petroleum Producers Association, aimed at developing alternative energy sources.

In recent years, many biofuel production projects have been launched in Western Africa. However, due to the time lag between plantation and full-scale production (up to 6 years), many of the new projects and plantations have not yet reached maturity. As a consequence, major projects that could be producing significant quantities of biofuels in the next few years are not yet reflected in production statistics.

Ethanol production

In terms of ethanol production, little is currently produced in Africa. However, short-term opportunities exist. Countries in the SADC (South African Development Community) region are using molasses from the sugar cane industry (a by-product of sugar production) to produce ethanol.

Biodiesel production

While biodiesel is not currently produced on a significant scale in Western Africa, widespread experiences are being carried out in many countries using existing cotton and palm oil resources and infrastructures. Many countries have experiences with Jatropha as a hedge or in plantations. Land and resources use is an issue to be considered in this development.

Biomass solid fuels

In all African countries involved in timber production the biomass residues represent a huge potential accessible in concentrated spots in quantities that equal or surpass the commercial timber production. Since the residues are already available there are no land use conflicts to arise.

PRESENTATION P4–4

Potential for sustainable production of second generation biofuels

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The IEA is working on a study looking into the possibilities for sustainable production of second generation biofuels, particularly in selected developing and emerging countries. The study consists of a general section on global biomass potentials and a discussion of sustainability of second generation biofuel production. The second section includes eight country profiles, conducted by local consultants, analysing the framework for production of lignocellulosic biofuels in certain countries.

The study's main focus lies in the potential utilisation of agricultural residues as the most sustainable feedstock for production of second generation biofuels.

Current policy targets are analysed regarding their influence on promotion of second generation biofuels, with particular emphasis on recent development in the US and the EU. A review of existing studies on biomass potentials is compared to the detailed feedstock assessment of the eight country profiles, to discuss the possibilities and constraints for the production of second generation biofuels in practice.

The following countries will be profiled: Brazil, China, India, South Africa, Mexico, Cameroon, Thailand and Tanzania. The choice of countries covers some major expanding biofuel markets as well as different regions and varying level of development. Within the profiles, potential sources for lignocellulosic biomass and the currently attainable yields from these sources are assessed. To ensure sustainability of biofuel production, biomass sources that are currently utilised, such as cattle feed, nutrient cycling and electricity production, are not taken into consideration as potential feedstock.

Furthermore, the country's suitability for the production of second generation biofuels with regard to infrastructure, human capital and political environment is characterised. In each country, possible "hot spots" that offer most favourable conditions for the installation of biofuel refineries, are identified. The conducted conclusions discuss the country's feasibility to produce second generation biofuels and highlight expected benefits and major obstacles for its implementation. Furthermore the option to produce second generation biofuels is compared to other bioenergy conversion routes, to evaluate the most suitable technology for the country. Finally it will be discussed if, and to what extent the results of the country profile are representative of the whole region.

PRESENTATION P4-5

Reduction of emissions from deforestation and forest degradation

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Deforestation and forest degradation, through agricultural expansion, conversion to pastureland, infrastructure development, destructive logging, fires etc. account for nearly 20% of global greenhouse gas emissions, more than the entire global transportation sector and second only to the energy sector. To have an impact on climate change, the global average temperatures must be stabilized within 2 degrees Celsius. This cannot be achieved without reducing emissions from the forest sector, in addition to other mitigation actions. Reducing emissions from deforestation and forest degradation in developing countries (REDD) aims to create a financial value for the carbon stored in forests, offering incentives for developing countries to reduce deforestation and the investments to follow low-carbon paths to sustainable development. It is predicted that financial flows for REDD could reach up to US$30 billion a year. The United Nations Collaborative Programme on REDD (UN-REDD Programme) was created in late 2008 to support the decisions made in the United Nations Framework Convention on Climate Change. This interagency programme supports countries to develop capacity to reduce emissions from deforestation and forest degradation; to measure, report and verify the emission reductions; and to prepare for the implementation of a future REDD mechanism in a post-2012 climate regime. A large-scale mechanism for REDD will require advancing from current readiness activities to capacity building, institution strengthening and ultimately, to performance-based compensation on the basis of measured emissions reductions from deforestation and forest degradation. An effective REDD framework has the potential to transform the forest sector in developing countries and enable multiple benefits to people that depend on forests and the environment that is at risk of becoming degraded. These benefits include climate change mitigation, poverty reduction, economic growth and conservation of biodiversity.

PRESENTATION P4-6

Bioenergy have we lost sight of the forest for the trees?

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The use of bioenergy as a replacement for fossil fuels in the transportation system has been promoted in various countries over the past 40 years. The claimed merits of bioenergy have been energy security, environmental improvement, and economic development. These pillars of support for bioenergy have been used in most countries and while the strength of each pillar has changed from region to region and from time to time these are still the same foundations for bioenergy today. However, after some success in increasing the rate of adoption of biofuels around the world, the past several years have seen bioenergy energy attacked on a variety of fronts. These include increasing greenhouse gas emissions, causing food shortages, and destroying valuable eco systems.

Have the issues that drove the development of biofuels changed so dramatically that biofuels have become part of the problem rather than part of the solution? Or are the arguments against bioenergy taken out of context? Do the arguments consider the implications of all of the costs and benefits?

PRESENTATION 1-1

Energy, agriculture, forestry and environmental policies for short rotation crops

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The production of energy from agricultural and forestry (primary industry) sources is challenging technically. Policy also needs to develop to meet these opportunities and issues focussing on the balance between existing and evolving production systems, a changing biophysical environment and resource allocation priorities, and the expectations of society.

The integration of various issues and country-based objectives is required to deliver analyses to inform policy that enable sustained and sustainable bioenergy production (either stationary energy or biofuels). Much of the current policy development aims to increase the opportunity for bioenergy to address components of: Energy security; Environmental quality; and Economic opportunity.

Many of the developments require a balance between new and existing industries in a changing biophysical environment. Policy development increasingly aims to integrate emerging expectations from society that recognise issues such as sustainability (of the supply chain) and consumer demands (e.g., food security). For short rotation crops the issues for development are focussed on adaptation of existing industries (e.g., rotation of trees for fibre production and residues) or the development of new industries (e.g., exploitation of coppicing species in existing farming systems).

In Australia, for example, there is significant development of policy initiatives at a national level (e.g., the development of the Carbon Pollution Reduction Scheme) and at a regional level (e.g., through the New South Wales Government's introduction of ethanol and biofuel mandates through the Biofuels Act 2007). Enhancing industry capacity by setting clear goals and targets is one of the objectives of such initiatives. Developing sustainable production systems are also important.

In this paper we report on some of the latest policy implications for short rotation crops from different regions of the world. We aim to identify some of the positive outcomes as well as the challenges for new industry development.

PRESENTATION 1-2

Cross-country comparison of drivers, challenges and opportunities for bioenergy

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A systematic review of IEA Bioenergy Task 31 country reports was conducted to evaluate and analyze the drivers, challenges and opportunities for bioenergy from sustainable forestry in participating countries. Similarities and differences in bioenergy systems were evaluated for countries in Europe and North America. The review revealed some striking differences and potential to expand bioenergy production.

The strongest driver affecting biomass utilization in some countries was the lack of fossil fuel reserves, especially for Finland and Sweden. Conversely, large, cost-competitive fossil fuel reserves in Canada (oil) and the US (coal) largely explain their low uptake of biomass. However, recent, record-high oil prices and the need for independent supplies have spurred development of bold biofuel policies in the US.

Security and stability of domestic forest biomass supply is also a large constraint to biomass utilization. Finland, the Netherlands and the UK report low forest biomass availability, and therefore rely to a large extent on imports. Increased international trade in biofuel will likely be a key element in sustaining bioenergy sector demand within these countries. Additionally, growing competition for logging residues poses some risk for stable, cost-competitive feedstock supply, especially in Sweden and Canada. Landscape topography and infrastructure concerns (Finland), private land ownership (Finland, Norway), and sustainable harvest levels have also been noted as potentially limiting factors to biomass utilization.

However, there are growing opportunities for increased biomass consumption within all countries reporting. All countries identify the benefits for reducing GHG emissions. In Europe, targeted GHG emission reduction policies have been developed, which generally favours biomass expansion. Several European countries (Finland, The Netherlands, Sweden) expect that more efficient recovery of residues will contribute to increased biomass supply, while there is potential for increased amounts of whole tree harvesting especially in North America. Finland, Canada and the US, have also identified forest bioenergy as a potential stimulant of rural economies, and diversification of the forest sector is welcomed in all countries.

We predict that energy policy and international trade of biomass will be key drivers to further expansion of bioenergy in North America and Europe.

PRESENTATION 1-3

The potential of short rotation willow coppice on agricultural land in northern Europe based on empirical data.

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The development of short rotation coppice for bioenergy requires accurate and reliable estimates, based on empirical experience. The research presented is based on the analysis of 13 000 ha of willow plantations for bioenergy in Sweden during the period 1986-2005. It is studied the geographical spread of willow cultivation, linked to the changes in the policies of promotion of wood-energy crops and to the local economic framework. For that, a geo-statistical method based on kernel analysis is applied, in order to identify the grouping patterns of plantations, and therefore areas where the cultivation was successful. In addition, based on the performance of the plantations studied, there are presented estimates of current, expected and potential regional productivity of short rotation willow plantations for Sweden and nearby countries in Northern Europe. The estimations for current productivity are based on the performance of the Swedish plantations, using assumptions concerning management intensity, and geographically extrapolated by productivity areas, using regional cereal yields as indicators. The estimates of expected yield rely on the current trends of yield increase from commercial willow plantations Sweden. The estimates for potential yield are based on climatic restrictions.

The results show that the establishment of an infrastructure, a market for willow chips and the existence of consumers that can guarantee a long-term demand for willow chips, are essential preconditions for the development of short rotation coppice for bioenergy. Concerning productivity, the results show potential average yields of 9.5, 6.8, 7.9, 9.0, 9.3, and 8.0 odt ha-1 yr-1 for Denmark, Finland, Estonia, Latvia, Lithuania and Sweden, respectively. However, there is a wide regional variation between the different countries. In Denmark, Finland and Sweden there is a convergence between the future forecasts and the climatic potential yields, in the areas of high productivity. The Baltic countries seem to present lower estimates of current productivity, reflecting possible socio-economic restrictions, although they show a high biomass potential if only included climatic restrictions.

The outcomes of this study can help to evaluate the possibilities of short rotation coppice for bioenergy, in areas where energy crops are under consideration, as a basis for future economic or policy applications.

PRESENTATION 1-4

Feasibility of short rotation coppice and high-yield afforestation for bioenergy in Canada

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Bioenergy forest plantations are generally considered a carbon-neutral source of clean energy for industrial, domestic and heating purposes. However, while the possible role of biomass-based fuels as an alternative energy source is well recognized, better quantifying the economics of the bioenergy plantations and understanding key biophysical and economic drivers of their regional variation remains an important issue for government and private sector investors in Canada. Our work is examining biomass production from short rotation coppice woody crops and high-yield afforestation established specifically for the purposes of bioenergy production in Canadian conditions. Our assessments include regional variation of growth rates due to climatic suitability and heterogeneity of local site conditions. We present what we call "current expectations" and "aspirational targets" that reflect features such as increased growth rates and lower costs, both of which could come from technological change. Included in our results are scenarios that map out carbon price conditions that may be required to make this kind of biomass production more economically attractive.

PRESENTATION 1-5

Jerusalem artichoke as a platform for inulin, ethanol and feed production in Canada

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Jerusalem artichoke (JA, Helianthus tuberosus) is a tuberous perennial plant, native to the North American plains. JA is a non-food, low input crop that tolerates marginal lands. It is a high biomass producing crop with dry matter yield averaging 13-18 tonnes (dry stalks) and 18-25 tonnes (tubers) per hectare in Alberta. Fresh JA tubers contain about 20% of water soluble carbohydrates, which occur predominantly in the form of inulin. Several health promoting benefits are associated with intake of inulin. High volumes of dry residual aerial biomass left after tuber harvest contain 40 to 50% water soluble carbohydrates, mostly fructans and fructose that are fermentable to ethanol. Fructans require a pre-fermentation hydrolysis step utilizing enzymes or weak acid to result in carbohydrates of a fermentable form. Under optimal climatic conditions, some studies have suggested that JA can yield more ethanol per ha than sugarcane. At Alberta Research Council (ARC) in Vegreville, we are developing JA as a multi-product crop platform for inulin, ethanol, polymers and animal feed. We utilize a 'seed to final product' technology development approach that includes new variety development, agronomy/production and processing to final products. ARC currently has the exclusive North American rights to several high yielding JA cultivars. Working with Olds College in Alberta, we have developed an extraction process and completed engineering process design with economic feasibility studies for commercial inulin production from JA tubers. We are developing and optimizing biomass handling, efficient extraction and fermentation process that would make ethanol production from JA stalks commercially viable. Using hot water extraction technique and low liquid to JA stalk ratio, we have achieved >40% total water soluble carbohydrates (fructan and monosaccharide sugars) per gram of biomass. We have isolated microbes capable of simultaneous hydrolysis and fermentation of JA fructans to ethanol thereby eliminating the need for weak acid or enzymatic hydrolysis. We estimate that a 400 hectare plantation of JA in Alberta, Canada would produce approximately 1,500 tonnes of inulin and 1.5 million liters of ethanol per annum in a pilot scale bio-refining plant. The residual solids after inulin extraction and ethanol fermentation can be recovered and sold as cattle feed.

PRESENTATION 1-6

Biomass production for energy from sustainable forestry

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Several factors drive the present increasing interest in bioenergy, including global climate change, the need for security of energy supply, and the desire to reduce reliance on imported energy. These drivers have increased demand for biomass from the forest sector, while competition for forest biomass resources for many uses is also increasing. In this environment, careful policy decisions and management strategies are required to ensure sustainability of forestry systems. IEA Bioenergy Task 31 aims to support development of such policies and strategies through its work of collecting, synthesizing and sharing leading-edge science and technology on sustainable production of biomass for energy from naturally regenerated forests and plantations. Its approaches emphasize integration within the woodfuel supply chain and between environmental, economic and social aspects of forest management. The Task strives to help meet the need for sound scientific and technical information and practical guidelines for ensuring sustainability within the principles of sustainable natural resource management.

The paper reviews current and recent activities of the Task contributing to fulfillment of these aims. Annual international workshops bring together policy makers, industry and scientists to share information and research findings on current sustainability issues and directions. In close collaboration with the Food and Agriculture Organization of the UN, a book is being produced offering a complete set of criteria and indicators for sustainable woodfuel production, with practical application in both developed and developing countries. Technology papers address specific issues, including certification of forest fuel production systems, reliability of forest biomass supply estimates, and nutrition management for sustainable forest biomass production. Input is provided to development of international policy related to a sustainability scheme for energy uses of biomass. As well as organizing workshops, and producing scientific and technical publications, country reports and policy papers, the Task also shares knowledge and experience through field tours, industry-oriented seminars and the Internet (www.ieabioenergytask31.org).

The paper provides an introduction and background context to other related papers within the general topic area of biomass production and management.

PRESENTATION 1-7

A real-time, web-based optimal biomass site assessment tool (BioSAT): Module 2. An economic assessment of mill and logging residues for the eastern U.S.

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Key to ensuring long-term, sustainable cellulose supply is the assessment of the economic availability of woody and agricultural-derived biomass feedstocks. The genesis for any emerging or existing industry is the ability to successfully secure commercial business loans with a defendable business plan for the expansion of existing plants or development of new manufacturing facilities. A key component of any business plan must include a profitable strategy for the geographic location of a cellulose using facility. This study addresses the problem with the development of web-based system for optimal siting of cellulose using mills called the Biomass Site Assessment Tool (BioSAT) The project integrates contemporary web-based information technology (e.g., Virtual Earth and Microsoft SQL) with existing U.S. Forest Service FIA data, agricultural data, harvesting, and transportation models. BioSAT has real-time database update capabilities. Transportation networks of truck and truck/rail combinations are presented for least cost solutions by zip code tabulation areas for a potential demand site. Optimal sites are selected for 33 Eastern United States using linear logistic regression and non-linear feature extraction methods. Producers' marginal cost curves are presented for optimal site locations.

PRESENTATION 1-8

The challenges of improving biomass inventory for southeastern Ontario, Canada

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The ongoing credit crisis has exacerbated a long-term downward trend in the Canadian forest sector, which has resulted in the closure of many sawmills and pulp and paper facilities in the province. This trend, combined with the Ontario government's policy decision to phase out coal-fired electricity generators by 2014, as well as continued volatility in energy prices worldwide, has generated increased interest in the potential for forest-based bioenergy production in Ontario.

Development and deployment of forest-based bioenergy in Ontario will require a good understanding of the availability of wood biomass in the province. In the past, Ontario's forest inventories have focused on the central and northern parts of the province, and have been almost exclusively devoted to acquiring data on merchantable species and dimensions of wood. Future demand for bioenergy, however, will be heavily centered in more urbanized areas in the southeastern part of the province, and will be able to utilize a broad range of woody feedstocks beyond the 'merchantable' definition. The last forest inventory carried out in southern Ontario was completed in 1978; the lack of up-to-date information on biomass availability presents great challenges to the emerging bioenergy sector. A biomass inventory to serve the bioeconomy will have to be built from the ground up.

The authors will describe the current status of biomass inventory of the southeastern part of Ontario, define the gaps in this inventory; and discuss how the University of Toronto and Queen's University are working to fill these gaps. The role of existing projects, such as the Southern Ontario Land Resource Information System (SOLRIS) database, will also be discussed. Key gaps identified include: the lack of agreement on a common used method for biomass inventory, the patchiness of currently available inventory data, and the lack of awareness of property boundaries (particularly on private land). The role of a central (online) data storage facility is explored, as are the utility of newly developed imaging tools such as Light Detecting and Ranging (LiDAR). The ability of inventories to build on First Nation's experiences and Traditional Ecological Knowledge (TEK) is also discussed.

PRESENTATION 1-9

Moisture management, energy density and fuel quality in forest fuel supply chains

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Moisture is the main quality factor of woody biomasses for energy. The amount of water in solid wood fuels has a remarkable effect on transportation efficiency, combustion efficiency and emissions. Moisture content (MC) can be decreased during storing by natural or by artificial drying. In favorable conditions and by good management, moisture content can be decreased from typical fresh cut 50-55% of MC down to 20-30% in relatively short periods of storing. In fuel wood supply chains, natural drying can be boosted effectively by minor modifications. This natural drying effect can have remarkable effects on the total energy efficiency and emissions of supply chains. In this study, the main focus is in supply chain design in order to promote natural drying and estimating the effects on supply chain and its energy efficiency. The effect of improved packing density on transportation phase, and the needs to control other quality aspects like chip size distribution and purity of chips are discussed. The total cost effect will be calculated by the procedure developed at the University of Joensuu and in the Finnish Forest Research Institute. The procedure will consider transportation costs and emissions according to transportation fleet and moisture content of the transported fuel.

PRESENTATION 1-10

Sustainable forest biomass harvesting research in the Canadian Forest Service: an overview

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Since the time of the oil crisis of the 1970s, the Canadian Forest Service has carried out research on the environmental sustainability of biomass harvesting from managed forests for bioenergy. Initial research focussed on developing allometric equations for estimating tree components for bioenergy feedstock production (tops, branches, foliage) from standard mensurational measurements and the nutrient concentrations and contents of these components, from which nutrient losses in biomass removals could be estimated. Recognizing that simple nutrient budgets were crude indicators of site sustainability, the CFS concomitantly funded development of an early predictive site productivity model, FORCYTE, which has been continuously improved by UBC researchers since then. Empirical nutrient cycling data was developed in a series of whole-tree harvesting field trials initiated from 1989 to 1990 in eastern Canada; later Long-Term Soil Productivity (LTSP) trials examined combinations of growth limiting factors on harvested sites, including logging residue removal. Atmospheric deposition work merged with harvesting impacts research and increased our understanding of the role of base cations. Forest carbon research has also grown in importance since the 1970s and has direct relevance to the fate of forest carbon through both on-site residue management and use of tree components as energy feedstock. National inventory programs now include tree components that will become harvesting residue and hence potential bioenergy feedstock. In conjunction with Agriculture and Agri-Food Canada and Environment Canada, CFS research feeds into a national inventory of all biomass sources (Biomass Inventory and Mapping Assessment Tool; BIMAT) for informing policy and planning decisions. For managed forests, this tool will include site suitability information to net-down total potential logging residue inventory to the proportion that can be removed while ensuring environmental sustainability.

The pace of development of the forest bioenergy sector necessitates closer-than-ever partnerships amongst research organizations, industry, and agencies with legislative responsibility for forest management. As part of this linkage, the CFS has developed a simple field trial protocol for application by industry that will enhance monitoring capability in light of a changing future climate. It is also important that research fills key knowledge gaps, be forward-looking, and anticipates trends in future forest management.

PRESENTATION 1-11

The framework for sustainable harvest of forest biomass in British Columbia.

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In many parts of the world, government policies have been implemented to create incentives for the development of the renewable energy sector, and to ensure that feedstock sources are environmentally sustainable. Sustainable forest management (SFM) is a cornerstone of all forest management, whether for traditional forest products or for the emerging bioenergy feedstock market. In British Columbia, research on the environmental effects of forest management has been carried out for many years. Scientific knowledge has been generated to address traditional SFM concerns about harvest-related soil disturbance and erosion, site occupancy by roads and trails, biodiversity, and water quality. This knowledge has informed a comprehensive set of science-based regulations and policies with the objective of ensuring soil and water conservation. Removing additional biomass as feedstock for bioenergy is an increasingly common activity in BC's forests. These removals incrementally increase machine traffic and organic matter removals on sites beyond that experienced with traditional harvesting methods. Two avenues are available for validating whether the traditional SFM framework in BC is robust enough to address current and future intensive harvesting practices: (1) review the existing knowledge of the environmental effects of intensive harvesting that informed biomass harvest policy development elsewhere, and (2) review existing knowledge generated by relevant studies in BC, such as compaction trials, and the Long-term Soil Productivity (LTSP) network. Regardless of the new challenges created by intensive harvesting practices, the principles of soil conservation remain the same. The current framework for BC's soil conservation policy is reviewed to confirm that it addresses the major sustainability issues that are likely to arise in the province with intensive biomass harvesting. We also discuss the extent to which currently available scientific knowledge is sufficient to inform policies in the short term, and evaluate the need for new science-based approaches for monitoring the long-term sustainability of biomass harvesting in BC.

PRESENTATION 2-1

Energy from solid waste in IEA countries: Policies and trends

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This paper reviews the experience of the nine countries participating in the IEA Task 36 on energy recovery from solid waste. It examines problems and proposed solutions, both through policy and through advanced processing; and it reviews trends in solid waste management and their potential impacts on energy recovery from solid waste.

Waste management options within the nine IEA Task 36 member countries are not so very different. Indeed, in a number of these countries policy is directed by implementation of EU legislation, leading to common drivers. Despite this there are a range of approaches being taken to solid waste management arising from past practices, country specific policy and public perception of what is acceptable. This makes for interesting comparisons between countries and for divergence of waste management practice. For example, experience of mechanical biological treatment and development of solid recovered fuel is fairly advanced in Germany; the Netherlands have a centrally planned approach to energy from waste, including a ban on landfilling of combustible waste; Sweden's waste strategy aims to achieve the maximum use of the resource represented in waste; and in many areas in the UK there is strong public opposition to waste incineration, which means increased interest in alternatives including complex separation and recovery prior to energy recovery in advanced conversion plant. In contrast in North America, represented by Canada, cost effective treatment is a major driver; as are solutions for rural areas; and recycling is increasingly important in some provinces.

Nevertheless there are common themes leading to similar solutions being examined in all countries. For example, in general participating countries attempt to decrease landfill biogas by decreasing the disposal of biodegradable waste to landfill using tax incentives; and it is becoming increasingly common to encourage more efficient energy recovery from waste by establishing incentives for more efficient processes (particularly combined heat and power). Furthermore, in Europe at least, there is a recognition that resource recovery should consider the carbon impact of recovery technologies and this may well encourage energy recovery from waste fractions that are not easily separated and recycled.

PRESENTATION 2-2

Comparing the environmental impacts of residual waste management options

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Options for treating the residual component of municipal solid waste (i.e. after kerbside recycling) range from combustion based techniques to mechanical biological treatment (MBT) options. The latter use sorting techniques to recover recyclable materials such as metals, and then typically split the waste into an organically based component which can be biologically treated through anaerobic digestion (AD) or composting and another fraction – a refuse derived fuel (rdf) which can be combusted. IEA Bioenergy Task 36 has conducted a study to examine how the environmental impacts of these different types of waste management options vary and whether it is possible to establish a hierarchy of environmentally preferred options.

The study examined the environmental impacts using an integrated waste management life cycle analysis tool, WRATE[1]. This calculates the potential impacts of all stages in the collection, management and processing of municipal waste, and takes account of infrastructure and its operation as well as any benefits associated with materials recycling and energy recovery. Five options, ranging from energy from waste (EfW) plant, to MBT options based on AD and composting were assessed and compared to landfill,

The study found that all of the waste management options considered had lower environmental impacts than landfill, but that the ranking of the options varied depended on the environmental impacts considered, so that there was no unique hierarchy. In addition, the relative impacts of options were strongly influenced by assumptions about the type of electricity generation displaced by any electricity produced from the waste. The efficiency with which both energy and materials, particularly energy intensive materials such as aluminium and plastic, are recovered, is important for some environmental impacts such as climate change and acidification. If reducing emissions of greenhouse gases (GHGs) is of key importance, then EfW plant can offer significant benefits where the electricity mix is predominantly based on coal and/or gas. These benefits are reduced if the electricity which is produced displaces a lower carbon electricity mix is considered, and where very low carbon technologies such as hydro or nuclear are considered, then other biologically based options may have a lower climate change impact.

[1] Waste and Resources Assessment Tool for the Environment, see www.environment-agency.gov.uk/research/commercial/102922.aspx

PRESENTATION 2-3

Energy recovery from MSW – one step further

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The member-countries of IEA Bioenergy Task 36 (France, Sweden, Norway, United Kingdom, the Netherlands, Canada and Germany) presented the energy recovery from Municipal Solid Waste (MSW) and drivers and barriers for the use of MSW for energy in their country during a workshop in April 2008. The variety in energy recovery and drivers and barriers made it difficult to provide a simple overview of drivers and barriers. Due to the differences in their current position this also seems less relevant. However it seems possible to describe the different phases of energy recovery from waste and the most important drivers and barriers for that stage. This paper could provide countries with insight into moving energy recovery one step beyond where they are now.
Despite the major differences in the reporting countries, interesting conclusions can be drawn on the drivers and barriers at the different stages of development for energy from waste.

Main driver is the policy to reduce the landfill of combustible waste which has resulted in an increase in recycling and incineration. Note that not the energy production but the reduction of landfill gas, an important source of the greenhouse gas methane, is the main driver behind the policy incorporated in most EU countries and Canada.

There is a higher priority for recycling over incineration which must be recognised without underestimating the potential benefits of energy production out of waste. Open debate where different options are discussed is essential to gain social support. Mutual trust between NGO's and proponents of energy from waste is often problematic. The status of mechanical biological treatment versus incineration for mixed municipal waste should be addressed.
The country-comparison showed that high energy recovery rates were achieved in countries where waste incineration was connected to district heating. Early stage decisions for waste incineration provided opportunities to optimise the use of the heat produced from municipal solid waste. Long term planning and policy is important as these projects require intensive, long-term (contract) security and a stable political environment.

Countries with well developed energy from waste infrastructure, could improve their energy of recovery through energy and innovation policy with potential assessment methods will be discussed. The example of Sweden shows that an energy recovery of over 95% is possible.

PRESENTATION 2-4

Residential waste – an often overlooked bioenergy source

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Bioenergy is always high on the agenda once politicians present their ideas how best to overcome the dependency on fossil energy sources and how to antagonise the CO_2 induced climate change. However, the expected resources were by far not sufficient to meet the demand and allow a full replacement of fossil fuel. Furthermore there is no agreement to what extent specific types of biomass are climate neutral.

There is a type of biomass which is often neglected in bioenergy promoting programmes: the biogenic fraction of waste. The EU Network of Excellence (NoE) Bioenergy investigated the status of 'waste-to-energy' in the 8 member state of the NoE. On the basis of these more detailed data and complemental information from other sources it can be concluded, that in most countries, industrialised as well as developing ones, more than 50% of the energy inventory of municipal solid waste (MSW) originates from the biogenic matter. The annual per capita MSW generation in the industrialised world exceeds typically 500 kg, its average lower heating value varies between 8 and 12 MJ/kg and is comparable to low-grade lignite. When considering the potential of residual MSW (the fraction left over after material recycling and recovery), a good estimate is that MSW could contribute 1-2% to the total primary energy and 2-3% to the total power demand in industrialized countries. The actual data show that the potential of MSW for energy recovery is far from exhausted, partly because of the common lack in public acceptance of waste incineration, partly for economic reasons. A socio-economic evaluation will bring the comparably high energy costs into perspective with the benefits concerning the operation of aftercare free disposal sites.

PRESENTATION 2-5

Process for bionatural gas production from forestry residue

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Natural gas provides 22% of the global energy demand. Displacement of fossil natural gas with methane from renewable energy sources is an effective method to mitigate CO_2 buildup in the atmosphere. Limiting factors to large scale displacement include the high cost of bio-methane versus fossil natural gas, reluctance of gas utilities to accept unproven gas cleanup technology, high feed-in and monitoring costs for minor amounts of biogas, and limited opportunities for biogas from anaerobic digesters and landfills. We discuss an advanced proprietary process to produce large quantities of competitively priced and pipeline quality bio natural gas from forest biomass. The bio-natural gas production can be fed by sustainably removable forest biomass and creates many green collar jobs. A model of distributed bio natural gas generation and injection into existing gas grid provides for low cost deployment and distribution. The technology is near commercial.

PRESENTATION 2-6

Application of biomethane in private and public transport

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Biogas can be used in all utilities designed for natural gas: in hot water and steam boilers, combined heat and power plants (CHP), fuel cells and as a vehicle fuel. Increasingly it is fed into the natural gas grid after a careful upgrading process.

Most biogas is used for electricity and heat production in CHPs driven by spark ignited gas engines. A few hot fuel cells (molten carbonate) and micro turbines are in operation as well.

In Sweden, Switzerland and recently, in Austria and Germany, biomethane (i.e. biogas upgraded to natural gas quality) has been routinely used as a car fuel, with fuelling directly at the digester site or fed into the grid and fuelling with a pump at a station.

Worldwide there are about 7.5 million natural gas fuelled vehicles in operation, mainly in Argentina, Brazil, Pakistan, Italy, India and the US (Sizler, 2008) This equals about 0.8% of the world vehicle stock. Most of the cars are retrofitted with gas however; European car manufacturers start to have an increasing interest in NGV's and develop real gas engines. In Europe about 10 makes with about 35 models are available with a gas engine. However, only half of the makes are factory built; the others are retrofitted. The shooting star is the new Passat 1.4 liter that passed the ADAC test (german car drivers association) as the first car ever with a ranking of five stars.

An increasing number of European cities are introducing (bio-) gas driven buses for public transport. The advantages being lower emission, noise and operating cost. Berne (Switzerland) is one of the demonstration projects sponsored by the EU. Biomethane is produced at the WWTP, upgraded and sold to the grid operator of Berne (ewb). The gas is transported to the public transport company BERNMOBIL to power 35 (out of 42) buses and the buses are fuelled over night in the world's first indoor filling station. The buses have been highly accepted by the customers and collaborators of BERNMOBIL and the bus drivers have welcomed the higher power of the gas buses over the old diesel buses. The presentation will highlight Berne's experience with this public transport system.

PRESENTATION 2-7

Modern technologies of biogas upgrading

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The process of upgrading biogas opens new possibilities for utilization of biogas since it then can be used as vehicle fuel or to replace natural gas. However, upgrading ads cost to the biogas production. It is therefore important to have an optimized upgrading process in terms of low energy consumption and high efficiency giving high methane content in the produced gas. For environmental reasons it is important to minimize the methane slip from the upgrading plant.

Several techniques for upgrading of biogas exist today: pressure swing adsorption (PSA), water scrubber, organic physical scrubber, chemical scrubber and membranes. These techniques are continuously being improved. In parallel new techniques are under development or are in the research stage. One of the newer techniques being developed is the cryogenic upgrading. With low temperature upgrading the raw biogas is cooled down to temperatures where the carbon dioxide in the gas condensates or sublimates and can be separated as a liquid or a solid fraction, while methane accumulates in the gas phase. The reason for this is the difference in boiling/sublimation point of carbon dioxide and methane. A technique that is in the research stage is in situ methane enrichment. Since carbon dioxide is to some extent soluble in water some carbon dioxide will be dissolved in the liquid phase of the digester tank during biogas production. In upgrading with the in situ methane enrichment process, sludge from the digester is circulated to a desorption column and then back to the digester. In the desorption column carbon dioxide is desorbed by letting air flow through the sludge. Another example of techniques being researched is the so called ecological lung. By using the enzyme carboanhydrase, which is e.g. present in our blood where it catalyses the dissolution of carbon dioxide, the dissolving of carbon dioxide in a scrubber would be facilitated.

The latest developments for biogas upgrading using the techniques mentioned here as well as developments of cleaning technologies for biogas, will be reviewed.

PRESENTATION 2-8

Anaerobic digestion as a biofuel production technology from crops

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The methane produced from the anaerobic digestion of energy crops represents an elegant and economical mean of generating renewable biofuel. Anaerobic digestion is a mature technology and is already used for the conversion of organic municipal wastes. The conversion of energy crops into methane is facing the same initial barrier as for the production of ethanol e.g. hydrolysis of the crops. However the pretreatments required for the anaerobic digestion could be less intensive than those of ethanol biorefineries. The net energy yield is potentially greater since the whole substrate but lignin is theoretically convertible into methane, and less energy would be used to obtain it, since namely the biogas distillates off by itself from the liquid. As a result, ca. three times more net energy yield can be obtained per hectare of crops by making methane instead of biodiesel or bioethanol.

A variety of soft pre-treatments has be tested with respect to the increase of of the yield in methane production of switchgrass, a lignocellulosic tall plant considered as an alternative to starch or sugar crops. The pre-treatments tested were grinding, blending, chopping, sonication, microwave, alkalinization, heat, heat and pressure, and different enzymes. Temperature, sonication and autoclaving had only a slight impact on the switchgrass, as shown by the similar volatile solids and soluble COD concentration before and after pretreatment. An hydrolysis of 24 and 43 % of the switchgrass was achieved with the alkali pretreatment, by itself or coupled with autoclaving. This resulted in a final net methane production increased by 56 % for the pretreated switchgrass, at 126 ± 2 and 197 ± 5 LSTP CH4/kgVSSadded. Similar results could be obtained from the addition of lignin and manganese peroxidase, with 179 ± 2 and 193 ± 12 LSTP CH4/kgVSSadded. The combination of an alkali pretreatment with the peroxidases did not improve the methane yield significanly, suggesting that the solubilizing effect of the alkali on the lignin impacted the switchgrass in a similar way as the peroxidases.

In conclusion, even low intensity pre-treatment (mechanical, soft alkali, enzymatic) may significantly improve the methane yield of anaerobic digestion of lignocellulosic crops.

PRESENTATION 2-9

Ranking the renewable energy options for a district heating system in Vancouver using multi-criteria decision making

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This paper presents the evaluation and ranking of different energy sources for a district heating system in Vancouver, Canada. The considered energy sources are natural gas, biomass (wood pellets), sewer heat, and geothermal heat. Energy options are ranked considering cost, GHG emissions, particulate matter emissions, maturity of technology, traffic load and local source criteria using the PROMETHEE method. Two different scenarios are examined to indicate how the communication between the stakeholder groups involved in the district heating project would change the ranking of alternatives and facilitate reaching consensus when a multi-criteria approach is taken.

PRESENTATION 2-10

Biofuel sustainability: Recent developments and ways forward

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The sustainability of producing 1st-generation biofuels has recently been questioned, with debates arising over the ultimate end use of agricultural feedstocks ('food vs. fuel') as well as the potential impact of indirect land use change ('carbon debt'). This has led to the introduction of sustainability criteria into biofuel policy, which has been addressed by the International Energy Agency's Bioenergy Task 39 'Commercialization of Liquid Biofuels'. The developers of 2nd-generation biofuels, including cellulosic ethanol and other advanced biofuels, need to assure both governments and consumers that these fuels will be generated on a sustainable basis. This in turn requires a mechanism for collecting, processing, and disseminating information on a range of issues, including environmental, economic, and social parameters. Key among these are questions around life cycle methodologies, employment opportunities, and regional development. This paper considers recent international developments in measuring biofuel sustainability across the membership of IEA Bioenergy Task 39, including efforts at the European Commission level as well as examples from individual countries. Models for ensuring sustainability, including certification systems, are discussed. A list of criteria for biofuel sustainability, based on key issues raised by members of Task 39, are proposed, in order to inform a framework that will permit the bioenergy industry to develop at a rapid but sustainable rate.

PRESENTATION 3-1

Microalgae biofuel economics

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Microalgae mass cultures can be used for the production of biomass suitable for conversion to renewable biofuels: methane, ethanol, biodiesel and hydrogen, as well as nitrogen fertilizers. Microalgae cultures must be supplied with an enriched source of CO_2, such as from power plants flue gases, biogas or ethanol plants and similar sources. They would abate greenhouse gases by producing renewable biofuels that substitute for fossil fuels and by providing environmental services that reduce greenhouse gas emissions, such as wastewater treatment and nutrient recycling.

Currently microalgae are cultivated commercially mainly in shallow (~ 30 cm deep), raceway-type, paddle wheel mixed, open ponds to produce high value food supplements. Large, unmixed and undivided, ponds, some over one hundred hectares in size, are also used in algae production and municipal wastewater treatment. However, these systems are, respectively, either too expensive or of too low a productivity for the production of biofuels.

Engineering cost analyses, to be reviewed in some detail, project sufficiently low capital and operating costs for large (several hundred hectares) raceway, mixed, open-pond cultivation systems to be considered for biofuel production, if current algal biomass productivities could be doubled, to about 100 tons mt/hectare-year of biomass with a high content of extractable vegetable oils (triglycerides) or fermentable starches. Co-products and co-processes could improve the economics of such systems. The algal cultures must be stably cultivated and cheaply harvested, such as by a simple spontaneous flocculation-settling process ("bioflocculation").

Achieving these goals of culture productivity, stability and harvestability will require a combination of long-term applied and fundamental R&D into algal physiology, genetics, photosynthesis, mass cultivation, the control of grazers and 'weed' algae, as well as of technologies for low-cost harvesting and processing of the biomass. Co-production of biofuels with treatment of municipal and other wastewaters is a relatively nearer-term application of microalgae biofuels production.

The potential of microalgae biofuels, as that of other biofuels and renewable energy technologies generally, will be limited by many constraints, for microalgae the requirements for simultaneous availability of water, CO_2, flat terrain and favorable climatic conditions. Such technologies must be developed for the long-term sustainability of our societies.

PRESENTATION 3-2

European Union policy promoting bioenergy

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Bioenergy has traditionally contributed around two-thirds of all renewable energy in Europe. At the turn of this century the percentage of renewables in the total energy mix was 6%. Policy developed since 2007 has set an ambitious target of 20% renewables in the gross energy supply by 2020, and 10% renewable fuels in the transport sector. Biomass is expected to make a major contribution. This paper describes the main components of legislation with an impact on bioenergy

The new 2009 EU renewables directive defines the criteria for reaching the targets. There are no individual targets for different renewable sectors. The 10% renewable transport fuels target is set for each country. While the initial proposal called for 10% biofuels, the final adopted position is that the 10% may be achieved with a mixture of biofuels, renewable electricity and other fuels such as hydrogen. The minimum CO_2 (equivalent) saving for biofuels is 35% (compared with petrol and diesel), rising to 50% in 2017 and 60% for new biofuel production coming on-line after 2017. As such, the directive recognises the potentially large contribution sustainability issues could have on reaching the 10% target. The existing biofuels sustainability scheme could be extended to include an element of land use change in the future. Specific measures are established to reduce obstacles to grid connections, both for electricity and for gas (biomethane), and ensure no discrimination compared with traditional fossil energy or gas sources. Publication of connection tariffs will be required.

The renewables directive also calls for biomass sustainability to be addressed and for an appropriate sustainability scheme to be developed. Agricultural residues such animal slurries have to be treated to avoid ground water contamination (nitrates directive) while nutrients from all residues need to be recycled to the soil. The sustainability issue means biomass residues and wastes are particularly attractive. The EU waste framework directive sets the legal framework for treatment of wastes and promotes both recovery of energy and materials from biowaste, favouring biogas production, and encourages high conversion of energy by incineration that should maximise renewable energy production from the biomass component of mixed waste.

PRESENTATION 3-3

From biomass to sustainable biofuels in southern Africa

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The production of biofuels from biomass in Africa has numerous advantages, including environmental benefits, improved energy security, economic development and social upliftment. Biofuel projects have to be evaluated rigorously to ensure that these benefits are realized, for example, 1st generation technologies does not score well due to marginal energy balance, negative life cycle impacts or being detrimental to biodiversity. On the other hand, the production of biofuels from lignocellulose scores well on environmental (energy balance and life cycle analyses), biodiversity, energy security and social upliftment, but the cost of processing remains expensive. The development of local technologies and integration of technologies across the biofuels value chain provide opportunities to substantially impact the cost of lignocellulose processing, thus enabling the commercialization of 2nd generation biofuels production.

The Senior Chair of Energy Research (CoER) : Biofuels at Stellenbosch University focuses on the technological interventions required to develop commercially-viable 2nd generation lignocellulose conversion technologies to biofuels in Southern Africa. The CoER : Biofuels research programme undertakes to develop both biochemical and thermo-chemical technologies for complete conversion of plant biomass to biofuels. These technologies will be discussed briefly and how we envisage establishing South Africa as a technology- and services-provider to biofuel producers in southern Africa. With these technologies in hand, we can challenge the establishing societies that produce sustainable biofuels in an environmentally responsible way to unlock Africa's potential as bio-energy provided, but managing our natural resources and biodiversity in a positive way. At the same time these technologies could also assist in job creation in the agricultural sector, wealth creation in general and helping southern Africa to become less dependent on crude oil and associated security risks.

PRESENTATION 3-4

Commodity chemicals from forest biomass (bioforest)

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The objective of this study is to create an economic process for production of commodity chemicals from forest biomass and recycled fibers i.e. Bioforest-process. Tree tops, limbs, twigs, stumps and recycled papers can be used as feedstock for fermentation of butanol, ethanol and isopropanol. This mixture of solvents can be used to replace gasoline in internal combustion engines.

The fractionation process will be adapted to mixed biomass so that the cellulose is more degraded and amenable to biochemical conversion. The presence of SO_2 leads to dissolution of hemicelluloses in high yield as monomeric sugars, while the lignin becomes soluble through sulfonation. The presence of ethanol leads to rapid penetration of the woody biomass thereby preventing lignin condensation and shortening treatment time. Recent ethanol/water/SO_2 pulping results with spruce chips and beech chips in our laboratory at a liquor-to-wood ratio of 6 L/kg showed that after a total treatment time of 80 minutes at 135 °C more than 90% of the original lignin went into solution, while about 80% of the hemicelluloses were dissolved mostly as monomers.

According to the preliminary trials the hydrolysates and extracts with different degree of polymerization are readily fermentable feedstocks for *Clostridia*-bacteria. Butanol, ethanol and isopropanol is produced from glucose and hemicellulose sugars.

The Bioforest-process has important advantages over the other fermentation processes aiming to produce transportation fuels: 1) low temperatures minimize the production of furfurals and other inhibitory products of fermentation processes; 2) it eliminates the need for conventional pretreatment, enzymatic hydrolysis of the pretreated lignocellulose and for making enzymes to carry out the hydrolysis; 3) *Clostridia*-bacteria can naturally ferment hemicellulose sugars and it is viable in real industrial hydrolysates and extracts.

PRESENTATION P3–5

The US biomass energy program – current effort and transition to the development and implementation of fungible fuel technologies

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Biomass is expected to play a major role in the sustainable energy supply, and therefore in the biobased economy by the biorefinery approach. Limited local availability of biomass resources will create a demand for a global supply of certified sustainable biomass.

The Biomass Program (OBP) has near term (2012) cost goal for conversion of biomass to ethanol as a fuel (aka Minimum Ethanol Selling Price or MESP). The majority of our current RD&D is focused on achieving those near term goals. Our long-term goals are aimed at developing and commercializing technologies for production of Fungible Fuels.

OBP has a seamless and planned transition strategy for the conversion platforms. This strategy's near-term focus is on developing technologies for the production ethanol, and its long-term focus is on developing technologies for biofuels that are fungible with the existing fuels infrastructure (a.k.a. Fungible Biofuels)

Currently, the thermochemical conversion platform is the only biomass conversion pathway capable of producing transportation bio-fuels (liquid or gaseous) that are completely fungible with the current infrastructure. However, and quite importantly, the Program is studying, analyzing and planning to develop a suite of technologies to produce these fungible fuels via several conversion routes. This effort is shape by our Strategy for Transition to Fungible fuels. This Strategy has three primary tenets that will be implemented, via our annual research planning process (e.g. budget request, appropriations and annual operating plan), and will result in a detailed multi-year Research Plan. These tenets are Research, Development and Demonstration (RD&D) Activities, Biofuels Market and Budget.

In summary, the US Department of Energy is developing and implementing a strategy to transition from cellulosic ethanol to fungible biofuels. This transition will be required to secure an environmentally sound, and sustainable, supply of bioenergy in the future. I will present the cooperative actions between government, laboratories, universities and industry to realize this transition.

PRESENTATION 3-6

Developing opportunities for commercial production of second generation biofuels in southern Africa

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The South African government launched an industrial biofuels strategy in December 2007, which targeted the commercial production of second generation biofuels by 2013. Thus far, the development of the biofuels industry in Southern Africa has primarily focused on commercial production of 1st generation biofuels, such as bio-ethanol from sugarcane, sweet sorghum and sugarbeet, together with biodiesel from jatropha. The production of bio-ethanol from sugar-crops has shown strong economic, social development and environmental benefits, while the availability of associated lignocellulosic feedstock represents substantial opportunities for second generation biofuels production.

Commercial opportunities exist in South Africa and neighboring states for second generation biofuels production, whereby the latter can benefit from infrastructure and utilities created for first generation biofuel or coal-to-liquids fossil fuel production plants. The key is the development of both biological and thermo-chemical technologies that make optimal use of the characteristics of locally available feedstocks. Integration of technologies across the biofuels value chain provide opportunities to substantially impact the cost of lignocellulose processing, thus enabling the commercialization of 2nd generation biofuels production.

This is being addressed by the Chair of Energy Research (CoER) : Biofuels at Stellenbosch University, in which both biochemical (pretreatment, hydrolysis, fermentation) and thermo-chemical (pyrolysis and gasification) technologies for complete conversion of plant biomass to biofuels are being developed. Development work includes the engineering of sugarcane and sweet sorghum feedstock for energy yield per hectare, fermentable sugar yield and processability in pre-treatment/hydrolysis. Co-gasification of biomass with coal at levels of 5 to 10% in existing coal gasifiers are also being investigated, together with feedstock preparation by pyrolysis.

The key challenge to both first and second generation liquid biofuels production in Southern Africa has been economics, considering that most funding for these projects have come from private investors, with limited government support. The evaluation of process alternatives by means of process modeling for mass- and energy balances is a key activity for determination of the economic attractiveness and sustainability of proposed production processes.

PRESENTATION 3-7

Political framework and tail pipe emissions for rapeseed oil based fuels

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Rapeseed oil is used as transportation fuel in different ways. A very specific German way, which, however, could also be interesting for other countries, is the use of neat rapeseed oil in modified diesel engines. The other pathways are concerned with transesterified rapeseed oil, which means rapeseed oil methyl ester. Here we know also the neat application (B100), which was very common in Germany until a new taxation for biofuels became valid. Other forms are blends of the biofuel with fossil diesel fuel as B5, or B7 with a further addition of 3% hydrogenated vegetable oil. In the U.S., B20 is a common product, and for France B30 might become available, since the French car manufacturers announced to release their products for this fuel blend starting from the year 2009. For all of these fuels it is necessary to know the political framework under which they may be traded and used. On the other hand, their emissions behaviour concerning legally regulated and some important non-regulated tail pipe emissions compounds must be considered, too. In this contribution, the regulated emissions concerning CO, HC, NOX, and PM are presented as well as particle size distributions, PAH emissions and effects on the mutagenic potency of the exhaust gases. It is shown that the effects do not vary in linear dependence of the blend composition.

PRESENTATION 3-8

Opportunities and challenges for the production of ethanol from lignocellulosic biomass in western Canada.

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The ethanol industry is established mainly in the United States and Europe. In the US, over 95 percent of ethanol is corn-based. This ethanol production pathway has been criticized for having an unfavourable net energy balance and significant arable land and water requirements, as well as environmental impacts such as soil erosion, loss of biodiversity, and higher volatile organic compound and NOx pollution. The legislation to limit green house gas (GHG) emissions is a key driver of lignocellulosic ethanol which has been shown to reduce GHG emissions drastically (88%). The feed versus fuel debate is also driving lignocellulosic feedstocks such as agricultural and forestry residues (canola straw), herbaceous (alfalfa, switch grass) and woody crops. For this reason, major ethanol producers such as the US have identified agricultural and forestry residues, municipal solid wastes, herbaceous and woody crops as feedstocks for the production of transportation fuel. In Canada, ethanol production is still grain based and dominated by wheat and corn. These, however, only make a small contribution (0.24 billion litres/year production capacity) to the international ethanol market. There is emerging interest in lignocellulose-based ethanol production in Canada. At commercial level, Ottawa-based Iogen Corporation successfully operates a cellulosic ethanol plant which is recognised as economically and environmentally viable. There are existing and emerging ethanol plants in Western Canada with great potential for the production of lignocellulosic ethanol. However, there are drawbacks related to production in Western Canada; these include complex conversion mechanisms, techno-economics, and sustainable feedstock supply throughout the year. Although there are efforts towards improving the economics of enzyme-based processes, very little is known about techno-economics in Western Canada. This study has several objectives: to review the extent to which cellulosic ethanol in Western Canada represents a more cost-effective process, including its impact on the environment and generation of a greater energy output to input ratio relative to grain-based ethanol; to assess sources of lignocellulosic biomass, their availability and potential for use as feedstocks for ethanol production in Western Canada; to analyze potential challenges in sustaining a lignocellulose-based ethanol industry in Western Canada.

PRESENTATION 3-9

Canadian progress on biotechnologies

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It takes collaboration and an integration of many technologies to make biofuels, bio-chemicals and bio-products from renewable resources competitive with commodities derived from depleting non-renewable resources. Unsubsidized viability will come from respectful utilization of the best emerging technologies and full life cycle costing of the sustainable development costs and benefits of all options. There is significant innovation in many technologies, some old – some new, which I will describe. I will briefly describe progress in innovations in technologies moving from R&D towards commercialization in many bio-based areas: genomics of growing feedstocks, harvesting, transport and storage of biomass, use of heterogeneous wastes (including specified risk materials), pretreatment processes and moisture removal, combustion, pyrolysis, gasification (including plasma torches), syngas cleaning, catalytic reformation, aerobic and anaerobic digestion, fractionation, enzymatic and acid hydrolysis, fermentation, concentration, dehydration, purification, membranes, transesterfication, hydrogenation, bio-pesticides, bio-fibres, bio-plastics, bio-polyols, glycols, resins, etc.

PRESENTATION 3-10

The potential for bioenergy in Portugal: Introducing the activities of the R&D programme at the National Laboratory of Energy and Geology

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The main technology challenges for the next 10 years to meet the 2020 targets for the reduction of greenhouse gas emissions, as well as to comply with the 2050 vision of their reduction by 60-80%, as stated in the EU Strategic Energy Technology Plan, include transport-related issues: environmentally-friendly second generation biofuels, more efficient energy conversion and end-use devices and systems, amongst others. The aim of this work is to present the Bioenergy for the transportation sector programme at the National Laboratory of Energy and Geology, a recently created State Laboratory that emerged from the extinction of INETI. This programme was designed to contribute for a low carbon economy through the use of biomass as the most important renewable energy source worldwide. In the near term, biomass-derived biofuels (bioethanol, biodiesel, bio-H2 and other liquid and gas biofuels) must be deployed worldwide and the current technical constrains solved through scientific research. The new European RES Directive targets for 2020, established a mandatory quota of 10% of renewables (including biofuels) for all transportation sectors. Critical issues will be the integration of higher value products into biorefinery fuel and power output to meet an overall profitability of next generation biofuels. This Bionergy Programme is also cross-linked with the Clean Power Sources and Plug-in Hybrids Programme, also on-going at LNEG. The widespread adoption of plug-in electric PHEVs and fuel cell vehicles has the potential to significantly reduce non-renewable fossil fuel consumption, while reducing the associated greenhouse gases emissions. Critical issues are the requirements for electrical and (bio)hydrogen storage, introduction of a smart grid infrastructure and multipurpose refueling/recharging stations. It will be presented the current state-of-the-art about R&D activities considered instrumental to a medium-term strategy for an innovative model and meaningful to attain sustainable mobility, supported on the bioenergetic potential of Portugal.

LNEG is a founder of EERA-European Energy Research Alliance (http://www.eera-set.eu) grouping 10 large Energy R&D Institutes in Europe. The presenting author is the LNEG representative on the ongoing EERA discussions for a pan-european joint cooperation on Bioenergy and Biofuels.

PRESENTATION 4-1

Global feasibility of large-scale biofuel production

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There is currently great confusion and uncertainty regarding the role biofuels should play in the world's energy future. In response, we have initiated a project to test the hypothesis that the welfare of both humanity and the environment can be better with large-scale production of biofuels than without it. The project is structured in three stages:

1) Hold public meetings at five locations around the world during the second half of 2009 and first half of 2010, to develop a project plan, form a team, and recruit support for stage 2.

2) Answer the question: Is it possible for biofuels to meet a substantial fraction of future world mobility demand without compromising other vital needs: feeding humanity, providing fiber, maintaining and where possible improving soil fertility, air and water quality, biodiversity and wildlife habitat, and achieving large greenhouse gas emission reductions that are not substantially negated by land use changes.

3) Given an affirmative answer to this question, broaden the analysis and team as necessary to address desirable transition paths and policies, ethical and equity issues, impacts of climate change, and local-scale analysis including rural economic development.

Our proposed approach is distinct from prior studies of biomass resource availability as it considers and incorporates mature conversion and feedstock production technologies, integration of feedstock production into agriculture, food production efficiency, impact of dietary changes, high efficiency transportation systems, and effects of climate change. Such an approach likely necessary if a low-carbon transportation future is to be realized. Project results will provide critical guidance, both toward the overall feasibility of a biofuel-intensive future, and toward defining the policy and land use trajectories that foster this outcome.

PRESENTATION 4-2

International sustainable bioenergy trade – an overview from IEA Bioenergy Task 40

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Peter-Paul Schouwenberg will present an overview of the ongoing work within IEA Bioenergy Task 40 of the past year. This work will cover amongst others :

The main results of an inventory of barriers and opportunities for global bioenergy trade, with focus on wood pellets, biodiesel and bioethanol, discussing the impact of amongst others import tariffs, technical standards, logistical barriers, sustainability criteria

The main results of a global vegetable oil market study carried out by Task 40, including global overview of the main vegetable oils (palm, soybean, rapeseed, sunflower), ii) identify the main market trends; iii) identify the major players of the vegetable oil markets (exporters and importers), iv) assess the role of biodiesel in the vegetable oil markets; v) identify major policy developments and possible future trends

Recent developments in biomass certification and possible implications for bioenergy trade

Depending on available time, highlights from several Task 40 country reports published in July and August 2009

PRESENTATION 4-3

Future structures of bioenergy markets

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The features of international trade of bio-energy differ from other fuels and commodities in many respects. It is still immature and is lacking established institutions and norms. Although the efficiency is improving, much remains to be improved with regard to technology and methodology. Drivers and incentives vary and are frequently changed. In general, ignorance and unawareness of opportunities and relevance are commonly found in media and among planners.

The principal messages in this presentation are that the future trade structure have to be created, they do not appear "by themselves". A system approach needs to be applied, meaning need for crossing of boarders, roles for actors, entrepreneurs and innovators. Moreover, "bio-energy" is not a uniform product; the various energy bearers should be treated differently as they are subject to varying logics.

Political visions and targets for renewables and climate mitigation that have been presented in recent years assume a great role for bio-energy for their implementations. Studies have presented values of very high potential opportunities for the development of biomass resources. It is also obvious that the demand is found in geographical areas often far away from the production areas. Thus, an increase in bio-energy trade would be logical.

This presentation provides a review of the various bio-energy sources that can be made available in the short (5 years) perspective. These sources are mainly in the form of residues and side products. However, in the longer view and to meet the visions and targets mentioned above, thorough changes need to be made with regard to land use, legislation, trade structures, attitudes, etc. Important aspects are organization and control of the trade and new roles of stakeholders.

PRESENTATION 4–4

Needs for certification of biomass

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The production of energy crops and the removal of biomass residues from forest and agricultural systems for energy production can result in negative ecological impacts, changing land-use patterns, socio-economic impacts and GHG emissions (e.g. for transport and vs. alternative use on-site). With considerable increase in feedstock and biofuels expected, sustainable production is becoming a key concern and is considered as a requirement for market access, e.g. in the EU Renewable Energy Directive. Setting standards and establishing certification schemes are possible strategies that can help ensure that biofuels are produced in a sustainable manner.

Over the last years a set of sustainability criteria have been developed for biomass. These criteria have been either formulated into laws (Renewable Energy Directive) of the EU, or in national standards (Netherlands: NTA 8080). Certification systems are needed to provide evidence of sustainability of biomass. This paper describes the needs and options for governments to implement these certification schemes.

A set of sustainability criteria and corresponding sustainability indicators have been formulated in the Netherlands (Cramer Criteria). The criteria and indicators have been divided into six themes. The first three themes are relevant for biomass, while the last three themes relate to the triple P approach (people, planet, profit), which are the starting-points for corporate social responsibility. The six themes are the following: Greenhouse gas balance; competition with food, local energy supply, medicines and building materials; biodiversity; prosperity; well-being; and environment. In the Netherlands these sustainability criteria are transformed into a national standard: NTA 8080.

On a European level the Renewable Energy Directive sets criteria for: Greenhouse gas balance; biodiversity and food security and to some extent countries will have to report on the other themes mentioned above. In order to eliminate further problems with the expected increase of use biomass and biofuels there is a need for widely accepted and harmonised certification schemes. The European Commission leaves it up to the Member States to prove that the biomass and biofuels used meet the criteria as mentioned in the RE Directive. The member states then invite industry to come up with certification schemes to prove the evidence of sustainability. It is expected that existing schemes will be used in this respect.

PRESENTATION 4–5

A criterion for selecting renewable energy processes

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The interest in renewable energies is motivated by a desire to reduce the buildup of greenhouse gases (GHGs) in the atmosphere. Society faces a wide range of choices of renewable feedstocks and end energy forms, and proposals from technology promoters to subsidize or mandate a wide variety of processes. A key question is what choices maximize the social good of reduced GHG. We propose that minimum incremental cost per unit of GHG reduction, in essence the carbon credit required to economically sustain a renewable energy plant, is the most appropriate social criterion for choosing from a myriad of alternative processes and end energy forms. The application of this criterion is illustrated for four processing alternatives for straw/corn stover: production of power by direction combustion and biomass integrated gasification and combined cycle (BIGCC), and production of transportation fuel via lignocellulosic ethanol and Fischer Tropsch (FT) syndiesel. Ethanol requires a lower carbon credit than FT, and direct combustion a lower credit than BIGCC. For comparing processes that make a different form of end use energy, in this study ethanol vs. electrical power via direct combustion, the lowest carbon credit depends on the relative values of the two energy forms. When power is \$70 MWh^{-1}, ethanol production has a lower required carbon credit at oil prices greater than \$80 bbl^{-1}.

PRESENTATION 4–6

Life cycle analysis of multi-crop lignocellulosic material (perennial grasses) for bioethanol production in western Canada: A review.

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Lignocellulosic biomass is the centre of attention for the production of bioethanol. Various energy crops like Aspen wood, poplar, and switchgrass have been used mostly in bioethanol plants in the United States. The development of lignocellulosic biorefineries in western Canada needs to take into account a different set of constraints for the sustainability of western Canadian energy crop systems. The competing uses of agricultural land and competitiveness of biomass energy requires an increase in the performance of bioenergy systems in western Canada, based on abundantly available lignocellulosic crops and residues, which currently have little or no value. The cost of raw material is very crucial in the process of bioethanol production. The use of low valued lignocellulosic crops and residues can substantially decrease production costs and improve the economic viability of biorefineries. In order to understand and optimize process engineering, a thorough life cycle analysis of western Canadian lignocellulosic biomass is required. In this research, life cycle analyses of multi-crop lignocellulosic biomass will be reviewed and presented; Economic aspects of the ethanol fuel system such as biorefinery operating costs will be investigated, including potential improvements in biorefinery economics generated by pretreatment, hydrolysis, and fermentation processes. An analysis of eco-efficiency will be conducted by comparing economic parameters versus selected environmental parameters. This study also compares the efficiency of western Canadian lignocellulosic biorefinery with grain-based dry milling ethanol plants which produce ethanol plus distillers' dried grains and solubles (DDGS) used as animal feed. Life cycle assessment is conducted to determine the environmental performance of a lignocellulosic western Canadian bioethanol biorefinery.

PRESENTATION 4–7

Integrated biomaterial and bioenergy benefits of balanced forest fertilization in Sweden

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In this study we estimate the primary energy and greenhouse gas (GHG) implications of increasing biomass production by fertilizing 10% of Swedish forest land. We estimate the energy use and GHG emissions from forest management including production and application of fertilizer. The fertilization regime includes N and NPK fertilizers applied to Norway spruce stands at times and in amounts based on nutrient analysis of tree needles. Depending on region and initial site productivity, a total of 800-1500 kg N/ha is applied in 5-10 separate applications during a rotation period. Based on modelled growth response, we then estimate the net energy and GHG benefits of the integrated use of biomaterials and biofuels obtained from the increased forest biomass production. Large-diameter stemwood is assumed used as construction material to replace non-wood materials, and residues from wood processing, on-site construction, and end-of-life building demolition are used as biofuel to replace either coal or fossil gas. Small-diameter stemwood, harvest residues, and stumps are also assumed used as biofuel. The results show an increased usable biomass production of 8.3 million t dry matter per year, of which 37% is large-diameter stemwood. The net primary energy implication of this increased production is about 160 PJ/year, or 7% of Sweden's energy supply in 2006. Of the 160 PJ, 20% is biofuel from small-diameter stemwood, 17% from processing and construction residues, 17% from stumps, 14% from building demolition residues, and 22% is decreased material production energy use due to material substitution. The resulting annual net GHG emission reduction is 3.4 million or 5.3 million tCequiv, if the reference fossil fuel is fossil gas or coal, respectively. This annual emission reduction corresponds to 19% or 30%, respectively, of the total Swedish GHG emission in 2006. An additional one-time carbon stock increase of 41 and 54 million tC occurs in wood products and forest trees, respectively. These results suggest that forest fertilization is an attractive option for increasing energy security and reducing net GHG emission.

PRESENTATION 4–8

Harvesting standing trees for energy applications: Impact of harvest and pelletization emissions on overall greenhouse gas balance

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Emissions resulting from the use of coal are currently responsible for one fifth of global greenhouse gas (GHG) emissions. Co-firing or full substitution of coal with biomass fuels can contribute to reducing these emissions while also increasing renewable electricity generating capacity. Forests in the U.S. and Canada contain a significant quantity of wood that could be sustainably harvested for energy applications but is currently left unharvested due to ongoing market conditions in traditional wood product industries. It is preferable for harvested wood to be pelletized, producing a dry, solid fuel of even proportion that is more easily transported and handled and has better properties for electricity generation than unprocessed biomass. Pelletization may also be seen as a means of standardizing the feedstocks to support a variety of future biorefining applications. Forest harvesting and pelletization, necessary processes to utilize standing trees for energy applications, require inputs of fossil fuels, biomass, and electricity beyond that required for processing residue feedstocks, thereby impacting the potential GHG benefit.

This study investigates, on a life cycle basis, the relative impact of forest harvest and fibre pelletization on the GHG balance of utilizing wood pellets as a fuel for co-firing with coal and 100% pellet utilization in two existing coal generating stations in Ontario. Biofibre is sourced from the Great Lakes – St. Lawrence Forest Region of Ontario where approximately 40% of the sustainable harvest is available for alternative uses. The production and delivery of pellets to the generating stations emits 133 kg CO_2 eq./tdry pellet, of which 32% occurs during forest management (road construction, harvest, renewal) and 30% during pelletization. Fossil energy use for forest management and pelletization consumes 0.44 and 0.52 GJ/ tdry pellet, while the drying stage of pelletization consumes an additional 3.7 GJ/ tdry pellet biomass. Energy consumption during these stages is equivalent to 23% of the energy content of the wood pellet product, indicating a net energy gain. Despite the emissions associated with forest management and pelletization, substituting harvested wood pellets for coal and natural gas for electricity generation provides life cycle GHG reductions of 91% and 78%, respectively.

PRESENTATION 4–9

Shipping study – international biomass supply and maritime trade routes

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Increasing fossil fuel costs, energy security and climate change concerns have resulted in increased demand for biomass for energy production. Raw biomass availability varies between countries, and therefore international trade in biomass fuel is projected to increase. However, there are major barriers to international maritime trade of these products. This analysis will examine production and trade in solid biomass (wood chips, wood pellets, torrefied wood, bio-char) and liquid biomass (ethanol, biodiesel, pyrolysis oil).

The analysis will include a summary of physical properties of biofuels, a description of the types of ships used to transport them, and current trade routes. Barriers to increased competitive trade will be exposed, including shipping of other products, reliability of biomass supply, port inadequacies, lack-of-back haul, and biofuel characteristics necessitating specialty shipping.

The study will conclude with a projection of new and expanded trade routes, and the shipping capacity necessary to handle increased trade.

PRESENTATION 4 –10

Breaking agricultural barriers: The ABIP Canadian Cellulosic Biofuels Network

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While second generation renewable fuel production faces considerable technological and economic challenges, many countries around the world are investing hundreds of million dollars in industrial and academic infrastructure in order to break down the barriers that limit the emergence of a ligno-cellulosic biofuel industry. It's great potential to produce huge amounts of energy from agricultural and forestry biomass recently sparked several industries to build cellulosic ethanol plants in eastern Canada and on the Canadian prairies. Barriers to the use of agricultural crop residue for cellulosic ethanol production in Canada include economic and environmental issues related to maintaining sufficient feedstock supply, compacting/storing and transporting feedstocks across large distances, finding optimum physico-chemical pretreatments and enzymatic cocktails, and improving the fermentation process.

Recently the Canadian Dept. of Agriculture initiated the Agricultural Bioproducts Innovation Program, a research funding program that led to the successful establishment of the Canadian Cellulosic Biofuels Network. This research network comprises an integrated set of expertise (~50 scientists) in government labs and universities across Canada focused on eliminating the constraints to using agriculture crop residue or Canadian biomass plant species as bioethanol feedstocks. Research within the Network ranges from genomic, proteomic and metabolomic studies on plants and microbes, evaluation and optimization of pretreatment and enzyme cocktails, plant breeding, yeast/fungi/enzyme selection, environmental tolerance mechanisms and technologies for plant biomass species, expression of cell wall hydrolytic genes in plants, and compaction and harvesting of agricultural residue. In addition to supporting the development of an environmentally-sound ligno-cellulose biorefinery industry, the research within this network is expected to generate tangible economic benefits for rural communities and farms in Canada.

PRESENTATION 5–1

The thermochemical revolution: Biofuel production via gasification

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Mainstream biofuel R&D and commercialization has been largely dominated by processes based on the sugar-fermentation platform (corn, enzymes, acid-hydrolysis). However, industry experts now widely recognize that fermentation biofuels can not be relied upon to provide a viable long term solution to our global energy needs. Biofuels should not compete with food crops or agricultural lands, and they should ideally be derived from waste streams.

Thermochemical biofuel production solves many of the dilemmas faced by fermentation. It can accommodate virtually any carbonaceous feedstock (MSW, beetle infested wood, etc), is drastically more efficient (feedstock to alcohol conversion in minutes versus days/weeks), capable of producing alcohol yields significantly higher than any fermentation process (current yield 110gpt / theoretical yield 290gpt), and can provide a real sustainable solution to the world's energy and biofuel needs.

The presentation will aim to demystify the Thermochemical Biofuel Production Process and reveal the steps being taken to commercialize the technology. Technically, the presentation will cover: Fisher Tropsch (FT) gasification process, Syntec's proprietary catalysts, product yields and technological advantages. The commercial development portion of the presentation will cover: comparative economics between fermentation & Thermochemical processes, hypothetical case study of an MSW Biofuel facility, market development for the alcohols & byproducts, commercial facility costs and financial numbers, and future development initiatives.

PRESENTATION 5–2

Demonstration of small scale biomass gasification for combined heat and power production

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Increasing concerns of climate change and fluctuating energy prices have brought renewable energy to the forefront as an alternative to fossil fuels. Biomass based renewable energy is of interest due to the abundance of biomass material, including pine beetle killed wood, residual from harvesting and wastes from wood mill operations. Canada also has a large number of remote communities for which the cost of electricity and heat produced from fossil fuels are very high. Small scale biomass fueled combined heat and power systems would be well suited for targeted applications such as remote communities or industries with biomass based residual products. This study aims to investigate the benefits and possible issues surrounding the implementation of small scale, biomass combined heat and power systems.

A review of commercial and near commercial technologies for power and heat generation from wood was done to identify the best suited technology for this type of application. Based on this review, gasification in combination with internal combustion gen-set based power generation was identified as most suitable for this type of deployment at the scale targeted (< 100kW). A small pilot scale unit was purchased from Community Power Corporation. This system was then used to investigate and define the system performance using different feedstocks and under varying operating conditions. The demonstration allowed the evaluation of the performance and maintenance requirements as well as overall issues associated with the operation of such a system. The findings provide a basis to study the feasibility of large scale exploitation of this technology and vital information to elaborate an approach for the successful deployment of small scale biomass fuelled combined heat and power.

PRESENTATION 5–3

Reducing greenhouse gas emissions from heat and power production by biomass gasification

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Gasification of biomass is a technology that was originally developed in the 1800's as a cheap solution for heating and district lighting. The technology was superseded by lower cost fossil fuels, but has recently re-emerged as a viable energy alternative, due primarily to volatile fossil fuel costs. In addition, the past decade has seen a phase shift in public opinion toward renewable energy sources to combat the effects of climate change.

Nexterra Energy Corp. has developed a simple, clean and efficient gasification technology, which converts wood residuals, such as bark, into synthesis gas or "syngas". The first generation of the technology, based on a fixed-bed, updraft gasification approach, has been extensively researched and developed and has been commercially deployed for heat and steam applications. A number of facilities have been built, providing heat and power to commercial wood veneer dryers, university campuses and residential housing and office complexes.

The second stage of product development involved the conveyance and direct firing of syngas into rotary kiln and boiler burners. Nexterra has performed successful trials of these direct-fire applications at pilot scale and is in the process of commercializing this solution with a first installation at a tissue mill to provide high pressure steam.

In collaboration with GE Energy and its gas engine division, GE Jenbacher, Nexterra is currently developing a new commercial biomass gasification-to-power solution. Commercial sized systems will range in size from 2 – 10 MWe. This work is being conducted at Nexterra's Product Development Center in Kamloops, B.C., where a 250 kWe Jenbacher engine is being installed which will be powered by cleaned syngas produced in a pilot scale gasifier.

PRESENTATION 5–4

Advantages of computer modeling in biofuel production and utilization processes

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The process of Biofuel production and utilization is a combination of complicated chemical reactions, multi-phase fluid flow, and convective, conductive, and radiative heat transfer. A deep understanding of the process is required to obtain high efficiencies and low emissions, and can be approached by utilizing three-dimensional computer modeling. Biomass gasification is an example of Biofuel production, in which the product gas quality and process stability are strongly dependent on the mixing of biomass and gasification agent, the temperature level and distribution, and the feeding design of biomass and gasification agent. PSL/UBC have applied the computer modeling to a packed bed biomass gasifier, an entrained-flow gasifier of black liquor, and a Battelle fluidized bed biomass gasifier. Outputs of the modeling are predictions of fuel and gas temperature distributions, velocity distributions, and product gas composition. Parametric studies are carried out to enhance the understanding of the process and to optimize the process and the design of the gasifier. The product gas of biomass gasification can replace natural gas or oil in lime kilns and boilers. In these applications of Biofuel, the performance and efficiency of kilns and boilers are important concerns for the plant operators, and the economic benefits of Biofuel production and utilization are important decision factors. Several lime kilns have been modeled to predict the kiln performance of co-firing wood syngas and also to assess the replacement ratio. Modeling is also used to optimize the design of dual kiln burners and boiler burners/igniters. Direct firing of biomass such as bark and lignin in a lime kiln has also been investigated by the computer modeling. It was shown that 100% replacement of oil/gas by biomass was possible while maintaining the quality of the product. It is believed that computer modeling can be further applied to many other processes for bioenergy production and utilization because it helps in process design, optimization, and scaling.

PRESENTATION 5–5

Combustion and heat transfer technologies for biomass combustion

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Improving biomass combustion in the world energy markets has increased in importance. Energy production has increased rapidly and biomass has become a significant contributor to world energy needs. Increasing the efficiency of the biomass combustion process and the subsequent production of energy for electrical generation, heat and bio-fuel production has been addressed by an innovative material science technology that enhances thermal properties and performance of existing combustion processes. This technology is called Emisshield® and originated from the NASA's space research and development program. Emisshield® alters and significantly improves the surface physical properties of materials and hence the efficiency of combustion and heat transfer for: 1) Combustion Chambers; 2) Heat Transfer to Process Tubes and Similar Heat Exchanger Surfaces; 3) Burners; and 4) Emission Control Systems.

Improving the physics and heat transfer dynamics by the application of Emisshield® to refractory and metals in biomass combustion systems has resulted in improvements in numerous areas of facility operations. Field installations at biomass facilities including walking grate and bubbling bed combustors ranging in size from 4 MW to 20 MW have seen the following general results: increased production efficiency of combustion, 5% - 10+%; facility operation closer to stoichiometric air to fuel ratio; Fuel changes/ reduced fuel cost (5 – 10% less fuel and less expensive fuel); improved air emissions reducing NO_X, 10 – 20%, particulate 10 – 20%, and CO_2 with improved efficiency; reduced fly ash and soot formation- longer run times with reduced ash disposal cost; improved uniform heating of metals and a resulting decrease in thermal stresses and longer life; increased refractory, process tubes, and burner life; and reduced facility maintenance and down time.

Emisshield® has been installed to numerous existing biomass facilities in Sweden with similar results. The enhancements made by Emisshield® are multifunctional effecting facility efficiency, output and environmental impact. In general significant advancements in design have not occurred to any significant extent. Introduction of these unique materials can improve the combustion process and heat transfer systems.

PRESENTATION 5-6

Challenges in biomass combustion and cofiring: the work of IEA BioenErgy Task 32

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IEA Bioenergy Task 32
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Biomass combustion still plays a key role in the expansion of bioenergy capacity across the globe, on widely varying scales and for various types of biomass to produce heat and, eventually, also power. Still, there is a continuous thrive to further lower investment and operational costs and broaden fuel flexibility while at the same time improving reliability, combustion efficiency and environmental performance. Through better understanding of the combustion process, existing combustion technologies can be further optimised to promote further market uptake. Also, several radically new biomass combustion related technologies are being developed and successfully introduced in the market if they are able to meet the above challenges.

Within the IEA Bioenergy Agreement, the Task on Biomass Combustion and Co-firing facilitates exchange of strategic technical and non-technical information amongst equipment suppliers, research organisations, end users, environmental NGO's and government agencies in order to strengthen the existing momentum in market introduction of improved combustion and co-firing systems in its member countries, as well as the export position of OECD-based manufacturers to non-OECD member countries. The Task covers issues related to a wide variety of both biomass fuels and technologies (from woodstoves to grate furnaces, fluid bed furnaces and cofiring applications) that can be used in its member countries. The relevance of the various technical and non- technical issues that hinder further market introduction of biomass combustion technologies varies for different scales:

In addition to the technical challenges that are addressed, the maturity of combustion technologies makes market acceptance issues more relevant if compared to other technologies that may still be in an earlier development phase. For example, there are numerous examples where a negative public perception of certain biomass cofiring concepts has restricted the application of certain fuel-technology combinations in practice, particularly for industrial scale installations and cofiring systems. It is important that objective information is being made available to a wider audience so that valid arguments are exchanged between various stakeholders. Also, there is experience with various financial incentives on the effectiveness of promoting appropriate biomass combustion technologies.

PRESENTATION 5-7

The role for biomass at Nova Scotia Power

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Nova Scotia Power Inc is a vertically integrated electric utility supplying power to 97% of Nova Scotians. We produce more than 13,000 gigawatt hours of electricity each year, with generating capacity of 2,293 megawatts through power plants province-wide. We have a fleet of five thermal, one tidal and 33 hydro plants, as well as four combustion turbine and two wind turbine sites. We use a fuel mix including hydro, tidal, wind, coal, oil and natural gas to generate electricity.

The province of Nova Scotia has a Renewable Energy Standard with targets for the addition of renewable energy by 2010 and again in 2013. There are also draft regulations for reduction of carbon emissions beginning in 2010. NSPI is planning for the future with these government policies in mind.

The burning of biomass in our power plants is one approach to meeting future environmental requirements. Before the company can embark on that path two critical pieces of work must be completed. Firstly, we must determine the technical feasibility of burning biomass in our particular type of coal plant. Secondly, we must assess the sustainability of biomass in our province for the generation of electricity.

This work must be completed in conjunction with stakeholders who have an interest in the topic, with consideration to government policy objectives, and with a focus on least cost economics to meet our customer's needs.

PRESENTATION 5-8

Biomass health and safety

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Information resulting from a Biomass Health and Safety Study performed for Ontario Power Generation (OPG) will be presented. This important and timely information was collected to support the planned conversion of OPG coal fuelled plants to biomass. The presentation will include results of the study of conventional safety items such as fire and explosion hazards as well as industrial hygiene hazards. The scope of the study encompassed a review of global experience with biomass industrial hygiene and process safety issues, global standards, and a review of related industry biomass experience, all with a view to addressing potential risks during the conversion project planning and execution phases. The study incorporated strong employee involvement at all OPG coal-fuelled plants. At OPG, employee and public health and safety is of the highest importance. There are known hazards with biomass storage, handling and combustion which must be mitigated as part of the conversion process.

PRESENTATION 5-9

Biomass Particle Reactions: Experimental and Model Results

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Individual biomass particle behavior in suspension determines, to a large degree, system behavior for most entrained-flow reacting systems, including the regions of recovery boilers above the bed. The entrained particles combine with bed effluents and light gases to form the complex, particle-laden flow in the remaining furnace. The particles experience both reducing and oxidizing environments, temperatures over broad ranges, and complex flow patterns and geometries. Particle behavior critically impacts boiler operation, placing a premium on sophisticated understanding of particle reaction rates and mechanisms, and heat, mass, and momentum transfer.

This document summarizes many aspects of entrained-flow particle behavior. Both experimental and model results illustrate typical behaviors, often by comparison to traditional biomass and coal. Experimental data include several first-of-their-kind results, such as images with pixel-by-pixel resolution of temperature and emissivity, 3-D reconstructions of particle shape and size, and simultaneous internal, external temperature, mass loss, off- gas composition, and size/shape data on particles under oxidizing and reducing environments. This document discusses a sophisticated model of particle behavior that captures most of these trends and illustrates the profound influence of individual particle reaction processes on overall reaction and heating rates. In these regards, biomass fuels react much differently than coal particles and require models with much more sophistication than are commonly appropriate for pulverized coal. In particular, the size, typically aspherical shape, and low density of biomass particles change overall conversion time substantially (factors of about 3) relative to what it would be if these characteristics were ignored. Biomass particles also develop internal temperature gradients of many hundreds of degrees, leading to vaporization still occurring at the particle center while pyrolysis occurs on the surface. The model predictions and experimental data together represent a reasonably detailed understanding of these complex processes, yet it remains clear that several essential questions remain to be answered.

PRESENTATION 5–10

Biomass torrefaction – a promising pretreatment method for thermochemical conversion technologies

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The major challenges in the thermo-chemical conversion of biomass into liquid fuels are the inconsistent and low energy density of biomass, poor handling and feedstock properties, the formation of tar and other compounds (e.g., H_2S, NH_3, alkali metals) that degrades syngas quality, and the formation of coke precursors in pyrolysis bio-oil. This results in expensive downstream gas cleaning operations for syngas to liquid fuels and rapid inactivation of catalyst used in upgrading bio-oil to liquid fuels. Torrefaction thermally degrades biomass (via solid state, selective decomposition of hemi-cellulose) at relatively low temperatures (180-300°C) under anoxic conditions resulting in an energy dense, stable char or coal-like material that also eliminates or minimizes coke forming precursors, such as acetic acid. Removal of these coke forming precursors could significantly improve catalytic upgrading of the bio-oil generated by pyrolysis. It is anticipated that integrating biomass torrefaction with thermo-chemical conversion processes will not only improve the energy density and quality of bio-crude oil/syngas, but also minimizes the downstream cleaning cost. Cofiring torrefied biomass with coal will also minimize GHG emissions without compromising the energy efficiency and plant production capacity. Although torrefaction pretreatment holds great promise, there is little fundamental understanding of the process especially related to biomass pyrolysis and gasification. This paper presents the recent findings on the torrefaction characteristics of biomass and the effect of torrefaction on the pyrolysis and gasification products. The benefits of biomass torrefaction on the transport and storage of biomass will also be discussed.

PRESENTATION 6–1

The development of cellulosic biofuels

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Because plants can be deployed on a large scale to capture and store solar energy, one way of moving toward the development of carbon neutral energy sources is to use plant biomass for production of fuels. The US Secretary of Energy has called for the replacement of 30% of the liquid fuels used in the US with biofuels by 2030. It is expected that the majority of gasoline and diesel replacements will ultimately be derived from cellulosic biomass. This would require at least 650 million dry tons of biomass each year. In brief, the efficient production of biofuels by routes other than gasification will require innovation in three main areas: sustainable production of feedstocks that do not compete with food production, depolymerization of feedstocks, and conversion of feedstocks to fuels. Thus, there is interest in identifying plants that have optimal biomass accumulation on land that does not compete with food production or ecosystem services, and understanding the production issues associated with large-scale cultivation and sustainable harvesting of such species. There are a number of substantially different technologies under development for conversion of biomass to fuels. Thus, even though it is currently possible to produce cellulosic fuels, there is currently a significant capital risk because of the possibility that a particular design may be rendered uncompetitive by a competing technology. This effect may restrain the rate at which commercial development proceeds during the next decade.

PRESENTATION 6–2

Key technical factors enabling today's biochemical biorefineries

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The increasing demand and price volatility of fossil fuels and the environmental concerns associated with their use are stimulating the development and growth of a new industry based on the conversion of biomass into renewable fuels, biomaterials and "green" chemicals. A variety of biochemical and thermochemical biorefining technologies have been proposed which are becoming the foundation of these emerging biomass-based fuel and chemical industries. Our presentation will address the key technical factors we believe will enable the wide commercialization of today's biochemical biorefineries. Special attention will be paid to aspects related to the bioconversion of polysaccharides into monosaccharides, down-processing of monosaccharides into fuels and chemicals, and lignin co-product development. The advantages of biochemical biorefining will be also discussed. Real-life examples of biomass refining will be presented to illustrate the technical viability of a biochemical biorefinery. A description of Lignol's Integrated Biorefinery will be presented as an example of a biochemical biorefining platform with the ability to process a wide range of biomass species including softwoods, hardwoods, and annual fibers, into renewable fuels, biomaterials and chemicals.

PRESENTATION 6–3

1st or 2nd generation bioethanol – impacts of technology integration and on feed production and land use

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Liquid bio fuels are perceived as a means of mitigating CO_2 emissions from transport and thus climate change, but much concern has been raised to the energy consumption from refining biomass to liquid fuels.

Integrating technologies such that waste stream can be used will reduce energy consumption in the production of bioethanol from wheat. We show that the integration of bio refining and combined heat an power generation reduces process energy requirements with 30-40 % and makes bioethanol production comparable to gasoline production in terms of energy loss.

Utilisation of biomass in the energy sector is inevitably linked to the utilisation of land. This is a key difference between fossil and bio based energy systems. Thus evaluations of bioethanol production based on energy balances alone are inadequate. 1st and 2nd generation bioethanol production exhibits major differences when evaluated on characteristics as feed energy and feed protein production and subsequently on land use changes.

1st generation bioethanol production based on wheat grain in Denmark may in fact reduce the pressure on agricultural land on a global scale, but increase the pressure on local/national scale. In contrast to that 2nd generation bioethanol based on wheat straw exhibits a poorer energy balance than 1st generation, but the induced imbalances on feed energy are smaller.

Proteins are some of the plant components with the poorest bio synthesis efficiency and as such the area demand for their production is relatively high. Preservation of the proteins in the biomass such as in feed by-products from bioethanol production is of paramount importance in developing sustainable utilisation of biomass in the energy sector.

PRESENTATION 6–4

Alberta renewable diesel demonstration: An assessment of winter operability and infrastructure integration

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Alberta Renewable Diesel Demonstration (ARDD) was Canada's first on-road demonstration of cloud point adjusted low level renewable diesel blends using both fatty acid methyl ester (FAME) and hydrogenation derived renewable diesel (HDRD). Managed by Climate Change Central and guided by a multi-stakeholder group representing the petroleum industry, biofuel producers, commercial trucking fleets and industry associations, engine manufacturers and government regulators, ARDD created valuable observations and hands-on experience for a wide range of diesel fuel industry stakeholders.

ARDD was the first Canadian on-road demonstration to use both FAME and HDRD fuels at low blends in cold Canadian winter conditions—meeting cloud point specifications of -33°C in Calgary and -37°C in Edmonton and Lloydminster, Alberta. It was also the first demonstration to include a CPPI member petroleum refiner, Shell Canada Ltd, as the petroleum supplier and blender for an on-road demonstration, and was designed to address an identified need for such demonstrations set out in Environment Canada's 2006 Notice of Intent to Regulate a Renewable Fuel Standard. ARDD was also the first demonstration to address cloud point adjustment using ultra low sulphur kerosene via integration of terminal-level in-line blending infrastructure, with fuel sold though existing commercial cardlocks. This demonstration dispensed over 1.6 million litres of blended fuel, representing over 5.5 million kilometers traveled by participating ARDD vehicles.

The ARDD Final Report and its sister study, the Renewable Diesel Characterization Study (RDCS) provide a broad range of information about the quality and performance of neat renewable diesel fuels made from a variety of feedstocks and processes, as well as their blends with petroleum diesel and kerosene, and notably, the amounts of kerosene required to achieve winter CGSB 3.517 and 3.520 cloud point specifications in Alberta's cold winter markets at 2% FAME, or B2, using canola methyl ester or 2% HDRD from mixed feedstock. ARDD transitioned to B5 and 5% HDRD for spring/summer operation, at which point no kerosene was required.

PRESENTATION 6–5

2009 Update of the nrel biomass-to-ethanol biochemical process design report

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A detailed technical and economic analysis is presented for a corn stover-to-ethanol conversion process. This 'design report' is intended to update and expand upon previous such reports published by NREL (Aden et al. 2002; Wooley et al. 1999) by including the most current conversion and integration research performed by NREL and others. The overarching process design is dilute-acid pretreatment of corn stover, followed by enzymatic hydrolysis and co-fermentation to ethanol with recombinant *Zymomonas mobilis*. Ethanol is purified from the fermentation broth by distillation and the remaining solids are combusted to produce steam and electricity. Material and energy balances and flow rate data generated for this process by Aspen Plus simulation software are used to size and cost process equipment. Equipment and raw material costs have been updated for 2009 and are consistent with good engineering practice. New vendor proposals were obtained for the larger unit operations. A discounted cash flow rate of return analysis is performed using these capital and operating costs to determine the minimum ethanol selling price (MESP, $/gallon) for the process. The result is a so-called technoeconomic model that reasonably estimates a production cost for this pre-commercial process, which can be used to assess its competitive potential in the marketplace and highlight areas where economic improvements are needed. Key updates to the technoeconomic model to be discussed are (a) the feedstock composition has been updated to be more representative of corn stover (b) ammonium hydroxide conditioning of the whole hydrolyzate slurry has replaced solid/liquid separation with lime conditioning of the liquid fraction (c) cellulase enzyme is produced on-site rather than purchased. Several minor enhancements to the model will be covered as well.

PRESENTATION 6–6

Biofuels and bioprocessing research and development in South Dakota

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The Center for Bioprocessing Research and Development (CBRD) has been established through the Governor's 2010 Initiative for Economic Development and brings together the bioprocessing research and development resources of South Dakota School of Mines and Technology (SDSMT) and South Dakota State University (SDSU). The overall goal is to reduce the national dependence on imported fuels by developing and utilizing carbon-neutral, waste-free technologies that mitigate the environmental impact of greenhouse gas emissions and combat climate change. The mission of the Center is to provide the State of South Dakota with expertise in advanced and transformative technologies, research facilities, education, training and administrative support. The principle areas of research are grouped in six project thrusts: 1) Feedstock development and logistics; 2) Feedstock pretreatment; 3) Enzymatic hydrolysis; 4) Biochemical conversion to fuels and chemicals; 5) Thermo-chemical conversion to next-generation biofuels; 6) Product recovery and downstream processing. For development of more efficient and economically viable bioconversion technologies, scientists and engineers at CBRD are utilizing extremophilic microorganisms with distinctive cellulolytic capabilities isolated from the former Homestake Gold Mine (now known as the NSF Deep Underground Science and Engineering Laboratory, DUSEL) in Lead, South Dakota. The deep subsurface of the mine (8000 ft) offers extreme environments for microorganisms introduced by mining activities over 125 years. CBRD researchers have recently grown wood-rotting microbes from the 4850 ft level which secrete cellulose-deconstructing enzymes with high temperature optima (70-85oC) and prolonged thermostability. The use of cellulolytic extremozymes in conjunction with thermotolerant ethanologens would allow saccharification and fermentation to proceed simultaneously at temperatures closer to optimal with added benefits of reduced cooling costs and risk of contamination. To overcome limitations related to the low biomass density, CBRD researchers are developing a novel bioreactor for high solids fermentation that will provide the advantages of increased product concentration, lower energy requirements, increased productivity and smaller effluent volumes. A possible integration of high solids pretreatment, enzymatic saccharification and liquefaction with ethanolic fermentation would result in a further reduction of the bioprocessing costs for a cost-effective production of renewable bioenergy in South Dakota. The recent progress in this area will be presented and discussed.

PRESENTATION 6–7

Chemical conversion of hemicellulose coproducts from forest biorefineries to polymers and chemicals

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The pretreatment process in biorefining opens up the biomass structure, releases hemicelluloses and overcomes the resistance to enzymatic hydrolysis. The state of released hemicellulose whether polymeric, oligomeric or monosaccharides depends mostly on the pretreatment process conditions. Generally acidic pretreatment hydrolyze the hemicellulose and release monosaccharides, while steam explosion treatment also generates oligosaccharides, while alkaline processes release hemicellulose mostly in polymeric form. Although the hemicellulose can readily hydrolyze to monomeric sugars, its mostly C_5 sugars are not easily fermented by native organisms. A profitable use of C_5 sugars in monomeric, oligomeric and polymeric forms is critical for a viable wood to bioethanol process. Hemicellulose is the second most abundant carbohydrate, yet its industrial applications are few. Hemicellulose composition varies depending on the biomass source. Generally, it is lower molecular weight than cellulose, contains branching, and is comprised of several different monosaccharides. Despite the structural variety, a changing political and economic climate can make hemicellulose coproducts from a lignocellulosic biorefinery feasible replacements for some petroleum products. These potential hemicellulose chemicals and materials will be discussed.

PRESENTATION 6–8

Integrated biofuel facility, with carbon dioxide consumption and power generation

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Integration of multiple processes is a superior method for economical implementation of technologies that benefit the environment. A recently developed photobioreactor (PBR) for improved cultivation of the microalgae species *Chlorella vulgaris* has been scaled up for industrial carbon dioxide consumption. We have also demonstrated that this photosynthetic culture can act as a novel biocathode in a microbial fuel cell (MFC), which when coupled to a typical yeast anodic half cell, results in a complete biological MFC. This novel photosynthetic MFC produces not only electricity, but also valuable biomass and by-products from both the yeast and the microalgae cultures, for instance bioethanol and oil for biodiesel.

This novel photosynthetic microalgae cathodic half cell provides the opportunity for design of an integrated biofuel facility. A series of novel PBRs for continuous operation can be integrated into a large-scale bioethanol facility, where the PBRs serve as cathodic half cells and are coupled to the existing yeast fermentation tanks which act as anodic half cells. These coupled MFCs allow for generation of power for use within the biofuel facility. The microalgae growth provides oil for biodiesel production, in addition to the bioethanol from the yeast fermentation. The photosynthetic cultivation in the cathodic PBR also requires carbon dioxide, resulting in consumption of carbon dioxide from bioethanol production.

The details of economical design of a large-scale integrated biofuel facility for coupled production of bioethanol and biodiesel, with carbon dioxide capture and power generation, will be discussed. Several designs will be offered, for both batch and continuous culture operations, taking into account all costs and revenues associated with the complete plant integration. The effect of plant design on net present worth (NPW) and internal rate of return (IRR) will be presented.

PRESENTATION 6–9

Fermentation of biomass to fuel ethanol: Adding value prior to pulping

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Fermentation and ethanol production research is a major component of a large Value Prior to Pulping Project (VPP) for the Forest Biorefinery initiative at the Forest Products Laboratory in Madison, WI. The VPP project goal is to demonstrate the technical and commercial feasibility of introducing a new value stream into existing pulp and paper mills, essentially transferring extracted hemicellulose to a liquid transportation fuel. The hemicellulose extract will be hydrolyzed and conditioned to remove inhibitors, if necessary. The hemicellulose fraction will consist of pentose and hexose sugars proportionate to the extraction chemistry and the wood species. Three experimental microorganisms are being evaluated for efficient and rapid fermentation of sugars to ethanol.They include a modified commercial yeast, experimental yeast and bacteria. Characteristics of successful microorganisms include hydrolyzate and ethanol tolerance, pH stability, and rate of fermentation. The experience gained from all of these tasks will have broad benefits for the other teams and partnerships in the VPP Project. In summary, our overall goal is the economically viable high-yield production of fuel ethanol from woodchips extracted prior to pulping, while still being able to produce a commercially acceptable pulp for paper and paperboard production.

PRESENTATION 6-10

Liquid transportation biofuels research, demonstration and commercial deployment in the Asia Pacific region

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This presentation will examine liquid transportation biofuels research, demonstration and commercial deployment activity in the Asia Pacific region. The Asia Pacific region is very diverse in terms of economic and social drivers for biofuel industry development, the capacity of nations to conduct R&D and take outcomes through commercialisation. For example Pacific small island countries (PICs) have almost no capacity to conduct R&D and relatively small greenhouse gas emissions despite many using diesel almost exclusively for electricity generation. Some PICs have significant capacity for agriculture but also strong culturally driven concerns about loss of biodiversity. However PICs have much to loose as climate change impacts of sea levels. By comparison Australia and New Zealand have strong R&D and agricultural production capacity, but relatively low populations with large distances from agro-industrial enterprises to markets. Australia also has very large coal reserves and to some extent publicly funded R&D and government policy is driven by the desire to maintain or grow Australia's coal export industry. Asian nations generally have very large populations and strong capacity for R&D and commercialisation. Asian nations differ in their agricultural production capacity and in their rate of economic growth. With this diversity across the Asia Pacific it is not possible to review all activity in the region. Instead this presentation will highlight significant recent events.

PRESENTATION 7–1

Business models in forest based bioenergy production – "show me the money"

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Forest energy business is remarkably different when compared with traditional oil, gas and coal based energy production. Value chains are different, operators are not as experienced, markets are changing rapidly and partnership is needed in order to make profit, which has to be divided in a way fair way among operators to keep wheels running. In the presentation, two major branches of business models typical in Finland will be expressed, namely heat entrepreneurship and subcontracting-based large scale forest fuel procurement models. In the heat entrepreneurship model, the longest possible part of the value chain will be taken care of by the entrepreneur and the final product, heat, will be sold to the customer. Sometimes the whole supply chain from forest to heating plant is owned by the same company. Other variations, however, can function successfully as well. In sub-contracting based large scale forest fuel procurement, the wood fuel strategy is often based on minimal raw material cost accompanied with effective resource allocation and economies of scale. In the presentation, the know-how transfer will be supported by explaining the business models and earning logics in order to find corresponding elements and actors in new operational environments.

PRESENTATION 7-2

Assessing drivers for bioenergy: An economics perspective

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The identification of stakeholders together with their economic and social drivers is essential to narrow the gap between policy making and its actual implementation by agents in the economy. This presentation investigates the motivations or drivers of agents in a market or mixed economy to understand their behaviour with respect to energy choices. Agents seeking an optimal level of bioenergy use in the economy must be cognizant of the drivers and behaviour of other agents in the economy.

PRESENTATION 7–3

Progress in biomass utilization in the north-west Croatia

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Recent restructuring of the market for grid-based energy systems in Croatia has significantly affected the possibility of introducing bioenergy of enhancing its use. The ratification of the Energy Law, the Energy Market Law and the Heat Production, Distribution and Supply Law together with numerous sub-legislative documents provided Croatia with all necessary state policy supporting instruments and mechanisms for renewable energy. Very important instrument supporting bioenergy development in Croatia has been establishment of an Environment Protection and Energy Efficiency Fund in 2004. To-date, the Fund has co-financed 300 projects and provided almost 20 million euro of direct support. This instrument has been especially important to the development of biomass district heating and pellet production plants.

Today Croatia faces a new situation where bioenergy is considered an important part of all future development strategies and where new and exciting projects are being developed rapidly. With the aim of better utilization of local resources and environment protection, many biomass district heating projects were recently started by local communities in collaboration with North-West Croatia Regional Energy Agency. Some of the most important projects are: 1) Pokupsko Municipality (planned installed heat capacity 1MW); 2) Zakanje Municipality (planned installed heat capacity 1MW); 3) City of Jastrebarsko (planned installed heat capacity 0,6MW); 4) City of Slunj (planned installed heat capacity 4MW).

Construction of biomass district heating systems in the above-mentioned municipalities will trigger series of positive social and economic effects, as well as contribute to increased use of renewable energy sources and reduction of environment pollution. This paper will deal with the most important details of the above-mentioned district heating projects as well as with their socio-economic background and expected results.

PRESENTATION 7–4

Renewable fuels policy development: Canada

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Canada has emerged as global powerhouse in conventional fuels, accomplished in part with massive investment in heavy 'oilsands' development in western Canada. Federal and provincial governments have more recently developed complimentary renewable fuels strategies to diversify the carbon profile of Canadian refined products and, to a lesser extent, achieve energy security through increased domestic refining capacity. Other resource based sectors (agriculture, forestry) expect to benefit from the development of a broad renewables portfolio of first and second generation technologies and feedstocks.

Canada's renewables framework was developed comparatively late in a global context. For example, renewable fuel standards in Canada are being enacted with domestic production under-capacity while the EU and US both have significant overcapacity relative to their renewable content policies. Canada is joining the renewable fuel world stage with supply and demand side programs, such ecoEnergy and federal and provincial mandated renewable fuel requirements, starting with the British Columbia 5% renewable fuel mandate on January 1, 2010.

Canadian Bioenergy Corporation has been at the forefront of renewable fuel market and policy development in Canada with top executive and board director roles in various industry associations including the Canadian Renewable Fuels Association, Canola Council of Canada, BC Biodiesel Association, Alberta Biodiesel Association, BC BioProducts Association, and Life Sciences British Columbia. From its corporate activities as a biodiesel supplier, as well as from the company's industry building efforts, Ian Thomson is uniquely able to provide an informed perspective on the development of renewable fuel policy development in Canada.

The presentation will examine: the policy framework for renewable fuels (1G, 2G) 2005 – 2015; learnings re: hurdles to reaching carbon reduction targets; the applicability of EU, US and other international policy approaches to the Canadian situation, with an assessment of policies that may be most adaptable for Canada; the opportunities and challenges for Canada in transitioning its 1G biofuels platforms to a 2G world, on a regional level; a description of the most appropriate Canadian policy framework by 2015 that would integrate emerging technologies, domestic feedstocks, N.A. carbon policies, and other important variables in meeting emission reduction targets.

PRESENTATION 7-5

Indirect land use change, low carbon fuel standards, and cap & trade: The role of biofuels in greenhouse gas regulation

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Even as the United States moves towards joining other industrialized nations in regulating greenhouse gas (GHG) emissions, there is little consensus on how biofuels should be treated under a carbon cap and trade regime. Revenue from the auction of emissions allowances could be a critical source of funding for commercialization of advanced biofuels. A case can be made for offset eligibility for biofuels projects in developing countries or restoration of degraded land via perennial biomass crops. The concept of a Low Carbon Fuel Standard (LCFS), which sets a declining limit on the lifecycle GHG intensity of the transportation fuel supply, is gaining traction, with California, several other states, and Congress all implementing or considering an LCFS. But the growing controversy over possible Indirect Land Use Change (ILUC) impacts of biofuels production has thrown the standard concept of lifecycle GHG computation into doubt, forcing policy makers to decipher a highly complex scientific issue even as they write GHG legislation.

This presentation will explore the challenges and opportunities in current efforts to incorporate biofuels into GHG regulation.

PRESENTATION 7-6

In search of the holy grail-unequivocal environmental data to inform / support Canada's biofuels agenda

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The Canadian federal government and a number of provincial governments have recently embarked upon a very ambitious and aggressive renewable fuels agenda-designed to wean Canadian drivers off of their current and complete reliance upon the use of petroleum based feedstocks, and towards increasing amounts of renewable and alternative sources of fuels-fuels deemed in theory to be more cleaner, climate change friendly, and environmentally benign. However, for these future expectations to be realized, it is important to have robust Canadian environmental biofuels data available - data ideally representative of Canadian conditions - so as to better inform biofuels decision makers, allow for an orderly and prior assessment of any environmental claims, avoid the environmental legacy from previous experiences with petroleum development in Canada, and to ensure a systematic, sustainable, and responsible transition towards increased use of biofuels in Canada. Initially this has proven to be a difficult task - given the multitude of existing and rapidly evolving bioenergy sources, complexities of physical, chemical, and biological conversion processes, and variability's in site specific environmental conditions across Canada. This presentation will provide an overview of Environment Canada's scientific research activities and current efforts now underway, to generate and validate this baseline environmental data - throughout key stages of representative and targeted biomass to biofuels life-cycles - and designed to both facilitate and help guide biofuel decision makers in their efforts towards increased use of biofuels in Canada.

PRESENTATION 7–7

Development of a community electricity and heating system in Quesnel, BC

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The community of Quesnel has undertaken an extensive Bio-energy/Bio-Products Strategy as part of Quesnel's comprehensive "Prosperity and Sustainability Action Plan". The Prosperity and Sustainability Action Plan was developed to help Quesnel take advantage of the region's natural resources, make the best of the impacts of the pine beetle epidemic, improve the long-term viability of Quesnel, and reduce the community's greenhouse gas emissions. The Plan is supported by an overall Green City vision for long term sustainability and a "bio-economy" development model.

The Bio-energy/Bio-Products Strategy began with an analysis of options for recovering value from waste materials and waste heat. After extensive analysis and consultation, a Community Heat and Electricity System was selected for development.

The Community Heat and Electricity System will take advantage of excess capacity available in an existing biomass energy system at a local sawmill to produce electricity and heat for industry and the community. Electricity will be generated with low-temperature Organic Rankine Cycle units, and waste heat from electricity production will be delivered to clients through insulated district heating pipes.

The system will replace natural gas by providing heat for industrial buildings, the local hospital, City Hall, a retirement lodge, Provincial government offices, a recreation centre, and other buildings. Half of the required heat energy will be derived from efficiency improvements in the sawmill biomass energy system, with the remainder coming from a modest increase in hog fuel consumption. The system appears to be the first of its kind in North America.

Development of the system involved applications for feasibility funding from the federal government and BC Hydro, a technical feasibility study, a business case, an application for Provincial capital funding, and negotiations with the City of Quesnel, potential community energy clients, and the owner of the sawmill energy system. The economic, social, and environmental benefits of this system will be considerable, and lessons learned during the development are highly applicable to other communities.

PRESENTATION 7–8

North America's first modular pellet plant

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SBC Firemaster is based in British Columbia and has been in operation for over 25 years. The business has expanded from a manufacturer of bundled firewood to being an innovative leader in the bioenergy field. The company has diversified their product mix which now includes: firewood, kindling, pellets, baled shavings, various animal bedding products, pellet stoves, portable campfires, roasting sticks, firestarters, chemical free insect deterrents and most recently pellet manufacturing equipment.

In 2008, SBC Firemaster applied for a grant from the Government of British Columbia's Innovative Clean Energy fund (ICE) to manufacturer the first modular pellet plant in North America. The funding was approved and the company is currently installing the equipment at our facilities in Kamloops, BC.

SBC Firemaster started one of the first traditional pellet plants in British Columbia in 1994. This plant provided the ownership with insight into many challenges that traditional pellet manufacturing facilities face. These included: the dependence on primary lumber production to obtain fibre, the cost of equipment, the inability to relocate operations affordably, the piece meal approach to pellet plant assembly, the large footprint of traditional equipment and ongoing engineering costs required to increase production.

The company sold their shares in this business but learnt a great deal in the process. The knowledge gained from their involvement in traditional pellet manufacturing led the company to think outside of the traditional box and to design, engineer and now build a new method of pelletizing.

The PelletMaster Mod Mill will be fully operational by June of 2009 and provides many benefits to traditional manufacturing including: an all inclusive design (hammermill, drying system, pellet presses, cooler/conditioner and bagging system), a low initial investment of typically half the cost of a traditional pellet manufacturing facility with the same production volume, small footprint and stackable modules which allows for affordable expansion/reduction of production and affordable and practical relocation of equipment as they fit into conventional shipping containers, profitable on small volume production (as low as 10,000 MT), and makes round log and non-traditional wast fibre utilization practical. Financing options are available.

PRESENTATION 7–9

Wood pellet optimization

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A key focus of our research at University of British Columbia is on wood pellets, a well established industry in British Columbia which produces more than 1 million metric ton every year for export. The entire feedstock engineering cycle transforms raw bulky biomass to a consistent pellet with a high energy density of 20 GJ Mg^{-1}. The process line consists of a set of modular unit operations sorting devices for dry fractionation, thermal treatment reactors for drying and carbonization, double extrusion unit for steam pulping, filter press for dewatering, grinders, pelletization mill and a cooler. Instrumentations are required for recording data and to develop validation tools for process modeling. Current research is on off-gassing of carbon monoxide and other gases from wood pellets in confined spaces. Other related research are physical and chemical characterization of, simulation and optimization of pellet production, steam treatment to produce durable, and dust and emissions controls. This presentation provides key experimental data from these research efforts.

PRESENTATION 7–10

Bioenergy development: Issues and impacts for poverty and natural resource management

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Bioenergy has been critical to humanity since the cave dwellers first used wood to cook their food and stay warm at night. Ancient forms of bioenergy – firewood and cow dung patties – remain primary fuel sources for rural and poor people. New sources of bioenergy including "black liquor", biodiesel, cellulosic ethanol and many more, have great promise and generate great controversy.

This paper gives an overview of bioenergy developments and examines the main issues and possible socioeconomic implications of these developments and their potential impacts on land use and the environment, especially with respect to forests. The paper presents an introduction to bioenergy, provides a background and overview of solid biomass and liquid biofuels, and examines opportunities and challenges at the regional and country level. It also examines potential impacts for specific types of bioenergy.

The paper does not pretend to be definitive, especially with respect to the controversial interplay of subjects like the impact of bioenergy on food prices, but it does try to suggest the tradeoffs that need to be examined in considering bioenergy policies, and it has five main findings: 1) Solid biomass will continue to provide a principal source of energy and should not be overlooked; 2) There will be major land use implications resulting from bioenergy developments; 3) It is critical to consider tradeoffs, including those related to poverty, equity and the environment, when considering bioenergy policies; 4) There is considerable potential for greater use of forestry and timber waste as a bioenergy feedstock; 5) The climate change impacts of bioenergy development are uncertain, and highly location and feedstock specific.

PRESENTATION 8–1

Creating value from wood – the Borregaard biorefinery

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"Biorefinery" is currently a hot buzzword, but in reality very few industrial sites can claim to operate according to the concept, manufacturing an optimum mix of bio energy, bio fuel, bio chemicals and bio materials.

Biomass is not a cheap alternative to oil, and additionally current focus on "food versus fuel" represents a challenge. The implication, both for food and non-food raw materials is that all fractions must create value added contributions to the total concept. Many of the new 2nd generation technologies do not cope with this challenge in a convincing manner. From 1000 kg dry wood, our process gives 400 kg specialty cellulose, 400 kg lignosulphonate, 70 kg solid bio fuel, 50 kg ethanol, 50 kg carbon dioxide and 3 kg vanillin. Well under 5 % of the total input ends up in the waste treatment plant, but even a large portion of this is converted to bio gas which is used to power drying equipment on site. Many of the new 2nd. generation technologies do not cope with this challenge in a convincing manner.

For the same reasons as above, energy cannot be wasted. Whatever mass that is left over in the process must be utilized for energy production. Cogeneration is an attractive part of the solution, but one often tend to forget that a large portion of the energy input ends up as steam. Again, integration into the other parts of the manufacturing process is the keyword.

It is a considerable challenge to create value added products from all fractions of the bio mass. Borregaard answer has been innovation and specialization. About 20 % of the current product portfolio have been introduced the last 5 years. Lignin represent a far bigger challenge than cellulose when it comes to sellable products. Major applications is additives for concrete admixture, pellet binders and various other specialty products. Large amounts from lignin will probably be available from the 2nd generation bio fuel industry, and we are currently evaluating several opportunities that will be further discussed.

PRESENTATION 8–2

Comparing biorefinery systems to conventional processes – the methodological approach of IEA Bioenergy Task 42

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all members of IEA Bioenergy Task 42 "Biorefineries: Co-production of Fuels, Chemicals, Power and Materials from Biomass" (www.biorefinery.nl/ieabioenergy-task42).
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The increase usage of biofuels in transportation sector is the driving factor for the development of advanced processes to produce biofuels in biorefineries efficiently, whereas for the co-produced bio-based materials additional economic and environmental benefits might be gained. The main question is, what are the advantages of a biorefinery as a "multi-product" system compared to conventional bioenergy systems e.g. single product systems. The advantages might be in terms of environmental, economic, technical or social benefits. In IEA Bioenergy Task 42 a methodology is under development to establish a framework for such a comparison, which is applied to several biorefinery examples.

The aim of the work is to describe and discuss possible economic, ecological or other benefits of biorefinery systems compared to conventional systems or single product systems. This is done based on biorefinery examples: (1) Green biorefinery with grass; (2) Bioethanol biorefinery with straw and wheat; (3) Bioethanol and phenols from wood.

This presentation will discuss the relevant issues of the comparison including the standardized framework of comparison.

PRESENTATION 8–3

U.S. Department of Energy investment in the integrated biorefinery: Research, development, demonstration, and deployment

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The U.S. Department of Energy Office of Energy (DOE) Efficiency and Renewable Energy (EERE), and managed by the Office of the Biomass Program (OBP) is investing heavily in the lignocellulosic biorefinery industry through many funding opportunities. The Biomass Program is helping transform the nation's renewable and abundant biomass resources into cost competitive, high performance biofuels, bioproducts, and biopower.

Projects that are either in the process of award, or whose applications are being reviewed address many areas of the end-to-end integrated biorefinery system. Of particular interest are biochemical and thermochemical conversion, bioenergy feedstock development, and energy feedstock logistics.

One specific area of involved in biorefinery project development is the process whereby National Environmental Policy Act (NEPA) requirements are satisfied through a clearly defined, yet sometimes cumbersome process. The NEPA process involves many parties including individual citizens, industrial sector applications, organized special interest groups, and many representatives of federal, state, local, and other agencies. Understanding the process, and therefore participation in the NEPA process can assist all parties in understanding the environmental impacts, and inform how both environmental increments and decrements may be managed.

This presentation describes the breadth of DOE funding for biorefinery and biorefinery-related research, development, demonstration, and deployment, as well as the NEPA process whereby environmental effects are accounted for and determined. It also outlines the Office of the Biomass Program research and development platform activities which are analysis, sustainability, communications and outreach, feedstocks, processing and conversion, and infrastructure.

PRESENTATION 8–4

Sustainable biorefinery business models for rural development in western Canada: A critical review

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Lignocellulosic biorefineries represent an opportunity for Canadian rural communities to capture tangible economic benefits. Canada's rural economy continues to experience significant structural change characterized by the diminishing role of agriculture as the primary occupation. These agricultural trends have led to significant rural unemployment and population decline. In western Canada, for instance, agriculture's contribution to employment declined from 25% in 1978 to only 8.7% in 2007. Rural communities expect rural biorefineries to ignite new industries that draw on production agriculture and whose economics dictate rural locations that create high value employment. However, the integration of rural lignocellulosic biorefineries will entail new manufacturing and business paradigms, some of which may not be sufficient to guarantee the delivery of tangible benefits for rural communities. For instance, it is well known that the Canadian bioproducts sector comprises two identifiable segments: large companies with traditional chemistry products for whom bioproducts are currently a subsidiary activity; and small companies which are typically start-up companies (SMEs) with an emphasis on the development of industrial biotechnology and bioproducts. In Canada, SMEs comprise the majority of firms in this segment and are likely to be characterized by 1) limited capacity to attract investment to a rural region against a backdrop of high capital investments typically associated with biorefineries; 2) significant gaps in business core competencies, business structure and depth in terms of having a large critical mass of geographically or regionally linked and self-contained firms, R&D organizations, service providers from discovery to commercialization as is typified by the Porter-type cluster model. What business strategy and model is required for the successful integration of a rural Canadian biorefinery which integrates rural communities and companies in the production of products and services from the biorefinery? What kind of systems thinking is required with respect to the market and the sustainability of the entire value chain? Currently, there is little empirical knowledge about the business trajectories for such enterprises economic as well as potential impacts of cellulosic biorefinery development on rural communities. This paper proposes to address these issues in detail as well as offer policy and business direction.

PRESENTATION 8-5

Materials Selection for the biorefinery

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Many process options are available to companies wishing to make chemicals and liquid/gaseous fuels from biomass. Some are based on green-field plants loosely tied to existing infrastructure, while others are designed to be closely integrated into the production capabilities of processing plants like pulp or paper mills. In either case, introducing new process technology requires careful selection of materials of construction to find the most cost-effective option, and to avoid costly damage or failure as a consequence of corrosion. A single catastrophic failure can result in millions of dollars in lost revenue, not including the cost of making the repair or replacing the failed equipment. It is prudent to identify appropriate materials of construction in advance of design and procurement of these new biorefineries. This presentation will review the important considerations.

PRESENTATION 8–6

Development of a biorefinery concept for integrated production of biomedicals, biochemicals, feed and fuels from selected plant materials (bioref)

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The aim of the project is to form a biorefinery concept that allows biological production of chemicals, drugs, feed and fuels using plant materials in well-defined cell-factories based on biochemical reactions. The idea is to use residuals from crop production, grasses and garden/park refuse that have no or low value for other uses but contain bound energy for biofuels and compounds with broad applications. The use of these selected low value plant materials will have an important impact on the environment by decreasing organic waste and CO_2 emissions. Moreover the production of biofuels and biochemicals will reduce the use of fossil fuel in the transportation sector and chemical industry, thereby decreasing the future dependency on fossil fuel import. Among the important goals is discovery of new biocatalysts for production of enzymes, biochemicals and fuels. Emphasis within this part will be on thermophilic enzymes and thermophilic biofuel-producers which will economise the processes in the biorefinery. Furthermore, production of high-value compounds of industrial importance is highly appealing in addition to biofuels even when this production makes use of the same substrate. This opportunity will be pursued along with development of new methods that effectively extract compounds from the pretreated biomass material for direct use as food and feed additives, chemicals and drugs. With this project we intent to make the basic steps for introducing the biorefinery concept into the Danish research environment.

PRESENTATION 8–7

The great history and challenging future of forest based bioenergy in Finland

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Finland has been one of the world leading countries in the use of forest based bioenergy in the world. One fifth of the primary energy is currently produced by wood based fuels. Forest industry has played the crucial role in this development. About 45% of all woody material harvested and used in Finland has ended up to the energy production either directly or indirectly as a side product or by recycling. Current economic depression and ongoing re-organisation of forest industries are causing major challenges for Finland, if 38% national objective of renewable energy production until 2020 will be kept. Forest resources in Finland is not the limiting factor, annual growth is about 100 million m^3 while the use has been about 70 million m^3. If traditional industrial use will drop, it releases more forest resources for energy use as well. In the study, current situation of forest energy in Finland is analysed and future scenarios will be presented in the context of changing forest industry and energy industry. Also the role of traditional forest industry as energy producer is analysed in order to find new business opportunities supporting the existing forest industry facilities.

PRESENTATION 8–8

Green technolgies for the conversion of crop residues to biochemicals

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Straw from wheat and other crops can be fractionated and each of its major constituents—cellulose, hemicellulose, lignin and extractives—can be converted into biochemicals or biomaterials. In this research, we investigated supercritical fluid extraction (SFE) with CO_2 to successfully extract cuticular wax of straw, pressurized low polarity water (PLPW) to extract and separate hemicellulose, cellulose, and lignin from flax shives and other crop residues, and pressure-driven membrane separation for the purification of xylo-oligosaccharides and to fractionate lignin from lignocellulosic materials. The versatility of pressurized solvents is excellent due to the physicochemical properties of the solvent, including density, diffusivity, viscosity, and dielectric constant, which can be controlled by varying the pressure and temperature of the extraction system. In this way the solvating power and selectivity of the solvent can be controlled. In the first part of this research, the key PLPW extraction process variables of temperature, pH, and flow rate, were optimized using central composite design (CCD). Temperature and pH of water had a significant affect on the fractionation of carbohydrates (cellulose and hemicellulose), lignin, and other phenolics. The optimal extraction conditions for the separation of hemicellulose and lignin, determined by the optimization using CCD, were 170 °C, pH 3.0, and a flow rate of 2.5 mL/min. Under these extraction conditions, 39.3% of the initial biomass or feed, 70.1% of the hemicellulose, 35.3% of the lignin, and 5.3% of the cellulose were extracted from the flax shives. In order to improve the purity and yield of the cellulose, a two-stage PLPW extraction was examined. The first stage was designed to remove hemicellulose by water at 170 °C and the second stage was intended for delignification by a pH 12 buffer at 220 °C. The two-stage PLPW extraction effectively removed 63.2% of the feed, 97.3% of hemicellulose, and 86.3% of lignin, while solubilizing 23.9% of cellulose. Scale-up and further optimization of the process in progress.

PRESENTATION 8–9

Biorefinery technology for renewable fuels and chemicals

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Lignol's technology is an advanced biorefinery solution. At the core is a solvent-based pre-treatment process that effectively separates a clean cellulose solid substrate from a liquor containing other components of the feedstock such as lignin and extractives. The substrate responds rapidly to enzymatic hydrolysis which is followed by yeast fermentation and distillation of fuel-grade ethanol. The liquor is further processed to produce a range of biochemical co-products notably high purity lignin (HP-LTM), a unique natural source of aromatic polymers with many interesting properties and high value applications. The process has been used with both wood feedstocks and with agricultural residues with equal success.

Lignol's technology is a true biorefining process where a highly complex feedstock is fractionated and, through chemical and biochemical processes, a range of products are produced; the process variables can be manipulated to adjust the quality and yield of some of the fractions. A key feature of the process is its ability to generate revenue and green house gas emissions reductions from a range of products, not just ethanol.

While Lignol and others have made enormous progress towards an economic solution for producing cellulosic ethanol there are certain technical issues that all in the sector face:

Enzymes and organisms that conduct or promote the bioconversion of cellulose to ethanol are expensive and their performance needs improvement.

The fermentation of five-carbon sugars that result from hemicellulose has the potential to increase ethanol yields from biorefining, yet the successful industrial scale demonstration of this has remained elusive.

A further challenge is the capability of the industry to build the capacity required to meet the Renewable Fuel Standard targets for cellulosic ethanol production set by the Canadian and US Governments. These challenges have been magnified by the turmoil in the financial markets and global economic slowdown.

PRESENTATION 8–10

Biomass, biocarbon, bioenergy & bioproduct

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The carbon-neutral aspect of biomass and its relationship to the control of green-house gases are briefly reviewed. In the use of biomass as a source of bioenergy, the critical factor is energy density. Wood-based bioenergy was revolutionized through the development of wood pellets. Whereas green wood chips have an energy density of ~9.5 GJ/te, a wood pellet has nearly double this amount. Coal, though, is the standard solid fuel in regard to power production, which has an energy density of ~30 GJ/te. Biocarbon, while produced from the same type of biomass as wood pellets, has an energy density equivalent to that of coal, or over 60% higher than a wood pellet. Biocarbon, also called char or charcoal, is manufactured from any biomass through carbonization. The energy/mass balance of thermochemical (pyrolysis/carbonization) processing of biomass is discussed.

PRESENTATION 9-1

Bioethanol production – from lab medium to large scale lignocellulosic fermentations

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Microbial ethanol production is a well established art, although moving from the first generation of bioethanol production to second generation of bioethanol production poses a number of challenges on the microbial production platforms. One of them being the requirement that the microorganism employed should be able to utilize all sugar units present in the lignocellulosic hydrolysates. In order to reach a large scale economical bioethanol fermentation process, development of the fermentation process as well as better designed microbial platforms are required.

The development of the process is driven towards higher gravities and better process integration in order to optimize energy input and water usage. From a microbial point of view this leads to more stressful conditions, including high inhibitor concentrations, high ethanol concentrations and poor nutritional conditions in the hydrolysates to be fermented. Furthermore, at large scale, process hardiness will be expected, including varying environmental conditions during fermentations, due to long mixing times, unsterile conditions leading to contaminations, which calls for solutions that improve the robustness of the fermentation process.

During this presentation these challenges will be discussed and examples of improvement strategies with regard to the fermentation process and design of the microbial production platforms will be given.

PRESENTATION 9–2

Genome shuffling of *Saccharomyces cerevisiae* through recursive population mating to evolve tolerance to inhibitors of Spent Sulfite Liquor

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Lignocellulosic substrates derived from waste biomass have become an attractive feedstock for the production of inexpensive, more environmentally-friendly biofuels. For example, spent sulfite liquor (SSL), a carbohydrate-rich effluent produced in sulfite pulping, can be used to add value to the pulp and paper industry by using the sugars it contains to produce ethanol. However, using SSL in such a capacity requires a robust, ethanologenic microorganism that can withstand the substrate toxicity that is due to the presence of inhibitory compounds like furfural, 5-hydroxymethylfurfural (HMF) and acetic acid. *Saccharomyces cerevisiae* is currently used for the production of ethanol from SSL. This industrially well-established yeast, though a robust starting organism for SSL fermentation, will succumb to toxicity and inhibition, especially in the most inhibitor rich forms of SSL such as hardwood SSL (HWSSL). To establish a *S. cerevisiae* strain that can overcome such a complex and incompletely understood form of inhibitory pressure, a genome shuffling method was developed to create a better SSL fermenting strain. This method aims to improve polygenic traits by generating pools of mutants with improved phenotypes, followed by iterative recombination between their genomes. Through five rounds of recursive mating and screening, three strains were obtained that are able to survive and grow in undiluted HWSSL. Our results show that the tolerance of these strains to SSL translates into an increased capacity to produce ethanol over time using this substrate, due to continued viability of the yeast population. Phenotypic analysis of the three strains demonstrated that the genome shuffling approach successfully co-evolved tolerance to acetic acid, NaCl (osmotic) and HMF. To establish the genetic basis for HWSSL tolerance, we have initiated a systems biology analysis of strain R57. Results of this analysis will be presented.

PRESENTATION 9–3

A study in enzymology of xylan degradation

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Xylan, the most abundant hemicellulose, is a linear polymer of 1,4-β-linked xylose residues, which can be substituted by methylated glucuronic acid, arabinofuranose or acetyl groups. Endo-1,4-β-xylanases (EC 3.2.1.8) are glycoside hydrolases capable of digesting the internal 1,4-β-D-xylosidic linkages of xylan and xylosaccharides. Other hemicellulases, such as α-glucuronidases, arabinofuranosidases and acetyl xylan esterases, cleave the various side chains from the xylose backbone. Xylanases have numerous industrial applications including the production of animal feed, bread-making, clarification of juice and wine, production of paper, and the synthesis of xylitol and ethanol from xylan. Although several xylanases are presently marketed for these applications, none possess the ideal substrate specificity, pH profile and temperature optima for any of these applications. Four fungal endo-1,4-beta-xylanases were cloned from cDNA and expressed in *Aspergillus nige*r using the Gateway system. Two genes encode family 10 glycoside hydrolases, XynGH10-1 and XynGH10-2, and the other two genes code for family 11 glycoside hydrolases, XynGH11-1 and XynGH11-2. XynGH10-2 possesses a type I carbohydrate-binding domain connected to the catalytic domain by a linker region. Phylogenetic analysis and protein modeling establish their evolutionary relationships, identified the active site residues and predicted their tertiary structures. The XynGH10-1, XynGH10-2, XynGH11-1 and XynGH11-2 enzymes have molecular masses of 36, 40, 21 and 23 kDa. Optimal activity was obtained at pH 3.4 and 50°C with XynGH10-1, pH 4.5 and 70°C with XynGH10-2, pH 4.5 and 37°C with XynGH11-1 and pH 6 and 55°C with XynGH11-2. Substrate specificity studies and the products released during the degradation of four types of xylan revealed significant differences in catalytic properties between the family 10 and the family 11 xylanases. Major products of digestion by each xylanase on 4 types of xylan as well as unsubstituted xylo-oligomers were identified using thin layer chromatography and mass spectrometry. Combination of these xylanases with arabinofuranosidase and α-glucuronidase showed synergy on xylan, with this effect varying according to the source of xylan and therefore its side chain composition. We plan to continue to examine synergism with these and other classes of hemicellulases.

PRESENTATION 9–4

Genomic and proteomic approaches to identify and characterize fungal biomass-degrading enzymes

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Fungi are the major decomposers of terrestrial biomass. This makes fungi an ideal natural laboratory where we can search for the proteins involved in the breakdown of woody biomass, which we aim to harness and duplicate. Since fungi use predominantly extracellular proteins in the hydrolysis of biomass, we have started to systematically analyze fungal genome sequence to identify secreted proteins. We have developed computational pipelines to identify secreted proteins based on genome sequences of lignocellulolytic fungi. These results reveal a large repertoire of proteins that can potentially be involved in the decomposition of woody biomass. To narrow the search for promising candidate proteins, we have cultured fungi using agricultural and forestry residues as nutrients. Proteins obtained from the culture filtrates are analyzed by mass spectrometry and the RNAs extracted from the growing mycelia are examined using the Illumina/Solexa sequencing platform. Candidate genes encoding extracellular proteins identified by these approaches are expressed in the filamentous fungus *Aspergillus niger*. The recombinant proteins are characterized biochemically and tested for their utility in various industrial processes. This project is ongoing and the results obtained from analyzing the genomes of the industrial workhorse *Aspergillus niger* and the thermophilic, cellulolytic fungus *Sporotrichum* thermophile will be presented.

PRESENTATION 9–5

Metabolic engineering of the ethanol fermentation by *Saccharomyces cerevisiae* away from glycerol formation towards alternative products

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Glycerol is a major byproduct of the ethanol fermentation by *Saccharomyces cerevisiae* and typically 2-3 % of the sugar fermented ends up as glycerol. Elimination of glycerol from the ethanol fermentation process and possible replacement with other alternative products could have significant commercial advantages. Yeast maintains a balance of redox equivalents for growth. Under fermentative conditions yeast re-oxidizes excess NADH through glycerol production which involves NADH-dependent glycerol-3-phosphate dehydrogenase (Gpd1p and Gpd2p). Deletion of these two genes renders the cells incapable of maintaining fermentative activity under anaerobic condition due to accumulation of NADH. We investigated the possibility of converting this excess NADH to NAD+ by transforming a glycerol synthesizing double mutant (Δgpd1, Δgpd2) with genes that could restore the redox balance in the yeast. Transformation with genes encoding a NADH dependent sorbitol dehydrogenase or NADH dependent sorbitol-6-phosphate dehydrogenase resulted in respectively 2 and 7 % of the sugar being fermented to sorbitol, a sugar substitute with pharmaceutical applications together with partial improvement of the fermentative ability. The ethanol yields were maintained between 46 and 48 % of the sugar mixture. Transformation of the glycerol synthesizing double mutant with genes encoding glycerol dehydrogenase, aldose reductase and methylglyoxal synthase yielded a strain that produced in addition to ethanol, 1, 2 propanediol, a major commodity chemical currently derived from non-renewable resources. In a 10 % sugar broth, 0.28 g/l 1,2 propanediol was produced and the ethanol yield was 47 %. Overexpression of the PDC1 gene and deletion of the ALD6 gene in a *S. cerevisiae* gpd1Δgpd2Δ double mutant partially restored fermentative ability and improved the ethanol yield by ~ 5 % but significant amounts of acetate were produced. The metabolic and biotechnological implications of these findings will be presented.

PRESENTATION 9–6

Bioproducts from kraft and sulfite dissolving pulp manufacturing

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Canadian market kraft pulp mills are currently under threat due to increasing global competition and the recent economic downturn. In the last four years, 12 mills have permanently closed, representing approximately 25% of Canadian capacity. Many other mills are taking market related downtime. The idea of diversification to produce hemicellulose and lignin based materials as well as pulp has been a common theme of much recent biorefinery research. However, northern bleached softwood kraft pulp has traditionally been sold based on strength properties, and removing hemicellulose from such pulps often leads to fibre strength loss. An alternative approach is to target the dissolving pulp market, where hemicellulose removal is a necessity. We have been working with an eastern Canadian hardwood mill that has chosen this approach. Various prehydrolysis conditions were investigated prior to kraft cooking in order to maximize sugar production. Mono- and oligosaccharides were quantified. The predominant sugars were pentoses which can be isolated and purified or further converted to furfural, xylitol, or ethanol. The dissolving pulp yield and properties were also assessed. In another project with a sulfite dissolving pulp mill, it was possible to supplement the current production of ethanol from spent sulfite liquor sugars by high consistency hydrolysis of cellulosic residues available at mill site. The capital cost of this process is low, but enzyme costs are still a challenge.

PRESENTATION 9–7

Pretreatment and hydrolysis of recovered fibre for ethanol production

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Recovered fibre from pulp mills represents a potentially significant feedstock for conversion to ethanol. Enzymatic hydrolysis of untreated recovered fibre (86.5 Kappa, 13% lignin) resulted in a hexose yield of approximately 23%, which highlighted the need for an effective pretreatment. Recovered fibre was pretreated as a substrate for enzymatic hydrolysis using oxygen delignification. An experimental design was used to optimize temperature (90 – 150°C), caustic loading (2 – 10%), and reaction time (20 – 60 min.). The post-delignification Kappa values ranged from 76.7 (11.5% lignin) under the mildest pretreatment conditions, to 20 (3% lignin) under the most severe pretreatment conditions. The effect of caustic load appears to have an increased effect at higher temperatures, with the Kappa number ranging from 76.7 (90°C, 2% caustic, 20 min.) to 56.0 (150°C, 2% caustic, 20 min.) and from 64.7 (90°C, 10% caustic, 20 min.) to 38.0 (150oC, 10% caustic, 60 min.). These changes in Kappa number reflect changes in percent lignin of 3.1% and 4% respectively. Increasing the caustic load from 2 to 10% decreased the oxygen delignification yield from 93.5% to 87.9% at 90°C and 20 minutes reaction time, and 80.3% to 74.7% at 150°C. The effect of time on oxygen delignification yield was found to be most significant in the first twenty minutes, which correlates with the drop in Kappa number that was observed.

The pretreated fibre was subjected to enzymatic hydrolysis using commercial enzymes Celluclast (80 FPU/mL, 20.1 CBU/mL) and Novozym (640.5 CBU/mL). A series of enzyme loadings ranging from 19 – 77 FPU/g were utilized on solids loading ranging from 20 – 100 grams of dry fibre per liter. Based on the pretreatment and hydrolysis results an empirical model was developed that can predict hydrolysis sugar concentrations based on the Kappa number, enzyme loading, and initial recovered fibre concentration.

PRESENTATION 9–8

Morphological alteration of wood fibres in the process of enzymatic hydrolysis of cellulose

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Substrate pretreatment has been identified as one of the key steps in bioconversion of various biomass including wood, agricultural residuals and designated grasses into biofuels. It has been widely recognized that the rate and extent of cellulose hydrolysis are determined by not only the chemical but also the physical and morphological properties of biomass substrate. The goal of the pretreatment is to generate maximum substrate accessibility to the cellulases. The size, specific surface area, internal pore size, degree of polymerization of cellulose, crystallinity of lignocellulose particles or fibres have been investigated by a number of studies to correlate these traits to the efficiency of cellulose hydrolysis.

The present study focuses on the morphological change of wood fibres in the enzymatic hydrolysis process. FE-SEM, TEM and AFM were used to observe the change in the fibre wall structure on a micro or nano-scale with cellulose hydrolysis. Fibres resulting from pretreatment processes such as steam-explosion, organo solv pulping were used and were compared with Kraft pulp fibres. Cellulase actions on substrate fibres including peeling, cutting, splitting, and erosion were observed. Some of these actions were observed in situ with a special experimental setup. The results shed light on elucidating how cellulases act on the substrate fibres and how the chemical and physical characteristics of the substrate, especially the presence of lignin on the fibres, affect the cellulose actions and the efficiency of cellulolytical hydrolysis.

PRESENTATION 9–9

Enzymatic valorization of hemicellulose and cellulose polymers

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Although petrochemicals and plastics account for less than 10 % of petroleum consumed, its economic value is nearly equal that of fuel. Likewise, it is anticipated that high-value co-products will be critical to the economic viability of future biorefineries whose main product is bioenergy. Biodegradable polymers, including polylactides, polyhydroxyalkanoates, thermoplastic starch, and soy-based plastics, are now commercially available. However, the overall benefit of biopolymers that are synthesized from edible feedstocks depends on the end application and projected improvements to production efficiency. By contrast, lignocellulose-derived polymers can be recovered in polymeric form, do not compete with food supply, and have competitive strength properties.

The objective of our research program is to expand the range of biomaterials generated from lignocellulose feedstocks. Our approach is to harness two fundamental biological capabilities. The first is the regio- and stereo-specificity of enzyme catalyzed reactions, which allow discrete and reproducible modification of highly-functionalized plant polymers with minimal impact on fibre length or viscosity. The second is the ability of lignocellulosic polymers to self assemble through hydrogen-bonding, which can be exploited to graft enzymatically modified hemicellulose onto cellulose microfibrils. This presentation will describe the identification, isolation, and application of two classes of enzymes for fibre engineering, namely esterases and oligosaccharide oxidases. While lipases and carbohydrate esterases will be developed for transesterification of xylan and phenolic or aliphatic compounds, oligosaccharide-oxidases will be developed to activate lignocellulosic polymers through the oxidation of specific hydroxyl groups. To date, over 40 novel lipase and esterase enzymes from more than 15 microorganisms have been recombinantly expressed, purified and characterized. Each enzyme was evaluated for stability in non-aqueous conditions that promote transesterification activity. Small-scale assays are now underway to screen esterase enzymes for ability to catalyze the transesterification of xylo-oligosaccharides. While fewer than five oligosaccharide oxidases have been reported, this presentation will describe the significance of this enzyme family for chemo-enzymatic modification of plant fibre. The impact of enzyme structure on substrate specificity, and strategies to increase the activity a glucooligosaccharide oxidase on polymeric substrates, will be presented.

PRESENTATION 9–10

Biofuel production via cellulosic fermentation

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The "Bioengineering for Biofuels and Bioproducts through Biorefining" research team at the University of Manitoba integrates microbial physiology & metabolism, molecular biology & genome sciences, and bioprocess engineering to investigate consolidated bioprocessing for synthesis of biofuels and value-added co-products using insoluble cellulosic substrates. Here we summarize recent results of biofuel (ethanol and hydrogen) production by fermentation of cellulosic substrates using batch and continuous cultures of *Clostridium thermocellum* ATCC 24705. Growth curves of *C. thermocellum*, and end-product synthesis profiles, were determined using cellobiose, α-cellulose, delignified wood fibers, and natural cellulosic substrates such as hemp hurds, flax fines, and barley hulls at various concentrations, and at different temperatures. Growth on cellobiose has allowed us to monitor fluctuations in gene expression and enzyme activities under "high carbon flux" conditions relative to cellulosic substrates. Comparative genomics has enabled comparisons of end-product patterns relative to genome content in other cellulolytic organisms. Overall, higher rates of ethanol and hydrogen were synthesized by *C. thermocellum* cultured on delignified cellulose fibers compared with natural cellulosic substrates, and higher rates of ethanol were synthesized by *C. thermocellum* cultured on delignified cellulose fibers compared with all other substrates at 65 oC versus 60 °C. A continuous culture of *C. thermocellum* using α-cellulose was established and maintained for over 3000 hours. The pH and temperature of the reactor were maintained at 7.0 and 60 °C, respectively, throughout the study. Substrate concentrations were varied from 1 to 4 g L^{-1} and the feed was introduced with continuous nitrogen gas sparging to prevent clogging of the feed-line. Acetate and ethanol were the major soluble end-products, while lactate and formate were greatly reduced compared to production in batch cultures. Concentrations of all metabolites increased with increasing substrate concentration, with the exception of lactate. Despite a number of short-term electrical and mechanical failures, the system recovered quickly, exhibiting substantial robustness. Carbon balance analysis revealed that all end-products were accounted for, with final results indicating near 100% carbon recovery. This study shows that long-term, stable biofuel production can be achieved during direct fermentation of an insoluble cellulosic substrate under continuous culture conditions.

PRESENTATION 1

The U.S. Department of energy – sun grant initiative relationship: Regional feedstock partnerships

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The Sun Grant Initiative (SGI) is working with the U.S. Department of Energy (DOE) Energy Efficiency and Renewable Energy (EERE) Office of Biomass Program (OBP) to develop and implement a Regional Biomass Partnership to address barriers associated with the development of a sustainable and predictable supply of biomass feedstocks.

The joint DOE/USDA Billion Ton Study[2] established the resource base and future potential for a large-scale biorefinery industry. Industry expansion from grain to lignocellulosic ethanol is expected and agriculture crop residues and forest residues will be the first available for biorefinery purposes. Energy crops (herbaceous and wood) will develop and be integrated as the biorefining industry matures and creates a demand for those resources. Each Sun Grant Region has held multiple biomass workshops to address each region's unique capacity to contribute to producing a billion tons of biomass feedstock. Collaborations among the regional partnerships will be critical in developing sustainable biomass production and crop rotation strategies for existing and new biomass resources.

The Regional Feedstock Partnership activities have been charged by the DOE Office of Management and Budget (OMB) with three tasks; 1) biomass resource assessment, 2) biomass resource development, and 3) biomass resource education and outreach. The Feedstock Partnership is assembling national task teams to complete these OMB tasks.

Biomass resource assessment task assesses currently available resources as documented through many existing sources of data to understand how these resources relate to, and can be brought to bear in the near-term for the biorefinery development.

Biomass resource development involves assessing those resources discovered as well as understanding through a nationwide network of biomass resource field trials, the implications for development of a biorefinery industry. The resource development activities include components of agricultural residues, forest resources, energy crops produced that are both herbaceous and woody, as well as the potential to assess other available resource for the biorefinery.

This presentation will describe the multiple activities involved in this interagency and multi-university activity.

[2]Biomass as Feedstock for a Bioenergy and Bioproducts Industry: The Technical Feasibility of a Billion-ton Annual Supply. April 2005. Wright, Lynn; Perlack, Robert; Graham Robin; Stokes, Bryce; Turhollow, Anthony; Erbach, Donald. Oak Ridge National Laboratory, DOE and ORNL.

PRESENTATION 2

Examining root dynamics of willow plantations in Saskatchewan

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Bioenergy is progressively becoming the focal point of more and more research due to the increasing demand for renewable resources. Willow is one of the many renewable feedstocks under investigation for this purpose. Thus far, a vast majority of the research on willow has been focused on aboveground portion of the system, but what's happening underground? Willow root systems are an integral part of the plant and the contribution to its bioenergy potential. Many different methods have been developed to quantify below ground biomass. This poster will discuss the minirhizotron method for quantifying root turnover, how it is applied in the field, and analytical procedures utilized to gain a better understanding of willow root systems in Saskatchewan. The poster will also present some of the findings that have been observed for this study thus far.

PRESENTATION 3

Evaluating different techniques for estimating biomass in short-rotation willow plantations

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Successful purpose-grown willow production systems require regular monitoring of willow growth to apply timely management techniques for increased productivity, and timing of harvest for maximizing profit. The objective of this study was to compare a conventional allometric technique defined by a simple empirical relationship between stem size and mass with a novel alternative method measuring light attenuation through the willow crop canopy (i.e., Stem Area Index; using a LAI-2000 Plant Canopy Analyzer) and relate these data to harvested willow biomass. Two different hybrid willow clones with contrasting growth form, either single stem (Charlie) or multi-stem (SV1), were studied. The observed allometric models were stronger for multi-stemmed SV1 (R2 = 0.81) compared to the single-stemmed Charlie (R2 = 0.67); however, the allometric relationships in this study were not as robust as those typically reported in the literature for willow and is probably due to the uncoppiced management of the study plantation. Given the strong correlations (R2 > 0.98) between Stem Area Index and harvested willow biomass, regardless of growth form, it appears that this novel mensurative technique is a promising alternative to conventional allometry.

PRESENTATION 4

Production of short rotation willow biomass with and without irrigation using treated effluent water from a municipal sewage treatment plant

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At Whitecourt, Alberta, a short rotation coppice (SRC) willow plantation is being grown with and without irrigation using treated municipal sewage wastewater. This project is part of a nation-wide Canadian Biomass Innovation Network study, led by Natural Resources Canada, Canadian Wood Fibre Centre, that is investigating growing of SRC willow as a bioenergy feedstock. The Whitecourt site was chosen because of its accessibility for demonstration purposes, its proximity to a wastewater treatment facility, and the fact that a potential end user of the wood fibre produced (a waste-wood fired power plant) is located in the community. Five willow clones are being monitored for their performance with and without irrigation. Growth, survival, biomass yield, insect and disease issues, heavy metal uptake by the willow, and accumulation of heavy metals in the soil are being monitored. The use of wastewater for irrigation offers the opportunity to increase yields of willow biomass by augmenting low rainfall in western Canada, to reduce environmental impacts of waste water disposal and to decrease the need for manufactured fertilizers. This has the potential to reduce operating costs and improve the net carbon budget of plantations. Other uses of SRC willow include site reclamation, riparian buffers, phytoremediation, and nutrient cycling and management. Analysis of winter 2008-09 harvest volumes is underway. The presentation will give some background on short rotation woody crop production, outline the project purpose, objectives and methods, and will present the results to-date.

PRESENTATION 5

Biomass feedstock cost structure from forest residues: an analysis from Inner Mongolia, China

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By replacing fossil fuels as an energy source, bioenergy is widely recognized as one means to reduce greenhouse gas emissions. In China, the development of bioenergy using forest residues is still in its infancy, nonetheless progress is being made. One of the most critical issues affecting the economics of bioenergy projects is the feedstock cost for existing and proposed biomass cogeneration power plants. It logically follows then that the first objective of this study is to describe and analyze the feedstock costs along the supply chain from the forest to the final delivery at the power plant. A second objective is to compare the feedstock cost structures for an existing plant, where the woodfuel comes mostly from collective forest land, with a potential new plant where the feedstock is from state-owned forest land. A case study approach was used to collect cost data and other relevant information in two locations (Arxan and Naimanqi) in Inner Mongolia during the winter of 2008. In-depth personal interviews were carried out with all personnel involved in forest biomass logistics to reveal the viewpoints of all participants and capture all related costs. Preliminary results indicate that: 1. Labour costs are a significant component of total feedstock cost in both locations as little mechanized equipment is used in the collection of forest residues. 2. The total average feedstock costs differ greatly between sites because of differences in harvest logistics, type of hauling equipment, transportation costs and administration costs. 3. Transportation costs are lower in the Naimanqi case since skidding and hauling phases are one system and the distance from the forest to the centralized collection sites is much shorter than in Arxan. 4. The Arxan Forestry Bureau, who manages the state-owned land, includes the cost of tree planting in the feedstock cost unlike the farmers harvesting from the collective forest land in Naimanqi.

PRESENTATION 6

Nitrogen uptake by willow bioenergy cropping systems in Saskatchewan, Canada

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The detrimental effects of climate change and the threat of diminishing fossil fuel reserves is causing society to search for alternative sources of energy. Renewable biomass energy, such as Short Rotation Woody Crops (SRWC), has the potential to replace petroleum and other fossil fuel energies and/or be converted to other bio-products and provide environmental and economic benefits. Willow (*Salix spp.*) are an ideal SRWC because they are fast growing, easily propagate from cuttings and have a large amount of exploitable genetic diversity that can be used in conventional breeding and molecular biotechnology. Producing and maintaining yields in willow SRWC requires an adequate supply of nutrients. If the soil reserves cannot meet crop demands, these nutrients can be provided by synthetic fertilizers, organic residues such as green manure, animal manure and sewage sludge. Little has been determined in regards to how much fertilizer nitrogen (N) needs to be supplied to meet plant requirements within the first year. To better understand fertilizer N requirements, four willow clones were grown in a SRWC system north of Prince Albert, Saskatchewan. One month after planting, trees were fertilized with a liquid solution of 10% double-labeled ammonium nitrate (15NH415NO3) applied to the soil surface in a 30 x 30 cm area around each tree. At the end of the growing season, trees were harvested and separated into roots, cutting, shoots and leaves. Soil samples were collected at depths of 0-10, 10-20 and 20-30 cm within the 30 x 30 cm area around the trees. Plant and soil samples were analyzed for %N and atom %15N excess on an isotopic ratio mass spectrometer to determine the uptake and accumulation of the 15N-labeled fertilizer in the plant as well as the leaching of 15N through the soil profile after the first growing season.

PRESENTATION 7

The assembly of comprehensive utilization bio-gas obtained from swine manure by zymolysis in high consistency biomass at constant temperature for bio-gas power generation

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At present, the scarcity of energy resources all over the world, the development of biomass energy is an effective way to solution this problem. It was proved that the bio-gas obtained by anaerobic fermentation of organic waste, the residues of liquid and solid can be used as fertilizer for agricultural production. There was the technology about efficient utilization of methane for Bio-gas power generation.

We have disposing of swine manure by this technology because the huge amount of organic waste in China. Using this technique can to reduce greenhouse gases and curb the spread of germs. However, the constant temperature environment can not be required in fermentation of organic matter in the winter of Chinese northern. A low concentration of biomass was using in the majority of large-scale zymolysis system at present. Our research shows that there was the enormous energy consumption in that system. The concentrations of biomass was descended from 12% to 8%, the energy consumption was 1.85 times of the original in experiment system. Enhancing the concentration of organic matter are the key for energy-saving. A strong homogenate power for the high concentration of biomass was must, the beat up of large-scale zymolysis system for the high concentration of biomass was difficile. Our assembly of comprehensive utilization bio-gas can solution this problem.

Our system can easily meet the demand of homogenate power and constant temperature in the high concentration of biomass Fermentor, and can be a very good deal with different demands regarding the quantity of matches. According as the principle based on a low-cost operation, We developed the technique to transform biomass solid waste into energy source and generate electricity. It was funded by the Spark Program of The Ministry of Science and Technology of P.R. China. We are carrying out this project in Liaoning of China. A patent registered as The Assembly of Comprehensive Utilization Bio-gas Obtained from Biomass by Zymolysis in Constant High Temperature was granted by State Intellectual Property Office of P.R. China. We are the inventor and owner of this patent.

PRESENTATION 8

Integrated biomass supply analysis & logistics (IBSAL) – framework for model validation

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A simulation model requires extensive verification and validation over a large range of feasible inputs in order to develop confidence in the model. The Integrated Biomass Supply Analysis & Logistics (IBSAL) model consists of a number of sub-models each simulating operations and processes involved in harvesting and post-harvest treatments of biomass (agriculture and forestry). The time dependent model is a visual representation of the real system, i.e. subject to climate and biological constraints. In order to validate the model, each sub-model and the aggregate of these sub-models must be validated using classical methods of model verification and validations: rationalism, empiricism and positive economics. As a first step, the internal structure of the model has been verified with the experimental data. A frame work for large scale validation of the overall model response has been defined including data characteristics and design of experiments. The paper discusses the formulation of the model, experimental data for internal verification, and protocols for systems behavior validation and sample outputs.

PRESENTATION 9

Lignocellulosic biomass logistics and rural farm value-chain integration in rural Canada

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The development and design of an efficient lignocellulosic feedstock supply system is fundamental to the economics of a rural based Canadian biorefinery. Lignocellulosic biorefineries have an advantage of using a variety of feedstocks, including agricultural residues, perennial grasses, and dedicated energy crops such as switchgrass. Harvest windows are different across these diverse species. This enables the utilization of harvest and collection machinery throughout many months, thereby reducing fixed costs of harvest equipment per unit of feedstock. However, unlike current Canadian grain crop systems, lignocellulosic biomass in Canada does not have a well-developed harvesting and transportation system from farm to the end-user. It is possible that some farmers own harvest equipment that could be used to harvest lignocellulosic biomass. However, it is not clear whether most farming regions is Canada have adequate investment in harvesting machinery needed to provide enormous quantities of lignocellulosic biomass that is uniform, consistent, and orderly in flow to a biorefinery throughout the year. Because lignocellulosic biomass is spatially and physically diverse, a uniform feedstock supply system that connects lignocellulosic feedstock supply system to cellulosic feedstock resources and to biorefinery conversion facilities is vital for operational and economic efficiency. In particular, attention needs to be paid to how such activities as harvest and collection, storage, transportation, handling and queuing, and pre-processing are sequenced. For instance, would certain types of lignocellulosic biomass need to be pretreated on-farm prior to delivery? Would the biomass need to be swathed and left on the ground to dry prior to collection? How is the farm and rural community integrated? In spite of the intensifying research in the development of lignocellulosic biomass crops, most biorefinery feasibility studies have not addressed the critical issue related to the logistics of designing an orderly flow of lignocellulosic feedstock to a biorefinery. In vast regions of Canada, this challenge requires special attention. This study will develop a mixed integer mathematical programming model incorporating integer decision variables that allow investment in densification technology, mobile treatment, hub-and-spoke systems, and harvest machines that provide monthly harvest capacity based upon expected harvest days.

PRESENTATION 10

Numerical modelling of a biofuel gasification reactor

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The direct utilization of biomass in power generating systems is not viable due to high concentration of alkali in the ash. One of the ways to improve the fuel quality is gasification, which is the conversion of the biofuel into the gas mixture consisting of carbon monoxide, hydrogen, methane, and other gases that can be easily burnt in the conventional equipment. Two vessel gasification systems that separate combustion and gasification zones have the potential of producing the high quality production gas due to substantial reductions of nitrogen content because combustion products do not enter gasification stream. However, this promising technology has not become widespread. Certainly, there are considerable challenges in the design and operation of such a system. In order to overcome these challenges, it is necessary to improve the fundamental understanding of the process. We use the numerical modelling tools to simulate the two vessel gasification process. Due to relatively large solid loading in the reactor, we will use a multi-fluid Eulerian description for solid particles movement. To reflect variations in particle size several solid phases are included. In order to close the system of mass and momentum balance equation, we use an intuitive extension of the kinetic granular flow theory to multiple solid phases. The model is applied to the prototype gasification reactor that close to the one installed in Gusseling, Austria [Hofbauer, H., Veronik, G., Fleck, T., Rauch, R., 1997. The FICIB gasification process. Developments in Thermochemical Biomass Conversion, 2, 1016-1025, Banff, Alberta, Canada.] This fluidized bed reactor uses silica sand to transfer heat from the combustion to the gasification zone. The model provides information on the process characteristics, phase velocities, temperature distribution and gas composition. Modelling results show transient hydrodynamic behaviour of the sand and fuel particles, and allow us to evaluate the effectiveness of the mixing between them. The obtained solution demonstrates qualitatively correct trends and behaviours. Modeling provides a very useful tool in process design and optimization.

PRESENTATION 11

Studies on physical properties and grinding energy requirements for barley, wheat, oat, and canola straws

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The physical properties and grinding energy requirements of agricultural straws play a major role in understanding the compaction behavior of these materials during briquetting or pelleting. In the present study, the physical properties namely, moisture content, particle size, bulk density, tapped density, and specific energy requirements of wheat, canola, oat and barley straws procured from a farm in Central Butte area of Saskatchewan were determined. Initially, moisture content of the straws were about 12-15%. Particle size reduction experiments were conducted in two steps. In the first step, a chopper was used and in the second step, a hammer mill was used to grind the chops using 19.05, 25.4 and 31.75 mm screen sizes. The physical properties of the chops (wheat, barley, canola and oat chops) measured included particle size, bulk density, tapped density and specific energy requirement with values in the range of 2.5-4.0 mm, 25-35 kg/m3, 35-45 kg/m3 and 2.0-3.0 kWh/t, respectively. Further, the moisture content of the chopped straws was adjusted to 12-13% to conduct studies on physical properties of hammer mill ground material. It was observed that canola had the highest bulk and tapped density of about 80 kg/m3 and 120 kg/m3, respectively, whereas wheat had the lowest bulk and tapped density of 80-90 kg/m3 for chops ground with hammer mill having a 19.05 mm screen size. The results also indicated that the bulk density and tapped density are inversely proportional to the particle size of the grinds. The average mean particle diameter of oat grind was found to be the highest, followed by barley, wheat and canola grinds for all the three hammer mill screen sizes. The specific energy requirements of oat straw was found to be the highest at about 5.68 kWh/t for 31.75 mm grinds followed wheat, barley and canola.

PRESENTATION 12

Pyrolytic conversion of lipid feeds for bio-chemical and bio-fuel production

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Lipid pyrolysis was investigated as a means of producing deoxygenated liquid hydrocarbons for renewable fuel and chemical applications. Oleic acid (n-$C_{17}H_{33}$COOH, mono-unsaturated) and linoleic acid (n-$C_{17}H_{31}$COOH, di-unsaturated) were used as unsaturated model free fatty acids and pyrolyzed in 15 mL batch micro-reactors under N_2 atmosphere. Products were analyzed by gas chromatography and mass spectrometry and compared to previous work investigating pyrolysis of a fully saturated free fatty acid, stearic acid (n-$C_{17}H_{35}$COOH), as well as fatty acids hydrolyzed from animal fats and vegetable oils to determine the effects of unsaturation on thermal cracking behavior and product distribution. The primary reaction in oleic acid pyrolysis was decarboxylation to heptadecene ($C_{17}H_{34}$) and CO_2, which is consistent with stearic acid pyrolysis. The presence of n-heptacecane (n-$C_{17}H_{36}$) indicates some hydrogen addition. Unlike stearic acid pyrolysis, which yielded a distinct series of n-alkanes and a-olefins, only the C_9 and lower alkane/alkenes were present in notable concentrations indicating that cracking at the double bond was a dominant reaction. In addition, the C_{10}-C_{20} alkanes/alkenes were not easily distinguishable from other compounds that were found to be alkane isomers (branched and cyclic hydrocarbons). Reaction temperatures (350-500°C) and time (0.5-8 hours) were shown to have a significant effect on the product mixture. Lower temperatures and shorter reaction times gave low acid conversion while higher temperatures and longer reaction times increased conversion but eventually led to degeneration into aromatic compounds. Preliminary observations from linoleic acid pyrolysis (di-unsaturated) indicate that product distributions are consistent with cracking trends observed for saturated and mono-unsaturated fatty acids. Pyrolysis of fatty acids separated from hydrolyzed beef tallow, poultry tallow and canola oil yielded similar series of alkanes and alkenes and the product distribution was consistent with an additive effect of the constituent saturated and unsaturated fatty acids. This work provides insight on the effect of unsaturation on thermal cracking and product distribution and demonstrates that renewable fuels and chemicals can be produced through pyrolysis of lipid feedstock.

PRESENTATION 13

Pelleting characteristics of selected agricultural biomass – density and energy models

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Abstract: Agricultural biomass has the potential to be used as feedstock for biofuel production. However, crop residue after harvest must be gathered, processed and densified in order to facilitate efficient handling, transportation and usage. Densification studies were conducted on four selected biomass samples (barley, canola, oat and wheat straw) at 10% moisture content (wb) and 1.98 mm grind size using four pressure levels of 31.6, 63.2, 94.7 and 138.9 MPa. The mean densities of barley, canola, oat and wheat straw pellets ranged from 907 to 988 kg/m^3, 823 to 1003 kg/m^3, 849 to 1011 kg/m^3 and 813 to 924 kg/m^3, respectively; while the mean total specific energy ranged from 3.69 to 9.29 MJ/t, 3.31 to 9.44 MJ/t, 5.25 to 9.57 MJ/t and 3.59 to 7.16 MJ/t, respectively. Best predictor equations having highest coefficient of determination values (R2) were developed for both pellet density and total specific energy required to compress the ground straw samples. The resulting R2 for pellet density from barley, canola, oat and wheat straw were 0.77, 0.90, 0.87 and 0.73, respectively, and for total specific energy values were 0.96, 0.98, 0.97 and 0.92, respectively.

PRESENTATION 14

Bio-upgrading of synthetic gas into hydrogen

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Several bioconversion routes exist to turn biomass into gas or liquid fuels. A significant portion of biomass is however difficultly and/or slowly biodegradable by microorganisms, due to its heterogeneous and polymeric nature. When relatively dry, an alternative might be to gasify organic biomass, which results in a synthetic gas (syngas) mainly composed of carbon monoxide (CO), CO_2 and hydrogen. Syngas can be used directly to power industrial boilers, gas turbines or fuel cells to make electricity. Syngas could also be upgraded into H_2. Thermochemical processes such as catalytic water-gas shift reaction could be used so to improve the syngas content in H2, although they are energy intensive, and may be problematic when impurities are present. To circumvent these disadvantages and use milder treatments with minimal chemical and energy, we can harness the power of microorganisms to convert the syngas compounds into gas biofuels. A small number of microbes contain an intricate enzymatic system initiated by the oxidation of CO to CO_2 by a CO-dehydrogenase and closed by the reduction of two protons to form H_2. In short, the syngas can be a substrate for those carboxydotrophic hydrogenogenic microorganims that grow chemolithoautotrophically on CO, such as Carboxydothermus hydrogenoformans, an extreme thermophile (70-72 ºC).

However this research domain is yet in its infancy. Actual batch culture of C. hydrogenoformans under 100% CO at 70ºC showed an activity rate in the range of 200 mmol CO/g protein.hr with an H_2 yield around 0.9 mol H_2/mol CO. Surprisingly, grown biomass showed a large content in inorganic material (up to 94%) made of Ca and phosphate (65%). Likely due to phosphate and calcium in excess in the medium. Those crystals may seriously impediment the gas mass transfer rate and the bacterial activity. Preliminary results show that an optimized media (2.5mM phosphate, 5mM bicarbonate, 0.1mM Ca and 0.5mM Mg) could significantly reduce the cell mineral content (by a factor of ten) while improving the strain bioactivity (by 50%). We may also present preliminary performance results of an hollow fiber bioreactor inoculated with C. hydrogenoformans, fed on the continuous mode with a reconstituted syngas made of 40% CO, 30% H_2, 30% CO_2.

PRESENTATION 15

Pyrolysis modeling with emphasis on thermal properties of wood

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Liquid fossil fuels can be substituted for wood-derived liquid bio oil. This bio oil is produced from wood by thermochemical pyrolysis process. In industrial scale the rate of pyrolysis process is usually controlled by internal heat transfer of wood and limits of existing pyrolysis models are in the use of arbitrary values for physical properties of wood. Hence, a better knowledge of the physical properties of wood-fuels is needed to improve the predictive capabilities of pyrolysis models.

Phenomena of wood pyrolysis and physical properties of wood have been studied at Tampere University of Technology (TUT). The present paper reports modeling work conducted for pyrolysis of a thermally-thick wood particle. Special emphasis is given to thermal properties of wood and wood char, and focus is on their dependence on temperature and degree of conversion. The main emphasis is given to Finnish softwood, namely pine. Thermal properties that are used in the modeling work are based on laboratory experiments and literature survey that were conducted at TUT in 2008-9.

Modeling work is conducted during spring 2009 and results will be reported in the final conference paper. The results will be compared to other modeling results that were found in the literature survey. The model will be verified with drop-tube pyrolysis experiments that will be conducted at TUT in 2010.

PRESENTATION 16

Plant biomass briquetting- a review

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Abstract Straws and crop residues are relatively abundant renewable resource. Some of the straws can turned into forage by ensiling or pelleting, and most of them can be made into briquettes for biofuel or energy applications, to help remedy for the dwindling energy resources of the world. This paper reviews the investigations of factors that affect the quality of briquette, such as the loading pressure, particle size of the chopped material, the preheating temperature, the moisture content and residence time of the die, and many others. It also discusses the briquetting study results of such materials as corn stover, switch grass, alfalfa, cotton stalks and reed canary grass. The main briquetting related technologies, systems and equipment will also be discussed. According to literature and the need of briquette production, further research should be extended to other biomass materials. There is a need to study on developing technologies, determining parameters and selecting or developing facilities and systems for briquetting a wide range of biomass materials should be carried out to obtain high quality briquette, improve efficiencies and produce economically competitive feedstock.
Keywords: densification, bioenergy, biofuel, briquetting system

PRESENTATION 17

Thermochemical hydrolysis of hemicellulose under atmospheric pressure

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The main component of the hemicellulosic fraction of lignocellulosic residues is the biopolymer xylan, a polysaccharide made from xylose units that can be hydrolyzed to this sugar by mineral acids or xylanase. Hemicellulose is much easier to hydrolyze compared to crystalline cellulosic components of biomass because of its relatively low degree of polymerization and heterogeneous structure. In this research work, oat hull was used as a hemicellulose-rich feedstock in hydrolysis process for xylose production to be used as a substrate for xylitol production and to provide a byproduct rich in cellulose. To investigate the kinetics of this depolymerisation reaction, sulfuric acid concentration (4% to 8%) and temperature (80 to 100°C) were employed as variables under atmospheric pressure. After measurements of components in the hydrolysates, reaction rate constants (kn) and yields of the materials as well as activation energy at each stage were determined.

PRESENTATION 18

Jatropha:a perfect feedstock for biodiesel

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Seventy five to eighty five percent (75%-85%) of the cost of operating a typical biorefinery is made up of the cost of feedstock. Logically, it stands to reason that the ability to control the cost of feedstock is the key to profitability of a biodiesel refinery. However, the cost of traditional feedstocks such as soyabean oil, rapeseed oil, palm oil, canola and sunflower oil have risen in tandem with the rise in the price of crude oil-eroding the gains in competitiveness which would have accrued to biodiesel refineries. For instance, a US$100 per barrel of crude oil on the world market makes almost all biofuels competitive to petroleum based transport fuels without the need for subsidies. Worst of all, biofuels in general have gained bad press for competing for feedstock which could have been used to feed the 850 million humans who suffer from hunger world wide. A recent study by the World Bank indicates that the use of stable food as feedstock for biofuels had contributed to 75% rise in the price of stable foods on the world market. Biofuel companies had reacted to these negative developments by either closing down their refineries to reduce their losses or shelved expansion plans. We think that a more sustainable long term strategy is adopt a non edible feedstock which does not contribute to increases in the price of stable foods nor have energy intensive cultivation methods such as soyabean oil. The jatropha plant seems to perfectly fit this ideal feedstock profile. This paper is an attempt to outline the advantages of jatropha as a biodiesel feedstock over traditional biodiesel feedstocks. I will also highlight on the ingredient for formulating agronomic and business model for cultivating jatropha cheaply and sustainably.

PRESENTATION 19

Potentials of sporl technology for commercial ethanol production from forest biomass

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Forest biomass will be a critical part of the biomass feedstock supply. About 368 million dry tons of woody biomass (or ~30% of the total biomass) can be sustainably produced annually in the US. Forest biomass has several advantages over agricultural biomass for producing biofuel and bio-products. Its high density significantly reduces transportation cost, the flexible harvesting time eliminated storage cost. However, due to its unique physical structure and high lignin content, forest biomass exhibits a higher degree of recalcitrance for biochemical conversion than agricultural biomass. Two main barriers unique to forest biomass must be effectively removed through efficient pretreatment before forest biomass can play a significant role in the future biobased economy: (1) the significant energy consumption in physical size-reduction of forest biomass from logs to fiber/fiber bundle level for effective biochemical conversion, (2) the low enzymatic cellulose conversion efficiency especially biomass derived from softwood species, available in large quantities in many regions of US. In this presentation we will discuss recent advances we made that addresses these two critical barriers to forest biomass conversion. Specifically, we will discuss the SPORL pretreatment process that capable of achieving near complete cellulose conversion to glucose for softwoods with excellent hemicellulose sugar recovery and very low fermentation inhibitors. We will also discuss the post-pretreatment size-reduction approach for significant reduction of energy consumption for woody biomass size-reduction to about 50 Wh/kg, equivalent to those used by agricultural residues. Finally we will present some preliminary data on ethanol yield through fermentation, and the lignin properties for value-added product utilization.

PRESENTATION 20

Identification of fungal cellulases for efficient biomass conversion.

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Currently most biofuels are generated using feedstocks derived from sugarcane and corn, two feedstocks that are also used for human food. Cellulose, the major renewable carbon source on earth, can be obtained from plants that are not used for the production of food. Cellulosic feedstocks require prior enzymatic hydrolysis before they can be fermented into bioethanol. Our goal is to create an efficient cellulolytic enzyme system to overcome the current prohibitive costs and catalytic limitations of existing cellulolytic enzyme systems. In order to generate a more efficient cellulolytic enzyme system, we are searchig for new cellulose active enzymes that enhance the catalytic efficiently of existing cellulase systems. There are three main categories of enzymes that work cooperatively to degrade cellulose, cellobiohydrolases, endoglucanases and β-glucosidases. We are investigating 320 cellulase genes from 23 fungal species. The genes were selected via tblastn and have similarity to either one of two cellobiohydrolases from *Trichoderma reesii*, one of five endoglucanases from *T. reesii*, or a β-glucosidase from either *Aspergillus niger* or *Aspergillus oryzae*. All genes were PCR amplified, cloned in an appropriate expression vector and expressed in *A. niger*. The initial screen for functional expression of each gene is by measuring cellulolytic activity using a chromogenic substrate specific for each enzyme type. The most highly active enzymes are chosen for further biochemical characterization. The characterization includes pH and temperature optimum, temperature stability and measuring the substrate specificity. The candidates are then compared with commercially available enzymes and tested in combination with existing enzyme systems to assess their ability to improve cellulose hydrolysis. Lastly, promising new enzyme formulations will be tested for activity on pretreated lignocellulose feedstocks derived from various agricultural wastes and forestry residues.

PRESENTATION 21

Optimizing microbial conversion of biomass to liquid fuels

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Microbial conversion of woody biomass to liquid fuels depends on the robustness of fermentative microorganisms in the extraction and hydrolysis streams prior to pulping. Chemical and physical extraction to facilitate release of hemicelluloses can produce fermentation inhibitors. Inhibitors prevent or slow microbial fermentation and/or conversion of hemicelluloses to fuel ethanol. Although several inhibitors, such as acetic acid and furfural, are known, microbial inhibitors in woody biomass extraction streams are largely unknown. Our laboratory has established a bioassay and analytical procedures to identify and characterize inhibitors of a commercial yeast that is an effective hexose fermentor and an experimental yeast that is an effective fermentor of both pentose and hexose. Identification and characterization of inhibitors is a first step toward developing needed information about (a) process removal of inhibitors from extraction streams, (b) related costs and environmental impact of removal, and (c) microbial markers for strain improvement. This presentation will describe the bioassay used in extract processing of two industrially important wood species and discuss relevance of the findings for future biorefinery research at the Forest Products Laboratory.

PRESENTATION 22

Techno-economic analysis and optimization of wood biomass utilization in the greenhouse heating systems in British Columbia

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This paper presents a techno-economic analysis on a typical wood pellet and wood residue boiler for generation of heat to an average sized greenhouse in British Columbia. The variables analyzed included greenhouse size and structure, boiler efficiency, fuel types, and source of carbon dioxide (CO_2) for crop fertilization. The Net Present Value (NPV) showed that installing a wood pellet or a wood residue boiler to provide 40% of the annual heat demand is more economical than using a natural gas boiler to provide all the heat at a discount rate of 10%. A linear programming model is also developed to determine the optimum mix of wood pellet and wood residue for the heating application.

PRESENTATION 23

Extraction and purification of ferulic acid and vanillin from flax shives and other feestocks

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Extraction of ferulic acid and vanillin from flax shives, wheat bran and corn bran were carried out using two extraction methods, non-pressurised alkaline hydrolysis (0.5 M NaOH) and pressurised solvents (0.5 M NaOH, water, ethanol and ammonia). There were no differences in the content of products extracted with non-pressurised and pressurised 0.5 M NaOH solution yielding mostly ferulic acid, p-coumaric acid and small amounts of vanillin. Pressurised low-polarity water (PLPW), pressurised aqueous ethanol (PAE) and pressurised aqueous ammonia (PAA) were efficient in the one-step production of vanillin from ferulic acid in flax shives (guaiacyl-rich), wheat bran and corn bran (ferulic acid-rich). Vanillin was produced from the bound-ferulic acid via cleavage of the aliphatic double bond under the pressurised conditions. Higher content of ferulic acid in the corn bran yielded higher amounts of vanillin compared to wheat bran and flax shives. A simple and efficient purification procedure for ferulic acid from the alkaline extracts is presented. This procedure exploits the solubility of ferulic acid at different ethanol concentrations.

PRESENTATION 24

Triticale bran and straw are potential new sources of phenolic acids, proanthocyanins, lignans and alkyl resorcinols

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The distribution of phenolic acids (free and bound), proanthocyanidins, and lignans in defatted triticale bran and straw was determined. For comparison, wheat, rye and oat brans as well as triticale flakes and leaves were also assayed. In addition, optimal solid-liquid extraction conditions for alkylresorcinols (phenolic lipids) in triticale bran were determined. Most phenolic acids were present in the bound forms (89-98%), and released under alkaline extraction conditions. The content of phenolic acids ranged from 65.2 to 252.5 mg/100g in samples in which ferulic acid predominanted. Triticale straw was the richest source of proanthocyanidins, containing 862.5 mg/100g (catechin equivalents) of tissue. Triticale straw contained 0.27 mg/100g of lignan secoisolariciresinol diglucoside (SDG), whereas the bran had only 0.01 mg/100g. For alkylresorcinols (ARs), a total content of 270.3 mg/100g of triticale bran was obtained after extraction with acetone at 24ºC for 18-24 h and a solid to solvent ratio of 1:40. Saturated and unsaturated AR homologues, including C15:0, C17:0, C19:0, C19:1, C21:0, C21:1, C23:0 and C25:0 were detected in triticale bran. These results show that Canadian triticale by-products are good sources of phenolic acids, proanthocyanidin, lignans and alkylresorcinols and may have potential for use as nutraceuticals and/or functional food ingredients.

PRESENTATION 25

Pressurized low polarity water fractionation of lignocellulosic biomass for the production of bioproducts

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Lignocellulosic biomass is and attractive feedstock for the product of natural bioproducts due to their large quantity and low cost. Most lignocellulosic biomass is obtained from agricultural residues (straw from cereals and grains), hard and softwoods (chips, sawdust, other waste streams), or dedicated grass species. Pressurized low polarity water (PLPW) is a green technology that has shown promise in the fractionation and extraction of bioproducts from a wide variety of lignocellulosic feedstock. Our work has focused on the scale-up of the PLPW technology from a laboratory-scale unit, to a small production capable pilot-scale unit. At an operating temperature of 190ºC, the pilot-scale system produces a cellulose rich product containing 59.9% cellulose, 32.7% lignin, and 1.25% hemicellulose. This is comparable to the laboratory-scale system which delivers a product containing 63.7% cellulose, 28.5% lignin, and 2.0% hemicellulose at an operating temperature of 220ºC. Results indicate that the majority of the hemicellulose is extracted in the first 12 to 17 min of a 65 min extraction after which sugar monomers and degradation products appear.

PRESENTATION 26

Supercritical carbon dioxide and soxhlet extraction of waxes, polycosanols and phytosterols from flaxstraw

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The chemical composition and selected physical parameters of wax extracted from flax straw with supercritical CO_2 (SC-CO_2) and hexane have been determined. From the GC/MS results, clear variations in composition and component distributions were observed between SC-CO_2 and hexane extracted samples. The major components of SC-CO_2 and hexane extracts from three flax cultivars were: fatty acids (36-49%), fatty alcohols (20-26%), aldehydes (10-14%), wax esters (5-12%), sterols (7-9%) and alkanes (4-5%). Purification of SC-CO_2 extracted wax with silica gel chromatography yielded 0.4-0.5% (dry matter) and was composed primarily of wax esters (C-44, C-46 and C-48) and alkanes (C-27, C-29 and C-30). UV-Vis scans of the purified wax samples exhibited two main peaks indicating the presence of conjugated dienes and carotenoid or related compounds. FT-IR results showed prominent peaks at 2918 (-C-H), 2849 (-C-H), 1745 (-C=O), 1462 (-C-H), 1169 (-C-O) and 719 cm-1 (-(CH_2)n-), with NorLin wax showing a slightly deviated pattern compared to other samples. Thermal analysis by differential scanning calorimetry (DSC) revealed a mean melting point of 55-56 °C and oxidation temperatures at 146-153 °C for purified wax from flax straw processed using different procedures.

PRESENTATION 27

Genetic diversity for fermentable carbohydrates production in alfalfa

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Alfalfa (*Medicago sativa L.*) possesses several attributes that makes it a key element for sustainable bio-ethanol production. It is a low input perennial legume widely adapted to very diverse environmental conditions with essentially no nitrogen fertilizer requirements. However research is needed to develop biofuel-type alfalfa with enhanced biomass production and standability, increased persistence, and superior cell wall degradability. In addition, genetic improvement for the accumulation of readily fermentable non-structural carbohydrates (NSC) could significantly increase the ethanol conversion rates from alfalfa biomass. Genetic gains for these traits are tributary to the availability of screening techniques for the precise identification of superior genotypes within populations with large genetic diversity. We recently undertook a screening project to identify genotypes with superior cell wall degradability and NSC accumulation within 300 genotypes randomly selected within six genetic backgrounds from European and North American origins. Biochemical analyses of dried stems revealed a large genetic variability for NSC content with concentrations ranging from 20 to 100 mg g^{-1} DW. Interestingly, NSC variability was markedly higher in a genetic background of European origin as compared to the other populations, further highlighting the potential for genetic improvement for that trait. A modified commercial enzymatic cocktail (AccelleraseTM 1000, Genencor) is currently being developed to optimize the degradation of alfalfa biomass. An efficient enzymatic assay specifically designed for alfalfa biomass is a prerequisite to the identification of genotypes with contrasted degradability. Moreover, DNA extracted from genotypes with superior (30 highest) and inferior (30 lowest) cell wall degradability and/or NSC accumulation will be pooled and used for bulk segregant analysis of DNA polymorphisms using the PCR-based sequence-related amplified polymorphism technique. Identification of genetic markers associated with these traits will help accelerate the commercial release of biofuel-type cultivars of alfalfa.

PRESENTATION 28

Sructural carbohydrates, lignin, and micro-components in straw of selected canadian crops

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Agricultural crop residues are a major source of lignocellulosic material with considerable potential for use as a source of both renewable energy and high value chemicals. Canada has over 36 Mha of cropland available for agricultural crop production, which represents a significant opportunity to ensure environmental, social, and economic sustainability. In this study, structural carbohydrate, lignin, protein, and micro-component, including uronic acids, and acetyl groups content of wheat (CPS and Durum), barley, oat, triticale and flax straw were determined. The effect of biomass type, variety, presence of extractives and particle size on the measurement of chemical composition was examined. Results indicated that removal of extractives with water and 95% ethanol extraction significantly reduced the measured acid insoluble lignin values of all the feedstocks. Extraction time was positively related to the amount of extractives removed. The 24h water extraction of Ultima trticale straw produced an extractive value of 20.2% while the 12h water extraction yielded and exactive value of 17.7%. In addition, results showed that particle size affected measurement of the chemical composition of biomass, and the effect of particle size was influenced by biomass type. Varietal differences were also observed in some biomass types. Pronghorn triticale straw had higher values of total glycans and total lignins than Ultima triticale straw with a common particle size. Comparison of cereal crop straw types (wheat, barley, oat and triticale) in medium particle size, indicated that triticale and barley straws had the highest values of total glycans, 64.9 and 63.9%, respectively, while barley straw had the highest value of total lignin, 19.4%. Overall, total glycans, total lignins and extractives values in the cereal crop straws were in the ranges of 56.6-64.9, 14.7-19.4, and 6.8-20.2%, respectively. Total glycan values obtained from flax straw was relatively lower than those of cereal crop straws, yet the value of total lignins was highest in flax straw. This work has shown that optimization of processing conditions (water/ethanol/steam extraction conditions and particle size) are essential for effective utilization of agricultural crop residues as bioresource. Additionally, biomass type and variety may affect optimization of processing conditions.

PRESENTATION 29

Classifying Biorefinery Systems – The Approach of IEA Bioenergy Task 42 "Biorefineries"

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The increase of biofuels in transportation sector is the driving factor for the development of advanced processes to produce biofuels in biorefineries efficiently, whereas for the co-produced bio-based materials additional economic and environmental benefits might be gained. According to IEA Bioenergy Task 42 a "Biorefinery is the sustainable processing of biomass into a spectrum of marketable products" – (transportation) biofuels and bio-based materials, where other energy carriers (e.g. electricity) might be co-produced". With this perspective a biorefinery classification method for biorefinery systems was developed. The selection of the most interesting transportation biofuels until 2020 – biodiesel, bioethanol, biomethane, synthetic liquid biofuels, bio-hydrogen - is based on their characteristics to be mixed with gasoline, diesel and natural gas, reflecting the main advantage of using the already existing infrastructure; except hydrogen, which is a transportation biofuel and an important chemical.

The classification relies on four main features to describe a biorefinery system: 1) Platforms: e.g. C6 sugars, syngas;; 2) Products: transportation biofuels (e.g. FT-biofuels) and bio-based materials (e.g. glycerin); 3) Feedstock from forestry, agriculture, aquiculture, trade&industry; 4) Processes: e.g. thermo-chemical processes.

The platforms as the most important feature might be intermediates from raw materials towards biorefinery´s products, linkages between different biorefinery concepts and already final products. The number of platforms is an indicator for the complexity of a biorefinery. Each of the features consists of subgroups for detailed specification. All the platforms, products, feedstocks and conversion processes of the most promising biorefinery systems are combined in the classification network. A biorefinery is classified by the involved platforms, products and feedstock.

The next step is to develop acronyms for a quick classification of biorefinery systems and use this classification approach to describe the 10 – 15 most promising biorefinery system up to 2020 for IEA Bioenergy Task 42.

PRESENTATION 30

Integrative investment analysis of lignocellulosic biomass-to-bioethanol biorefineries in western Canada

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The continued development of the bioethanol industry is western Canada is demonstrated by the recent opening of two new plants in Saskatchewan in 2008. Both plants are wheat-based systems. New bioethanol paradigms based on lignocellulosic biorefineries are the focus of current initiatives by the public and private sector. However, there is no quantitative analysis of new bioethanol paradigms as investment concepts. Lignocellulosic conversion systems are considered to be theoretically more efficient than wheat-based ethanol systems. Within the context of the prairies, this assumption has not been quantified as an investment construct aimed at providing important parameters for both public and private sector investment in the emerging lignocellulosic biorefinery concept for western Canada, especially given the technical challenges associated conversion of lignocellulosic biomass to ethanol. To be a feasible investment proposition, the array of steps involved in the fractionation and conversion of the raw material input into a mixture of products including biodiesel, co-products, and direct energy need to be integrated and must economically and technically support the lignocellulosic refinery concept in terms of economies of scale and product yield at various capacities, increased productivity, lower production costs, maximized use of all feedstock components, by-products and waste streams, common processing operations, raw material supply, transportation cost, and equipment. This study undertakes a multi-region, multi-period, mathematical optimization model to analyze the system integration of the biorefinery in terms of optimal size of biorefinery plant, the trade-off between increasing transportation costs for feedstocks and decreasing average plant costs as the plant size increases; value of chemicals produced as co-products with bioethanol. The optimization model is used to identify key cost components and potential bottlenecks, and to provide parameters for reducing costs and prioritizing research. The study focuses on Saskatchewan and Manitoba to determine specific regions in the two provinces that are the most economical sources of lignocellulosic biomass, including timing of harvest and storage, inventory management, biorefinery size, and biorefinery location, as well as the breakeven price of ethanol, for a hydrolysis-fermentation process.

PRESENTATION 31

Bayesian network modelling of regional biofuel supply chains

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We present a Bayesian network model of bioenergy supply chain dynamics. The model links conditional dependencies between climate variables with cropping area selection, seeding, fertilizer and water additions, harvesting, collection, pre-treatment, storage, transport, conversion and co-products. This approach incorporates uncertainty and can be easily interrogated, adapted and expanded as knowledge of a wide variety of resource stakeholders improves. The model is tested with spatial data on yield distribution and climate for energy crops in Western Canada. We present preliminary findings comparing crop mixtures and supply logistics. This work will compare network designs against future demand scenarios and known ecological constraints.

PRESENTATION 32

Establishment to biorefinery by supercritical fluid technologies

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Due to human activities on the mass-production, mass-consumption and mass-waste, environmental issues such as global warming and acid rain became increasingly serious in the world. In such environmental situations, biomass resources, which are renewable, carbon-neutral and remarkably massive in amount on the earth, are getting important as an alternative of fossil resources. For the chemical conversion of biomass resources, on the other hand, supercritical fluid has recently received an attention as a new reaction field due to its unique properties. In this paper, therefore, current progress in research and development for environmentally benign supercritical fluid technologies is introduced as one of the approaches for biorefineries from biomass resources, through chemical conversion of lignocellulosics by supercritical and subcritical water as well as alcohols. With these academic achievements, zero-emission type biomass conversion system will be proposed for establishing biorefineries of biofuels and biochemicals.

PRESENTATION 33

Quantification of the major carbohydrates, alcohols and toxic components in a bio-based medium by dual detection hplc analysis

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Bio-based media derived from cellulosic biomass resulting from depolymerisation or bioconversion processes are complex media composed of several chemicals and biochemicals. In this study, the main components of a hemicellulosic-based medium was analyzed using a dual detection HPLC method to separate and determine concentrations of the major monosaccharides (glucose, xylose and arabinose), alcoholic and acidic components (ethanol, xylitol and acetic acid) and furanic compounds (furfural and hydroxyl methyl furfural (HMF)) using one separation column (Aminex HPX-87H) and two detectors. The analyses were performed under isocratic condition with mobile phases consisting of 5mM sulfuric acid and acetonitrile in different mix ratios from 0 to 0.061 mole fraction of acetonitrile. Finally, based on the analysis duration and chromatogram quality, the optimum condition was determined for simultaneous determination of the components.

PRESENTATION 34

Differential adsorption and desorption of cellulase components may promote the development of an effective enzyme recycling strategy for cellulosic bioethanol production

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Global warming and the world's dependence on fossil fuels have generated a considerable interest in transportation fuels derived from renewable resources. Bioethanol is a cleaner and more sustainable option for transportation fuels than fossil fuels, and its use is associated with low greenhouse gas emissions. Problems associated with the use of food resources for bioethanol production have sparked interest in the second generation bioethanol that is generated from lignocellulosic biomass such as forest and agricultural residues. Lignocellulose is the most abundant renewable material on the planet, and the cellulose can be enzymatically hydrolyzed to glucose for bioethanol production. However, cellulosic ethanol production has not reached an economical scale because of the complex nature of the starting material. Compared with starch or sucrose, the feedstock for the first generation bioethanol, lignocellulose is more resistant to enzymatic attack, and its conversion to fermentable sugar is a more complex, difficult, and hence expensive process.

To bring the production of lignocellulosic bioethanol into a commercial scale, a further reduction in production costs is necessary. This cost reduction may be achieved by reusing the enzymes for multiple rounds of hydrolysis. A previous study has indicated that cellulases, the enzymes used to hydrolyze cellulose to glucose, are robust and have a high affinity to the substrate. The temperature stability of a commercial cellulase mixture was investigated over an extended period of hydrolysis. Understanding the kinetics of the enzyme adsorption and desorption from the substrate is key to enzyme recycling. By studying the differential adsorption capacities among different enzyme components, key enzyme components that may go missing either through unproductive binding to the residue after several rounds of hydrolysis could be identified. Gel electrophoresis will be used to follow the presence of enzyme components in the hydrolysate. Developing a comprehensive recycling strategy for the whole array of cellulase components is the ultimate goal of this study.

PRESENTATION 35

Optimization of ruminococcus albus endoglucanase cel5-cbm6 production in plants by incorporating an elp tag and targeting to different subcellular compartments

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Biofuels seem to be the key for energy sustainability and a clean environment. However the production of biomass-based biofuel depends on the deconstruction of a cellulosic matrix and requires a cocktail of enzymes that hydrolyze glycosidic bonds to release fermentable sugars used in the production of ethanol. Endoglucanases are one of most important groups of natural cellulosic hydrolytic enzymes that act on cellulose by cleaving β-1,4-glycosidic linkages. Reducing the cost of producing cellulases is critical to meet ethanol production cost targets. In the past decade, plant-based expression systems have emerged as a serious competitive force in the production of recombinant proteins. Genetically engineered transgenic plants are one of the most economical systems for large scale production of recombinant proteins due to the large quantity of enzymes that can be produced with minimal input. It has been demonstrated that cellulases present different levels of expression in different subcellular compartments. Cel5-CBM6 is a fused protein containing an endocellulase from *Ruminococus albus* (Cel5) and a cellulose binding domain (CBD) of *Clostridium stercorarium* and has been described to accumulate in the chloroplast and cytoplasm. However, when expressed in the cytoplasm, severe growth defects were observed. It is essential that others subcellular compartments such as endoplasmic reticulum (ER) and vacuole be evaluated and compared to determine the best compartment for production and activity of cellulases. Also, elastin-like polypeptide (ELP), a pentapeptide repeat polymer (Val-Pro-Gly-Xaa-Gly) that forms an aggregate above its transition temperature and has utility in the purification of recombinant proteins, has been shown to increase recombinant protein accumulation in plants. We have evaluated the effects of incorporating an ELP tag and a retrieval signal peptide (KDEL for ER, CTPP for vacuole) on the expression levels of Cel5-CBM6.

* This work is part of the CBioN network

PRESENTATION 36

Assessment of multi-enzyme operon engineering of tobacco chloroplast genome for high-level simultaneous expression of cellulolytic enzymes

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Biofuels draw a lot of attention nowadays as an environmentally-friendly substitution for depleting fossil fuels. Yet, currently commercially produced biofuels are mostly generated from starch or sugar and supply only a limited fraction of global fuel requirements. Alternatively, cellulosic biomass can serve as abundant and renewable source of fermentable sugars. The major obstacle in the process of the biomass-to-fuel conversion is the high cost of the pre-treatment and the cellulolytic enzyme cocktails, which are at present expensively produced in microbial bioreactors.

Plant genetic engineering techniques provide an economically-attractive base for production of recombinant proteins due to the low-cost of the growing "bioreactors". Transformation of tobacco chloroplast genome has proven to be very prolific in terms of recombinant protein yield, which usually reaches 10-20% (up to 46%) of total soluble protein. Furthermore, being of bacterial origin, plastid transcription-translation machinery allows simultaneous expression of several genes from artificial operons, providing a possibility for engineering a number of proteins in one transformation step.

Our goal is to produce transplastomic tobacco plants bearing single genes as well as operons of cell wall-degrading enzymes for high-level expression. In tobacco chloroplasts we will attempt to reproduce an engineering approach, demonstrated in bacteria, for the generation of a potent mini-cellulosome. We will evaluate combinations of enzymes produced for their ability to degrade biomass. Possibility of using crude extracts of highly-expressing plants as an additive in the biomass fermentation process will be examined. In addition, plants transiently expressing cellulolytic enzymes which are directed to other cellular compartments (endoplasmic reticulum, vacuole) will be compared with transplastomic plants in terms of productivity.

PRESENTATION 37

Screening of natural isolates and metagenomic libraries for novel cellulases/xylanases

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This paper would discuss isolation and molecular characterization of fungal isolates (mesophilic/thermotolerant) as well as metagenomic libraries from landfills for novel cellulases/hemicellulases. The aspect like purification, characterization and multiplicity of cellulases/xylanases as well as their sequential and differential expression in response to different simple and complex molecules would be discussed. The use of 2D based proteomic approaches for identifying novel cellulases is also envisaged. The application of cellulases in saccharification of agro residues for ethanol fermentation as well as role of these cellulases in biological deinking will also be highlighted.

PRESENTATION 38

Diverting electron fluxes to hydrogen in mixed anaerobic communities

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Hydrogen production using a batch anaerobic mixed culture maintained at 21°C and adjusted to pH 7.6 was assessed in the presence of linoleic acid (LA) and oleic acid (OA). Inhibiting methane production in the mixed culture was successfully achieved using LA and OA. Hydrogen was produced when glucose was added together with LA or OA. When the methane production rate decreased with increasing LA (500 to 2,000 mg l^{-1}) and OA (500 to 2,000 mg l-^{1}) concentrations, increasing hydrogen yields were observed. The maximum hydrogen yield detected for LA and OA fed cultures were 1.1 and 1.3 mol/mol glucose, respectively. In the presence of LA, the volatile fatty acid (VFA) produced included formate, acetate, propionate and butyrate. However, in the case of cultures receiving OA, the VFA produced were acetate, propionate and butyrate. Acetate, propionate butyrate, formate and hydrogen accumulation suggests inhibition of aceticlastic methanogens, propionate degraders, butyrate degraders, formate degraders and hydrogenotrophic methanogens, respectively. Formate accumulation is a major issue in culture fed with LA because it is an intermediate in the formation of methane and in addition its production is linked to decreasing hydrogen production. Hydrogen was produced when glucose was added again on day 4.

The acetate to butyrate ratio served as an indicator of pathway dominance. For cultures receiving 500 mg l^{-1} LA the ratio was large on days 1, 5 and 7. The acetate levels observed in cultures receiving ≥ 1,500 mg l^{-1} LA were elevated on days 5 and 7; however, the quantities were less and those fed with 500 mg l^{-1} LA. In comparison, for cultures receiving 2000 mg l^{-1}OA a strong dependence towards acetate production was observed up to day 2. Acetate production was greater than butyrate production in cultures fed with ≥ 1,500 mg l^{-1} OA. In general, larger quantities of acetate were produced in cultures fed with OA and the hydrogen yield was the greatest in cultures receiving 2,000 mg l^{-1} OA. The electron equivalence distribution was analyzed using a stoichiometric metabolic network model (Cell Network Analyzer). The model predicted the electron fluxes were diverted towards hydrogen production instead of methane.

PRESENTATION 39

Bioethanol production from lignocellulosics with hot-compressed water treatment followed by acetic acid fermentation and hydrogenolysis

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A new ethanol production system which involves hot-compressed water treatment coupled with acetic acid fermentation and subsequent catalytic hydrogenolysis has been developed. In order to optimize the hot-compressed water treatment, the semi-flow type two-step treatment was adopted to Japanese beech wood (*Fagus crenata*) with appropriate conditions; 230°C/10MPa for 15min in the first-step, and 270°C/10MPa for 15min in the second-step. Under these conditions, 54% of hemicelluloses (15.6wt% in wood basis), and 71wt% of cellulose (32wt% in wood basis) were effectively hydrolyzed, respectively. However, around 12wt% of wood was decomposed into dehydrated and fragmented products, which further into organic acids. At the same time, about 88% of lignin (22wt% in wood basis) was decomposed by ether linkage cleavage and collected as water-soluble and oily portions. These various compounds such as poly-saccharides, oligo-saccharides, mono-saccharides, their decomposed compounds and lignin-derived compounds were then studied on their fermentability to acetic acid. As a result, mono-saccharides, some decomposed compounds and lignin-derived compounds were all found to be fermentable to acetic acid with *Clostridium thermoaceticum.* Particularly, glucose, xylose and fructose could be effectively converted to acetic acid with 70-80% in yield. Oligo-saccharides and poly-saccharides were, however, converted with C. thermocellum to glucose and organic acids etc. as by-products. Therefore, *C. thermoaceticum* and *C. thermocellum* were co-cultured and even oligo-saccharides and poly-saccharides were found to be effectively fermented to acetic acid. Therefore, almost all compounds obtained by the hot-compressed water treatment were proven to be converted to acetic acid in co-culture fermentation. For ethanol production from acetic acid, one-step hydrogenation method to ethanol was evaluated, with a flow-type reactor assembled in our laboratory. As a result, with 5% Ru-C catalyst, acetic acid was directly to ethanol at > 320°C/2.0MPa even in a stoichiometric molar ratio of hydrogen to acetic acid being 2. In this system, very dilute aqueous solution of acetic acid was effectively hydrogenated to ethanol. By combining these three steps of hot-compressed water treatment followed by acetic acid fermentation and hydrogenation, the ethanol production from lignocellulosics was made more efficient, compared with the conventional yeast fermentation.

PRESENTATION 40

Genome shuffling of pentose-fermenting yeast pichia stipitis for improved tolerance to hardwood spent sulphite liquor

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Genome shuffling is a powerful microbial strain improvement technique that uses iterative cycles of genome recombination and selection to combine the useful alleles of many parental strains into single cells showing the desired phenotype. Genome shuffling involves generation of mutant strains that have an improved phenotype, followed by multiple rounds of mating among the mutants to allow recombination between genomes. In this study, we used genome shuffling based on the natural mating and sporulation ability of the pentose-fermenting yeast *Pichia stipitis* to isolate stable mutants with improved tolerance to inhibitors in hardwood spent sulfite liquor (HW SSL). Six UV-induced mutants of *P. stipitis* were used as the starting strains for 4 rounds of genome shuffling. Mutant libraries were established after each round and these improved strains served as the starting pool for the next round of shuffling. After every round, improved strains were selected based on their growth on HW SSL gradient plates. Tolerance to HW SSL increased progressively with each round of shuffling. Fermentation performance of the 2 best HW SSL tolerant strains was tested in defined media and in diluted HW SSL. Both mutant strains utilized 4% (w/v) of xylose or glucose more efficiently and produced more ethanol than the WT. They also utilized 4% (w/v) of mannose or galactose and produced ethanol at the same level as *P. stipitis* wild type (WT). The genome shuffled strains produced ethanol in 85% and 90% (v/v) HW SSL. In contrast, the WT was unable to produce ethanol at 60% (v/v) or higher concentrations of HW SSL. Since HW SSL contains many of the same inhibitors commonly found in other lignocellulosic hydrolysates, it would be of interest to test the performance of genome shuffled strains in other lignocellulosic hydrolysates.

PRESENTATION 41

Seedling tolerance of Ethiopian mustard to metal salts

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Canada has vast acreages of marginal land, which are unsuitable or uneconomic for food crop production, but may be suitable for industrial crops if varieties with stress tolerance and low inputs can be selected. Ethiopian mustard (Brassica carinata) is being developed as a biorefinery seed crop for extraction of biodiesel, natural pesticides, valuable proteins, and a low-fibre fish feed. It is also being investigated for its potential to contribute into an inventory of biomass feedstocks for cellulosic ethanol. Yellow-seeded proanthocyanidin/lignin-reduced types rather than brown-seeded proanthocyanidin/lignin-rich types are being utilized by plant breeders to achieve several of these biofuel objectives.

To explore B. carinata potential for growth on prairie saline or metal-contaminated land rather than utilizing valuable cropland, we tested growth and tolerance mechanisms for seedlings of two near-isogenic yellow-seeded and brown-seeded lines on several metal salts. Initial results with the non-physiological lithium chloride showed that exposure of seedlings to increasing concentrations of lithium affected the germination rate, root length, chlorophyll content and fresh weight of both lines, but lithium hyper-accumulated, the lipid and phenolic composition dramatically changed, and seedlings survived moderately high concentrations of lithium (>150 mM) in the brown-seeded line. This suggested the development of a tolerance mechanism, in which sinapic acid esters and chloroplast lipid were replaced by benzoate derivatives, the valuable anti-oxidant resveratrol, and oxylipins. In contrast, the yellow-seeded plants maintained identical phenolic and lipid compositions before and after exposure to lithium and did not tolerate the higher lithium concentrations tolerated by the brown-seeded line. Microarray analysis using a Brassica napus 15, 000 expressed sequence tag (EST) array indicated a total of 89 genes in the brown-seeded line and 95 genes in the yellow-seeded line that were differentially expressed more than 20-fold after treatment with lithium chloride, and 1083 genes changed expression more than two-fold. Differentially expressed genes included proteins involved in defense, primary metabolism, transcription, transportation, secondary metabolism, cytochrome P450 and unknown functions. Expressed genes differed between the two lines exposed to lithium, and the expression patterns generally supported the phytochemical data. The presentation will compare these lithium-directed responses with B. carinata responses to growth on sodium sulphate (the prime component of prairie saline soils) and cobalt chloride.

PRESENTATION 42

Sugar rush: prospects for a global market in sugarcane ethanol

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This paper examines the prospects for a global market in sugarcane ethanol from an economic perspective. Sugarcane ethanol is thus far the most efficient feedstock for ethanol. However, there are severe obstacles to such trade, including lack of standards and protectionist barriers. Once those barriers are overcome, we can lay out the contours for the supply and demand for a potentially vast and lucrative global market that would change the fortunes of many developing countries and possibly provide a feasible means of reducing global dependency on petroleum.

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