Bioenergy Research @ UNBC

Special Edition

This special edition issue of the newsletter coincides with the grand opening of the UNBC Bioenergy Plant. We are highlighting research projects being conducted at UNBC related to non-traditional uses of biomass. The research profiled in this issue is contributing to an improved understanding of these 'growing' applications

Harold Hume, Research Project Officer

Project: Biomass Energy in Central British Columbia: Framing the issues
Steve Helle, Art Fredeen, Mike Rutherford, Greg Halseth, Mike Gillingham, Ken Parker, Hugues Massicotte

A group of UNBC researchers have produced a paper on bioenergy opportunities in BC's Central Interior.
Bioenergy, or energy derived from biomass, was the predominant energy source for humans from prehistory to the mid- 19thcentury. With on-going energy security issues, rising greenhouse-gas (GHG) levels by fossil fuel energy consumption and volatile natural resource prices, the biomass energy of yesterday is no being re-evaluated as the energy source for tomorrow. The technology of bioenergy production has evolved considerably in recent years, such that heat, electricity and liquid fuels for transportation can all be derived from a wide variety of biomass starting materials. Though the transformation of sunlight energy into chemical biomass energy in plants is in theory an endlessly renewable process, the way in which we manage our lands to generate this biomass energy can be degradative and unsustainable when all of the land–use values are taken into account. This paper evaluates bioenergy through the prism of sustainability, highlighting issues relating to the physical and temporal scales of the resource and impacts of its use, technological opportunities and limitations, net environmental impacts, and community concerns and needs. The geographic focus is the central interior of British Columbia, however, the issues raised in this paper will be relevant to all locations considering bioenergy.
Please see http://www.unbc.ca/assets/nres/nres_op_04_helle_et_al_2009.pdf for full text of the paper.

Project: Analysis and Optimization of UNBC's Heat Distribution System
Esteban Flores and Aaron Rodriguez Lopez, supervised by David Claus and Steve Helle

Two international exchange students, Esteban Flores and Aaron Rodriguez Lopez, are modelling the UNBC district heating system. A major upgrade was completed on the piping that comprises the distribution system in 2010 to improve its hydraulic efficiency and prepare for implementation of a biomass gasification heat source. The students are analyzing the performance of this piping system that distributes heat from the Bioenergy Plant to the eight central buildings on campus. This will allow the system to be optimized thus ensuring that pumping requirements are minimized. This will make the UNBC campus more energy efficient.

Project: Material and Energy Balance of Pellet Heating System
Stanley Brown, supervised by Steve Helle and Michael Rutherford

Using data collected from the IK Barber Enhanced Forestry Laboratory pellet heating system, Stanley Brown carried out a detailed energy balance to determine both the efficiency of the new system and a calculation of the fossil fuel CO_2 emission savings compared to the natural gas heating system that was used previously. Using a chemical analysis of the pellets and ash, and measuring the amount of ash produced, a material balance on the system was also completed.

Steve Helle & Michael Rutherford

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Project: Terahertz Technology for Bioenergy Applications
Matt Reid, Erik Jensen and Ian Hartley, with undergraduate student Kimberly Lawyer

This research project, funded by the Canada Foundation for Innovation and the British Columbia Knowledge Development Fund, involves the assembly of a terahertz (THz) time-domain spectroscopy unit to be deployed on UNBC's bioenergy systems. This work will enable further development of the technology, which has potential practical applications. The project will undertake spectroscopy of rotationally active molecules expected in the flue gases of bioenergy systems, including CO, H_2O, NO_x and SO_x.

The first stage of the project is to determine the limits of detection for individual species and mixtures of species for emissions monitoring of flue gases, and to assess the utility of the instrumentation as a non-contact, remote-sensing technology using silicon view ports that have been installed on the stack of UNBC's bioenergy systems.

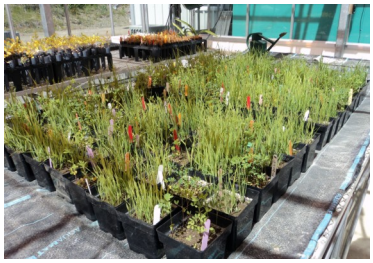
The second stage of the project will be to undertake detailed studies of the effects of temperature and pressure changes on the rotational absorption lines of these same molecules. The goal of these investigations will be to determine the suitability of THz technology to simultaneously probe the concentration, temperature and pressure of the species. If successful, deployment of the technology close to the combustion process should allow engineers to extract new and valuable information about the combustion process. These capabilities could potentially allow for improved efficiencies and/or reduced emissions from combustion systems.

The third stage of this project is to study the scattering of THz radiation off of particulate to determine if THz technology can be used for real-time particulate monitoring in flue gases. Because of the longer wavelengths associated with THz technology, there is a reduced sensitivity to thermal background radiation which causes difficulties with infrared technologies, and decreased insensitivity to larger aggregations of particulate which causes problems for optical technologies.

This study will be undertaken with three summer undergraduate research projects in conjunction with the a graduate student (coming in the fall 2011), all of whom will work with the principal and co-investigators.

Project: Utilization of Biochar and UNBC Ash as Amendments in Agricultural Soil
Stanley Brown, supervised by Michael Rutherford and Steve Helle

Biochar has been proposed as a soil amendment to enhance soil properties, sequester carbon and increase the yield of agricultural crops. But biochars differ in their properties and various soils respond differently to biochar addition, as do different plant species. Ash materials produced through combustion or gasification also have the potential to improve soil properties by increasing soil pH and by supplying plant nutrients. This study investigated the influence of biochar and ash addition on soil properties, biomass yields (alfalfa, orchard grass and timothy grass) and metal uptake by plants grown in an agricultural soil typical of north-central BC. Complementary undergraduate projects in the UNBC Environmental Science 418 course also examined the influence of these amendments on soil physical properties (biochar) and soil biota (ash). In-kind support for this work was provided by Alterna Biocarbon.



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Project: Gasification of Boiler Ash
Nicholas Finch, supervised by Steve Helle

A feasibility study was conducted using the gasification process to recover some of the energy residue in typical wood ash. Often wood combustion is not complete, leaving a small portion of the original carbon and energy content in the ash residuals. Gasification of the carbon will recover the residual energy and have the added benefits of reducing the ash volume for disposal, increasing the ash suitability for alternative uses such as land application, and result in better utilization of the fibre resource.

Project: Characterization and Mobility of Biomass Ash Constituents
Erwin Rehl, supervised by Kerry Reimer and Michael Rutherford

Erwin Rehl

Ash materials produced through combustion or gasification have potential uses as soil amendments. Soil application is attractive compared to the more common alternative of landfilling. But there are pros and cons to soil application and research is needed to carefully characterize ash materials and determine their impacts on soils, plants and the receiving environment. M.Sc. student, Erwin Rehl, is studying the characteristics of UNBC ash materials (pellet plant and gasifier ashes), including the mobility of metals (including nutrients), and the reaction of ash constituents with soil components. The information gained in these studies will contribute to better ash management practices in north-central BC.

Project: Biomass Combustion Residues
Nathan Park, supervised by Michael Rutherford and Ron Thring

A project has been completed characterizing two different types of ash produced from the university wood pellet furnace. This ash was then used as a soil amendment for two local soils in a greenhouse study. The ash was shown to be a powerful liming agent and a valuable nutrient source for plants. Plant growth was significantly increased in some cases. Plant uptake of environmentally sensitive trace elements was not increased.

Mr. Park is also working on a project involving the use of biochar as a soil amendment. Biochar is produced by the incomplete combustion of biomass. It is similar to ash, but has a higher carbon content. Nathan is investigating the ability of biochar to retain plant nutrients in soil and prevent the leaching of heavy metals.

Project: Biochar Enhances Seedling Growth and Alters Root Symbiotic Fungi in Forest Soils
Susan Robertson, Michael Rutherford, Hugues Massicotte and Juan Carlos López-Gutiérrez

Biochar is produced during the low-temperature pyrolysis of waste biomass materials. This charcoal-like material may be used as a soil amendment to sequester carbon and promote plant growth. But little is known about how biochar may influence beneficial root symbionts in forest soils. With generous in-kind support from Alterna Biocarbon, the group investigated the response of pine and alder seedlings, soil properties and the occurrence of root symbionts (mycorrhizal fungi) in forest soils. Biochar addition enhanced early growth of alder and pine seedlings, and increased the frequency of mycorrhizal presence on pine roots.

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Special Edition

Project: Immobilization of Heavy Metals by Co-Pyrolysis of Contaminated Soil with Woody Biomass
Fikre Debela, supervised by Joselito Arocena and Ron Thring

This project involved investigating the potential application of pyrolysis (heating to a high temperature in a low-oxygen environment) to a mixture of woody biomass and metal-contaminated soil as an alternative eco-friendly option to stabilize metals in soils. The specific objective was to test combinations of high heating temperature and heating time to determine the effectiveness of different treatments to successfully encapsulate metals from the contaminated soil into a soil-biomass matrix. Various ratios of soil and biomass were treated under different heating temperatures and time combinations in a laboratory batch reactor. Physicochemical and morphological characterizations, as well as leaching tests, were conducted on the treated samples. The study demonstrated that several factors including the type of metal, heating temperature, heating period, and the amount of biomass influence the efficiency of pyrolysis to immobilize metals in a contaminated soil.

Project: Catalytic Upgrading of Chemi-Mechanical Pulp Mill Sludge
Jamie Hill, supervised by Ron Thring

Pulp mill sludge from a nearby chemi-mechanical pulp mill was pyrolized (heated in a low-oxygen environment) in a fixed-bed reactor with and without catalysts. Two heterogeneous (zeolitic) catalysts were employed along with reaction temperatures in the 450 to 550ºC range. Depending on the reaction conditions, the products ranged from gaseous to liquid to solid. The experiments with catalysts produced more liquid products compared to those without catalyst when the same reaction conditions were employed. The gases produced were analyzed and found to be comprised mostly of methane, carbon monoxide, carbon dioxide, some ethane, and small amounts of hydrogen. Characterization of the liquid and solid products is still ongoing.

Project: Co-Processing of Organic Waste Mixtures using Heterogeneous Catalysts
Harpuneet Singh Ghuman, supervised by Ron Thring

This research project is primarily focused on exploring the potential of co-processing of local organic waste mixtures using selective reforming processes and heterogeneous catalysts to generate valuable hydrocarbon fuels and chemicals. The choice of organic waste and catalyst will be based on several criteria, including compatibility as well as ease of recovery and separation of catalyst and products. The project aims to address three major issues:

1. Determine the degree of waste-catalyst compatibility and product yield;
2. Assess the broad kinetics of the important reactions under controlled conditions; and
3. Assess the final product characteristics and the amounts of valuable fuels and chemicals.

Two groups of waste will be studied, one with a wood component and the other with an oil component. The research is consistent with the principles of green chemistry as it employs wastes as inputs and produces useful outputs, without using large amounts of solvents. A laboratory-scale reactor will be used for most of the experimental work. Catalyst choices will be limited to specific forms of zeolites, known to produce good yields for hydrocarbon-type fuels and other useful chemicals.

Harpuneet Singh Ghuan

Bioenergy Research @ UNBC

Special Edition

Project: Anaerobic Digestion
Nathan Park, supervised by Ron Thring

A study has recently been completed in conjunction with the City of Prince George on the anaerobic co-digestion of organic waste and sewer sludge. The Lansdowne wastewater treatment plant in Prince George utilizes anaerobic digestion to reduce the volume of biodegradable solids in the city's wastewater. Methane gas is produced as a by-product of the process, and this flammable gas can be utilized on site to produce electricity or heat. Nathan undertook a six-week pilot project involving the anaerobic co-digestion of over 15,000 kilograms of local supermarket organic waste in an attempt to increase the methane production of the digesters. Average daily methane production was increased slightly when compared to previous years with no negative effect on digester performance. Nathan is also modelling and comparing greenhouse gas emissions between different disposal methods and disposal options for organic waste within the City of Prince George.

Project: Characterization and Identification of Useful Liquid and Solid Products from Catalytic Upgrading of Pulp Mill Sludge
Nathalie Rehl, supervised by Ron Thring and Quanji Wu

The liquid and solid fractions produced from the pyrolysis (exposure to heat in a low-oxygen environment) of pulp mill sludge were chemically characterized using appropriate analytical chemical methods. The chemical functionality of the solid products changed quite dramatically, especially with increasing pyrolytic temperature. Also, the liquid fraction was found to contain a variety of components, including useful and high-octane aromatic hydrocarbon compounds such as toluene and xylene normally contained in gasoline-type fuels. The potential for producing these commercial fuels from renewable waste resources instead of petroleum is again shown in this study.

Recent UNBC Bioenergy awards

- UNBC and Harvard: #1 Campus Sustainability Project in North America awarded by the Association for the Advancement of Sustainability in Higher Education (AASHE), November 2010. (for enhanced forest laboratory pellet project.)
- Technology and Industry News Maker of the Year at the Northern BC Business and Technology awards, January 2011. (North American award for campus sustainability as result of the construction of the Bioenergy Plant.)

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UNBC Northern Analytical Laboratory Services (UNBC-NALS)

UNBC is home to an extensive suite of analytical science instrumentation that allows the institution to undertake a broad spectrum of biological, chemical and physical analyses. This analytical capability is unique in northern BC. *UNBC is proud to announce that we will be making these services available to the private, public and non-profit sectors in the near future.*

UNBC intends to offer the following analytical laboratory services:

- Water/Air/Soil Environmental Analyses
- Soil/Rock Mineralogical Analyses
- Agricultural Products/Food Products Analyses
- Microbiological Analyses
- DNA Sequencing
- Wood/Wood Products Analyses
- Bioenergy Analyses
- Petroleum Analyses

Stay tuned for further information! In the interim, please visit our websites (www.unbc.ca/cel and www.unbc.ca/genetics/index.html) for details about some of the capabilities that will soon be available.

If you have any questions, please don't hesitate to contact Dr. Francis Appoh, Analytical Chemistry Services Manager, at appoh@unbc.ca or 250-960-6650. We welcome your feedback!

Pacific Institute for Climate Solutions
Knowledge. Insight. Action.

UNBC

British Columbia
The Best Place on Earth
Year of Science

Understanding Forests, Carbon, and Climate Change

Workshops in Prince George March 22nd, Terrace March 24th, and Quesnel March 29th. To register for this event please visit www.unbc.ca/pics.

The Pacific Institute for Climate Solutions, UNBC and the BC Year of Science are hosting three workshops in Northern BC to help uncover the new opportunities provided by our forests. The workshops start by asking the question; what is wood? Understanding the basic processes of a growing forest helps to understand the important relationship they hold with climate change. Why biomass fuel from forest wastes is considered carbon neutral will be discussed along with the issue of forest sustainability.

The next step in the workshops will be to take a practical look at the uses of wood energy and the options available to organizations and individuals for use. The biofuels to be discussed include: wood pellets, hog fuel, and liquid biofuels such as ethanol, biodiesel, and biogasoline. The process of gasification will also be explained in great detail to showcase the UNBC bioenergy project.

Following an explanation of what biofuels from wood are, the workshop will change focus to carbon offsets from forestry. Carbon offsets can not only be created by using bioenergy instead of traditional fossil fuels but also by growing trees to absorb and sequester carbon dioxide from the air. To this end, the final section of the workshops will answer the question; how much carbon is in this tree?