A NEW GRADUATE COURSE TEACHING CHEMICAL ENGINEERING IN USE OF RENEWABLE RESOURCES

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Abstract: Fossil fuel resources such as natural gas, oil and coal will be used up in the future. Moreover, the current use of these resources has led to environmental risks such as global warming. Energy and materials based on fossil resources must be produced from other substitute resources in order to suppress the carbon footprint that has been planted, and maintain and improve the current life styles of human beings in the future. Renewable resources, or biomass, are one of the substitutes from which energy including liquid fuel, and materials can be produced.

To bring students the awareness of utilizing renewable resources, a new graduate course, entitled *Chemicals and Energy from Renewable Resources,* has been implemented in the Department of Chemical Engineering, University of Saskatchewan lately. This course is divided into two parts. Part one deals with the basic processes such as gasification, pyrolysis, catalytic conversion and synthesis, separation unit operations in chemical and energy production from renewable resources. The content of this part includes reactor design, catalytic chemical engineering, and separation processes. Part two presents case studies of processes that produce energy and chemicals from biomass. Attentions are given to technology development, potential emission and pollution controls and production economics.

The format of the course includes lectures, class discussion, literature review, project oriented assignments and student presentation. The case studies are closely combined with the research work of the students. The course has been welcomed not only by the graduate students from this department but also those from other departments and colleges.

Keywords; engineering education, renewable resources, chemical engineering, sustainability awareness.

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1. INTRODUCTION

As it is realized that the use of fossil fuels has created environmental problems and led to sustainability concerns, more attention has been drawn to the utilization of renewable resources,

attempting to produce chemicals and energy with more environmentally friendly, more carbon-neutral, and less hazardous processes. Unlike processes producing chemicals and energy from fossil feedstock, special considerations have to be taken when the feedstock becomes renewable resources. In addition to the preparation of raw materials, the chemical routes of producing the same products can be different. For example, fuels such as gasoline and diesel are produced in refining crude petroleum oil, whiles diesel is produced by transesterification of bio-oil and gasoline is produced by Fisher-Tropsch synthesis route from the synthetic gas generated from biomass gasification. Students, especially graduate students, working in the relevant disciplines must be aware of these differences and be prepared for the change when renewable resources are used. To meet the needs from students in this regard, a new graduate course in chemical engineering entitled *Chemicals and Energy from Renewable Resources* has been created and has been taught for five years in the University of Saskatchewan.

The purpose of this paper is to share how the course was initiated, developed, and offered, what contents are included, and the feedback of the students who have taken the course.

2. COURSE DEVELOPMENT

In 2005/06, a new reading course was initiatively offered for graduate students in the College of Engineering at the University of Saskatchewan. The course wanted to bring to students the awareness of using renewable feedstock to produce commodity chemicals and energy and its environmental and sustainable benignity. For the first three years, the course was offered as a reading class. Then, the College of Graduate Studies and Research of the University of Saskatchewan approved this course to become a regular graduate course. Unlike a course in which giving lectures accounts for the main class events, this course combines lectures, class discussions, student presentations, and term paper assignments. Lectures that the instructor presents offer introductory concepts and information associated with the utilization of renewable resources and its environmental footprint, and examples of such a production process with considerations of sustainability and environmental friendliness. Chemical engineering principles and unit operations with consideration for the specialties related to the utilization of renewable resources are also included in lectures. In the events such as class discussion, student presentations and term paper assignments, students are encouraged to involve their ongoing or future research topics. If the research area is associated to using renewable resources, students can bring the topic to the class. If the research is not related, they can add renewablility or sustainability elements in their research topics and present the work in this class. This way, students not only learn from the lectures that the professor presents but also learn from the work of their fellow students in class. To evaluate the performance of students in class, students are required to give two powerpoint presentations and submit two term papers. The assignments like these also offer opportunities for students to improve their public speak ability and technical writing ability. The first presentation and term paper discuss the general overview of a topic associated with the utilization of renewable resources, and the second set deals with the processes and operations of the utilization.

To provide more information of how this class is operated, the latest course syllabus is given in the attachments.

Table 1 Student enrolment and home departments

School year	*Enrolment number*	*Home department and student number*	
2005/06	1	Agricultural and Bioresource Engineering	1
2006/07	3	Chemical Engineering	3
2007/08	6	Agricultural uateand Bioresource Engineering	2
		Chemical Engineering	4
2008/09	8	Chemical Engineering	8
2009/10	15	Agricultural and Bioresource Engineering	1
		Chemical Engineering	10
		Food and Bioproduct	4

3. STUDENT ENROLMENT AND DISCIPLINES

From 2005/06 to 2009/10, thirty-three students from the Department of Chemical Engineering and the Department of Agricultural and Bioresource Engineering in the College of Engineering and the Department of Food and Bioproduct in the College of Agriculture and Bioresource have chosen this course. The enrolment is listed in Table 1. It can be seen that the course now becomes more popular to graduate students from a variety of disciplines. It has been realized that the appropriate class size is 10 to 15 students from different disciplines so students could have sufficient opportunities to learn from each other under the format of this course. A small class will not allow delivering this strength. If the class is too big, the time given to a student for class discussion, presentation, and student-with-professor meetings would be limited.

4. TOPICS AND PROJECTS

Table 2 lists the topics involved in the past five years. The projects of the course discuss every aspect of production from renewable resources, from feedstock to products, from processes to operations, and from fundamentals to applications. Some present broad perspective of a topic, some focus on particular issues of a topic. Table 2 indicates that topics of biofuels production from renewable biowaste resources are heavily covered by student projects. This is because there is a large research group led by a faculty member in our department who is the Canada Research Chair in Bio-Energy and Environmentally Friendly Chemical Processing. The feedstock resources include lignocellulosic mass such as agriculture residue and wood residue, green seed canola oil, wastes from slaughterhouses, algae, and pongamia. Products from the topics involve hydrogen, syn-gas, bio-oil, ethanol, and biodiesel. The routes include gasification and pyrolysis, hydrolysis and fermentation, and transesterification. Materials with particular functions developed from renewable resources are also presented. The examples are adsorbent from barley straw and bioactive lipids from diary waste streams. Topics involving new ideas are ion-exchange resin as transesterification catalysts, microbial fuel cells, and value-added synthesis from by-product glycerol. Projects associated with sustainability issues such as hydrogen production from industrial waste H2S and geothermal energy are also seen in the list.

Table 2 Topics and projects undertaken

School year	*Project title*
2005/06	**05A.** Chemical and energy from biomass
2006/07	**06A.** Hydrolysis as a method to generate renewable energy
	06B. Fundamentals of clean energy: gasification and pyrolysis
	06C. H2S sorbent regeneration for more sustainable operation
2007/08	**07A.** Energy from renewable hydrogen
	07B. Analysis of meat and bone meal as energy feedstock
	07C. Bioethanol production from sugar cane in Brazil
	07D. Biomass and gasification
	07E. Fundamentals of syn-gas production from crop residues
	07F. Hydrogen recovery from biomass gasification
2008/09	**08A.** Nickel biosorption using barley straw
	08B. Ion-exchange resins as catalysts in biodiesel production
	08C. Electricity production with microorganisms via a fuel cell
	08D. Bio-oil upgrading processes
	08E. Hydrogen production from industrial waste H2S
	08F. Hydrogen production from renewable biomass through gasification
	08G. Bioethanol production system from wheat straw
	08H. From biowaste to electricity using microbial biofuel cell
2009/10	**09A.** Lignocellulosic bioethanol production processes in Western Canada
	09B. Biodiesel production from green seed canola oil in Canada
	09C. Microbial fuel cells for energy production from renewable biomass
	09D. A bioactive lipid, sphingomyelin, from diary waste streams
	09E. Fermentable sugars from lignocellulosic biomass
	09F. Bioethanol production from lignocellulosic biomass
	09G. Hydrogen production routes from sulphur-containing industrial wastes
	09H. Bioethanol production through tranesterification of rapeseed and canola oils
	09I. An industrial scale microbial fuel cells
	09J. Hydrogen production from biomass gasification
	09K. Biodiesel production from algae
	09L. Production and separations of positional isomers of hydroxystearic acid
	09M. Geothermal energy and its recovery
	09N. Biodiesel production from pongamia
	09O. Value-added utilization of glycerol in biodiesel production

5. STUDENT FEEDBACK

Student feedbacks are regularly invited by formal or informal questionnaire at the end of class every year. The questions used for 2009/10 year are the following:

1) Why would you have considered taking this course? If you have 2 or 3 reasons that helped you have selected this course, what are they?

2) Before you took this class, what were your expectations of learning in this class? After taking this class, have you learned what you had expected? If there is any difference between your expectations and what you have experienced and/or any disappointment, what is it?
3) In terms of renewability and sustainability, have you been more aware of them after taking this course? What is your opinion on utilization of renewable resources? Have your opinion changed after taking this course?
4) Do you pay attention to the United Nations Climate Change Conference in Copenhagen and do you have a hope on it (optional)?

Typical answers to question (1) include getting to know the up-to-date knowledge of using renewable resources and its importance to a sustainable human society, combining course work and research work in one, and the opportunity of improving the oral and writing presentation skills. To question (2), most students thought their expectations in learning had been met after taking this course. Some provided suggestions in how to improve the course contents for the next year. For instance, it was suggested that economic feasibility should be included when a process of using renewable resources is taken into consideration. Others hoped we should look at the sustainability of the new technologies and avoid creating new troubles resulted from the ignorance of this. 100% of the participating students were positive to question (3), giving views of their own on sustainability of economic activities and renewability of resources. However, what surprised me was that half of the participants did not think the Copenhagen conference can do anything helpful to the world situation in environmental problems.

6. CONCLUDING REMARKS

The utilization of renewable resources to produce chemicals and energy becomes more and more important when environmental friendliness and sustainability are addressed. For the same production, there are special technological considerations when renewable resources are used. Students have to be prepared for the change. This new graduate course meets the needs from this regard. The untraditional format of the course combines lectures and project based assignments, allowing students to learn not only from instructor but also from their own work. The course directly brings graduate students to the frontier of the research and development of the technologies of using renewable resources as feedstock for chemical and energy production. I believe with the training offered by this course students will be prepared to face the challenges in the transition of replacing fossil feedstock with using renewable resources for a better environment and sustainable economy.

(Attachment: Course syllabus of 2009/10 version, page 6-8)

UNIVERSITY OF SASKATCHEWAN

COLLEGE OF ENGINEERING
DEPARTMENT OF CHEMICAL ENGINEERING

ChE 888.3 – Chemicals and Energy from Renewable Resources

Winter 2009/10

Instructor: **Hui Wang**
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Lectures: Eng 2C90: T, Th 8:30-9:50 am

Reference Books

- Chemicals and materials from renewable resources / Joseph J. Bozell, editor
- Allen, David T; Green engineering : environmentally conscious design of chemical processes,
- Green chemical syntheses and processes / Paul T. Anastas, Lauren G. Heine, Tracy C. Williamson, [editors]
- Green chemistry : challenging perspectives / edited by Pietro Tundo and Paul Anastas
- Handbook of green chemistry and technology / edited by James Clark and Duncan Macquarrie
- Other materials from journal papers

Website:

Assessments:

Term Paper #1: **Fundamentals of a Process that Uses Renewable Resources**	
Presentation	20%
Paper	25%
Term Paper #2: **A Process that Makes Use of a Renewable Resource**	
Presentation	20%
Paper	25%
Class Discussion	10%
Final Exam	

The mark distribution is only approximate. Final grades will be assigned at the discretion of the instructor subject to the University Council and College Regulations on Examinations.

Objectives:

The objectives of this course are as follows:

1. To introduce a manifest perspective of the processes that produce chemicals or/and energies from renewable resources.
2. To study the application of the fundamental principles of chemical engineering in the processes that generate chemicals or/and energies from renewable resources.
3. To bring the students to the frontier of studies and research on the processes that generate chemicals or/and energies from renewable resources.

By the end of this course, it is expected that students are stimulated with a broad interest in the research areas of the production of chemicals and energies from renewable resources.

Description:

Fossil fuel resources such as gas, oil and coal will be used up someday in future. Energies and materials based on such resources must be produced from other substitute resources in order to maintain and improve the current life styles of human being. Renewable resources, or biomass, are one of these substitutes from which energies and materials can be produced. Saskatchewan is a province that has abundant renewable resources.

Processes that produce energies and chemicals from renewable resources consist of basic chemical processes such as combustion, gasification, pyrolysis, catalytic conversion and synthesis, and separations. When dealing with these processes with renewable resources, fundamental principles of chemical engineering are applicable but special attentions have to be paid. Among these processes, some produce energy, fuel and other chemicals simultaneously, and others just generate particular chemicals or materials. Fuels and chemicals can be synthesized from synthesis gas, carbon monoxide and hydrogen, which are produced from the gasification or pyrolysis of biomass; or they can be processed from the renewable feedstock directly.

This course is divided into two parts. Part one deals with the basic processes such as gasification, pyrolysis, catalytic conversion and synthesis, extraction, and etc in the production from renewable resources. The content of this part includes reactor design, catalytic chemical engineering, and separations. Part two presents case studies of processes that produce energy and chemicals from biomass. Emphasis and attention will be directed to the development of such processes that consume only renewable raw materials and energy, make highly efficient use of raw materials and energy, reduce or eliminate the use and generation of hazardous substances, and reduce or eliminate the release of substances harmful to humans and the environment.

Detailed Course Outline:

Approximate Lecture or Class Discussion Hours	Information
1	Introduction to Green Chemistry and Chemical Engineering
2	Renewable Resources and environment Awareness
2	Gasification and Pyrolysis
2	Separations
2	Processes Using Synthesis Gas
3	Application of Catalysis
12	Chemicals from Renewable Resources
- 3	- Fuels
- 3	- Polymers
- 3	- Other chemicals
- 3	- Energy (Electricity, etc)

Students should be aware of and follow the new University of Saskatchewan Academic Honesty/Dishonesty definitions, rules and procedures that are available on the web at www.usask.ca/honesty.