# Bioenergy & Biofuels (ENGG*6090)
# Winter 2013 Course Outline

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**Instructor**:

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**Lab Technician:**

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**Lectures:**

Wednesday (10:00 am – 1.00 pm), Room: Thrn 1427

**Textbook:** Lecture notes

**Reference Books:**

1. Christopher Higman: Gasification, Elsevier, 2008
2. Peter Quaak, Harrie Knoef and Hubert Stassen: Energy from Biomass-A Review of Combustion and Gasification Technologies, World Bank Technical Paper No. 422 Energy Series 1999.
3. A.V. Bridgwater: Advances in Thermochemical Biomass Conversion, Springer, 2008
4. H.A.M Knoef: Handbook Biomass Gasification, BTG, 2005.
5. Bhattacharya S.C. and Salam P.A.: A Review of Selected Biomass Energy Technologies, RERIC, 2006
6. Donald L. Klass: Biomass for Renewable Energy, Fuels, and Chemicals, Academic Press, 1998
7. C. Y. WereKo - Brobby and E. B. Hagan: Biomass Conversion and Technology, John Wiley and Sons, 1996.
8. Souza-Santos M.L,: Solid Fuel Combustion and Gasification, Marcel Dekker Inc. 2004.
9. Prabir Basu: Combustion and Gasification in Fluidized Beds, CRC, 2006
10. Prabir Basu: Biomass Gasification and Pyrolysis: practical design and theory, 2010

**Notes:**
Copies of lecture presentation materials, plus supplemental material, will be posted on Courselink. (Note: posting of all materials shown or discussed in class is not guaranteed.)

**Rationale:**

Biomass is one of the most important sources of energy in the developing countries, and provides 14% of the world's energy. Recently, Biofuels is considered to be one of the most important sources of energy in transportation sector, and expected to provide energy security. This course deals with the technologies of converting biomass into upgraded fuels as well as direct combustion

**Learning Objectives:** Canadian Engineering Accreditation Board – Graduate Attributes

| Graduate Attribute | Taught | Assessed | Graduate Attribute | Taught | Assessed |
|---|---|---|---|---|---|
| 1. Knowledge Base | Y | Y | 7. Communication | N | Y |
| 2. Problem Analysis | Y | Y | 8. Professionalism | N | N |
| 3. Investigation | Y | Y | 9. Environment & Society | N | Y |
| 4. Design | Y | Y | 10. Ethics and Equity | N | N |
| 5. Engineering Tools | Y | Y | 11. Project Mgmt | N | N |
| 6. Individual & Team Work | N | Y | 12. Life-long learning | N | N |

**Catalog Description:**
Introduction to biomass conversion; physical conversion of biomass: drying and dewatering, densification and separation of biomass; thermochemical conversion of biomass: torrefaction, pyrolysis, gasification and combustion; Heat and power applications; biogas production: digester design and kinetic considerations; ethanol, methanol, and bio-diesel conversion technologies: properties and technologies for production from energy crops and lignocellulosic materials; and environmental impacts.

Pre-requisites: Consent of Instructor

**Course Outline:**

I. Introduction
   1. Biomass Resources
   2. Modes of Biomass Utilization for Energy
   3. Routes of Biomass Conversion Processes and biofuels production technologies

II. Characteristics of Biomass Fuels
   1. Composition
   2. Ultimate and Proximate Analyses
   3. Heating Value

III. Physical Conversion
   1. Dewatering and drying: Fundamentals, moisture content and conversion requirements, methods
   2. Size reduction: Fundamentals, Steam explosion
   3. Densification: Types of Densification Devices, Properties of Densified Fuels
   4. Separation: Municipal solid waste, Virgin biomass, Extraction

IV. Thermochemical Conversion
   1. Pyrolysis: Torrefaction, Slow and Fast Pyrolysis, Charcoal Production.
   2. Gasification: Fundamentals, Fixed bed Gasifiers, Technical and operations; problems with Fixed bed Gasifiers, Fluidized bed Gasifiers, Entrained Bed Gasifiers, Comparison between Fixed bed and Fluidized bed Gasifiers, Gas Treatment, Equilibrium and Kinetic Considerations.
   3. Combustion: Fundamentals, Furnaces, Fixed bed systems, Fluidized bed systems, Emission reduction, Steam cycle, Residential and small commercial systems, Solid waste incineration, Electric power production, operating problems

V. Biological Conversion
   1. Biogas Production: Types of Substrates, Digester Design, Operational Problems, Kinetic Considerations.
   2. Ethanol Production: Basic Production Processes from Sugar Biomass, Starch Biomass, lignocellulosic materials, Distillation
   3. Methanol Conversion Technologies: Methanol properties, Methanol Production from biomass
   4. Biodiesel Conversion Technologies: Properties (vegetable oil, biodiesel, diesel), Biodiesel Production from vegetable oil, and biomass

VI. Environmental Impacts

**Journals and Magazines:**

1. Energy
2. Energy Sources
3. Biomass conversion and biorefinary
4. Energy & Fuels
5. International Journal of Energy Research
6. Biomass and Bioenergy
7. Chemical Engineering Science
8. Fuel
9. Fuel processing technologies

**GRADING SCHEME**

| | |
|---|---|
| Group project | 15 % |
| Individual project (Aspen Plus) and Lab | 25 % |
| Semester paper (review) and presentation | 20 % |
| Final Exam | 40 % |

**Project/Lab/Paper:**
Each project/lab will be documented in a report that will be submitted. Project marks will be based on project reports. Topics of the project will be determined in consultation with the instructor. Reports submitted after the due date will be assessed a penalty of 10% of the report mark per day. Further details on the reports will be given in class.

**Final Exam:**
The final exam will cover the material presented for the entire course and will be closed book. Permitted aids will be announced prior to exam. Failure to attend the exam will lead to a zero for that exam unless valid documentation is provided for medical or compassionate grounds.

**METHODOLOGY**

Every lecture will be organized in a way that favors a good comprehension of the presented concepts and an active appropriation of knowledge. Generally, the instructor's formal lecture will alternate with problem solving presentations and period of questions and answers. In order for the student to actively participate during the lectures, they would need to have read the class materials before hand.

**DISCLAIMER**

The outline above is the course plan at the time this outline is distributed. The instructor reserves the right to change any or all of the above as the course progresses (including specifics of assignments, labs, projects and exams), subject to University of Guelph Academic Regulations. In the event that subsequent information about assignments, projects or exams differ from this outline, the more recent information will supersede this outline. Any course changes from those listed in this course outline will be announced in class and posted on the course Courselink page.

Notify the instructor immediately if you identify a conflict between course requirements and religious requirements, such as holy days of obligation.

Assignments, projects and exams in this course are individual assignments. While students are encouraged to assist each other with learning and understanding the course concepts, and to utilize a range of information sources, each student must submit their own unique work for assignments, projects and exams. Proper referencing of sources in reports is essential: if you are unsure what this means, consult with the instructor *before* submitting your work. Any cases of suspected academic misconduct will be reported to the Director of the School of Engineering.

Academic misconduct, such as plagiarism, is a serious offence at the University of Guelph. Please consult the current Undergraduate Calendar and School of Engineering program guide for offences, penalties and procedures relating to academic misconduct.
http://www.uoguelph.ca/registrar/calendars/undergraduate/current/c08/c08-amisconduct.shtml

# Group Project: ENGG: 6090 Bioenergy & biofuels

A Study and Report on Alternative Technologies to Transform Biomass into Energy in the agricultural sector for Ontario

**Goal:** The goal of this project is to examine several emerging technologies as alternatives to the OPG (Ontario Power Generation) combustion market to determine which ones are ready for implementation on farms, groups of farms or in rural communities and could enable producers to generate income from the energy market.

**Scope of the Project:**
Energy represents a significant input into agricultural production systems. With recent rapid increase in oil prices and projections that oil prices will continue to rise, producers have implemented strategies to mitigate these costs through conservation efficiencies, changes in production practices (tillage) and switching fuel sources, while others have sought to participate directly in energy generation as a means of offsetting their own costs and generating net revenue.

From an energy input perspective, producers utilize gasoline, diesel fuel, natural gas, propane, wood and biomass, and electricity to support their production systems. The choice of energy source is often limited by public infrastructure available to access the fuel at a specific farm location. Similarly, those wishing to generate and sell energy are also constrained by access to public infrastructure. The production of corn for ethanol production is an exception as producers have both a well-developed grain movement network and access to regional ethanol production facilities. However, development of similar biodiesel markets has lagged.

In recognition of energy supply issues, governments have supported innovative approaches to develop new technologies to transform non-traditional energy sources into dispatchable energy. Early efforts by governments to re-introduce on farm anaerobic digesters are an example of such efforts. This effort was also matched by public policy to create opportunities to convert bio-methane into electricity and sell into the Ontario electricity grid.

Producers have also been innovative in other areas to reduce the impact of energy prices. When feasible, greenhouse growers converted from oil to natural gas while others converted existing boilers to use biomass from crop residue or from purpose- grown biomass. While producers have concentrated on using new energy sources and new technologies, the advice to the sector on how to optimize the use of residual energy from their systems has been lagging.

Efforts to change the mix of energy sources in Ontario moved forward at an aggressive pace once the Province created and implemented the Green Energy Act of Ontario. This Act accelerated the introduction of renewable energy supplies such as solar and wind power in Ontario. Many producers participate or intend to participate in these markets either directly through FIT agreements or under contractual arrangements. Opportunities also exist in the renewable natural gas market. Globally, new technologies to transform and capture energy are being commercialized at an accelerated pace. In some instances, technologies have been marketed for implementation prior to being proven. When producers engage and invest in such technologies, they are faced with managing not only a technological risk but also a financial one.

The information generated can then be used by producers to support their investment decisions. Technologies such as torrefaction, anaerobic digestion, pyrolysis, gasification, combustion units, hydrogen enriched natural gas processes, and technologies to convert biogas into biomethane are in the scope of this study. The team is not limited to these technologies and may suggest additional ones for review. An important consideration will be on farm strategies to maximize conversion efficiencies from these technologies either through better systems and/or innovative uses for residual energy.
Teams are encouraged to review the following report: Energy Market Alternatives for Commercially Grown Biomass in Ontario available on the OFA website http://www.ofa.on.ca/issues/overview/biomass to obtain further background information.

**Understanding of the Project Requirements**

**1. Develop criteria for selecting technologies**

The team shall develop selection criteria to identify technologies suitable for farm implementation, multiple farm implementation or producer participation in a project at a community level.

**2. Identify potential transformative technologies and scenarios to access energy markets and their market opportunities available now or within the next 3-5 years**

- The team shall develop a comprehensive list of available technologies with documentation of market opportunities.
- The team shall document the steps in the transformative processes.
- Based on selected technologies and scenarios retained, the team shall then complete a readiness assessment of each technology, including documentation of interviews with researchers and leading companies that have either commercialized or at the cusp of commercializing various technologies.

**3. Examine how producers can develop opportunities to monetize the multiple benefits arising from implementing the technology on farm or in local communities**

- The team shall produce a list of multiple benefits and values associated with the various technologies.
- For farm installations, the team shall develop examples of how producers can utilize residual by-products (heat, $CO_2$ and others) in other farm processes or local business opportunities

**4. Identify opportunities for producers to capture a greater share of various value chains based on the various technologies implemented**