Queen's University

Senate Committee on Academic Development

Report to Senate – Meeting of April 22, 2010

Proposal to introduce a Collaborative Masters in Applied Sustainability Program, Faculty of Engineering and Applied Science and the School of Graduate Studies

Introduction

The proposal to introduce a Collaborative Masters in Applied Sustainability Program in the Faculty of Engineering and Applied Science was reviewed by the Senate Committee on Academic Development (SCAD) at its meeting of April 7, 2010. B. Surgenor, Associate Dean in the Faculty of Engineering and Applied Science and B. Brouwer, Associate Dean in the School of Graduate Studies, attended the SCAD meeting to speak to the proposal and to answer questions from members of SCAD. Members of SCAD were also provided with background documentation provided by the Faculty of Engineering and Applied Science and the School of Graduate Studies. A copy of the documentation is attached to this report.

Analysis and Discussion

The following should be noted:

- the proposed collaborative program is multidisciplinary in nature and involves six departments from within the Faculty of Engineering and Applied Science (Chemical Eng, Civil Eng, Electrical and Computer Eng, Geological Eng, Mechanical and Materials Eng and Mining Eng). Students will be registered from their home departments;
- students enrolled in the Collaborative Masters in Applied Sustainability (MAS) Program will have the option of pursuing either an M.Eng. Project Masters or a M.A.Sc. Thesis Masters degree;
- the Collaborative MAS will educate graduate students to advance their engineering skills and at the same time gain insights into how public policy impacts the success of engineering solutions to multidisciplinary sustainability challenges;
- graduates of the Program will meet the demands of industry for engineers who have the breadth and depth of knowledge and training in the emerging field of applied sustainability;

- the initial enrolment projection is 5 students in Year 1, growing to 20 students in Year 4;
- students enrolled in the Collaborative MAS Program will be considered for funding support through their home department. Therefore, no new financial resources will be required to mount the Program;
- there is potential for the Collaborative MAS Program to expand in the future by including other disciplines and fields of study.

Conclusions/Recommendation

Recommendation:
that Senate approve the introduction of a Collaborative Masters in Applied Sustainability Program in the Faculty of Engineering and Applied Science and the School of Graduate Studies, with an implementation date of 1 September 2010.

Respectfully submitted,

Bob Silverman
Chair, Senate Committee on Academic Development

Committee Members:

Members
N. Chesterley
J. Emrich
P. Fachinger
N. Fulford
A. Jack-Davies
P. Oosthuizen
T. Shearer
B. Silverman (Chair)
D. Stockley
R. Ware
P. Watkin (Secretary)

Senate Budget Review Committee

Report to Senate – April 12, 2010

II. Proposal to establish a Collaborative Masters in Applied Sustainability Program.

Introduction

On April 12, 2010, the Senate Budget Review Committee (SBRC) met to discuss the Proposal to establish a Collaborative Masters in Applied Sustainability Program.

Analysis and Discussion

B. Surgenor (Associate Dean, Faculty of Engineering and Applied Science) explained to the committee that this is a collaborative program, not only within the Faculty of Engineering and Applied Science but also includes the School of Policy Studies. The proposed program will draw upon existing course and research facilities. Although demand may be higher, it is anticipated that the program will admit 5 students per year so the proposal should have minimal resource and funding implications. The list of available master's courses includes several 4th year Applied Science courses. When asked whether any undergraduate students would be displaced by graduate students the Committee was assured that the 4th year courses were electives and could accommodate additional students.

Conclusions/Recommendation

Members of the committee saw no major resource implications with the proposed program and voted unanimously to recommend to Senate that they approve the Proposal to Establish a Collaborative Masters in Applied Sustainability Program.

Respectfully submitted,

D. Pointer,
Acting Chair, Senate Budget Review Committee

Committee Members:
H. Averns
P. Boag
I. Cameron
D. Janiec
S. Heard
J. Helland (Chair)
A. Husain
S. Kalb
E. Nkole
V. Pakalnis
D. Pointer

Senate Committee on Academic Development
and
Senate Budget Review Committee

Program Approval Submission

FACULTY/SCHOOL: GRADUATE STUDIES

PROPOSED NEW PROGRAM: COLLABORATIVE MASTERS IN APPLIED SUSTAINABILITY PROGRAM

PROPOSED IMPLEMENTATION DATE: SEPTEMBER 2010

DATE OF FACULTY OF ENGINEERING AND APPLIED SCIENCE COUNCILREVIEW: MARCH 10, 2010

DATE OF GRADUATE SCHOOL EXECUTIVE COUNCIL REVIEW: MARCH 15, 2010

SUBMISSION CONTACT

NAME: Vic Pakalnis

TELEPHONE: 613-533-3327

EMAIL: Vic.Pakalnis@mine.queensu.ca

SIGNATURE OF THE DEAN: _____ **DATE:** 03.29.10

The criteria requested in PART A should be regarded as the minimum criteria for the assessment of academic programs. Any unit planning a new program should show how not only the criteria listed below but also, where appropriate, those required by the Undergraduate Program Review Audit Committee and those of the Ministry of Training, Colleges & Universities have been taken into account. For further information, please refer to the Senate Policy "Policies and Procedures for Establishing New Undergraduate Programs" (http://www.queensu.ca/secretariat/senate/policies/newprog/index.html)

PART A

1. OBJECTIVES:

Please summarize the rationale for introducing this program. The program should be consistent with the Queen's mission, the academic plans of the unit including its teaching and research strengths, the relation of the unit with other academic units and the standards, educational goals and learning objectives of the degree. Explain how this program will achieve the expected academic quality. Please identify the Faculty, School or Department, which will be administratively responsible for the academic aspects of this program such as supervision of graduate students, curriculum development and the Internal Academic Review Process.

Building on the Faculty's strategic theme of applied sustainability, the Collaborative Masters in Applied Sustainability (MAS) program will educate engineering graduate students to work on engineering and policy issues on the subject of applied sustainability. The curriculum is based upon existing courses. But the program is much more than a collection of existing engineering and policy studies courses. A required lecture course and seminar series will serve to introduce students to the fundamental concepts of engineering for sustainability and sustainable development. The objective of the program is to expose engineering students to the theory and practical implementation of sustainable engineering solutions to the world's problems. To do this, students must not only advance their technical education, but must gain insights into how public policy impacts on the success of engineering solutions to multidisciplinary sustainability problems.

For the purposes of this program "applied sustainability" is defined as the application of science and innovation to meet human needs of the present without compromising the ability of future generations to meet their own needs. Applied sustainability has a much broader focus relative to what is termed "sustainable engineering". A student wishing to develop a background in applied sustainability needs to develop expertise in 3 things: energy use by system, natural resource management, and life cycle resource use. These 3 pillars are what the European Commission and the US EPA are using as their basis for sustainability policy, and are considered to be reflected by the courses listed within the MAS curriculum. Inclusion of the School of Policy Studies means that there is the opportunity to explicitly identify the means by which policymakers understand sustainability, and to train students in the language and concepts which are becoming accepted in the world as related to sustainability. Finally, it is fully expected that the curriculum of the MAS program will evolve, as new courses become available, as additional Queen's faculty become involved. The MAS program will provide a framework to build on Queen's expertise in applied sustainability.

As a reflection of the multidisciplinary nature of the subject, the MAS program is a collaborative effort with faculty from six programs within the Faculty of Engineering and Applied Science. A key aspect of the program is the involvement of School of Policy Studies, which is contributing five courses and three faculty members who will participate in the co-supervision of MAS graduate students. **Table 1** summarizes the partners in the proposal.

Table 1 - Departments of Participating Faculty

Participation from Faculty of Engineering and Applied Science	Participation through Cross & Joint Appointments
Chemical Engineering	Geography
Civil Engineering	Political Studies
Electrical and Computer Engineering	School of Environmental Studies
Geological Science and Geological Engineering	School of Policy Studies
Mechanical and Materials Engineering	
Mining Engineering	

The Collaborative MAS program is intended to:

a) formally link graduate education in the areas of research interest in Applied Sustainability currently being undertaken in each of the six constituent masters programs

b) expand education in this area of Applied Sustainability so that students are exposed to multidisciplinary issues, training and/or practice

c) offer education and a degree designation that identifies graduates as having specialized cross-discipline training in Applied Sustainability

d) provide a coordinated list of graduate courses with a breadth and depth that promotes the training of student engineers in the field of Applied Sustainability

e) bring engineering students together to learn about research methodology and professional practice in the field of Applied Sustainability

The participating Departments will retain administrative responsibility for graduate students and for curriculum development in their specific area of interest. The involvement of each department in the Collaborative Program will be reported as part of ongoing periodic appraisals. Letters of support are provided in ***Appendix A***.

2. ADMISSION REQUIREMENTS:

The admission requirements (preparation and achievement) should be appropriate for the learning objectives of the program and the institution to ensure the appropriate quality of student applicants. In no case should admission requirements be lower than the published minimum standards for the University. Indicators of student demand including applications, registrations, projected enrolment levels, and of the quality of students must be considered. Where admission is competitive, actual admission requirements may be higher than the published minimum standards.

Admission requirements for students entering the Collaborative MAS program are:

- Bachelor's degree in engineering or applied science with a B+ graduating average or higher (70% graduating average or a ranking in the top third of the graduating class where number grades are not available).
- Applicants with a Bachelors degree in a cognate science may be admitted. Grades from all four years are considered, but specific courses in the last two years are of particular importance.

The Collaborative MAS program will not consider students who do not meet the specific requirements of the member department in which they intend to register. Prospective students will apply in the normal fashion through their chosen home department. They need only enter "specialization in applied sustainability" on the standard application form.

3. CURRICULUM:

Provide a detailed overview of the proposed program, along with the proposed *Calendar* description. Details such as course requirements (core, supporting, recommended, optional courses), prerequisites, problems students may encounter and new courses being proposed for the program should be included. The structure and curriculum of the program should be appropriate for its learning objectives.

Table 2 and **Table 3** summarize the curriculum. Students would be required to:

a) satisfy the coursework, thesis and other requirements of their home department

b) enroll in an "Topics in Applied Sustainability" graduate course that provides an overview of the field with particular focus on implementation of engineering solutions (see ***Appendix B***)

c) participate in an "Applied Sustainability Seminar" graduate seminar series which features presentations from faculty members, graduate students or visitors, one afternoon each week to create a common learning experience and expose students to examples of research and practice in the field; this course would substitute for the existing seminar course where the home program has a compulsory seminar requirement; participation would be for two terms for the masters (see ***Appendix B***)

d) select remaining courses depending upon whether they are enrolled in a M.A.Sc. Thesis or a M.Eng. Project Masters, with courses organized by three lists, as given in **Table 4**.

Table 2 - M.A.Sc. Thesis Masters (4 term-length courses plus seminar plus thesis, 2 years to complete)

Number	Title	Instructor
CPAS 801	Topics in Applied Sustainability	course coordinator
1 elective	from list A	
1 elective	from list B	
1 elective	from list A, list B, list C or any eligible course in the Queen's Graduate Calendar with appropriate permissions	
CPAS 897	Applied Sustainability Seminar	seminar coordinator
CPAS 899	Thesis	member faculty

Table 3 - M.Eng. Project Masters (7 term-length courses plus seminar plus project, 1 year to complete)

Number	Title	Instructor
CPAS 801	Topics in Applied Sustainability	course coordinator
2 electives	from List A	
1 elective	from List B	
3 electives	from list A, list B, list C (no more than 2 from list C), or any eligible course in the Queen's Graduate Calendar with appropriate permissions	
CPAS 897	Applied Sustainability Seminar	
CPAS 898	Project	member faculty

Calendar descriptions for the above courses are given in ***Appendix C***.

Table 5 provides a comparison of the coursework requirements in the participating programs. The table illustrates that students who register in the MAS program out of the Departments of Civil Engineering, Electrical and Computer Engineering or Geological Science and Geological Engineering, will have a higher than normal workload because the required CPAS 897 seminar course is in addition to the departmental requirements. In the remaining three departments, students enrolled in the MAS program will substitute CPAS 897 for their departmental seminar series.

The M.A.Sc. degree requirement of four term-length courses is the same for all six programs and all have sufficient flexibility to accommodate the requirements of the MAS program within their existing framework.

The Department of Geological Science and Geological Engineering does not offer the project based degree of M.Eng. Their one year project based Master's degree is a M.Sc. degree in Applied Geology. Therefore, only students in the M.A.Sc. program in Geological Science and Geological Engineering are eligible to be considered for the MAS program. Hence the entry of "n/a" (not applicable) in **Table 5** under GSGE and M.Eng.

Table 4 - List A

Number	Title	Instructor
CHEE 8xy	Fuel Cell Systems: Design and Analysis (currently offered under CHEE 807 – Current Topics in Chemical Engineering, standalone approval to be sought for 2010/11)	Peppley, Brant
CHEE/MECH 837	Transport and Kinetics with Application to Fuel Cells	Karan/Pharoah
CHEE 882	Bioreactor Design	Daugulis, Andrew
CHEE 884	Bioremediation	Champagne Pascale
CIVL 885	Chemistry of Natural Waters	Champagne, Pascale
CIVL 886	Biological Treatment Processes	Anderson, Bruce
CIVL 890	Water Network Analysis and Design	Filion, Yves
GEOL 8yz	Mineral Resources and Sustainable Development (currently offered under GEOL 841 - Special Topics in Geological Engineering, standalone approval to be sought for 2010/11)	Olivo, Gema
GEOL 835	Environmental Impact of Mining	Jamieson, Heather
MECH 820	Solar Photovoltaics Materials, Cells and Systems	Pearce, Joshua
MECH 834	Solar Energy Conversion for Heating and Cooling	Harrison, Steve
MINE 836	Mineral Processing and the Environment	Kelebek, Sadan
MINE 862	Issues in Health, Safety and Environment	Pakalnis, Vic

List B

Number	Title	Instructor
MPA 843	Trade and Public Policy	Wolfe, Bob
MPA 845	Science and Technology Policy	Mabee, Warren
MPA 847	Environmental Policy	Mabee, Warren
MPA 877	Energy Policy	Harrison, Peter
MPA 887	Arctic and Northern Issues	Harrison, Peter

List C

Number	Title	Instructor
ELEC 433	Energy and Power Systems	Bakhshai, Alireza
MECH 424	Life Cycle Engineering	Jeswiet, Jack
MECH 425	Engineering for Sustainable Development	Pearce, Joshua
MECH 430	Thermal Systems Design	Harrison, Steve
MINE 422	Mining and Sustainability	Hodge, Tony
MDEP 437	Fuel Cell Technology	Pharoah, Jon

Calendar Description of the Program

The Collaborative Masters in Applied Sustainability (MAS) program offers M.Eng. and M.A.Sc. students training in a multidisciplinary environment spanning engineering departments and linking with researchers in the School of Policy Studies. The program allows students to undertake cutting-edge research under the supervision of internationally recognized investigators in diverse Applied Sustainability fields. This collaborative program provides opportunities for multidisciplinary research and learning that will be invaluable for the graduate student's career development. Areas of research interest include: 1) Applied Sustainability and Energy Technology, 2) Applied Sustainability and Fresh Water Systems and 3) Applied Sustainability and Resource Management.

Table 5 - Comparison of Coursework Requirements in the Participating Programs
(requirements not in-line with those of the proposed MAS program given in ***bold italics***)

Program name	Courses in M.Eng. in addition to project	Requirement for non credit seminar course		Restrictions on courses	
		M.Eng.	M.A.Sc.	M.Eng.	M.A.Sc.
Chemical Engineering	7	yes	yes	min. 4 inside dept*, 2 only 400 level permitted	min. 2 inside dept*, 1 only 400 level permitted
Civil Engineering	7	***no***	***no***	min. 4 in major and min. 2 in minor	1 only 400 level permitted
ECE	***6****	***no***	***no***	min. 4 inside dept	1 only 400 level permitted
GSGE	n/a	n/a	***no***	n/a	1 only 400 level permitted
MME	7	***no***	yes	min. 4 inside dept, 2 only 400 level permitted	1 only 400 level permitted
Mining Engineering	7	yes	yes	min. 4 inside dept, 2 only 400 level permitted	min. 2 inside dept, 1 only 400 level permitted

* course restriction can be waived with permission of supervisor and coordinator

** in ECE, M.Eng. course requirement is one less as project has weight of 1.0 credit instead of 0.50 credit

4. TEACHING:

Briefly explain how the intended mode of delivery (including, where applicable, distance or on-line delivery) and standards of instruction for this program are appropriate to meet the program's learning objectives.

All of the courses listed for the Collaborative Masters in Applied Sustainability program are existing courses offered through the member departments. CPAS 801 (Topics in Applied Sustainability) is a reworked and renumbered of version of MECH 836. CPAS 897 (Applied Sustainability Seminar Series) will replace existing seminar courses as appropriate from the member departments. No distance or online courses are currently envisioned for this program.

5. EVALUATION OF STUDENT PROGRESS:

Briefly explain the intended method of evaluation of student progress and how it is appropriate for this program.

Students will be evaluated based on their course work and research progress. Course work will be evaluated and assigned a numeric grade (subject to change to a letter grade under new University grading system). A Program Management committee will be established. One of the committee's responsibilities will be to monitor each student's progress in the program.

6. EQUITY:

This program's planning, development and implementation should be consistent with the equity goals of the University and must avoid direct, indirect and systemic discrimination.

The program has been developed according to the general regulations of the School of Graduate Studies. Any direct, indirect or systemic discrimination will be actively avoided.

7. HUMAN RESOURCES:

Please demonstrate that the number, quality and academic expertise of the faculty in the area of the proposed program are sufficient to meet the demands of the program. Where appropriate, the availability of support staff, teaching and laboratory assistants should be indicated. (Additional details should be provided on the Resource Implications Checklist in **PART B** of this form).

Twenty faculty members in the Faculty of Engineering and Applied Science and the School of Policy Studies have committed to participate in this Program. Their names are listed in **Table 6**. These faculty members have expertise in a number of areas of applied sustainability as outlined in ***Appendix D***. Details of their faculty appointments and some examples of their recent scholarly contributions are provided in ***Appendix E***.

Table 6 - Participating Faculty (for graduate student supervision or cosupervision)

1	Anderson, Bruce	Civil	11	Karan, Kunal	Chemical
2	Bakhshai, Alireza	ECE	12	Kelebek, Sadan	Mining
3	Champagne, Pascale	Civil	13	Mabee, Warren	SPS
4	Daugulis, Andrew	Chemical	14	Novakowski, Kent	Civil
5	Filion, Yves	Civil	15	Olivo, Gema	GSGE
6	Harrison, Peter	SPS	16	Pakalnis, Vic	Mining
7	Harrison, Steve	MME	17	Pearce, Joshua	MME
8	Jain, Praveen	ECE	18	Peppley, Brant	Chemical
9	Jamieson, Heather	GSGE	19	Pharoah, Jon	MME
10	Jeswiet, Jack	MME	20	Wolfe, Bob	SPS

The group has strong research grant and contract support including several millions of dollars awarded over the past two years, which comprises high levels of funding from the Natural Sciences and Engineering Research Council, Canada Foundation for Innovation, and Ontario Ministry for Innovation, in addition to research contract support from a variety of government and corporate sponsors in Canada and the United States of America.

8. PHYSICAL AND INFORMATION RESOURCES:

Please provide a summary of available or required program-specific resources, such as: classroom requirements, laboratories, information technology services and facilities, and library facilities and information resources (including unique and special collections). (Additional details should be provided on the Resource Implications Checklist in **PART B** of this form).

The proposed program will draw upon existing courses and research facilities. The member faculty have strong research support from the Natural Sciences and Engineering Research Council, the Canadian Foundation for Innovation, the Ontario Centres of Excellence, and the Ontario Ministry of Research and Innovation programs. The existing laboratory space, information technology services and facilities, and library and information resources will meet the needs of the program.

9. FINANCIAL RESOURCES:

There should be evidence of sufficient resources to introduce and maintain the program for a reasonable period of time. This should include consideration of any additional funds from internal sources and from government or other external sources as well as possible financial impact of the programs on other programs, within and outside the unit. (Additional details should be provided on the Resource Implications Checklist in **PART B** of this form).

Students enrolled in the collaborative program will be considered for funding support through their home departmental program. Students may be eligible to apply for funding through the appropriate Tri-Council competition or through other agencies (e.g. OGS). Applications will be ranked as required by the student's home department. Stipend funding of students in the Collaborative Program will be in line with policies of their respective home departments.

10. SOCIETAL CONTEXT (STUDENT DEMAND, SOCIETAL NEED, DUPLICATION):

Please provide a summary of how this program is expected to meet student demand and societal need. Evidence of student demand could include: projected enrollment levels, application statistics, origin of student demand (domestic and international), and duration of projected demand. Evidence of review and comment by appropriate student organizations should be provided. Please explain how the program will fulfill a societal need in specifically identified fields (academic, public and /or private sector) and consider the probable availability of positions on graduation, the likelihood of attracting out of province or international students and the equity implications of the program, In the case of a professional program, discuss its congruence with the regulatory requirements of the profession. Please cite similar programs offered by other institutions and provide evidence of additional societal need and/or student demand as well as indicate innovative and distinguished aspects of the program.

Enrolment projections for the Collaborative MAS program are 5 students in Year 1, growing to 20 students in Year 4. The number 20 stems essentially from the assumption of 1 graduate student per participating faculty member. Students in the program will enter through an existing home departmental program. It is expected that there will be no "net new" students. The first year will be direct transfers from existing programs. In future years, the program will compensate for an anticipated drop in enrolment in traditional program. A projected mix of 50/50 for domestic/international students is also anticipated, based upon current demographics.

Evidence of student demand is best demonstrated by the demand experienced at the undergraduate level. In recent years, three undergraduate courses in area of applied sustainability have been introduced (CIVL 380, MECH 425 and MINE 422). CIVL 380 is a core course and consequently has an enrolment on the order of 120 students. Both MECH 425 and MINE 422 had to be capped at 40 students due to student demand.

On a broader level, Engineers Canada conducts an annual study of emerging areas of engineering practice. The most recent report (dated Sept 2008) lists sustainable engineering as one of the top three emerging areas in environmentally related fields. The other two fields (ecological engineering and energy engineering) are arguably not distinctive. Regardless, the survey points out that elements of sustainable engineering can be found in most engineering programs in Canada, but mainly only as standalone courses. A number of engineering based research centres have arisen on the subject (eg. McMaster University's Dofasco Centre for Engineering and Public Policy, Waterloo Institute for Sustainable Energy, Carleton's Sustainable Energy Research Centre), but only three related graduate programs can be identified: 1) McMaster University Master of Engineering and Public Policy (MEEP), 2) University of Calgary Program in Sustainable Energy and 3) Carleton's Masters in Sustainable Energy. These three programs are course based, and are not restricted to engineering students. They are also focused on energy. The Queen's proposal has a much broader view of sustainability. Further background on other programs is given in ***Appendix F.***

The need for a program of this type can best be demonstrated by quoting from the letter of support from Donald Wallace, writing in his role as Executive Director of the Ontario Centre for Engineering and Public Policy (OCEPP) (see ***Appendix A***):

> *"The development and demonstration of clean technologies which provide solutions to issues of climate change, clean air, water quality and soil, and which deliver economic, environmental and health benefits to Canadians are essential. But these problems can only be solved by mobilizing our best technical minds in service of the bold solutions that must be found. Where this program shows real leadership is in its marriage between process and substance, between public policy and engineering ... To my eye, this proposed program (by Queen's) approaches sustainability from the right direction and is looking at the right questions.*
>
> *I see the following challenges facing the engineering profession:*
>
> - *To inform the citizenry and government about the importance of the engineering enterprise;*
> - *To be more visible and vocal;*
> - *To carry a message of the value, application, contribution and investment of technology to the people whose lives are shaped by these forces; and*
> - *To communicate more frequently, clearly and proactively.*
>
> *Very few of our graduate engineering programs equip students to meet these challenges and I am very encouraged to see that these challenges are well understood at Queen's.*

Within Queen's, there are existing programs, departments and centres whose mandates could be seen as overlapping with that of the proposed MAS program. This is not surprising given the broad scope and high level of interest in the area of sustainability.

For example, the School of Environmental Studies provides interdisciplinary undergraduate and graduate training that integrates the concepts of environmental toxicology and chemistry, ecosystems, human health, environmental policy and management, as well as the importance of social, cultural, and economic systems into the overarching theme of sustainability. The School offers integrative courses addressing the scientific, socio-political, philosophical and economic aspects of environmental issues. The School offers a Master of Environmental Studies (MES) that is currently running at its capacity of 16 students (over 2 years). As confirmed by Peter Hodson as the School's Director in his Letter of Support (see ***Appendix A***), the teaching and research with the School is seen as complementary to the MAS proposal, whose initial focus is on engineering solutions to sustainability problems within industry and environmental management. It is anticipated that as the MAS program matures, formal teaching links could develop as both the MAS and MES programs seek to develop a doctoral program. Research and supervisory links already exist, as three of the member faculty for the MAS program are already cross appointed to the School of Environmental Studies (Steve Harrison, Heather Jamieson, Joshua Pearce).

As a second example, the Queen's-Fudan Network for Environment and Sustainability Research (the "Network") was formally approved by Queen's Office of Research Services in March 2009, and the companion Fudan-Queen's Sino-Canada Center for Environment and Sustainable Development (the "Center") was launched in November 2009. These entities grew out of a long-established relationship between the universities and a common need for this kind of research, and are strongly supported by both universities. They feature a core group of Chinese and Canadian researchers focused on environment and sustainability. Given the mandate of the Network/Center, there appears to be a natural linkage with the proposed Master's program in Applied Sustainability, which would allow Chinese students to study at Queen's, and vice versa (perhaps in a 1+1 model, where students spend one year each at Queen's and Fudan). Linking of research supervisors from the 2 schools (and other member schools) would also be expected. In essence, the educational and training mandates of the Network/Center would benefit from establishing a link with the proposed degree program, and would be able to take advantage of the newly established linkages between Queen's and the China

Scholarship Council (Ministry of Education), wherein scholarship students from China would select Queen's as a preferred destination school.

11. LEARNING AND PROGRAM OUTCOMES:

While the aim of a university education is to produce educated individuals who possess good judgment and the capacity for critical thought, it is also important to consider specific indicators of learning and program outcomes, such as a graduation rate, length of studies, job placement, external scholarships, awards of graduating students, results of professional certification or licensing examinations, etc. Please discuss the anticipated outcomes of this program.

In general, it is anticipated that MEng students will graduate within 12 months and MASc students will graduate within 24 months, in keeping with expectations of the home departments. Registration in the Collaborative Program is not expected to prolong these times to completion as there is sufficient flexibility in the departmental programs to accommodate the requirements of the MAS program within their existing frameworks.

It is anticipated that graduates of this program will have no difficulty in finding employment with their unique skill set, as based upon the letter of Donald Wallace, writing in his role as Executive Director of the Ontario Centre for Engineering and Public Policy (OCEPP) (see ***Appendix A***) and anecdotal evidence in terms of the level of interest expressed by industry in the offering of this program

12. OTHER ISSUES:

Please describe any additional special considerations with respect to this program.

It is proposed that there be a Program Management Committee. The committee would be composed of a representative from each of the member departments, each serving a two-year term. The committee would elect a chair (normally for a two year period), to be designated as Director of the Queen's University Collaborative Applied Sustainability Program. This committee would liaise with the School of Graduate Studies and the constituent departmental graduate programs. The committee would be charged with:

- maintaining information associated with the graduate courses, participating faculty members and graduate students; the proposed list of graduate courses is given in ***Appendix C***
- keeping records of graduation data, including publications arising from student research and places of post-graduation employment
- coordinating the Applied Sustainability Seminar course (formal approval for this course will be sought once OCGS approval is granted for the proposed Collaborative Graduate Program)
- preparing publicity materials, including web listings advertising the graduate program
- preparing accreditation documentation for periodic appraisal in accordance with OCGS by-laws, as well as documentation required by the member Departments
- communicating with the Graduate Program Coordinators in each of the member departments
- confirming when each student has completed the degree requirements and whether they have completed the above-listed requirements of the Collaborative MAS program;

Appendix A: Letters of Support

1) Kimberly Woodhouse, Dean, Faculty of Engineering and Applied Science
2) Peter Harrison, Director, School of Policy Studies
3) Peter Hodson, Director, School of Environmental Studies
4) Donald Wallace, Executive Director, Ontario Centre for Engineering and Public Policy

February 11th, 2010

Dr. Patrick Deane
Vice-Principal (Academic)
Queen's University
Kingston, ON K7L 3N6

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Dear Dr Deane.

I am pleased to support the proposal for a Collaborative Masters Program in Applied Sustainability in the Faculty of Applied Science here at Queen's University. This is an exciting development offered by a team of faculty members from six departments with scholarship in the subject area. A key aspect of the program is the involvement of the School of Policy Studies, which is contributing courses and faculty members who will participate in the co-supervision of engineering graduate students. Understanding of the concepts of applied sustainability are crucial to the practice of engineering in the 21st century and this Masters program will place Queen's Applied Science at the forefront of programming in this area. It is unique in its course offerings and will bring dynamic and innovative graduate students to Queen's.

This initiative is one of the goals identified in the strategic framework for the Faculty of Applied Science. To quote directly from that document:

> "The purpose of the proposed Masters Degree in Applied Sustainability is to explore the theory and practical implementation of sustainability-compatible engineering. There are many potential areas of application. Three obvious examples are:
>
> - the broad range of applications included in the humanitarian engineering design philosophy currently being explored in Civil Engineering related to provision of fundamental needs and services - water, food, and shelter;
> - mineral resources management – encompassing the full project life cycle from exploration through to mine design, operation, and long-term post-closure; and
> - surety of energy supply: long term energy policy and the appropriate mix over time of conservation and the various forms of primary and secondary supply; the more specific issue of long-term management of used nuclear fuel."

These examples are in fact the areas addressed in the proposal.

The proposal was presented to Faculty Board on January 20th, 2010 and suggestions made at that time have been incorporated into the current document.

Sincerely yours,

Kimberly A. Woodhouse, Ph.D., P. Eng.
Dean
Faculty of Applied Science

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March 4, 2010

Professor Vic Pakalnis
Robert M. Buchan School of Mining
Faculty of Applied Science
Queen's University
Kingston, ON K7L 3N6

Dear Professor Pakalnis:

I have read through your recently revised proposal for a Master's degree in Applied Sustainability and am writing at this time to give my fullest support for this initiative. The project is timely and extremely innovative. As I have indicated to you before, the School of Policy Studies has a number of courses – which you have outlined in your proposal - that may be of interest to students in the program and the School would be happy to have appropriately qualified students from your program in our graduate courses.

The School of Policy Studies will benefit in many ways by incorporating students from the Masters of Applied Sustainability program. Students in the Masters of Public Administration program will profit by the contributions and perspectives offered by MAS students within individual classes. We also expect that participation in the MAS will allow our program to benefit from an improved reputation among technical students from engineering or natural sciences, and that we might see an increase in enrolment from these fields in future years. Finally, as an interdisciplinary School within Queens University, we feel responsibility to participate in this program. Our contribution to the MAS is one way that we can emphasize our role as a conduit that takes academic learning on campus and translates it into terms of relevance for government and industry across the country. This contribution also should be seen as a commitment to the Principals vision, as defined in *Where Next?,* of building programs and research that are innovative and interdisciplinary in nature.

I wish you well with the rest of the journey that this proposal must still complete; if you require further assistance from the School of Policy Studies, please do not hesitate to contact me.

Sincerely,

Director
and
Stauffer-Dunning Chair in Policy Studies
School of Policy Studies

School of
Environmental Studies

Memo

TO **Brian Surgenor, Associate Dean**
Faculty of Applied Science

FROM Peter Hodson, Director, School of Environmental Studies

DATE February 12, 2010

SUBJECT Proposed Collaborative Masters Program in Applied Sustainability

QUEEN'S UNIVERSITY AT KINGSTON

Dr. Peter V. Hodson,
3122, Biosciences Complex
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The School of Environmental Studies fully supports of the proposed Masters Program. The School offers an interdisciplinary Master of Environmental Studies (MES) centred on sustainability and related to the interactions between environmental degradation and economic and social impacts, including human health and well-being. Our teaching and research is complementary to the proposed applied science degree, which concerns engineering solutions to environmental problems and sustainable practices for industrial production and environmental management.

If the Applied Science program is approved, the School will be a resource of faculty members who could participate as members of supervisory and examining committees, and as co-supervisors for specific projects. Our MES program offers two courses annually which may be of interest to Applied Science Students, including ENSC 801 *Methodological and Conceptual Basis for Environmental Studies* and ENSC 802 *Global Environmental Problems: Issues in Sustainability*. The target enrolment for the MES is 17, or about 8-9 new students/yr. Because the capacity of our courses is 16 or less (ideal about 10-12), we routinely fill extra places with students from other disciplines, including Applied Science. One of the greatest values of our courses is the opportunity for discussions among students from different disciplines.

In the future, the School plans to develop a doctoral program, and as much as possible collaborate with other disciplines in Arts and Science, as well as Business, Law, and Applied Science. The theses of many of our current students are directed by faculty members in other departments, particularly where the subject matter is issue based, interdisciplinary, and does not fit the profile of a degree program within a specific discipline. Hence our program offers opportunities for faculty members to expand their research into areas outside their departmental focus.

In summary, the proposed Applied Science program and the School's MES program are complementary and should offer benefits to students in both programs.

Yours sincerely

Peter V. Hodson

School of Environmental Studies
Master of Environmental Studies (MES)
Graduate Courses

ENSC 801 **Methodological and Conceptual Basis for Environmental Studies.**
The course examines methodological and conceptual issues arising from Environmental Studies position as an inter-, multi- and/or trans-disciplinary practice. It will focus on the inherent difficulties in overcoming disciplinary fragmentation in approaches to studying complex issues in environmental sustainability that require integrated understandings of the inter-relations between social and natural systems. The course will promote methodological literacy beyond student's own area of expertise, develop critical and reflexive thinking about how environmental studies might approach issues of sustainability, and encourage and facilitate communication across disciplinary paradigms. The course precedes and compliments ENSC 802*, familiarizing students with the historical origins, philosophical underpinnings and practical deployment of key approaches within the social and natural sciences and humanities.

ENSC 802* - Global Environmental Problems: Issues in Sustainability
This course focuses on real-world environmental problems analyzing their social, ethical, and biogeochemical origins, economic ramifications, and institutional frameworks for their mitigation and resolution in the context of environmental sustainability. This course would logically follow or run concurrently with ENSC 801*, and will deepen and continue the themes through consideration of the intellectual history of theories and concepts relevant to environmental studies, with a focus on the concepts of "sustainability" and "sustainable development

ENSC 816* - Environmental Chemicals
The course will compare and contrast the behaviour of persistent, bioaccumulative and toxic compounds, such as methyl mercury and chlorinated aromatic compounds, with the behaviour of less persistent chemicals such as petroleum hydrocarbons and modern pesticides. Subjects of interest may include sediment diagenesis, long-range transport, methylation processes, and interactions between biomagnification and ecosystem structure and productivity.

ENSC 840* – Directed Studies - This course provides an opportunity for students to independently study a selected topic under the supervision of one of more faculty members. For detailed information, consult course coordinator.

ENSC 897* - Seminar in Environmental Studies
This half-credit course spans four semesters and requires students to attend a minimum of 30 seminars, chosen from among those offered by the School of Environmental Studies (at least 18) and other units in any faculty at Queen's. Within the School's annual seminar series, they must also recruit and host one seminar speaker and present one seminar on their own project.

ONTARIO CENTRE
FOR ENGINEERING
AND PUBLIC POLICY

January 4, 2010

Professor Vic Pakalnis
The Robert M. Buchan Department of Mining
Queen's University
Kingston, ON K7L 3N6

Re: Proposed Program in Applied Sustainability

Dear Vic,

I am writing to express my strong support for the proposed Master's program in Applied Sustainability in the Faculty of Applied Science at Queen's University.

There can be no more important global public policy challenge than sustainable development. At the risk of being accused of conceit, I'd like to quote something I wrote over twenty years ago:

> Sustainable development is a term that comes from the World Commission on Environment and Development (the Brundtland Commission), which examined the relationship between the global ecological system and the existing patterns of economic growth, including such questions as the greenhouse effect, acid rain, and ozone layer depletion as well as the global depreciation of forests, fisheries, and agricultural soils. The term has been used to signify the need to harmonize economic development and environmental health and to formulate policies designed to provide greater environmental protection. In this context, environmental factors can act as a short-term constraint on economic growth, but the long-term goal is to integrate sound environmental decision making with sustainable economic development.

While we don't talk as much today about acid rain and the greenhouse effect, the term sustainable development has proved to have remarkable legs. Former Prime Minister Brundtland put it more simply: "Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs."

Quite simply the development and demonstration of clean technologies which provide solutions to issues of climate change, clean air, water quality and soil, and which deliver economic, environmental and health benefits to Canadians are essential. But these problems can only be solved by mobilizing our best technical minds in service of the bold solutions that must found. Where this program shows real leadership is in its marriage between process and sub-

stance, between public policy and engineering. I regret that, in the last few years, the concept of sustainability has acquired a rather elastic quality. In some business circles, for example, it has become synonymous with profitability. To my eye, this proposed program approaches sustainability from the right direction and is looking at the right questions.

I see the following challenge facing the engineering profession:

- to inform the citizenry and government about the importance of the engineering enterprise;
- to be more visible and vocal;
- to carry a message of the value, application, contribution and investment of technology to the people whose lives are shaped by these forces; and
- to communicate more frequently, clearly and proactively.

Very few of our graduate engineering programs equip students to meet these challenges and I am very encouraged to see that these challenges are well understood at Queen's.

Policy skills will help engineers to become opportunity finders, problem solvers, be seen as go-to professionals for public policy insights and to promote hard-wired link between infrastructure, technology, and quality of life. This program has the added attraction of having students work on real world problems through their industrial internships.

Engineers have a statutory obligation to protect public interest and to prevent any situation that might cause harm to public. More and more, engineers conceive of this responsibility in broader proactive terms. It is essential that the next generation of engineers be equipped with knowledge about societal and political forces to be able to mobilize their technical skills and aptitudes effectively. This program promises to do just that.

I applaud Queen's for such a far-sighted initiative and I wish you the best for its speedy approval.

Yours truly,

Donald Wallace, PhD
Executive Director

Appendix B: Draft Outlines for Required Courses

Lecture Course

General

Title (Number):	Topics in Applied Sustainability (previously listed as MECH 836 and will be designated as Applied Sustainability course CPAS 801)
Term:	Fall or Winter
Hours:	3 hours per week
Instructor(s):	B. Anderson, W. Mabee, J. Pearce and V. Pakalnis

Background

a. Course Objective

The objective of this course is to introduce students to the fundamental concepts of engineering for sustainability and sustainable development. It covers aspects of appropriate technology, green engineering and materials, resource conservation, renewable resources, and design for extreme affordability. Another emphasis of the course is to introduce students to a range of engineering problem solving methods: methods to identify and select sustainable solutions to design problems; methods of improving existing engineering solutions; and methods of systems thinking. Technical, economic, and social consequences of engineering practices and processes will be examined to better delineate the complex engineering decisions related to social and environmental issues.

b. Calendar Description

Applied sustainability is the application of science and innovation to meet human needs while indefinitely preserving the life support systems of the planet. This course provides an overview of the field with particular focus on implementation of engineering solutions. The course will be divided into three sections in which the technical and policy-related issues will be explored: 1) Sustainable Energy Technologies, 2) Sustainability and Fresh Water Systems and 3) Sustainable Resource Management. In the first section, the engineering necessary to transition from a nuclear and fossil fuel-based energy system to one utilizing a portfolio of sustainable energy technologies will be detailed. The use of thermodynamics, exergy, and dynamic life cycle analyses will be used to provide the basis for comparison between technologies. In the second section, society's unsustainable use of water will be examined and changes utilizing ecological principles and biomimicry necessary to meet the goal of long-term strategic and sustainable fresh water systems will be analyzed. In the third section, the historically challenging problem of resource management will be studied to provide safe, environmentally friendly and socially benign methods of resource extraction and waste disposal. In each section, emphasis will be given to the policy relevance of topics covered, including our ability to measure sustainability, develop lower-risk strategic plans and integrate technical concepts into planning and design.

Course Evaluation

The final grade will be made up of 20% presentations and 80% final project paper.

Seminar Course

General

Title (Number):	Applied Sustainability Seminar Series (to be designated as Applied Sustainability course CPAS 897)
Term:	Fall/Winter
Hours:	2 hours per month
Instructor(s):	TBA

Background

a. Course Objective

The objective of this course is to expose Applied Sustainability students to the different areas of Applied Sustainability research and practice, providing a shared learning experience to link students from each of the departments participating in the Collaborative Graduate Program in Applied Sustainability. An additional objective is to provide opportunities to develop and refine presentation skills, the ability to give and receive constructive criticism, and to pose and respond to questions.

b. Course Emphasis

The course will emphasise the broad scope and interdisciplinary nature of Applied Sustainability research and practice, through the preparation, delivery and audience participation in oral presentations.

c. Calendar Description

Seminar course to illustrate all areas of research and practice in Applied Sustainability; emphasis on breadth and interdisciplinary aspects; preparation, delivery and audience participation in oral presentations; the course links students from departments participating in the Collaborative Graduate Program in Applied Sustainability; opportunities are provided to develop and refine presentation

Seminar Schedule and Topic Selection

a. Six seminar hours will be held each twelve week term

b. Seminar sessions will alternate between one hour presentations by an invited guest, and 20 to 30 minute presentations by graduate students. Each year, each student will deliver one presentation in an area of Applied Sustainability. While most invited speakers will present seminars in the general area of Applied Sustainability, some presentations may cover topics like effective communication and use of library resources

Course Evaluation

Activity	Proportion	
Attendance at seminars	Pass/Fail	(at least 75%)
Presentations	80%	
Class participation	20%	

Appendix C: Course Descriptions

Graduate Courses Specific to Program in Applied Sustainability

CPAS 801 Topics in Applied Sustainability
(see Appendix B of this proposal).

CPAS 897 Applied Sustainability Seminar
(see Appendix B of this proposal).

CPAS 898 Masters Project (Course-based)
A project prepared under direction. A project report is submitted to an examining committee for approval.

CPAS 899 Masters Thesis
See Graduate School regulations concerning thesis requirements.

Graduate Courses in Faculty of Engineering and Applied Science (List A)

CHEE 8xy Fuel Cell Systems: Design and Analysis *(currently offered under CHEE 807 – Current Topics in Chemical Engineering, standalone approval to be sought for 2010/11)*
This course will examine the design of fuel cell systems for a variety of applications ranging from large multimegawatt stationary power systems to milliwatt scale portable electronics systems. Examples will be drawn from actual demonstration and pre commercial prototype systems operating on a range of fuels including conventional hydrocarbons with integrated external fuel processing subsystems, anaerobic digester gas with external clean up and preprocessing, natural gas fuelled systems with direct and indirect reforming, direct methanol fuel cells and hydrogen fuel cells. The design of combined heat and power systems (CHP) for large scale industrial applications and for small scale residential applications will also be examined. In each of these case studies the impact of system configuration and individual component performance on efficiency will be examined and strategies for optimizing performance and minimizing complexity will be developed. In addition the effect of system design on greenhouse gas emissions will be considered. The course will consist of three design projects of increasing complexity and a final examination. Students will be expected to give a presentation on their final design project. ***Brant Peppley***

CHEE-837 Transport & Kinetics with Application to Fuel Cells
(also as MECH 837 with Jon Pharoah)
The fundamentals of transport phenomena and reaction kinetics are considered and applied to fuel cells, with a view to a mechanistic understanding of fuel cell operation and limitations. Material covered includes the basic axioms of mechanics (conservation of mass, momentum, energy and charge) presented in indicial notation and applied to porous media. Emphasis is placed on the description of porous materials and the implications of porous media on transport, including the notion of effective transport coefficients. Ion transport in solid and polymer electrolytes due to electrochemical potential differences is considered. Diffusion models covered include Ficks law, Stefan Maxwell and Knudsen. Electrochemical reaction kinetics and mechanism are covered including rate-limiting steps, exchange current density and the fundamental definition of overpotential. The course includes individual projects. ***Kunal Karan***

CHEE-882 - Bioreactor Design
This course examines the important factors in the design and operation of stirred tank bioreactors. A variety of biokinetic models are examined and used in the design of ideal and non-ideal bioreactors. The effect of the rheology of fermentation broths on mass transfer, mixing, power requirement, etc. is considered, along with Residence Time Distribution Analysis as a tool for quantifying non-ideal behaviour. Novel fermentor designs and immobilized enzyme/cell systems are discussed. Scale-up criteria are examined. ***Andrew Daugulis***

CHEE-884 – Bioremediation
Bioremediation as an option to treat contaminated soils, ground water, fresh water and the marine environments. Advantages and disadvantages of bioremediation compared to nonbiological processes. Factors affecting choice of in situ or ex situ processes. Assessment of biodegradability; biostimulation vs. bioaugmentation; mineralization vs. partial degradation; factors affecting microbial activity (choice of electron acceptor, toxicity of pollutant, C/N/P ratio, co-substrates, soil humidity, pH and temperature); bioavailability of pollutant. Biodegradation of specific contaminants (e.g., diesel fuel, polychlorinated biphenyls, dyestuffs, aromatic and polyaromatic hydrocarbons) will be studied in detail.
Pascale Champagne

CIVL-885 Chemistry of Natural Waters
This course covers several topics in the area of natural water chemistry including: dilute aqueous solution chemistry of surface and groundwater systems; chemical kinetics and equilibrium; acid-base chemistry; coordination chemistry; precipitation, dissolution and complex formation; carbonate, phosphate and chlorine chemistry; oxidation-reduction reactions and corrosion; and solution of multi-equilibria problems. ***Pascale Champagne***

CIVL-886 Biological Treatment Processes
This course will develop the principles and operation of biological treatment processes with particular emphasis on the microbiological aspects of these operations. The application and design of different treatment methodologies, incorporating aerobic and anaerobic techniques, will be detailed for various wastes. The management, processing and disposal of treatment residuals will be presented. Selected advanced and innovative small-scale treatment options will be described. ***Bruce Anderson***

CIVL 890 Water Network Analysis & Design
Topics to include: review of basic fluid mechanics of closed-conduit flow; hydraulic characteristics of pumps, valves, tanks and reservoirs; network hydraulics (includes pipes in series and parallel, system of equations for steady state network flow and solution algorithms, fire analysis, unsteady flow conditions, extended period simulation, hydraulic transients); water quality simulation (includes transport mechanisms, reaction kinetics, mixing in storage facilities, transport and mixing in pipe network, steady state and dynamic water quality modelling); water demand and design standards; master planning of water networks. The course will also cover advanced topics in: water network optimization, sensor placement, contaminant detection, sustainable water systems, dual water systems and water re-use. ***Yves Filion***

GEOL-8yz Mineral Resources and Sustainable Development *(currently offered under GEOL 841 – Special Topics in Geological & Geological Engineering, standalone approval to be sought for 2010/11)*
This module course comprises discussions of major issues related to the role of mineral exploration companies and mining industry and of professionals working this field in providing well-being for people and ecosystems. This includes discussions of the challenge of providing mineral resources to maintain sustainable development. It involves contributions of professionals working in the mineral and mining industry as well related fields of expertise which may include Law, Environmental and Social Sciences.
Gema Olivo

GEOL-835 The Environmental Impact of Mining
This course will expose students to the concepts and the current practice of mine waste management including acid mine drainage, neutral-pH metal leaching, secondary mineral precipitates, prediction and permitting, site remediation, etc. Students who complete this course will have a comprehensive understanding of the nature of the environmental impact of mining on ecological and human health, the scientific principles behind the interaction between mine waste and the surface environment, and the tools that professionals use to predict, control, remediate and regulate metal mining activities. ***Heather Jamieson***

MECH-820 Solar Photovoltaic Materials, Cells and Systems Engineering
This course provides a graduate level introduction to solar photovoltaics: the materials science behind the technology, device physics and practical systems engineering applications. One third of this course will be dedicated to semiconductor materials for photovoltaics, including effects of microstructure, band theory, opto-electronics, and charge transport. One third will be dedicated to solar photovoltaic cell device physics:semiconductor junctions, principles of operation, structures, fabrication, and manufacturing of conventional, thin film, and "3rd generation" solar cells. The last third will be dedicated to photovoltaic systems engineering: the solar resource, power conditioning equipment and system integration techniques, mechanical elements (frames, supports, orientation mechanisms, and tracking), energy storage, residential grid-connected photovoltaic systems including engineering economics and government incentives. The course is meant for graduate students in Mechanical and Materials Engineering and Engineering Physics, while graduate students in other areas of engineering, physics and other physical sciences with a strong interest in this topic are also welcomed. ***Joshua Pearce***

MECH-834 Fundamentals of Solar Energy Conversion for Heating and Cooling Applications
This course presents the fundamental principles of solar energy conversion, storage and distribution. Both photovoltaic and thermal energy conversion systems will be introduced; however the primary focus of the course will be on solar thermal systems for heating and cooling applications. Topics covered include the nature and prediction of the solar resource, solar collector design and performance, thermal storage, heat transport and distribution. The modeling and design of complete solar heating and cooling systems will be studied and exercises completed. Students will be required to complete a major project related to one of the above topics. Course lecture material will be augmented with laboratory exercises. ***Steve Harrison***

MINE-836 Mineral Processing and the Environment
The objective of this course is to provide an introduction to mineral processing unit operations with regards to final product production. Process selection criteria will be highlighted including economics, efficiency, and geographic location. Environ mental issues associated with producing metals from a variety of ore types will be examined including tailings treatment/impoundment methods and pyrometallurgical and hydrometallurgical refining techniques. ***Sadan Kelebek***

MINE-862 Issues in Health, Safety and Environment
The following topics are covered: Introduction to Health and Safety and Environment, Risk Perception and Assessment, Occupational Hygiene, Indoor Air Quality, Principles of Safety Theory and Management, Risk Homeostasis, Principles of Occupational Toxicology, OEL , Toxic Effects of Airborne Contaminants, Dermal Exposure, Evaluation of Airborne Contaminant Levels, Noise, Vibration and Other Physical Agents, Radiation - Ionizing an Nonionizing, Ergonomics, Control Measures for Airborne Contaminants and Heat Stress, Diverse perspectives, Health, Safety and Environment Issues and Engineering Responsibilities, Government, Industry and Labour Unions. ***Vic Pakalnis***

Graduate Courses in School of Policy Studies (List B)

MPA-843 Trade and Public Policy
An introduction to the public policy issues associated with international trade, with particular reference to the World Trade Organization. ***Bob Wolfe***

MPA-845 Science and Technology Policy
This course provides a comprehensive overview of policy issues relating to science and technology policy, such as research funding, science-based public policy, science and the public, support of high-tech industries, regional cluster concepts, R&D tax incentives, competitiveness, etc. The focus is on Canada in the larger context of the OECD countries. ***Warren Mabee***

MPA-847 Environmental Policy
This course surveys the factors that influence the actions of major institutions, such as governments, industry and public interest groups, with respect to environmental issues. It looks for broad designations of competing approaches, such as command and control versus incentive-based instruments, to such tasks as the setting of standards, regulation and compliance, management of risks and the realization of effective public participation. It also attempts to look behind the pragmatic policy formulations to identify the fundamental values that shape attitudes toward environmental issues. ***Warren Mabee***

MPA-877 Energy Policy
This course examines, in detail, the development of Ontario's energy policy with respect to the electricity sector in the past ten years. It reviews the forces at work propelling the policy changes, including policy developments in other jurisdictions and then examines the policy options with respect to the future mix of technologies (renewables, fossil fuels, and nuclear) available for generating electricity in Ontario in the rapidly changing global context for the energy industry. ***Peter Harrison***

MPA-887 Arctic and Northern Issues
The objectives of this course are to introduce students to the complex issues facing the Arctic from both a Canadian and an international perspective, and to develop policy options for dealing with them. The course has been structured so that as many of the different stakeholder views as possible (but not all) will be presented, analyzed, and questioned. The topics covered in the course will range from an understanding of the rapid environmental change under way through to the geopolitical challenges which are emerging as the interest of non-Arctic nations in Arctic issues is enhanced. ***Peter Harrison***

Undergraduate Courses in Faculty of Engineering and Applied Science (List C)

ELEC 433 Energy and Power Systems
Energy resources and electric power generation with particular emphasis on renewable energy systems such as solar, wind, and biomass; review of balanced and unbalanced 3-phase systems; review of per-unit systems; real and reactive power, sequence networks and unsymmetrical analysis; transmission line parameters; basic system models; steady state performance; network calculations; power flow solutions; symmetrical components; fault studies; short circuit analysis; economic dispatch; introduction to power system stability, operating strategies and control; modern power systems and power converters; DC/AC and AC/DC conversion; and introduction to DC transmission. ***Alireza Bakhshai***

MECH 424 Life Cycle Engineering
This is an environmental design course in Mechanical Engineering. Life Cycle Engineering is an objective process to evaluate the environmental burdens associated with designing a product and the

manufacturing process required to make the product. Life Cycle Engineering includes methods of assessment, inventory and calculating environmental damage. Modern manufacturing engineering design concepts, such as design for assembly and design for disassembly, will be included in the course. ***Jack Jeswiet***

MECH 425 Engineering for Sustainable Development
This course introduces students to the fundamental concepts of engineering for sustainability and sustainable development. It covers aspects of appropriate technology, green engineering and materials, resource conservation, renewable resources, and design for extreme affordability. Another emphasis of the course is to introduce students to a range of engineering problem solving methods: methods to identify and select sustainable solutions to design problems; methods of improving existing engineering solutions; and methods of systems thinking. Technical, economic, and social consequences of engineering practices and processes will be examined to better delineate the complex engineering decisions related to social and environmental issues. The goal of this course is to assist students in the application of science and innovation to meet human needs while indefinitely preserving the life support systems of the planet. ***Joshua Pearce***

MINE 422 Mining and Sustainability
This course introduces the evolution of the principles of applied sustainability and their applications in the mining industry. Themes examined will include: the mining industry and society; the nature of the mining industry in Canada and around the world; the theory of sustainability and sustainable development; corporate social responsibility, reporting and assessment; mine closure; regulation of mine activities in Canada and elsewhere; mining and indigenous people in Canada and abroad; and future scenarios for the mining industry in North America. ***Tony Hodge***

MECH 430 Thermal Systems Design
This course is concerned with the technical, economic and environmental aspects of conventional and novel methods of energy supply and use. Emphasis will be placed on the analysis and design of thermal systems. Topics include: electric utility demand and supply; the analysis of thermal power generation systems including combined cycle and cogeneration plants; emission control; alternative energy systems. Laboratory work will include the analysis of thermal systems such as a steam generator and HVAC system. ***Steve Harrison***

MDEP 437 Fuel Cell Technology
Introduction to and history of various fuel cell systems. Fuel cell fundamentals including thermodynamics, electrode kinetics, fuel cell performance and transport issues. Systems covered include Polymer Electrolyte Membrane (PEMFC), Direct Methanol (DMFC), Alkaline (AFC), Solid Oxide (SOFC), and Molten Carbonate (MCFC). Fueling processing issues and combined heat and power systems. Overview of the current fuel cell industry. ***Jon Pharoah***

Appendix D: Details of Intellectual Focus: Areas of Applied Sustainability Research Expertise

The areas of research for the faculty members associated with the proposal are given in this appendix.

Applied Sustainability and Energy Technology

The focus of this group is on the application of science and engineering innovation to move from a nuclear and fossil fuel based energy system to one that is based on sustainable energy technologies.

Researchers:

- Alireza Bakhshai
- Steve Harrison
- Praveen Jain
- Kunal Karan
- Joshua Pearce
- Brant Peppley
- Jon Pharoah

Dr. Alireza Bakhshai is an Associate Professor in the Department of Electrical and Computer Engineering and is a member of the Interim Advisory Board for the Queen's Centre for Energy and Power Electronics Research (ePOWER). His areas of research interest include high power electronics and applications, renewable energy conversion, and control systems. In addition, he has demonstrated his ability to apply his knowledge in an industrial context, contributing to the application of FACTS Controllers and of New Motor Drive Technologies for a Cold Rolling Mill at the Mobarakeh Steel Company in Iran.

Dr. Steve Harrison is an Associate Professor in the Department of Mechanical and Materials Engineering and is cross appointed to the School of Environmental Studies. He is the Director of the Queen's Solar Calorimetry Laboratory. His research interests include test methods and standards for solar heating systems and components; design, analysis, modelling, and improvement of thermal systems (Heating, Ventilation and Air Conditioning (HVAC) and solar energy) and associated components. For nearly 20 years, he has been exploring alternative energy solutions to reduce the environmental impact of conventional energy sources. His patented innovations in solar hot water technology resulted in the development of a solar domestic hot water heater product now being sold on the North American market by EnerWorks Inc. of London, Ontario.

Dr. Praveen Jain is a Professor in the Department of Electrical and Computer Engineering, holds the Canada Research Chair in Power Electronics and is the Interim Director of the Queen's Centre for Energy and Power Electronics Research (ePOWER). His industrial experience has included work as a power electronics engineer for Canadian Aeronautics where he contributed to the design and development of high frequency power conversion equipment for the International Space Station, as an advisor for Nortel Networks, and as a consultant with Astec Advanced Power Systems, providing guidance for the research and development of advanced power technologies for telecommunications. ePOWER brings together academic and industrial researchers to develop a broad range of applications and expertise, from power transmission (generator to main distribution transformer) to alternative energy (including fuel cells, solar power and wind power) to power consumption (such as that found in communications and computer power systems) to power application-specific integrated circuits (PASIC). Fundamental and applied research conducted at ePOWER is resulting in the development of new energy efficient, cost effective and environmentally friendly power electronic technologies.

Dr. Kunal Karan is an Associate Professor in the Department of Chemical Engineering and is an Associate Director of the Queen's-RMC Fuel Cell Research Centre (FCRC). His areas of research interest include solid oxide fuel cell development characterization and modeling, polymer electrolyte fuel cell mathematical modeling, compact reactors for fuel processing, asphaltene adsorption and deposition kinetics. As a member of FCRC, he is part of a community of motivated researchers with a deep desire to unravel the challenging problems related to fuel cells specifically and energy issues in general.

Dr. Joshua Pearce is an Assistant Professor in the Department of Mechanical and Materials Engineering and is cross appointed to the School of Environmental Studies. His research in applied sustainability focuses on energy policy and opens source appropriate technology (OSAT). OSAT refers to technologies that provide for sustainable development while being designed in the same fashion as free and open-source software. Facilitated by advances in information technology software and hardware, new ways to disseminate information such as wikis and Internet-enabled mobile phones, the global development of OSAT has emerged as a reality. This research investigates how the sharing of design processes, appropriate tools, and technical information enables more effective and rapid development of appropriate technologies for both industrialized and non-industrialized regions.

Dr Brant Peppley is a Professor in the Department of Chemical Engineering and holds a joint appointment in the Department of Mechanical and Materials Engineering. He is the Canada Research Chair in Fuel Cells and is the Director of the Queen's-RMC Fuel Cell Research Centre (FCRC). His research interests include fuel cells, heterogeneous catalysis, reaction engineering, hydrogen production and bio-energy. Fuel cells hold the promise of dramatically reducing our greenhouse gas emissions but there are technical challenges that need to be overcome. At FCRC, he is project leader on two research programs that will help develop the needed technologies. One study is designed to increase the conversion efficiency of biogas to electricity using high temperature fuel cells at landfill and wastewater treatment sites. The second study focuses on improving geographically remote fuel cell power systems, which could provide power in northern Ontario where diesel generators can cause significant environmental damage to sensitive ecosystems.

Dr. Jon Pharoah is an Associate Professor in the Department of Mechanical and Materials Engineering and is an Associate Director of the Fuel Cell Research Centre. His research interests include fuel cells (high and low temperature), energy systems, transport phenomena, membrane separation and computational fluid dynamics. As a member of FCRC, he is part of a community of motivated researchers with a deep desire to unravel the challenging problems related to fuel cells specifically and energy issues in general.

Applied Sustainability and Fresh Water Systems

The focus of this group is on the application of science and engineering innovation to move from unsustainable water use to long-term strategic fresh water systems throughout the world. The researchers identified below all participate in a new Queen's research group initiative in the area of Water, Environment and Health that involves almost 40 faculty members from across the campus and other local universities and institutions.

Researchers:

- Bruce Anderson
- Pascale Champagne
- Yves Filion
- Kent Novakowski

Dr. Bruce Anderson is a Professor in the Department of Civil Engineering and is cross appointed to the School of Urban and Regional Planning. His research focuses on the use of natural and engineered

biological systems for environmental control and watershed/source water protection, with application to the problems of urban and semi-urban stormwater and agricultural runoff management (diffuse pollution), and the treatment and discharge of wastewater from small-scale unserviced areas and industries. These activities are all part of a new research focus on the creation of *integrated green and sustainable urban and semi-urban areas*, for the protection of human health and environmental health in Canadian and international settings.

Dr. Pascale Champagne is an Associate Professor in the Department of Civil Engineering and is cross-appointed to the Department of Chemical Engineering. Her research looks at solid waste management with a view to minimizing the impact of municipal, agricultural and industrial activities on surface water and groundwater contamination.

Dr. Yves Filion is an Assistant Professor in the Department of Civil Engineering. His research focuses on climate change mitigation and adaptation to make urban water systems sustainable. He is developing methods to design and optimize urban water systems to minimize negative environmental impacts and make them more resilient and adaptable to anticipated changes in climate.

Dr. Kent Novakowski is a Professor and Head of the Department of Civil Engineering. His work has focused on the protection and sustainability of particularly vulnerable water supplies in the bedrock aquifers common to eastern North America. He conducts field studies and numerical simulation of large watersheds in eastern Ontario and elsewhere which are vulnerable to impact from surface contamination occurring from urban development and agricultural activity, and from changes in recharge and discharge conditions due to large-scale groundwater abstraction and climate change.

Applied Sustainability and Resource Management

The focus of this group is on the application of science and engineering innovation to move to environmentally benign research extraction and the preservation of existing resources through life cycle analysis of manufacturing processes.

Researchers:

- Andrew Daugulis
- Tony Hodge
- Heather Jamieson
- Jack Jeswiet
- Sadan Kelebek
- Gema Olivo
- Vic Pakalnis

Dr. Andrew Daugulis is a Professor in the Department of Chemical Engineering and is cross appointed to the Department of Biology, and also the Department of Microbiology and Immunology. He holds the Queen's Research Chair in Biochemical and Cell Culture Engineering, and is Editor of Journal of Hazardous Materials. His research interests are in bioprocess development, specifically in the design of bioremediation technologies, and in the production of high value chemical intermediates from biomass-based feedstocks. This latter application reflects the growing global interest in the Biorefinery concept, which aims to displace non-renewable oil as a feedstock for chemical processes with renewable biomass using biologically-based processing. Both areas of research rely on a technology platform developed in the Daugulis Group called Two Phase Partitioning Bioreactors, a processing concept that has now been adopted by researchers in more than 15 countries around the world.

Dr. Tony Hodge was the first Kinross Professor of Mining and Sustainability in the Robert M. Buchan Department of Mining. For the past decade he has been an Associate with the International Institute for Sustainable Development. He was appointed President of the International Council on Mining and

Metarlurgy (ICMM) in May 2008, and took up the post on October 2008. He maintains a position at Queen's and teaches the course MINE 422 Mining and Sustainability.

Dr. Heather Jamieson is a Professor in the Department of Geological Science and Geological Engineering and holds a joint appointment with the School of Environmental Studies. Her research is in the area of environmental geochemistry, and most but not all of her activities focus on the environmental impact of mining. Current projects include the development of mineralogical controls on the chemical evolution of extremely acid mine waters at Iron Mountain, California and the identification and evaluation of arsenic-bearing minerals in tailings, soils and sediments from the Yellowknife area.

Dr. Jack Jeswiet is a Professor in the Department of Mechanical and Materials Engineering. His research interests include metal forming operations, especially Single Point Incremental Forming (SPIF). He has been involved in Sustainability-Life Cycle Engineering (LCE) issues since 1993, beginning as the secretary of the CIRP LCE Working Group, and has given many keynote papers and invited talks on Manufacturing and Sustainability topics. With respect to Sustainability issues, he conducts research and publishes with colleagues at the Danish Technical University (DTU) and Katholieke Universiteit Leuven and UNSW in Australia. He is currently involved with Energy use and CO_2 emissions in manufacturing and the IMS project CO2PE (Cooperative Effort on Process Emissions in Manufacturing) and EREE (ENERGY and RESOURCE EFFICIENCY & EFFECTIVENESS) initiatives in CIRP.

Dr. Sadan Kelebek is an Associate Professor in the Robert M. Buchan Department of Mining. He teaches courses related to methods of mineral separation, process plant design, flotation science and technology as well as mineral processing and the environment. His research focus in on the improved understanding and development of separation methods for minerals and metals in relation to recovery of value added products as well as minimization or elimination of environmental pollution.

Dr. Gema Olivo is a Professor in the Department of Geological Science and Geological Engineering. As a mineral deposit geologist, her main research interest is to understand processes involved in the genesis of hydrothermal ore deposits, particularly precious metal deposits using a multidisciplinary approach. This involves integrating detailed mapping, petrographic, mineral chemistry, isotopic and fluid inclusion studies, whole-rock geochemistry, and ore and alteration mineral stability investigations. Understanding of these processes will allow for developing more refined genetic models, which will lead to better exploration strategies, improving the odds of success for global mineral exploration.

Dr. Vic Pakalnis is the Kinross Professor of Mining and Sustainability in the Robert M. Buchan Department of Mining. In 2007 he was appointed the Ontario Public Service Amethyst Fellow in Public Policy, School of Policy Studies. He teaches courses in the Masters of Public Administration, Masters of Industrial Relations and Mining Engineering programs, on the subjects of policy implementation, project management, occupational health and safety. One of his graduate students is currently working on the issue of sustainable seabed mining. He has organized a number of First Nations conferences and is the lead on the Aboriginal access to mining engineering program approved in January 2010 for funding by the Ministry of Colleges and Universities.

Applied Sustainability and Policy Studies

The focus of this group is on the application of social science and innovation.

Researchers:

- Peter Harrison
- Warren Mabee
- Bob Wolfe

Dr. Peter Harrison is a Professor and a Director in the School of Policy Studies. He holds the Stauffer-Dunning Chair in Policy Studies and is cross-appointed to the Department of Geography. One of his

research interests is looking at the impacts of climate change and increased development on Canada's Arctic region. His research focuses on the means by which social systems in northern and aboriginal communities can be strengthened in order to respond to increasing demands upon the Arctic region for material and energy outputs, as well as expanded use of the Northwest Passage for international shipping. The policies required to build on existing strengths of these populations while safeguarding the coastlines and ecosystems of the Arctic are primary outputs of this research program.

Dr. Warren Mabee is an Assistant Professor in the School of Policy Studies and holds a joint appointment with the Department of Geography. He is the Director of the Queen's Institute for Energy and Environmental Policy (QIEEP) and is the Associate Director of the Sustainable Bioeconomy Centre (SBC). His research focuses on the interface between renewable energy policy and technologies, with particular emphasis on wood energy and biofuels. His interests also include environmental policy, international approaches to renewable energy development, and commercialization of new products and processes. In particular, he is interested in improving the uptake of new energy technologies, examining policy to support for renewable energy options, and the development of strategies to reduce our reliance upon fossil energy sources.

Dr. Robert Wolfe is a Professor in the School of Policy Studies and is cross-appointed to the Department of Political Studies. He has a research program that focuses on the analysis of trade policy. He is the coordinator of Canadian participation in the Canada-UK Colloquium and is a Senior Fellow of the Centre for International Relations. He teaches policy analysis and trade policy. In his courses, he approaches policy analysis from the inside, the view of practitioners, rather than from the outside perspective of analysts who observe the policy process. His focus is not on how decisions are made, but on how practitioners should think about policy problems.

Appendix E: Participating Faculty and Examples of Recent Publications

Sample publications from the faculty members associated with the proposal are given in this appendix.

Chemical Engineering

Andrew Daugulis:

Prpich, G.P., Rehmann, L. and **Daugulis, A.J.** (2008) "On The Use, and Re-Use, of Polymers for the Treatment of Hydrocarbon Contaminated Water Via a Solid-Liquid Partitioning Bioreactor", *Biotechnology Progress*, 24, pp. 839-844.

Morrish, J.L.E. and **Daugulis, A.J.** (2008) "Improved Reactor Performance and Operability in the Biotransformation of Carveol to Carvone Using a Solid-Liquid Two Phase Partitioning Bioreactor", *Biotechnology and Bioengineering,* 101(5), pp. 946-956.

Prpich, G.P. and **Daugulis, A.J.** (2007) "A Novel Solid-Liquid Two-Phase Partitioning Bioreactor for the Enhanced Bioproduction of 3-Methylcatechol", *Biotechnology and Bioengineering*, 98(5), pp. 1008-1016.

Kunal Karan:

Parmar, R.D., Kundu, A. and **Karan, K.** (2009) "Thermodynamic analysis of diesel reforming process: Mapping of carbon formation boundary and representative independent reactions," *Journal Power Sources,* 194(2), pp. 1007-1020.

Kenney, B., Valdmanis, M. C. Baker, J.G. Pharoah, and **Karan, K.** (2009) "Computation of TPB length, surface area and pore size from numerical reconstruction of composite SOFC electrodes," *Journal Power Sources,* 189(2), 1051-1059.

Wheeldon, I.R., Caners, C., **Karan, K.** and Peppley, B.A. (2007) "Utilization of Biogas from Ontario Wastewater Treatment Plants in Solid Oxide Fuel Cell Systems: A Process Modeling Study", *International Journal of Green Energy*, 4, pp. 221-231.

Brant Peppley:

Oosthuizen, P.H., Hussain, S. and **Peppley, B.A.** (2009) "A Numerical Study of the Performance of an Autothermal Reformer for use in a Fuel Cell Powered Auxiliary Power Unit for Trucks", *Chemical Engineering Transactions*, 18, pp. 653-658, DOI: 10.3303/CET0918106.

Wheeldon, I.R., Caners, C., Karan, K. and **Peppley, B.A.** (2007) "Utilization of Biogas from Ontario Wastewater Treatment Plants in Solid Oxide Fuel Cell Systems: A Process Modeling Study", *International Journal of Green Energy*, 4, pp. 221-231.

Peppley, B.A. (2006) "Biomass for Fuel Cells: A Technical and Economic Assessment" *International Journal of Green Energy*, 3(2), pp. 201-218.

Civil Engineering

Bruce Anderson:

Li, X., Manman, C. and **Anderson, B.C.** (2009) "Design and Performance of a Constructed WQT Wetland in a Public Park in Shanghai City", *Ecological Engineering,* 35(1), pp. 18-24.

Anderson, B.C., Watt, W.E., Marsalek, J., Ng, J. and Sneyd, B. (2008) "Integrated Stormwater Management for Land-restricted Lakeside Villages: The Case Study of Portland, Ontario", *Journal of Canadian Water Resources,* 33(3), pp. 295-306.

Martin, D.G. and **Anderson, B.C.** (2007) "Performance Evaluation, Comparison and Modeling of Passive Wastewater Treatment Systems", *Journal Environmental Engineering and Science,* 6, pp. 691-702.

Pascale Champagne:

Champagne, P. and Westman, T. (2010) "Land Application and Passive Stabilization of Pulp and Paper Biosolids: A Case Study", *International Journal of Environment and Waste Management*, 10(3/4).

Roy-Poirier, A., **Champagne, P.** and Filion, Y. (2009) "A Review of Bioretention System Research: Past, Present, and Future", *Journal of Environmental Engineering ASCE* (accepted).

Speer, S., **Champagne, P.**, Crolla, A. and Kinsley, C. (2009) "Hydraulic Performance of a Mature Wetland Treating Milkhouse Wastewater and Agricultural Runoff", *Water Science and Technology*, 59(12), pp. 2455-2462.

Yves Filion:

Herstein, L., **Filion, Y.R.** and Hall, K. (2009). "Evaluating Environmental Impact in Water Distribution System Design." *Journal of Infrastructure Systems*, ASCE, 15(3), pp. 241-250.

Filion, Y.R. (2008) "Impact of Urban Form on Energy Use in Water Distribution Systems." *Journal of Infrastructure Systems*, ASCE, 14(4), pp. 337-346.

Filion, Y.R., MacLean, H.L. and Karney, B.W. (2004) "Life Cycle Energy Analysis of a Water Distribution System." *Journal of Infrastructure Systems*, ASCE, 10(3), pp. 120-130.

Kent Novakowski:

Gleeson, T., **Novakowski, K.** and Kyser, T.K. (2009) "Extremely rapid and localized recharge to a fractured rock aquifer", *Journal of Hydrology*, 376, pp. 495-509.

Gleeson, T., **Novakowski, K.,** Cook, P. and Kyser, K. (2009) "Constraining groundwater discharge in a large watershed: integrated isotopic, hydraulic and thermal data from the Canadian Shield", *Water Resources Research*, 45, W08402, doi:10.1029/2008WR007622.

Levison, J. and **Novakowski, K.** (2009) "The impact of cattle pasturing on groundwater quality in bedrock aquifers having minimal overburden", *Hydrogeology Journal,* 17(2), pp. 559–569.

Electrical and Computer Engineering

Alireza Bakhshai:

Hui, U.C.Y. and **Bakhshai, A.** (2010) "A Hybrid Wind-Solar Energy System: A New Rectifier Stage Topology", *Applied Power Electronics Conference* (IEEE APEC 2010), Feb 21-25, Palm Springs, CA.

Eren, S., Pahlevaninezhad, M., **Bakhshai, A.** and Jain, P. (2010) "Grid-Connected Voltage Source Inverter for Renewable Energy Conversion System with Sensor-less Current Control," *Applied Power Electronics Conference* (IEEE APEC 2010), Feb 21-25, Palm Springs, CA.

Khajeohdin, S.A., Karimi-Ghartemani, M., **Bakhshai, A.** and Jain, P. (2009) "A Nonlinear approach to Control Instantaneous Power for Single-Phase Grid-Connected Photo-voltaic Systems", *IEEE Energy Conversion Congress and Exposition* (ECCE 2009), Sept 20-24, San Jose, CA, pp. 2206 - 2212.

Praveen Jain:

Karimi-Ghartemani, M., Khajehoddin, S., **Jain, P.** and Bakhshai, A. (2010) "Feedback Linearization Control for Grid-Interfacing of a Three-Phase Renewable Energy System", *International Symposium on Industrial Electronics* (IEEE ISIE 2010), July 4-7, Bari, Italy.

Agamy, M.S. and **Jain, P.K.** (2009) "A Three-Level Resonant Single-Stage Power Factor Correction Converter: Analysis, Design, Implementation," *IEEE Trans. Industrial Electronics*, 56(6), pp. 2095-2107.

Ye, Z., **Jain, P.K.** and Sen, P.C. (2009) "Phasor-Domain Modeling of Resonant Inverters for High-Frequency AC Power Distribution Systems", *IEEE Trans. Power Electronics*, 24(4), pp. 911-923.

Geological Science and Geological Engineering

Heather Jamieson:

Andrade, C.F., **Jamieson, H.E.**, Praharaj, T., Fortin, D., Kyser, T.K. (2010) "Biogeochemical Cycling of Arsenic in Mine-impacted Sediments and Co-existing Pore Waters. *Applied Geochemistry*, 25, pp. 199-211.

Rollo, H.A., **Jamieson, H.E.** (2009) "Interaction of Diamond Mine Waste and Surface Water in the Canadian Arctic", *Applied Geochemistry*, 21, pp. 1522-1539.

Akabzaa, T.M., **Jamieson, H.E.**, Jorgenson, N., Nyame, K. (2009) "The Combined Impact of Mine Drainage in the Ankobra River Basin, SW Ghana", *Mine Water Environment*, 28, pp. 50-64.

Gema Olivo:

Cloutier, J. Kyser, K. **Olivo, G.R.,** Alexandre, P., Haluburda, J. (2009) "The Millennium Uranium Deposit, Athabaska Basin, Saskatchewan, Canada: An Atypical Basement-Hosted Unconformity-Related Uranium Deposit:, *Economic Geology*, 104, pp. 815-840.

Almeida, C.M., **Olivo, G.R.,** Carvalho, S.G. (2007) "Platinum group element-bearing Ni-Cu ore from the Komatiite-hosted Fortaleza de Minas deposit, Brazil: Evidence for Hydrothermal Remobilization", *Canadian Mineralogist,* 45, pp. 751-773

Pitcairn, I. K., Teagle, D.A.H., Craw, D., **Olivo, G.R.,** Kerrich, R. (2006) "Source of metals and fluids in orogenic gold deposits: Insights from the Otago and Alpine Schists, New Zealand", *Economic Geology*, 101(6), pp. 1525-1546.

Mechanical and Materials Engineering

Steve Harrison:

Cruickshank, C. and **Harrison, S.J.**, (2007) "Comparison of Multi-tank and Single Tank Thermal Storages for Solar DHW Applications", *Energy Sustainability 2007* (Annual Conference of ASME), June 27-30, Long Beach, California, USA.

Cruickshank, C. and **Harrison, S.J.**, (2006) "Analysis of a Modular Thermal Storage for Solar Heating Systems", *SESCI 2006/NSERC Solar Buildings Conference*, Montreal, Quebec, Canada.

Mesquita, L.C.S. and **Harrison, S.J.** (2005) "Non-Isothermal, Flat-plate Liquid-desiccant Regenerators: A Numerical Study", *International Solar Energy Conference (ISES) Solar World Congress*, August, Orlando, Florida, USA.

Jack Jeswiet:

Nava, P., Diarra, D.C., **Jeswiet, J.** and Young, J.Y. (2010) "A Comparison of Carbon Emission Calculators for Manufacturers", *Transactions of NAMRI/SME 2010* (in press), 38.

Jeswiet, J. and Nava, P. (2009) "Applying CES to Assembly and Comparing Carbon Footprints", *Int. Journal of Sustainable Engineering*, 2(4), pp. 232-240.

Jeswiet, J. and Hauschild, M. (2008) "Market Forces and the Need to Design for the Environment", *Int. Journal of Sustainable Manufacturing*, 1(1/2), pp. 41-57.

Joshua Pearce:

Pearce, J.M. and Eleanor ter Horst, E. (2010) "Overcoming Language Challenges of Open Source Appropriate Technology for Sustainable Development in Africa", *Journal of Sustainable Development in Africa* (in press).

Doyle, W. and **Pearce, J.M.** (2009) "Utilization of Virtual Globes for Open Source Industrial Symbiosis", *Open Environmental Sciences*, 3, pp. 88-96.

Pearce, J.M. and Mushtaq, U. (2009) "Overcoming Technical Constraints for Obtaining Sustainable Development with Open Source Appropriate Technology", *Proc. IEEE Toronto International Conference - Science and Technology for Humanity* (TIC-STH), pp. 814-820.

Jon Pharoah:

Pharoah, J.G. (2005) "Fluid Mechanics of Serpentine Flow Fields on a Porous Media", *International Journal of Green Energy*, 2(4), pp. 12-18.

Litster, S., **Pharoah, J.G.**, McLean, G. and Djilali, N. (2005) "Computational analysis of heat and mass transfer in a micro-structured PEMFC cathode", *Journal of Power Sources*, available online 22 July.

Pharoah, J.G. (2005) "On the Permeability of Gas Diffusion Media used in PEM fuel cells", *Journal of Power Sources*, 144, pp. 77-82.

Mining Engineering

Tony Hodge:

Longo, J. and **Hodge, R.A.** (2007) "The Ecosystem Dilemma: Discordance between Nature and Culture", *Horizons: The Journal of the Policy Research Initiative,* 9(3).

Hodge, R.A. and Killim, R. (2003) "Practice Review: Post Mining Regeneration – North American Perspective", *ECUS Environmental Consultancy, University of Sheffield, International Review of Post-Closure Best Practices.*

Hodge, R.A. (2004) "Tracking Progress Towards Sustainability: Linking the Power of Measurement and Story", *Society for Mining, Metallurgy and Exploration (SME) Symposium – Sustainability from the Ground Up: Measuring Progress to Sustainable Development.*

Sadan Kelebek:

Kelebek, S. (2009) "Developments in mineral processing of pentlandite, chalcopyrite, pyrrhotite ores as a contribution to sustainability", *Journal of Cleaner Production* (submitted).

Kelebek, S. (2009) "Role of surface chemistry and flotation in tailing management issues related to mining industry", *Journal of Environmental Management* (submitted).

Kelebek, S. and Yalcin, E. (2009 "Use of complexing agents in flotation plants and potential risks in water treatment", *Journal of Environmental Management* (submitted).

Vic Pakalnis:

Pakalnis, V. (2009) "For Safety's Sake: An Act Worth Celebrating", *Canadian Government Executive*, pp. 18.

PPakalnis, V. (2009) "Understanding Key Drivers for High Performance in Mining Health and Safey", *Presentation to the 4th International Industry Summit on Mining Performance.*

Pakalnis, V. (2007)"Revolution in Ontario Mining Safety: How the Transformation Happened", *International Association of Labour Inspections Conference.*

Policy Studies

Peter Harrison:

Ricketts, P., and **Harrison, P.** (2007) "Coastal and Ocean Management in Canada: Moving into the 21st Century", *Coastal Management*, 35(1), pp. 3-22.

Warren Mabee:

Mabee, W.E. and Saddler, J.N. (2010) "Bioethanol from Lignocellulosics: Status and Perspectives in Canada. Bioresource Technology", *Journal Bioresource Technology*, (in press).

Sims R.E.H., **Mabee, W.E.**, Saddler, J.N. and Taylor, M. (2010) "An Overview of Second Generation Biofuel Technologies", *Journal Bioresource Technology*, 101(6), pp. 570-1580.

Zhang Y., McKechnie, J., Cormier, D., Lyng, R., **Mabee, W.E.**, Ogino, A., and MacLean, H.L. (2010) "Life Cycle Emissions and Cost of Producing Electricity from Coal, Natural Gas and Wood Pellets in Ontario", *Canada Environmental Science and Technology*, 44(1), pp. 538-544.

Robert Wolfe:

Mark, H. and **Wolfe, R.** [editors] (2007) *Process Matters: Sustainable Development and Domestic Trade Transparency* (Winnipeg: International Institute for Sustainable Development).

Phillips, P.W.B. and **Wolfe, R.** [editors] (2001) *Governing Food: Science, Safety, and Trade*, Montreal and Kingston: McGill-Queen's University Press.

Appendix F: Programs and Institutes at other Canadian Universities

McMaster University MEEP Program *(http://msep.mcmaster.ca/epp/program.html)*

The Master of Engineering and Public Policy (MEPP) program at McMaster University is said to be designed for tomorrow's science and engineering leaders who will have an enhanced understanding of the public policy process and its effects on technological, social and ecological systems. Students are required to take: a) four required courses b) four elective courses to be selected from the following six options and finally a project:

1) International Development and Public Policy
2) Green Engineering, Sustainability and Public Policy
3) Energy and Public Policy
4) Up to two graduate engineering courses from departments within the Faculty of Engineering
5) Up to two graduate course offerings from the Faculties of Social Sciences, Humanities, Engineering, Science, Health Science or selected Political Science courses
6) Relevant courses at neighboring universities

The program is 12 months in duration. Applicants must hold a baccalaureate degree in engineering, or closely related discipline.

MEEP Required Courses:

SEP 701 Theory and Practice of Policy Analysis: Frameworks and Models
Government structure and mandates for municipal, provincial and federal levels; procedures for legislation and policy setting; process of understanding societal values and preferences; establishment of policy goals and objectives; models and frameworks for the evaluation and analysis of public policy; application of frameworks and models to engineering and public policy problems.

SEP 702 Systems Engineering and Public Policy
Application of linear programming, integer programming and dynamic programming to public policy applications; application of simulation modeling to evaluate scenarios; application of decision analysis approaches and software for micro- and macro-policy analysis problems; coupling of GIS-based approaches with conventional systems engineering tools; project planning and project management; soft systems techniques.

SEP 703 Applied Microeconomics and Environmental Economics
Marginal benefit/cost analysis; willingness to pay and indifference curves; ecological economics; allocation of environmental services; estimation of externalities; measurement of environmental benefits; taxes; trading permits and other instruments; application of approaches to infrastructure renewal and environmental management problems.

SEP 709 Emerging Issues, Technology and Public Policy
The future problems of developed and developing regions will be examined, as permutations of those we are already attempting to address. Such threats include chemical contaminants and their effects, excess nutrients, climate change, exotic species, changes to the biological community, shoreline development, sprawl and transportation matters. Institutional effectiveness and policy implications for new programs will be examined.

University of Calgary Program in Sustainable Energy *(http://www.ucalgary.ca/sustainableenergy/)*

The Multidisciplinary Master's Degree in Sustainable Energy Development at the University of Calgary is said to be the only program of its kind in North America offering an interdisciplinary, comprehensive education relating to sustainable energy development issues. The program is designed to provide the technical background to those who do not have it while giving all a balanced education with instruction in the areas of law, business, engineering and environmental design. Participating faculty members are drawn from five schools:

- Engineering
- Environmental Design
- Law
- Haskayne School of Business
- Graduate Studies

Fourteen courses are taken:

1) Air Pollution and its Impact on the Energy Sector
2) Ecology, Sustainable Development and Indigenous Cultures
3) Energy Systems I: Non-Renewable Energy
4) Energy Systems II: Renewable Energy
5) Energy Systems III: Planning and Energy Economics
6) Environmental Impact Assessment in the Energy Sector
7) Environmental Law in the Energy Sector
8) Environmental Management Tools in the Energy Sector
9) Human Resource and Management in the Energy Sector
10) Individual Interdisciplinary Research Project
11) Land Pollution and Waste Management in the Energy Sector
12) Strategic Environmental Planning for Energy Organizations
13) Topic in Energy and the Environment: Energy Policy
14) Water Pollution and its Impact on the Energy Sector

In addition, students complete the following:

- Introductory framework
- Environmental Chemistry and Environmental Engineering Principles Upgrade Program (pre-requisite)
- Economics Overview Upgrade Program (pre-requisite)
- Recapitulation
- Oral examination

The program is 16 months in duration. Applicants are accepted from all professions, not just engineering.

Waterloo Institute for Sustainable Energy - WISE *(http://www.wise.uwaterloo.ca/index.html)*

The Waterloo Institute for Sustainable Energy (WISE) was established at the University of Waterloo in 2008. The Institute comprises more than 70 faculty members with graduate students and postdoctoral fellows working as multi-disciplinary research teams across Engineering, Science and Environment. The Institute is the focal point at UW for research in energy studies. In collaboration with utilities, private sector partners, government agencies and civil society groups, the Institute's goal is to foster the development of innovative technologies and alternatives to existing energy production and delivery systems, and to promote energy efficiency and environmental sustainability.

The faculty members involved with WISE provide the focus on energy research and sustainability. Master of Engineering degrees with departmental certificates in Sustainable Energy (E&CE) and Green Energy (Mechanical and Mechatronics Engineering) provide practicing or newly graduated engineers with specialized training in:

- green energy systems,
- fuel cell technology,
- hydrogen storage,
- wind energy, and
- solar energy

WISE is actively involved in the training of highly qualified personnel for industry and elsewhere. For example, the power research group in Electrical and Computer Engineering runs the Advanced Training Centre in Electric Power Engineering. This is a new initiative geared towards professionals working in the power industry and offers graduate diplomas (GDip) and Master's of Engineering degrees, as well as a variety of short courses for industry.

Institute for Sustainable Energy, Environment and Economy - ISEEE *(http://www.iseee.ca/)*

The University of Calgary created ISEEE in 2003 to ensure that the University is recognized internationally for its research, education and innovation in Energy and the Environment. ISEEE provides strategic leadership for initiatives that will achieve a top priority in the University's academic plan: "Leading Innovation in Energy and Environment."

ISEEE works in partnership with and support of Faculties and Schools at the U of C, including the Schulich School of Engineering, Haskayne School of Business, the Faculties of Science, Law, Environmental Design, and Social Sciences, and the School of Public Policy.

The mandate of the ISEEE includes:

- Supports Faculty and School appointments across the U of C campus
- Coordinates research initiatives across campus – especially multidisciplinary
- Attracts and distributes research grant funding
- Creates new graduate student programs
- Recruits graduates to existing and new programs
- Raises funding to support Faculty and School research chairs, programs and other initiatives

The ISEEE does not offer graduate program on its own, instead it supports programs that are offered by the partner Faculties and Schools. The Multidisciplinary Master's Degree in Sustainable Energy Development is one example.

Carleton's Sustainable Energy Research Centre - CSERC
(http://research.carleton.ca/CSERC/index.html)

CSERC was established in 2009 as part of a major initiative by Carleton University to develop research and teaching programs in the area of sustainable energy. CSERC will focus on innovative ways to reduce energy consumption, research and explore emerging renewable energy sources such as wind, solar and biofuels while looking at strategies for using traditional, non-renewable sources effectively and responsibly. Combining expertise from engineering and policy, the goal of the Centre, through research and teaching programs, is to address issues of both technology and policy, combining expertise from the Faculty of Engineering and Design and the School of Public Policy and Administration while reaching out to other faculties at Carleton. CSERC will help to guide research and teaching programs in the area of sustainable energy that tackles the technical, social, economic, legal and political dimensions of clean and renewable energy solutions facing Canadians.

Carleton has submitted an application to the Ontario Council on Graduates Studies (OCGS) for approval of a Masters in Sustainable Energy. The Program is expected to be offered in the fall semester of 2010. This multidisciplinary program will be offered in collaboration with the Faculty of Engineering and Design and the School of Public Policy and Administration. The proposal is for 3 different degrees: 1) a Master of Applied Science degree (M.A.Sc.), 2) Master of Engineering degree (M.Eng.), and 3) Master of Arts degree (M.A.) in Sustainable Energy. Which program a student takes depends upon the nature of their undergraduate degree. The program has three fields of study:

1. Mechanical Energy Conversion: This field covers advanced principles of sustainable energy engineering from a mechanical point of view and leads to either an M.A.Sc. or an M.Eng.
2. Efficient Electrical Energy Systems: This field involves research in technological devices, components and systems that are intended for sustainable electrical energy generation, conversion, distribution and monitoring, and leads to either an M.A.Sc. or an M.Eng.
3. Sustainable Energy Policy: This field is concerned with all aspects of the policy dimensions of sustainable energy and leads to an M.A. in Sustainable Energy Policy.

The requirement for admission is a four-year bachelor's degree in engineering, social science, or a related discipline, with an average of at least B+. Detailed admission requirements and pre-requisites for the policy stream are as for the MA in Public Policy.

PART B - RESOURCE IMPLICATIONS

1. SUMMARY OF RESOURCES REQUIRED

Summarize the ***additional*** resources needed to implement the program:

a) FACULTY: No additional faculty are required and there are no extra costs associated with extra workload, once the program is up and running. CPAS 801 (Topics in Applied Sustainability) will require development time, as it is a reworked version of MECH 836). CPAS 897 (Seminar Series) will also require setup time, but it replaces seminar courses where they exist in participating departments.

b) STAFF: No additional staff are required. Administration will be covered by the existing graduate assistant positions in the Faculty of Engineering and Applied Science

c) TEACHING ASSISTANTS: No new positions required.

d) PHYSICAL FACILITIES: Office space for students will be provided by project and thesis supervisors in their home departments.

e) INFORMATION FACILITIES

1. Hardware: Computers and related hardware will be made available on an as required basis by project and thesis supervisors in their home departments.
2. Software/Internet: No new requirements.
3. Audio- Visual: No new requirements.
4. Telecommunications: No new requirements.

f) LIBRARY SERVICES: No additional resources required

g) UNIVERSITY REGISTRAR

1. Scholarships: Full-time thesis students will be eligible for graduate fellowships.
2. Registration/ SIS: As this is a small program, this will have little impact.
3. Timetable: No requirements.
4. Admission: As this is a small program, this program will have little impact.
5. Convocation: As this is a small program, this program will have little impact.

h) OTHER UNIVERSITY SERVICES

1.Financial services: No additional resources needed.
2.Human Resources: No additional resources needed.
3.Advancement: As this is a small program, this program will have little impact.
4.Student services: As this is a small program, this program will have little impact.
5.Residences: As this is a small program, this program will have little impact.

2. NEW EXPENDITURES

There are no new expenditures associated with this new program. It is based upon existing courses, faculty and administrative resources.

	One Time$	Base Budget$
FACULTY	$0	$0
STAFF	$0	$0
TEACHING ASSISTANTS	$0	$0
OTHER NON SALARY QGA	$0	$0
TOTAL	$0	$0

3.FUNDING SOURCES

The following table presents a summary for year 1 with expected intake of 5 students.

	One Time$	Base budget$
DEPARTMENTAL BUDGET	$0	$0
FACULTY BUDGET	$0	$0
UNIVERSITY BUDGET (BIU)	$0	$0
TUITION REVENUE	$0	$0
OTHER SOURCES	$0	$0
TOTAL	$0	$0

4. IMPACT ON ENROLMENT

a) How many students are expected in the program? 20 (steady state after 4 years)

b) How many new students will the program attract to Queen's University? 0

c) How many students must be accommodated by other departments / units? 0

Students in the program will enter through an existing home departmental program. It is expected that there will be no "net new" students. The first year will be direct transfers from existing programs. In future years, new students that enroll in the program will compensate for an anticipated drop in enrolment in traditional programs. Thus, there will be no increase in overall enrolment.

5. NET IMPACT OF THE PROPOSAL

This proposal has minimal resource and funding implications. There will be no negative impact of the program as it will easily be accommodated within existing resources of personnel and services, space and equipment already supplied by the Faculty of Engineering and Applied Science. There will be a positive impact of the presence of a diverse group of interested engineering students, who will, in addition to enhancing the diversity and intellectual stimulation of existing students, help to provide an increasingly excellent team of TAs to tutor undergraduate students. There will be a positive impact on the enhanced reputation of the Faculty and Queens University as a location of excellence for the education and training of engineering in the area of Applied Sustainability.

6. SIGN-OFF

Following approval of Graduate Council, signatures from the following individuals listed below must be obtained to verify that they have reviewed this proposal. Supplementary comments may be appended and so indicated by checking the box beside the appropriate signature.

Title	Comments Appended	Signature
Head of Chemical Engineering		
Head of Civil Engineering		
Head of Electrical and Computing Engineering		
Head of Geological Sciences and Geological Engineering		
Head of Mechanical and Materials Engineering		
Head of Robert M. Buchan School of Mining		
Dean or Associate Dean		
Dean of Student Affairs		AVP/D
University Librarian		Barbara Keddie for Paul Waters
Director, Information Technology Services		
University Registrar		
Associate VP (Operations & Facilities)		
Vice-Principal (~~Operations &~~ Finance) t. Administration		2010.03.17
Vice-Principal (Academic)		