



UNIVERSITY OF
TORONTO

Research and Innovation in

Energy and the Environment

at the
University
of Toronto

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Vice President, Research
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University of Toronto

OFFICE OF THE VICE-PRESIDENT, RESEARCH

RESEARCH AND INNOVATION IN ENERGY & THE ENVIRONMENT AT THE UNIVERSITY OF TORONTO

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QUICK FACTS: ENERGY AND THE ENVIRONMENT RESEARCH AT U OF T

- There are over 350 faculty members at U of T working in the areas of Energy and the Environment. Their appointments range over 15 Faculties, Schools, or partnered hospitals.
- The total value of external research funding currently held by these investigators is over \$230M
- U of T ranks #1 in the world in the field of Environmental Engineering and 3rd in Environmental Sciences (Thomson ISI: based on the number of citations of papers published between 2003 and 2007)
- U of T holds 20 Canada Research Chairs in fields related to Energy & the Environment
- Commercialization activity in Energy & the Environment via [The Innovations Group](#) in the last 5 yrs:
 - 8 Commercialization Projects Initiated
 - 7 Licensing (and Supporting) Agreements Negotiated and Executed
 - 32 Patent Applications Filed
 - 36 Invention Disclosures Received

→ In addition, U of T researchers have been awarded commercialization grants¹ in the last 5 years, valued at over \$12M
- 24 faculty members in this area are Fellows of the Royal Society of Canada; 6 faculty members have won the prestigious E.W.R. Steacie Fellowship from NSERC
- In 2008, Ted Sargent, CRC in Nanotechnology, won one of 12 inaugural Global Research Partnership Investigator grants from the King Abdullah University of Science and Technology (Saudi Arabia). These prestigious \$10M five-year grants support research on topics relevant to the global society.
- U of T researchers are collaborating with their colleagues at top universities around the world, like Oxford University, Harvard University, Texas A & M University, Case Western Reserve University, Stockholm University, University of Tokyo, Hong Kong University of Science and Technology, University of Auckland and Harbin University of Science and Technology
- U of T researchers are also working closely with their colleagues across the country to tackle issues relevant to Canadians, including collaborations with: McGill University, Queen's University, Université de Montreal, Université Laval, University of British Columbia and University of Saskatchewan
- U of T has active industry-sector contracts with companies that include 3M Canada, ARISE Technologies Corp., DuPont, General Motors of Canada, Honeywell, IBM Canada, Inco Ltd. and Pratt & Whitney
- 27 different graduate programs offer degrees in fields related to Energy and the Environment, 6 of which are unique multidisciplinary programs such as Dynamics of Global Change, Environment & Health and Environmental Engineering; in the last 5 years, our Energy and the Environment faculty have supervised the completion of over 1200 advanced degrees (Master's or Doctoral).
- 14 U of T Researchers have contributed to the UN's Intergovernmental Panel on Climate Change (IPCC), co-winner of the 2007 Nobel Peace Prize

¹ Includes applications to the Ontario Centres of Excellence and the NSERC Idea to Innovation Program.

INTRODUCTION

In 2007, the Federal Government published its science and technology strategy [Mobilizing Science and Technology to Canada's Advantage](#). Outlined within this document are three advantages that the government committed to fostering, the Entrepreneurial, Knowledge and People Advantages, focused, respectively, on supporting advances in science and technology in the private sector, basic research and in training and employment. Within the Knowledge Advantage, four key areas where "...Canada can leverage our research strengths to achieve economic and social advantage" were identified:

- Environmental science and technologies
- Natural resources and energy
- Health and related life sciences and technologies
- Information and communications technologies

Similarly, in 2008, the Ontario Provincial Government released its own innovation strategy, [Seizing Global Opportunities: Ontario's Innovation Agenda](#), which also identifies four strategic areas that the government has committed to investing in:

- Bio-economy and clean technologies
- Advanced health technologies
- Pharmaceutical research and manufacturing
- Digital Media and information & communications technologies

Taken together, these two strategic documents and the overlapping priority areas outlined within them provide a unified framework for advancing science and technology research in Ontario and Canada. A survey of the research landscape at the University of Toronto reveals great and broad strengths across each of these priority areas.

This catalogue, "Research and Innovation in Energy & the Environment at the University of Toronto" represents the second in a series of catalogues developed by the Office of the Vice-President, Research to identify research at the institution in the governments' priority areas of investment. Addressing the first two Federal priorities a) environmental science and technologies and b) natural resources and energy, and the Provincial priority of bio-economy and clean technologies, this document showcases research at the U of T in areas related to Energy and the Environment, two broad areas that are inter-related and represent critical issues currently facing society.

One of the working definitions of the Federal S&T Strategy priority "Natural resources and energy" is **Sustainable Energy Systems** (Production, Distribution and Utilization)². Using this working definition, three specific research themes that are areas of focus and strength at the U of T were collected here under the heading of Energy and have been highlighted. These areas, **Renewable and Cleaner Energy**, **Fuel Cells** and **Biofuels**, represent key advances in technology that will provide viable and economic alternatives to petroleum-based fuels. Research has focused on improving the efficiency of power-generating technologies, harnessing sources of energy that are abundant within our environment, like wind and solar power, and investigating the physical, chemical and biological processing options for new biofuels that can easily replace petroleum products, but not interfere with the food supply. U of T researchers are world leaders in designing, developing and implementing these new and emerging sources of energy, with close to 60 research groups focusing on these issues, and a strong history of commercializing the technological results of their research (see page 46 for some examples of successful commercialization).

One of the working definitions of the Federal S&T Strategy priority "Environmental science and technologies" is **Healthy Environment and Ecosystems**². Using this working definition, five general research themes where U of T researchers are focusing their efforts have been collected under the heading of the Environment, and are showcased here. Over 300 U of T researchers and their staff are concentrating on the areas of **The Environment and Society**, **Climate Change**,

² The 2007 NSERC Strategic Project Grants Supplemental Competition was instituted to address the priorities outlined within the new federal S&T Strategy, and was open to applications addressing these specific research areas.

Pollution and Health, Sustainability, Recycling and Conservation and Water to better understand the impact of modern society on the global environment and on human health, to develop preventative and alternative measures to our standard industrial practices that have so negatively impacted our environment, to evaluate global water resources, and to explore societal issues around the environment, including environmental ethics, policy, law, education and economics. U of T researchers are studying diverse aspects of these issues and are asking and answering the difficult questions around the impact that our modern practices are having on the environment, and exploring the possibilities for mitigation of these effects.

In summary, this catalogue highlights the breadth of research at U of T within the areas of Energy and the Environment, showcasing over 100 current research projects. Over 350 faculty and countless graduate students and research associates are investing enormous time and energy to solve these critical societal issues. Research in Energy and the Environment at U of T spans every discipline, from Engineering and Physics, to Biology and Medicine, Law and Political Science (Figure 1). The leadership of our researchers is recognized globally, with many of our faculty the recipients of some of the most prestigious honours awarded to investigators in these fields. Faculty members working in these areas currently hold external research funding valued at over \$230 million. Importantly, U of T researchers are also committed to translating the results of their research into practice, and The Innovations Group, the University's commercialization arm, has supported numerous patents, licenses and spin-off companies related to new technologies in Energy and the Environment.

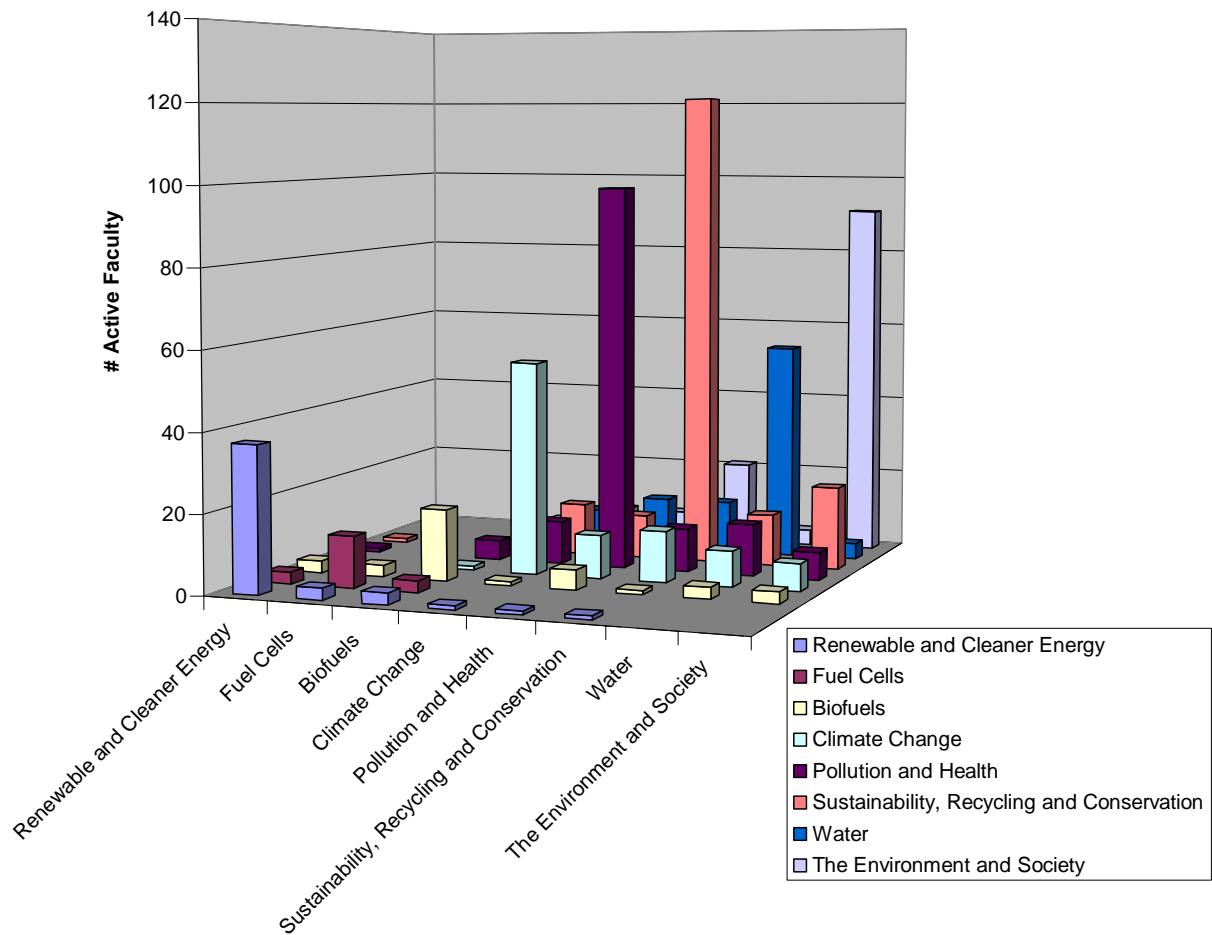


Figure 1: Faculty research interests in Energy and the Environment research at the University of Toronto. The primary bar under each of the eight themes identified in this catalogue indicates the number of faculty pursuing research within that area, while secondary bars show the number of faculty with multiple interests and where those interests lie.

Methodology:

A catalogue of faculty members actively pursuing research in areas related to energy and the environment was developed by screening various sources of information, primarily departmental and individual faculty websites and the University's Research Information System. The identification of the eight areas of research focus and strength emerged from both the government's areas of particular interest and after a critical mass of faculty researchers and their interests had been identified. These eight categories were then used to group faculty whose interests lie in related areas, and to continue to populate the catalogue. While most of the categories are self-explanatory, some were developed with specific inclusion criteria. Renewable and Cleaner Energy encompasses research into all forms of renewable energy, excluding biofuels (which is found in a separate section), but including wind, solar and hydrogen, even though some of the specific research in this area could also be categorized under Fuel Cells. The section on Fuel Cells was limited to those studying ways to improve the efficiency and performance of traditional fuel cells. Pollution and Health included researchers studying environmental contamination and/or the effects of contaminants on human health. Occupational health research was generally excluded. Sustainability, Recycling and Conservation gathered research with relevance to any of these areas, including sustainable transportation. Researchers exploring issues around the health of Canada's natural resources, including water, fisheries and forestry, were also included within the theme(s) Sustainability, Recycling and Conservation and/or Water (where appropriate). While some water researchers were included under other categories (e.g. Pollution and Health, Sustainability, Recycling and Conservation), a separate category was created because of the global importance of this resource and emerging data that suggest that, like the atmosphere, the human impact on the Earth's hydrosphere has been too long ignored. Despite these various inclusion and exclusion criteria, many faculty are listed under two or more categories as their research interests are broad or interdisciplinary.

While this catalogue does attempt to list all of the active faculty members pursuing research in the specific areas related to Energy and the Environment, and any prestigious awards bestowed upon them, related key words and a list of divisions where the research is taking place, space constraints limit the number of specific projects that could be showcased. The featured projects are meant to provide a sample of some of the current and exciting research that is being pursued in these areas. Content and illustrations for the featured projects was taken directly from faculty websites or other public sources of information (e.g. NSERC Awards Database or Wikimedia Commons, respectively).

External research funding data shown in the "Quick Facts" section and each theme's "Spotlight" indicate the total dollar amount of all external grants and contracts with an award end date after April 1, 2008, according to the University's Research Information System.

ENERGY: SUSTAINABLE ENERGY SYSTEMS

I. RENEWABLE AND CLEANER ENERGY

SPOTLIGHT	FEATURED PROJECTS: 12 RESEARCHERS IN THIS AREA: 43 FUNDING CURRENTLY HELD BY THESE INVESTIGATORS: \$64M
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RESEARCH KEYWORDS

bioenergy, bioremediation, fusion, hydro electricity, energy conversion systems, hydrogen, low-emission fuels, low-energy buildings, natural gas hydrates nanotechnology, nanotechnology, nuclear power, photovoltaics, quantum dots, semiconductors, solar cells, solar power, wind power

CANADA RESEARCH CHAIRS

Ted Sargent, CRC in Nanotechnology

PRESTIGIOUS AWARD WINNERS

American Physical Society Fellow – Peter Stangeby
 Award in Materials Chemistry, Royal Society of Chemistry - Geoffrey Ozin
 Brockhouse Canada Prize, NSERC – Sajeev John, Geoffrey Ozin
 Canada's Top 40 Under 40 – Ted Sargent
 Canadian Academy of Engineering Fellow – Douglas Perovic
 Canadian Materials Physics Gold Medal Award, Canadian Institute of Mining, Metallurgy and Petroleum – Douglas Perovic
 Canadian Society of Mechanical Engineers – James Wallace
 Chemical Institute of Canada Award - Mitchell Winnik
 CIAR Young Explorer – Ted Sargent
 CIC Medal, Chemical Institute of Canada – Mitchell Winnik
 Conservation Council of Ontario's Lieutenant Governor's Conservation Award – Adèle Hurley
 Dofasco Award, Metallurgical Soc. of the Canadian Inst. of Mining, Metallurgy & Petroleum – Uwe Erb
 Excellence in Innovation in Civil Engineering Award, Canadian Society for Civil Engineering – Jeffrey Packer
 E.W.R. Steacie Fellowship, NSERC – Greg Scholes
 Fellows of the IEEE – Francis Dawson, Reza Iravani
 Fellows of the Royal Society of Canada – Geoffrey Ozin, Mitchell Winnik
 Humboldt Research Award - Mitchell Winnik
 ISI Highly-Cited Researchers – Geoffrey Ozin, Mitchell Winnik
 Jules Stachiewicz Medal, Canadian Society for Mechanical Engineering – Charles Ward
 Killam Research Fellowship – Geoffrey Ozin, Mitchell Winnik
 King Abdullah University of Science & Technology Global Research Partnership Investigator – Ted Sargent
 LaSueur Memorial Medal, Society of Chemical Industry – Geoffrey Ozin
 Light Metals Award, Minerals, Metals and Materials Society – Torstein Utigard

NSERC-UNENE Senior Industrial Research Chair in Nano-engineering of Alloys for Nuclear Power Systems – Roger Newman
Rutherford Memorial Medal, Royal Society of Canada – Sajeev John, Greg Scholes
Research Innovation Award, Research Corporation – Greg Scholes
Roy W. Tess Award, American Chemical Society - Mitchell Winnik
Sloan Research Fellowship – Greg Scholes
Society of Automotive Engineers Fellow – James Wallace
Special Achievement Award, American Institute of Steel Construction – Jeffrey Packer r
Top 100 Young Innovators, MIT – Ted Sargent
T.P. Hoar Prize, Institute of Corrosion – Roger Newman
U.R. Evans Award, Electrochemical Society - Roger Newman
U.R. Evans Award, Institute of Corrosion - Roger Newman
Veylien Henderson Award, Society of Toxicology of Canada – Olev Trass
W.R. Whitney Award, NACE International - Roger Newman

ENDOWED CHAIRS

Bahen/Tanenbaum Chair in Civil Engineering – Jeffrey Packer
L. Lau Chair in Electrical and Computer Engineering – Reza Iravani

UT RESEARCHERS INCLUDE

Mansoor Barati, Timothy Bender, Sanjeev Chandra, Francis Dawson, R. Nigel Edwards, Uwe Erb, Cynthia Goh, Clinton Groth, Omer Gulder, Anthony Haasz, Danny Harvey, Adèle Hurley, Reza Iravani, Sajeev John, Ted Kesik, Nazir Kherani, Donald Kirk, Sally Krigstin, Peter Lehn, Zheng Hong Lu, Heather MacLean, Radhakrishnan Mahadevan, Bernd Milkereit, Charles Mims, Roger Newman, Jun Nogami, Geoffrey Ozin, Jeffrey Packer, Vladimiros Papangelakis, Douglas Perovic, K.D. Pressnail, Ted Sargent, Greg Scholes, C. Tattersall Smith, Peter Stangeby, Pierre Sullivan, Steven Thorpe, Olev Trass, Torstein Utigard, James Wallace, Charles Ward, Mitchell Winnik, Stefan Zukotynski, et al.

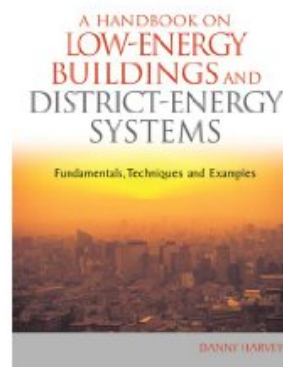
RESEARCH IN THIS AREA HAPPENS IN

Centre for Applied Power Electronics
 Centre for Environment
 Centre for Global Change Science
 Dept. of Chemical Engineering and Applied Chemistry
 Dept. of Chemistry
 Dept. of Civil Engineering
 Dept. of Electrical and Computer Engineering

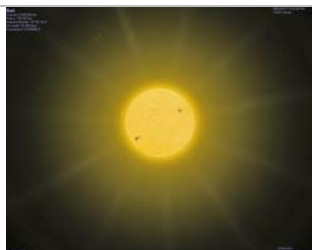
Dept. of Materials Science and Engineering
 Dept. of Mechanical and Industrial Engineering
 Dept. of Physics
 Faculty of Architecture, Landscape and Design
 Faculty of Forestry
 Institute for Aerospace Studies
 Program on Water Issues

PROJECTS INCLUDE:

A Handbook on Low-Energy Buildings and District Energy Systems - Buildings account for over one third of global energy use and associated greenhouse gas emissions worldwide. Reducing energy use by buildings is therefore an essential part of any strategy to reduce greenhouse gas emissions, and thereby lessen the likelihood of potentially catastrophic climate change. Bringing together a wealth of hard-to-obtain information on energy use and energy efficiency in buildings at a level which can be easily digested and applied, [Danny Harvey](#) offers a comprehensive, objective and critical sourcebook on lowenergy buildings. Topics covered include: thermal envelopes, heating, cooling, heat pumps, HVAC systems, hot water, lighting, solar energy, appliances and office equipment, embodied energy, buildings as systems and community-integrated energy systems (cogeneration, district heating, and district cooling). The book includes exemplary buildings and techniques from North America, Europe and Asia, and combines a broad, holistic perspective with technical detail in an accessible and insightful manner.



Harnessing Wind Power – Researchers in the Centre for Applied Power Electronics are working on developing technologies to harness the energy generated by wind turbines. [Peter Lehn's](#) research team is investigating how the energy generated by wind can be most effectively interfaced into the existing power grid. [Reza Iravani](#) is working with an industrial partner, Digital Predictive Systems, to design an affordable power converter for energy generated by wind turbines to interface with the North American grid. [Pierre Sullivan](#) is working with collaborators at Concordia, École Polytechnique and Natus Technology to develop small, simple wind turbines for power generation off the grid, for use in remote regions in Canada and in the developing world. [Jeffrey Packer's](#) group is investigating better designs for steel wind turbine towers.



High Efficiency Plastic Solar Cells – The sun emits large amounts of electromagnetic radiation across a large range of wavelengths. Therefore, using a single compound in a photovoltaic is neglecting a large portion of the available electromagnetic radiation. [Timothy Bender's](#) research group is focused on the design, engineering and application of new materials to enable a plastic/organic solar cell to harness ALL of the incident radiation received from the sun and to convert that radiation into electrical energy. This will be accomplished by the use of a novel array of phthalocyanines pigments/crystals (organic materials known to absorb light and produce electrical charge) that when used together will produce a flexible, organic solar cell capable of absorbing all of the incident radiation from the sun. By absorbing all of the radiation available, the amount of electrical energy produced will be increased: more absorption means more electricity: provide suitably long exciton lifetimes and suitable efficient electron transfer rates can be achieved.



Hydrogen Nano Fuel Cells– One of the criticisms of earlier methods of generating hydrogen from the electrolysis of water was that the process required a huge investment of energy, typically from our current sources, fossil fuels or nuclear power. [Steven Thorpe](#) and [Donald Kirk](#) have developed new nanomaterials that make the process more efficient and require less energy investment. This technology has been licensed to Hydrogenics, a hydrogen fuel cell developer, located in Mississauga. www.hydrogenics.com

IEA Bioenergy Task 31 - IEA Bioenergy is an organisation set up in 1978 by the International Energy Agency (IEA) with the aim of improving cooperation and information exchange between countries that have national programmes in bioenergy research, development and deployment. The objectives of [IEA Bioenergy Task 31](#) are to share, analyse, synthesize, disseminate and promote scientific knowledge and technical information leading to the economically and environmentally sustainable production of biomass for energy from integrated forestry systems. The work of the Task involves criteria for sustainable forest management of bioenergy production systems involving multi-use forestry with primary production of traditional forest products. The scope is world wide, including boreal, temperate, subtropical and tropical forest regions. The work includes sharing and synthesis of research information, analysis of policy relevance, and dissemination of this information to help promote the sustainable development goals of national programs in participating countries. The basis of the approach is an integrated concept of biomass production systems incorporating biological, economic, environmental and social components. Multi-disciplinary partnerships of key research, government and industry stakeholders and policy-makers are fostered in forest biomass production research, planning and operations. Associate Task Leader [C. Tattersall Smith](#) is leading U of T's contribution to the Task

	<p>The ITER Fusion Energy Project – An international collaboration to demonstrate the scientific and technical feasibility of fusion power. Fusion has the potential to be the predominant source of energy in the future, with no environmental impact, and abundant fuel sources. Anthony Haasz has been working on the development of materials for fusion reactors for many years, and more recently, he and colleague Peter Stangeby were asked by the ITER Project to help solve a major design impediment within the fusion device under development.</p>
	<p>Light Harvesting Layers for Organic Photovoltaics – Greg Scholes' research group has been investigating how to design more efficient solar cells, by modeling the structures that leaves use to gather light for photosynthesis. They have developed "light-harvesting antennae", which can increase the area of absorption of organic solar cells.</p>
	<p>Low Emission Engine Fuels for Air Transportation – Omer Gulder and Clinton Groth are collaborating with government and industry to develop a cleaner fuel for commercial aviation. The goal is the development of advanced combustion capabilities for lean premixed and hydrogen-enriched hydrocarbon fuels in gas turbine applications to reduce carbon dioxide and nitric oxides emissions. The collaborative research project will improve our understanding and gain combustion knowledge through fundamental flame studies, chemical kinetics, and supporting theoretical/numerical modelling work. Further utilization of hydrogen-enriched hydrocarbons in combustion systems is clearly highly desirable since it can lead to the progressive reduction in greenhouse gas emissions. This research addresses the basic science behind a common sense approach to this goal.</p>
<p>Paint-on Semiconductor Outperforms Chips</p> <p>Researchers at the University of Toronto have made a record-performance semiconductor device simply by painting a liquid containing nanoparticles onto a piece of glass. The work represents the first 'wet' semiconductor device to outperform conventional chips. Photodetectors are used in digital cameras, night vision and security systems and fibre optic communications.</p> <p>1 Gold electrodes are patterned on a glass slide.</p> <p>2 A drop of solution containing light-sensitive nanoparticles is placed on the glass slide.</p> <p>3 The droplet then spreads across the surface while the solvent evaporates. The layer of particles remains on the glass resulting in a smooth continuous semiconductor film.</p>	<p>Nanotechnology for Solar Energy – Ted Sargent will use his recently awarded KAUST Global Research Partnership Investigator award to create low-cost paint-on solar cells to convert the sun's power efficiently into electrical energy. The goal is to break the present-day compromise between high efficiency and low cost in solar cells. They will work with colloidal quantum dots – semiconductor particles a few nanometers in diameter. These particles can be sprayed from the solution phase onto large, flexible substrates. Quantum dots also represent a highly tunable materials system: their bandgap is determined not only by the choice of semiconductor material used, but also by the size of the particles. The group is also pursuing the realization of high-efficiency solar cells based on new classes of colloidal quantum dots. Successful optoelectronic devices based on this class of materials have, until now, included heavy metals such as lead or cadmium as constituent materials. They will optimize the properties of colloidal quantum dots that do not contain heavy metals, showing that these can be transformed into efficient solar energy harvesting devices. The research project will dovetail with KAUST's Solar Energy Research Center, with planned exchanges of personnel, know-how, and experimental capacity between the KAUST and University of Toronto-based collaborating teams.</p>
<p>Refining of Solar Grade Silicon - In order to make solar based electricity generation economic, it is required to decrease the cost of solar grade silicon. Torstein Utigard's research group is attempting to refine metallurgical grade silicon directly to solar grade silicon in one step decreasing the energy requirements, operating and capital costs, thereby making the refining process more cost effective.</p>	

 <p>SOLAR BUILDINGS RESEARCH NETWORK</p> <p>RÉSEAU DE RECHERCHE SUR LES BÂTIMENTS SOLAIRES</p>	<p>Solar Buildings Research Network - The Solar Buildings Research Network (SBRN) was launched in 2006 by the Natural Sciences and Engineering Research Council (NSERC) through its Research Network (now Strategic Network) Grant Program. For the first time, in a unique effort, 24 top Canadian researchers in solar energy and buildings from 10 Canadian universities have joined forces to develop the solar-optimized homes and commercial buildings of the future. U of T Researchers include Ted Kesik (Chair, Technology Transfer Committee), Nazir Kherani, and Stefan Zukotynski.</p> <p>www.solarbuildings.ca</p>
<p>Taking Solar Power Mainstream - A multi-disciplinary group of researchers, led by Nazir Kherani and including Stefan Zukotynski, Geoffrey Ozin, Jun Nogami, Uwe Erb and Douglas Perovic, have recently received major funding from the provincial government, their industrial collaborator, ARISE Technologies Corporation and the University of Toronto to tackle the challenges of taking solar power mainstream. The research and development program will focus on high efficiency silicon photovoltaics, the direct conversion of solar energy into electricity. Conversion is done through a photovoltaic device or solar cell. Every percentage increase of improvement in efficiency has a dramatic impact on reducing the overall cost per watt of solar electricity. The group is developing a set of 'thin film on silicon wafer' technologies that will result in the development of a prototype of a high efficiency silicon photovoltaic solar cell. Solar cells that are currently on the market have an average efficiency of just 15 per cent. The group aims to reach an efficiency target of over 20 per cent using low-temperature processing.</p>	

II. FUEL CELLS

SPOTLIGHT	FEATURED PROJECTS: 5 RESEARCHERS IN THIS AREA: 14 FUNDING CURRENTLY HELD BY THESE INVESTIGATORS: \$5.3M
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RESEARCH KEYWORDS

electrochemical energy storage, micro fuel cells, microturbine, proton exchange membrane (PEM), solid oxide fuel cells

CANADA RESEARCH CHAIRS

Olivera Kesler, CRC in Fuel Cell Materials and Manufacturing

PRESTIGIOUS AWARD WINNERS

American Association for the Advancement of Science (AAAS) Fellows - Cristina Amon

Canadian Society of Mechanical Engineers Fellow – Cristina Amon

Engineering Institute of Canada Fellow – Cristina Amon

Fellows of the IEEE – Cristina Amon, Francis Dawson

Jules Stachiewicz Medal, Canadian Society for Mechanical Engineering – Charles Ward

Light Metals Award, Minerals, Metals and Materials Society – Torstein Utigard

National Academy of Engineering, Member – Cristina Amon

UT RESEARCHERS INCLUDE:

Cristina Amon, Nasser Ashgriz, Aimy Bazylak, Foued Ben Amara, Christopher Cheh, Thomas Coyle, Francis Dawson, Donald Kirk, Frank Foulkes, Olivera Kesler, Peter Lehn, Keryn Lian, Torstein Utigard, Charles Ward, et al.

RESEARCH IN THIS AREA HAPPENS IN

Centre for Emerging Energy Technologies
Dept. of Chemical Engineering and Applied
Chemistry

Dept. of Electrical and Computer Engineering
Dept. of Materials Science and Engineering
Dept. of Mechanical and Industrial Engineering

PROJECTS INCLUDE:

Advanced Energy Storage Project – [Francis Dawson](#) and [Keryn Lian](#) are leading this project, the main objective of which is to demonstrate the feasibility of Advanced Energy Storage Devices that incorporate some combination of emerging advanced battery technologies, super capacitors, and/or hybrid systems and efficient charge-discharge power conversion equipment. The performance metrics are life cycle, weight, instantaneous discharge capability, instantaneous charge capability and reliability. The goal is to achieve a three order in magnitude improvement in life cycle, a factor of two reduction in the weight, a millisecond charging and discharging capability and a three order in magnitude increase in reliability.

Fuel Cell Kinetics - Fuel cell devices involve a number of molecular, atomic and electronic transport processes, as well as surface reactions. Some of the transport processes occur in bulk fluid and solid phases, but others involve molecular transport across the interface between bulk phases. In the design of these devices, one of the important issues is the identification of the rate-limiting process. [Charles Ward's](#) group is studying the sequence of processes leading from gas-phase hydrogen at the anode and the gas-phase oxygen at the cathode to water production by a fuel cell that is operating in steady state.

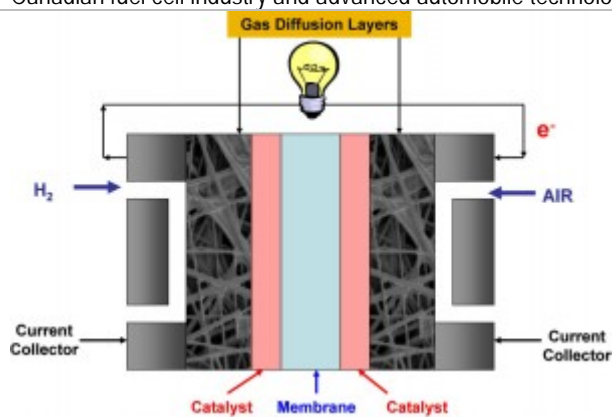
Fuel Cell Materials and Manufacturing - Solid oxide fuel cells (SOFCs) are the most efficient known energy conversion

device, producing electricity from a variety of fuels, including renewable biomass, hydrogen, or natural gas, with no pollution-forming emissions. However, their use remains severely limited by high costs, as well as by low durability and reliability. [Olivera Kesler](#), Canada Research Chair in Fuel Cells Materials and Manufacturing, is investigating how to lower the cost and improve the durability of fuel cells, both SOFCs and Proton Exchange Membrane Fuel Cells (PEMFCs), through the use of new materials and processing techniques to produce fuel cells more rapidly using a process that is easily scaleable for mass production. Work is also focused on understanding the electrochemical performance and degradation behaviour of SOFCs, in order to develop strategies to increase their durability.



PEM fuel cells for automotive applications – This project is part of the Auto21 Network Centre of Excellence. [Nasser Ashgriz](#) and colleagues at the Universities of Waterloo, Windsor, Victoria and Western Ontario are developing new Proton exchange membrane (PEM) fuel cells as a promising candidate for a zero-emission power source for transportation applications. The most critical technical challenges facing the commercialization of fuel cell vehicles (FCVs) are cost reduction and performance improvement, including durability/reliability, electrode performance, freeze/cold start and power density.

The project focuses on 1) key component materials development using nanotechnology; 2) modeling and simulation for improved fundamental understanding, leading to design tools for optimal stacks of low cost and better performance; 3) design and manufacturing for innovative product development, crucial for PEM fuel cell commercialization; and 4) optimization and system integration/response for better system level performance. The project's outcomes will have an immediate impact on the design and optimization of practical PEM fuel cells, stacks and systems; will be useful for existing design modification and improvement; and will aid in the optimal new designs with minimal time and effort. The research will help reduce the cost and enhance the performance of PEM fuel cells, as well as develop and train experts to expand and enhance the capability of the Canadian fuel cell industry and advanced automobile technologies. www.auto21.ca



Water Management in PEM Fuel Cells - In the polymer electrolyte membrane fuel cell (PEMFC), it is crucial for the gas diffusion layer (GDL) to remain free of water in order to provide a pathway for gaseous fuel transport. [Amy Bazylak's](#) group is investigating the GDL, a porous material composed of a dense array of carbon fibers, which also provides an electrically conductive pathway for current collection. The GDL must also provide a pathway for excess water removal. Excess water commonly leads to flooding, where liquid water accumulates in the GDL and gas channels resulting in fuel starvation. Although the GDL is commonly made hydrophobic to enhance water removal, in practice, flooding is still a major cause of PEMFC performance degradation.

III. BIOFUELS

SPOTLIGHT	FEATURED PROJECTS: 7 RESEARCHERS IN THIS AREA: 24 FUNDING CURRENTLY HELD BY THESE INVESTIGATORS: \$17M
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RESEARCH KEYWORDS

biodiesel, biogas, biomass, ethanol, food supply, methane, microbial fuel cells, vegetable oil, waste conversion

PRESTIGIOUS AWARD WINNERS

American Association for the Advancement of Science (AAAS) Fellows – D. Grant Allen
 Canadian Academy of Engineering Fellow – Levente Diosady
 Canadian Society of Mechanical Engineers – James Wallace
 Chemical Institute of Canada Fellow - D. Grant Allen
 Engineering Medal, Association of Professional Engineers of Ontario – Levente Diosady
 Killam Research Fellowship – Elizabeth Edwards
 LaSueur Memorial Medal, Society of Chemical Industry – David Boocock
 Project of the Year, Strategic Environmental Research Development Program – Elizabeth Edwards
 Society of Automotive Engineers Fellow – James Wallace
 Synergy Award, NSERC – Mohini Sain
 W.J.Eva Award, Canadian Institute for Food Science and Technology – Levente Diosady

UT RESEARCHERS INCLUDE

D. Grant Allen, Edgar Acosta, Nasser Ashgriz, David Boocock, Malcolm Campbell, Thomas Coyle, Levente Diosady, Elizabeth Edwards, Ramin Farnood, Harriet Friedmann, Donald Kirk, Sally Krigstin, Heather MacLean, Radhakrishnan Mahadevan, Emma Master, Peter John O'Brien, Mohini Sain, Bradley Saville, Grace Skogstad, C. Tattersall Smith, Murray Thomson, Honghi Tran, James Wallace, Ning Yan, et al

RESEARCH IN THIS AREA HAPPENS IN

Centre for Environment
 Dept. of Cell and Systems Biology
 Dept. of Chemical Engineering & Applied
 Chemistry
 Dept. of Civil Engineering
 Dept. of Ecology and Evolutionary Biology
 Dept. of Materials Science and Engineering

Dept. of Mechanical and Industrial Engineering
 Faculty of Forestry
 Faculty of Pharmacy
 Pulp & Paper Centre
 UTM: Dept. of Sociology
 UTSC: Dept. of Social Sciences

PROJECTS INCLUDE:

Advancing the Development of New Fuels from Biomass Feedstocks - Reducing our dependence on petroleum-based products and using alternative biofuels requires a deep understanding of the chemical and physical properties of those biofuels, especially combustion processes. [Murray Thomson's](#) Research group is investigating the combustion behaviour of biodiesel, bio-butanol, bio-oil, bio-kerosene and other biofuels. In particular, they are measuring the makeup of biofuel flames, developing detailed chemical kinetic models and are looking at how engines must be adapted to use biofuels. <http://www.mie.utoronto.ca/staff/profiles/thomson/>

Anaerobic Conversion of Pulp Mill Residuals to Energy - Energy cost and waste handling are two principal challenges for pulp mills in Canada's forest sector. Proper disposal of secondary sludge is of particular concern, given limited opportunity for land application, and increased production forecasts. Anaerobic conversion of effluent to methane is commonly practiced by other industrial and municipal treatment facilities, and the feasibility of anaerobic conversion of secondary sludge from certain pulp mills has been demonstrated. The objective of [Emma Master's](#) current research is to identify economic pretreatment technologies and opportunities for co-digestion that increase the efficiency of methane production from secondary sludge. The effect of pretreated secondary sludge on anaerobic microbial activity and composition will also be assessed to predict long-term impact on anaerobic reactor performance. <http://chem-eng.utoronto.ca/~bioproducts/research.htm#five>

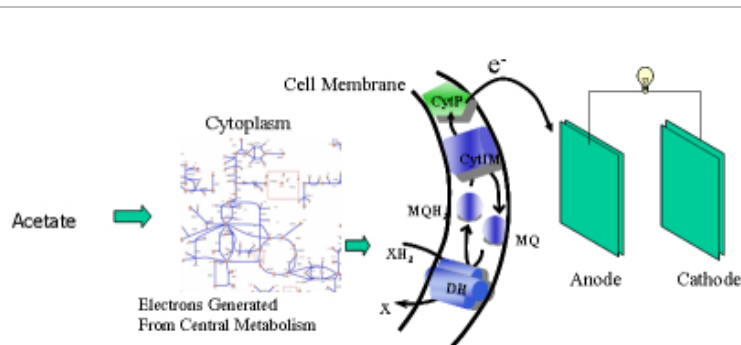


Better Biodiesel – the BioX Solution - Creating biodiesel from grease, waste animal fat, recycled vegetable oil and agricultural seed oils traditionally followed a slow and expensive production process. **David Boocock** developed a new process that not only improves the speed and efficiency of the conversion, but can also be used in conjunction with an acid-catalyzed step to convert previously unusable fatty acids. In 2000, BioX Corporation was formed, and its plant in Hamilton now produces 60 million litres per year in biodiesel. See page 46 for more information on BioX.

Hydrothermal Conversion of Biomass to Hydrogen and Methane - [Ramin Farnood](#) and his team are developing novel technologies for the production of hydrogen and methane from sludge based on catalytic hydrothermal processes. A key focus of this research is developing new stable and selective catalysts with improved yield of hydrogen. Since the drying of biomass is no longer required, this technology offers an economically promising alternative for the gasification of wet biomass.

Integrated Process for the Production of Food and Biofuels - Mustard is a major Canadian food crop. It grows in dry areas unsuitable for other cash crops. The Canadian mustard growers initiated the "Mustard 21" program to increase the revenues from mustard from \$ 70 million to \$ 570 million by 2021. Traditional food uses for mustard are saturated, but there is a huge potential for using the protein for human food, while recovering the oil for industrial uses. Biodiesel is such industrial use. Mustard oil is high in erucic acid, which makes it an excellent lubricant in high temperature applications. To capture the edible and industrial components an integrated processing system is proposed. Three technologies will be integrated. Enzyme assisted aqueous extraction will be used to recover a protein solution, an edible residue, which is suitable for food applications, and a protein stabilized water/oil emulsion. [Levente Diosady](#) and colleagues have patented technology for the purification and recovery of high purity (and value) protein isolates from alkaline aqueous extracts of mustard and canola seed, while **David Boocock** has patented and commercialized biodiesel technology based on the dissolution of both the polar and non-polar components of the trans-esterification reaction. They believe that a combination of these technologies will allow us to break the emulsion and release the oil for transformation to biodiesel without further co-solvent. They will develop an effective "biorefinery" that recovers the high valued food and nutraceutical ingredients without contact with organic solvents, and will recover the oil as a superior quality biodiesel that may command a significant premium over conventional soy or canola-based biodiesel. They will work with the support of two innovative Canadian firms: Hermann Laue Spice Company in the protein area and BioX Corporation in the biodiesel area.

Model-based Engineering for Microbial Fuel Cells - In addition to the bioremediation of toxic metals, Geobacteraceae members can also transfer electrons onto an electrode in a microbial fuel cell environment. Although the coulombic efficiency of this process is high, the rates of electron transfer is low. Hence, approaches for understanding the metabolic processes in a microbial fuel cell and redesign of metabolism is required for increasing the rate of electron transfer. [Radhakrishnan Mahadevan's](#) group has utilized metabolic models for engineering the metabolism in this bacteria to increase the rate of respiration as way of increasing the electron transfer onto the electrodes.





Second Generation (Lignocellulosic) Ethanol – An Alternative to Food Sources

Ethanol is a great alternative to gasoline, emitting less carbon dioxide, particulates and other greenhouse gases and pollutants. Currently, most ethanol for fuel is derived from corn, a practice that will not be viable for the massive production required for ethanol to truly become an alternative to gasoline due to the large land mass that is required for its growth and the investment of energy and resources required for harvesting. In addition, the use of corn for fuel production is controversial as it removes a valuable source of nutrition from the food supply. Researchers have targeted lignocellulose as the next source of ethanol for fuel. Lignocellulose accounts for the bulk of the mass of plants, a combination of lignin, cellulose and hemicellulose. In a bioreactor such as the one shown on the left, ethanol can be derived from lignocellulose through hydrolysis of the component cellulose, microbial fermentation of the resultant sugars and distillation to 99.5% ethanol. While the process to derive ethanol from lignocellulose is more complex, the raw material is considerably more abundant (**any** plant matter can be used, including waste residues and native grasses). [Heather MacLean](#) and her graduate students are performing Life Cycle Assessment of emerging bio-ethanol pathways to evaluate the benefits of lignocellulosic ethanol compared to corn ethanol and gasoline.

THE ENVIRONMENT: HEALTHY ENVIRONMENT AND ECOSYSTEMS

IV. THE ENVIRONMENT AND SOCIETY

SPOTLIGHT	FEATURED PROJECTS:	12
	RESEARCHERS IN THIS AREA:	91
	FUNDING CURRENTLY HELD BY THESE INVESTIGATORS: \$10.7M	

RESEARCH KEYWORDS

aboriginal peoples, automotive industry, carbon sequestration, developing nations, environmental activism, environmental economics, environmental education, environmental health, environmental history, environmental law, environmental management, environmental politics, environmental psychology, environmental sociology, environmental stress, ethics, food supply, globalization, global governance, international development, international trade, legislation, policy, pollinators, poverty, resource management, religion, sick building syndrome, social networks, socio-economic issues; suburban landscapes, sustainable cities, sustainable design, sustainable development, sustainable investment, sustainable forest management, traditional ecological knowledge, transportation, urban development, urban planning,

CANADA RESEARCH CHAIRS

Jing Chen, CRC in Ecosystem-Atmospheric Interaction

Tania Li, CRC in the Political-Economy and Culture of Asia-Pacific

PRESTIGIOUS AWARD WINNERS

Award for Scholarly Distinction in Geography, Canadian Association of Geographers – Ted Relph

Award of Merit, Federation of Chinese Canadian Professionals – Jing Chen

Canadian Academy of Engineering Fellow – Douglas Reeve

Canadian Association of Geographers Award for Service to Geography in Government and Business – Chuck Hostovsky

Canadian Institute of Forestry's Scientific Achievement Award – Shashi Kant

Conservation Council of Ontario's Lieutenant Governor's Conservation Award – Adèle Hurley

Fellows of the Royal Society of Canada – Steven Bernstein, Larry Bourne, Jing Chen, Stephen Clarkson, David Duff, Margrit Eichler, Andrew Miall, Ted Munn, Richard Sandbrook, Wayne Sumner

Governor General's Literary Award – Stephen Clarkson

Henry Friesen Award, Canadian Society for Clinical Investigation – Steven Bernstein

John S. Bates Memorial Gold Medal, TAPPI – Douglas Reeve

Killam Research Fellowship – Stephen Clarkson, Wayne Sumner

Massey Medal, Royal Canadian Geographical Society - Larry Bourne

McLaughlin Medal, Royal Society of Canada – Steven Bernstein

Officer of the Order of Canada – Steven Bernstein

Paper Industry International Hall of Fame – Douglas Reeve

Patterson Medal for Distinguished Service to Meteorology – David Duff

Polanyi Prize, Ministries of Education and Training, Colleges and Universities – Mark Stabile

Premier's Research Excellence Award – Shashi Kant
Professional Engineers of Ontario Medal – Douglas Reeve
Public Policy Scholar, Woodrow Wilson International Center for Scholars – Stephen Clarkson
Purvis Memorial Award, Society of Chemical Industry – Douglas Reeve
Queen's Award for Forestry, Commonwealth Forestry Association – Shashi Kant
Roy F. Weston Prize, TAPPI – Douglas Reeve
Scientific Achievement Award, International Union of Forest Research Organization – Shashi Kant
Synergy Award for Innovation, NSERC – Douglas Reeve, Luis Seco
Technical Award, TAPPI – Douglas Reeve

ENDOWED CHAIRS

Bahen/Tanenbaum Chair in Civil Engineering – Eric J. Miller
Gordon Stollery Chair in Basin Analysis and Petroleum Geology – Andrew Miall
Metcalf Chair in Environmental Law – Jutta Brunnée

UT RESEARCHERS INCLUDE

Jane Ambachtsheer, Sandra Bamford, Pierre Belanger, Steven Bernstein, Alana Boland, Larry Bourne, Kerry Bowman, Jutta Brunnée, Ron Buliung, Jing Chen, Stephen Clarkson, Tenley Conway, Frank Cunningham, Hilary Cunningham, Amrita Daniere, Pierre Desrochers, Donald Dewees, Richard DiFrancesco, Dan Dolderman, James Dooley, David Duff, Margrit Eichler, Harriet Friedmann, Andrew Green, Lino Grima, Mart Gross, John Hannigan, James Heller, Paul Hess, Matthew Hoffmann, Chuck Hostovsky, Adèle Hurley, Josée Johnston, Shashi Kant, Paul Kingston, John Kirton, Gary Knowles, Dmitry Krass, Tania Li, Yue Li, Douglas MacDonald, Laurel MacDowell, Virginia Maclaren, Heather MacLean, Sue McGeachie, Deborah McGregor, Murray Metcalfe, Andrew Miall, William Michelson, Eric J. Miller, Paul Muldoon, Ted Munn, Scott Munro, Barbara Murck, Jennifer Murdock, Michelle Murphy, Linda Muzzin, Dennis O'Hara, Edmund O'Sullivan, Erminia Pedretti, Steve Penfold, David Pond, Matthew Price, Scott Prudham, Douglas Reeve, Ted Relph, Gordon Richardson, Vincent Robinson, Richard Sandbrook, Beth Savan, Stephen Scharper, Luis Seco, Krystyna Sieciechowicz, Grace Skogstad, Mark Stabile, Ingrid Stefanovic, Richard Stren, Wayne Sumner, Peter Telford, James Thomson, Paul Thompson, Huilan Tian, Matthew Turner, Johannes Van Biesebroeck, Sarah Wakefield, Rodney White, Graham White, Mason White, Joseph Whitney, Adonis Yatchew, Barbara Zimmerman, et al.

RESEARCH IN THIS AREA HAPPENS IN

Centre for Environment	Dept. of Family & Community Medicine
Centre for Geoinformatics	Dept. of Geography & Program in Planning
Centre for Global Change Science	Dept. of Geology
Centre for International Studies	Dept. of History
Centre for Peace and Conflict Studies	Dept. of Mechanical and Industrial Engineering
Dalla Lana School of Public Health	Dept. of Philosophy
Dept. of Anthropology	Dept. Political Science
Dept. of Cell and Systems Biology	Dept. of Psychology
Dept. of Chemical Engineering & Applied Chemistry	Dept. of Sociology
Dept. of Civil Engineering	Faculty of Architecture, Landscape and Design
Dept. of Ecology and Evolutionary Biology	Faculty of Forestry
Dept. of Economics	Faculty of Law

Institute for the History and Philosophy of
Science and Technology
OISE
Program on Water Issues
Rotman School of Business
St. Michael's College
Trudeau Centre for Peace and Conflict Studies
UTM: Dept. of Anthropology

UTM: Dept. of Geography
UTM: Dept. of Historical Studies
UTM: Dept. of Management
UTM: Mathematical and Computational Sciences
UTM: Dept. of Political Science
UTM: Dept. of Sociology
UTSC: Dept. of Social Sciences

PROJECTS INCLUDE:

CANADA MORTGAGE AND HOUSING CORPORATION		
<p>Brownfield Redevelopment and Urban Growth – Richard DiFrancesco and colleagues have been studying cases from across the country, where brownfields have been remediated and redeveloped for residential purposes, and reviewing and analyzing the literature on this topic for the Canadian Mortgage and Housing Corporation.</p>		
<p>Challenges of the Agrarian Transition in Southeast Asia - Multi-disciplinary Collaborative Research Initiative funded by Social Science and Humanities Research Council 2005-2010. Directed by Professor Rodolphe de Koninck, CETASE, Université de Montreal. The agrarian transition represents perhaps the most profound process of social change of the last three centuries. In the wealthier countries of the global North it is a transformation that is largely complete, but in the developing societies of the global South it is still very much underway. The research team assembled to undertake this task comprises 23 researchers, drawn primarily from economic, cultural, and environmental geography, as well as other disciplines including history, sociology, anthropology, economics, women's studies, urban studies and planning. The team members, belonging to three generations of scholars, are attached to 18 different universities or research institutions: nine in Canada (Montréal, McGill, York, Toronto Tania Lj), UBC, UQAM, Laval, Trent and Waterloo), five in Southeast Asia, three in Europe, and one in Australia. The output of the project will include at least 45 graduate theses, most prepared at Canadian universities but in a highly international context, and a broad range of peer-reviewed articles and books. In addition, to ensure that policy-oriented results reach key stakeholders, workshops and seminars will be held on a regular basis and a knowledge base developed that will make our findings available to the wider public on the world wide web.</p>		
<p>Earth Scientists' Perspectives on Global Warming – A collaboration between Andrew Miall and Charlene Miall at McMaster University, this research in progress is situated within the interpretive tradition in sociology, drawing on social constructionist research on social problems and professions. The focus of this research is on how disciplines develop and change; and how knowledge produced by disciplines is used or not used within the discipline itself and in the wider community. Our focus is on the earth sciences, and more particularly, geology. They are interested in how the climate change debate taking place today is impacting on the discipline itself in terms of funding issues, the focus of university departments in training students, and the current and future focus of energy producing organizations. This research will make contributions to social problems research, disciplinary analysis, environmental sociology, and the sociology of professions in transition.</p>		
		
<p>EAST – Educational Alliance for a Sustainable Toronto - In May 2005, Toronto was selected as the location for one of seven Regional Centres of Expertise on Education for Sustainable Development by the United Nations University. Regional Centres from around the world seek to enhance access and quality of education for sustainable development (ESD). The Regional Centres of Expertise are one way that the United Nations is promoting the International Decade of Education for Sustainable Development (2005-2014). Toronto's RCE is co-chaired by Ingrid Stefanovic, Director of the Centre for Environment.</p>		

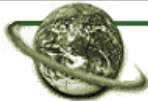


Stanley Stephen (Left) and Roger Wesley (right), Resource officers at the Constance Lake First Nation explaining the traditional values map to University of Toronto Researchers.

Economics of Aboriginal Land Use -The main objectives of this group grant led by [Shashi Kant](#) are: (i) to develop a valuation method to value Aboriginal land use activities and demonstrate its use; (ii) to modify the valuation method to assess the economic impacts of forest resource development projects on Aboriginal communities; (iii) to develop and analyze different scenarios to demonstrate the use of these methods; and (iv) to identify basic economic behavioral characteristics of Aboriginal people.



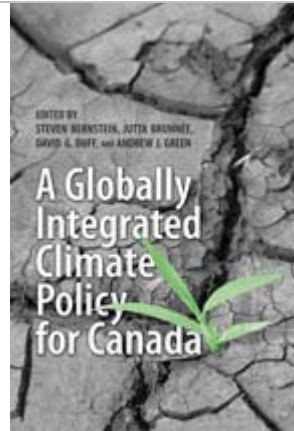
Edible Backyards: Residential Land Use for Food Production in Toronto - With the objective of developing an exploratory assessment of the contribution home food gardening makes to community food security in Toronto, [Sarah Wakefield](#) and [Robin Kortright](#) conducted in-depth interviews with gardeners in two contrasting neighbourhoods for a Centre for Urban Health Initiatives project titled "Edible backyards: Residential Land Use for Food Production in Toronto". A typology of food gardeners was developed, and this qualitative understanding of residential food production was then assessed from a community food security perspective. It was found that growing food contributes to food security at all income levels by encouraging and enabling a more nutritious diet. The sustainability of household food sourcing and gardeners' overall health and well-being also increased with food production. Secure access to suitable land to grow food and gardening skills were found to be the most significant barriers to residential food production.



EnviReform

Envireform: Strengthening Canada's Environmental Community through International Regime Reform - This program identifies effective ways for Canadians to participate more cohesively and directly in the international trade and finance systems that affect their natural environment, food, health and safety. It analyzes the social and environmental impacts on Canadians of existing trade liberalization through the World Trade Organization, North American Free Trade Agreement and other regimes, and explores new strategies for regulation and risk assessment, environmental information, standard-setting, voluntary activities, sustainability assessments of trade agreements and participation by civil society in international trade, finance and environmental institutions. These strategies aim at equipping Canadians to participate in more effective and unified ways in shaping international trade and finance regimes that enhance environmental quality, social cohesion and sustainable development at home and abroad. Co-investigators include: [John Kirton](#), [Stephen Clarkson](#), [Harriet Friedmann](#), [Virginia Maclaren](#) and colleagues, and partner organizations consist of various non-governmental organizations, including Pollution Probe, Foodshare and the Canadian Auto Workers.

<http://www.envireform.utoronto.ca/>

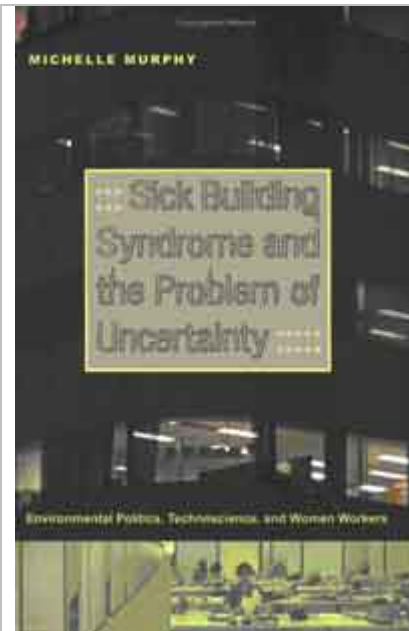


A Globally Integrated Climate Policy for Canada - Edited by [Steven Bernstein](#), [Jutta Brunnee](#), [David Duff](#), and [Andrew Green](#). University of Toronto Press © 2008 – From the Cover: *A Globally Integrated Climate Policy for Canada* builds on the premise that Canada is in need of an approach that effectively integrates domestic priorities and global policy imperatives. Leading Canadian and international experts explore policy ideas and options from a range of disciplinary perspectives, including science, law, political science, economics, and sociology. Chapters explore the costs, opportunities, or imperatives to participate in international diplomatic initiatives and regimes, the opportunities and impacts of regional or global carbon markets, the proper mix of domestic policy tools, the parameters of Canadian energy policy, and the dynamics that propel or hinder the Canadian policy process.

Industrial Symbiosis and Inter-Industrial Recycling Networks – One of the primary research interests of [Pierre Desrochers](#) is industrial symbiosis, a concept within the broader perspective of industrial ecology that analyzes some similarities between industrial networks and ecosystems. Industrial symbiosis occurs when one company's waste becomes another company's feedstock. He has argued that, in an effort to wring maximum productivity out of any given resource base, market enterprise has always naturally developed an ecology of recycling between firms.

Role of Religion in Environmental Movements and the Impact of Ecological Concerns upon Religion – [Stephen Scharper's](#) research on the role of religions in general and Christianity in particular in ecological and environmental movements is in keeping with renewed appreciation of the part religious groups can and do play in periods of significant social transformation. Currently, religious groups are very active in a number of political arenas and, in some cases, have acquired considerable influence over both national and international agendas. The roles that religious constituencies are playing in environmental politics is varied, but it is clear that they will remain important players as environmental policies and practices unfold over the next two decades.

Sick Building Syndrome and the Problem of Uncertainty – Duke University Press, 2006 – From the Publisher: Before 1980, sick building syndrome did not exist. By the 1990s, it was among the most commonly investigated occupational health problems in the United States. Afflicted by headaches, rashes, and immune system disorders, office workers—mostly women—protested that their workplaces were filled with toxic hazards; yet federal investigators could detect no chemical cause. This richly detailed history tells the story of how sick building syndrome came into being: how indoor exposures to chemicals wafting from synthetic carpet, ink, adhesive, solvents, and so on became something that relatively privileged Americans worried over, felt, and ultimately sought to do something about. As [Michelle Murphy](#) shows, sick building syndrome provides a window into how environmental politics moved indoors.



The University of Toronto Sustainability Office – Directed by Professor [Beth Sivan](#), the Office has had considerable success in bridging academia with action, by using the campus as a living laboratory to advance sustainability. Since its launch in 2004, the Office has involved 400 students directly and more than 4,000 indirectly through its operations and projects, and garnered over 50 articles and interviews in local and national media.

<http://www.sustainability.utoronto.ca>

V. CLIMATE CHANGE

SPOTLIGHT	FEATURED PROJECTS: 15
	RESEARCHERS IN THIS AREA: 57
	FUNDING CURRENTLY HELD BY THESE INVESTIGATORS: \$40M

RESEARCH KEYWORDS

Arctic, atmospheric chemistry, atmospheric dynamics, aviation, biodiversity, carbon dioxide sinks, carbon sequestration, climate change, ecosystem, emerging diseases, emissions, environmental genomics, forest management, global warming, greenhouse gases, habitat degradation, limnology, malaria, meteorology, microplankton, mountains, nitrogen flux, oceans, ozone, paleoecology, population dynamics, remote sensing, satellites, sea-level, soil microorganisms, stable isotope geochemistry, sustainable development, water resources, weather systems

CANADA RESEARCH CHAIRS

Jing Chen, CRC in Ecosystem-Atmospheric Interaction
Darrell Desveaux, CRC in Plant-Microbe Systems Biology
Jennifer Murphy, CRC in Atmospheric and Environmental Chemistry
Sean Thomas, CRC in Forests and Environmental Change

PRESTIGIOUS AWARD WINNERS

Alouette Award, Canadian Aeronautics and Space Institute – Robert Zee
American Geophysical Union Fellow - Richard Peltier, Jerry Mitrovica
American Meteorological Society Fellow - Richard Peltier, Ted Shepherd
Award of Merit, Federation of Chinese Canadian Professionals – Jing Chen
Augustus Love Medal, European Geosciences Union - Jerry Mitrovica
Bancroft Award, Royal Society of Canada – Richard Peltier
Canadian Association of Physics Gold Medal for Achievement in Physics – Richard Peltier
Canadian Meteorological and Oceanographic Society Fellow – Ted Shepherd
CIAR Young Explorer – Jerry Mitrovica
E.W.R. Steacie Fellowship, NSERC - Jerry Mitrovica, Richard Peltier, Ted Shepherd
Fellows of the Royal Society of Canada – Peter Abrams, Ian Burton, Jing Chen, Andrew Miall, Ted Munn, Richard Peltier, Ted Shepherd, Ron Williams
Guggenheim Fellowship – Peter Abrams, Jerry Mitrovica, Richard Peltier
Heritage Toronto Award of Merit – Nicholas Eyles
ISI Highly-Cited Researchers – Peter Abrams, Richard Peltier
J. Tuzo Wilson Medal - Jerry Mitrovica, Richard Peltier
Japanese Society Fellowship – Kent Moore
Killam Research Fellowship – Richard Peltier
Kirk Bryan Award of the Geological Society of America – Richard Peltier
Milankovic Medal, European Geosciences Union – Richard Peltier
Miroslaw Romanowski Medal – Richard Peltier
Patterson Medal for Distinguished Service to Meteorology – Richard Peltier, Ted Shepherd
Rutherford Memorial Medal, Royal Society of Canada – Jerry Mitrovica

Sloan Research Fellowship – Richard Peltier
Steacie Prize for Natural Sciences, Steacie Foundation - Jerry Mitrovica
Vetlesan Award, Vetlesan Foundation – Richard Peltier

ENDOWED CHAIRS

Gordon Stollery Chair in Basin Analysis and Petroleum Geology – Andrew Miall



UT RESEARCHERS INCLUDE

Jonathan Abbatt, Alan Abelsohn, Peter Abrams, Nathan Basiliko, Jorg Bollmann, Rudy Boonstra, Carole Burnham, Ian Burton, Malcolm Campbell, John Caspersen, Jing Chen, John Coleman, Sharon Cowling, Alexander Cruden, Hélène Cyr, Joseph Desloges, Darrell Desveaux, Nicholas Eyles, Sarah Finkelstein, Marie-Josée Fortin, William A. Gough, Jochen Halfar, Danny Harvey, Matthew Hoffmann, Donald Jackson, Paul Kushner, Douglas MacDonald, Jay Malcolm, Lisa Manne, Stella Melo, Andrew Miall, Charles Minns, Monirul Mirza, Jerry Mitrovica, Kent Moore, Scott Munro, Jennifer Murphy, Richard Peltier, Saroja Polavarapu, Russ Pysklywec, Patricia Romans, Rowan Sage, Tammy Sage, Ted Shepherd, Brian Shuter, Myrna Simpson, Kimberly Strong, Peter Telford, Sean Thomas, Shelly Ungar, Kaley Walker, Arthur Weis, Rodney White, Ron Williams, Ulrich Wortmann, Robert Zee, Ann Zimmerman, et al.

RESEARCH IN THIS AREA HAPPENS IN

- | | |
|---|--|
| Centre for Environment | Faculty of Forestry |
| Centre for Geoinformatics | Institute for Aerospace Studies |
| Centre for Global Change Science | Southern Ontario Centre for Atmospheric Aerosol Research |
| Dalla Lana School of Public Health | UTM: Dept. of Chemical and Physical Sciences |
| Dept of Cell and Systems Biology | UTM: Dept. of Geography |
| Dept. of Chemistry | UTSC: Dept. of Biological Sciences |
| Dept. of Ecology and Evolutionary Biology | UTSC: Dept. of Physical and Environmental Sciences |
| Dept. of Geography & Program in Planning | UTSC: Dept. of Social Sciences |
| Dept. of Geology | |
| Dept. of Physics | |
| Dept. of Sociology | |

PROJECTS INCLUDE:

	<p>Canadian Network for the Detection of Atmospheric Change (CANDAC) and the Polar Environment Atmospheric Research Laboratory (PEARL) – U of T Researchers Kimberly Strong, Kaley Walker and colleagues are part of the multi-institutional PEARL research program near the Eureka weather station in Nunavut. The CFI-funded station allows researchers to measure the chemical and physical properties of the Arctic atmosphere from the ground to around 100km, to monitor and model climate change. www.candac.ca</p>
	<p>The CanX-2 Mission is the second nanosatellite within the Canadian Advanced Nanospace eXperiment (CanX) program at the University of Toronto Institute for Aerospace Studies, Space Flight Laboratory (UTIAS/SFL), led by Robert Zee.. At 3.5 kilograms and the size of a carton of milk, CanX-2 launched on April 28, 2008. One of the goals of the mission is to use an atmospheric spectrometer, designed by collaborators at York University to measure greenhouse gases.</p>

Climate Change in the Greater Toronto Region - The Greater Toronto Region is highly vulnerable to climatic extremes- drought, flooding, tornadoes and heat waves, etc. Vulnerability of the region to climatic extremes is likely to increase in future. **Monirul Mirza** has recently completed a report which addresses the following major issues: Geography and Climate of Toronto, Changes in Climate, Human Interferences and Activities special focus on urban heat island effect, Climate Change Scenarios for the region from GCM, RCM and statistical downscaled and implications for water, energy, infrastructure (Intensity, duration and frequency curve) and human health.

C-SPARC – Canadian Stratospheric Processes and their Role in Climate – led by [Ted Shepherd](#), this Canadian branch of the World Climate Research Programme's core project involves multiple partners, including Environment Canada, the Canadian Space Agency and universities across the country. Researchers are measuring the chemical and physical properties of the stratosphere to monitor and model climate change.



Fluxnet Canada – A collaboration between the Government of Canada, Canadian Foundation for Climate and Atmospheric Sciences (CFCAS) and partner universities across the country, the Canadian Carbon Program and [Fluxnet](#) involves measuring and modeling carbon cycling in Canadian forests for accurate and predictive carbon cycle modeling. U of T professor [Jing Chen](#) and his research team are using hyperspectral remote sensing and laboratory modeling to evaluate carbon cycling in Canadian forests.

Global Sea-Level Rise - Sea-level variations are a sensitive indicator of climate change, yet the origin of these variations is uncertain. [Jerry Mitrovica](#) and colleagues have developed a 'fingerprint' technique that is based on patterns of sea-level change associated with the melting of distinct ice reservoirs and we are applying this technique to investigate the relative contribution of ice melting and ocean thermal expansion to the observed rate of global sea-level rise.



The Canadian Contribution to the Greenland Flow Distortion Experiment (GFDex) - [The Greenland Flow Distortion experiment](#) (GFDex) is an international fieldwork and modelling-based project to investigate the role that Greenland plays in distorting atmospheric flow over and around it: affecting local and remote weather systems and, via air-sea interaction processes, the coupled climate system. As part of his research program focused on understanding the physical processes that occur in the atmosphere and the ocean and their manifestation in a variety of weather and climate related phenomenon, [Kent Moore](#) is leading the Canadian contribution to this project.

Impacts of Climate Change on Limnetic Biodiversity and Fisheries in Ontario and Quebec - [Peter Abrams](#), [Donald Jackson](#), [Charles Minns](#), [Brian Shuter](#) and colleagues at the University of Guelph and the natural resources agencies of the Ontario and Quebec governments are engaged in an NSERC strategic grant funded project designed to provide the new ecological understanding needed to ameliorate the impacts of climate change on the fish communities and fisheries of the inland lakes of Ontario/Quebec. These lake ecosystems support a significant share of global freshwater biodiversity and their resident fish communities support human uses having high economic and social value. Theoretical work will focus on developing a deeper understanding of how ecosystem biodiversity is controlled by mobile top predators and how that control is itself shaped by the spatial pattern of habitat overlap among predators and prey. Empirical work will focus on: (i) stable isotope studies of food web structure in lakes where differences in lake climate and lake morphometry reshape spatial connectivity of habitats; (ii) telemetry studies of top predator movement among spatially disjunct habitats. The results of these studies will be used to develop new ecosystem models designed to provide policy makers with the ability to forecast the impacts of climate change on these fish communities, and the ability to identify interventions that might ameliorate those impacts.

Impacts of Global Warming on Biodiversity – [Jay Malcolm](#) and his research team are focusing on 1) habitat and species loss, both through migration limitation and habitat loss, 2) modelling the future responses of tree communities to global warming (via climate envelope and migration modelling), and 3) the design of future landscapes to facilitate species migration.



Lake Sediment Records of Arctic Ecosystem Responses to Holocene Climatic Changes - Arctic ecosystems are changing rapidly due to global warming, but the impacts of these changes are poorly understood due to lack of information about long-term ecological responses to climatic changes. Paleoenvironmental records document the effects of past climatic changes on ecosystem dynamics. [Sarah Finkelstein](#) and her team are using Holocene-age paleorecords from the sediments of Arctic lakes to (1) Reconstruct spatio-temporal patterns of Holocene paleoclimates in the Canadian Arctic, (2) Quantify the long-term impacts of climatic changes on terrestrial and aquatic ecosystems, and (3) Determine relationships between species composition, biological productivity, biodiversity, and responses to paleo- and recent climatic changes.

Middle Atmosphere Data Assimilation for Climate Applications - The goal of this work is to combine model forecasts from the Canadian Middle Atmosphere Model ([CMAM](#)) and available observations to produce a "best" estimate of the atmosphere for climate diagnostics. The 3-Dimensional Variational (3DVAR) assimilation scheme used by adjunct professor [Saroja Polavarapu](#) and colleagues at the [Meteorological Service of Canada \(MSC\)](#) to produce operational weather forecasts provides the data assimilation component. Observations include conventional tropospheric data (radiosondes, aircraft, surface stations, ships, buoys, TOVS radiances and cloud drift winds from GOES satellites), and will include middle atmosphere data from satellites (i.e. MLS, HRDI, [SWIFT](#)). This work is one of two projects that comprise [MSC's Middle Atmosphere Initiative](#). It is also a part of the [Global Chemistry for Climate \(GCC\)](#) project.



Polar Climate Stability Network – Led by [Richard Peltier](#) at the U of T, this team of researchers from across Canada examines the problem of climate change at high northern latitudes, the region of Earth that we expect will be most strongly affected by greenhouse gas induced global warming. Since the Canadian landmass and adjacent shelves of the Arctic Ocean constitute a major portion of this region, the issue of the stability of northern ecosystems to the expected, indeed already clearly evident, climate change is an important national concern. www.pcsn.ca



Reactive Nitrogen Fluxes at Haliburton Forest – [Jennifer Murphy](#), [Sean Thomas](#) and [Nathan Basiliko](#) are carrying out an NSERC Strategic Project Grant-funded project entitled: "Forest management under high nitrogen deposition: ecosystem processes and mitigation measures". This project builds on earlier research that indicates that the forest ecosystem is saturated with respect to nitrogen and other nutrients. Existing sites of earlier amendment experiments will be significantly enhanced by new large plots focused on studying the impacts of additions of nitrogen, phosphorus, biochar, and combinations of these treatments. Greenhouse gas fluxes and ecophysiological parameters will be tracked and compared between the different amendments to ascertain whether the ecosystem is indeed N-saturated, and whether locally available biochar is a useful forest fertilization treatment.

The Response of Marine Microplankton to Climate Changes - Little is currently known about how long-term and short-term climate variability affect the abundance, production, assemblage composition, diversity and evolution of marine microorganisms. [Jorg Bollmann's](#) research group is investigating how marine microplankton have been affected by rapid environmental changes such as the El Niño Southern Oscillation (ENSO) and Monsoons in the modern ocean as well as during the Holocene. This research involves the analysis of climate archives such as laminated sediments from key localities that sensitively record these rapid climate changes (e.g., the Gulf of California, the Cariaco Basin, Equatorial Atlantic and the Arabian Sea).

Terrestrial biogeochemistry and soil microbial ecology - Soil microorganisms play vital, yet poorly characterized roles in terrestrial ecosystems. [Nathan Basiliko's](#) work explores the microbial role in wetland and forest biogeochemistry. In particular his group focuses on microbial responses to human-induced environmental changes that have consequences for greenhouse gas fluxes, nutrient and carbon dynamics, and ecosystem sustainability. Our understanding of soil microbiology relevant to larger-scale ecosystem dynamics has grown tremendously in the past 15 years. This is a result of the development and refinement of rapid molecular ecological techniques for studying complex soil microbial communities and a realization that understanding controls on microbial dynamics in terrestrial ecosystems is essential to understanding how the biosphere will respond to unprecedented climate and environmental change and natural resource management.

VI. POLLUTION AND HEALTH

SPOTLIGHT	FEATURED PROJECTS:	26
	RESEARCHERS IN THIS AREA:	102
	FUNDING CURRENTLY HELD BY THESE INVESTIGATORS:	\$74M

RESEARCH KEYWORDS

air pollution, Arctic, asthma, atmospheric chemistry, aviation, bioremediation, cancer, carbon sequestration, chemical exposure, dioxin, drinking water, emerging diseases, emissions, environmental contaminants, environmental health, environmental psychology, epidemiology, genetics, "green" chemistry, groundwater, heavy metals, infectious disease, indoor air pollution, malaria, mercury, multiple mycology, noise pollution, particulates, pollution, polyaromatic hydrocarbons, radiation, respiratory health, sick building syndrome, soil, smog, smoking, soil contamination, soot, toxicology, transportation, treated wood, volatile organic compounds, waste treatment

CANADA RESEARCH CHAIRS

Prabhat Jha, CRC of Health and Development

Dylan Jones, CRC in Atmospheric Physics

Andreas Mandelis, CRC in Diffusion Wave Sciences and Technologies

Nancy Reid, CRC in Statistical Theory and Applications

Barbara Sherwood Lollar, CRC in Isotope Geochemistry of the Earth and the Environment

Ross Upshur, CRC in Primary Care Research

David Zingg, CRC in Computational Aerodynamics and Environmentally Friendly Aircraft Design

PRESTIGIOUS AWARD WINNERS

American Association for the Advancement of Science (AAAS) Fellows – D. Grant Allen, James Donaldson, Nancy Reid

Canadian Aeronautics and Space Institute Fellow – David Zingg

Canada's Top 40 Under 40 – Prabhat Jha

Canadian Environmental Scientist of the Year, Canadian Geographic – Miriam Diamond

Canadian Geophysical Union Young Scientist Award – Brian Branfireun

Chemical Institute of Canada Award - Mitchell Winnik

Chemical Institute of Canada Fellow - D. Grant Allen

CIC Medal, Chemical Institute of Canada – Mitchell Winnik

Conservation Council of Ontario's Lieutenant Governor's Conservation Award – Adèle Hurley

Ehmann Award, American Nuclear Society – Robert Jervis

E.W.R. Steacie Fellowship, NSERC - Barbara Sherwood Lollar

Fellow, Canadian Academy of Health Sciences - John Frank

Fellows of the Royal Society of Canada – Robert Jervis, Andreas Mandelis, Ted Munn, Nancy Reid, Barbara Sherwood Lollar, Mitchell Winnik

Guggenheim Fellowship – David Zingg

Henry Darcy Distinguished Lecturer, Association of Ground Water Scientists & Engineers - Barbara Sherwood Lollar

Hugh Nelson Award for Excellence, Occupational Hygiene Association of Ontario – Andrea Sass-Kortsak
Humboldt Research Award – Andreas Mandelis, Mitchell Winnik
ISI Highly-Cited Researchers – Nancy Reid, Mitchell Winnik
Killam Research Fellowship – Elizabeth Edwards, Barbara Sherwood Lollar, Mitchell Winnik
Mid-Career Award, Royal Society of Chemistry – Andre Simpson
New Pioneers Award, Skills for Change- Andreas Mandelis
Premier's Discovery Award – Andreas Mandelis
President's Award, Committee of Statistical Societies – Nancy Reid
Project of the Year, Strategic Environmental Research Development Program – Elizabeth Edwards
Roy W. Tess Award, American Chemical Society - Mitchell Winnik
Society of Photoptical Instrumentation and Engineers Fellow – Andreas Mandelis
Timofeev-Ressovsky Medal, Russian Academy of Sciences – Robert Jervis
Yeram S. Touloukian Award, American Society of Mechanical Engineers – Andreas Mandelis

ENDOWED CHAIRS

Bahen/Tanenbaum Chair in Civil Engineering – Eric J. Miller

UT RESEARCHERS INCLUDE

Jonathan Abbatt, Alan Abelsohn, Edgar Acosta, D. Grant Allen, Nasser Ashgriz, Cornelia Baines, Terry Blake, Susan Bondy, Paul Bozek, Brian Branfireun, Jeffrey Brook, Patrick Brown, Monica Campbell, John Caspersen, Quentin Chiotti, Mary Chipman, Bernard Choi, Donald Cole, Paul Cooper, Paul Corey, Don Cormack, Alexander Cruden, Sharon Dell, Donald Dewees, Miriam Diamond, Dan Dolderman, James Donaldson, Vy Maria Dong, Elizabeth Edwards, Greg Evans, Roberta Ferrence, Murray Finkelstein, John Frank, Roberta Fulthorpe, Dionne Gesink Law, Sunling Gong, Lois Green, Patricia Harper, James Heller, Fred Hendriks, D. Linn Holness, Paul Horgen, Roland Hosein, Adèle Hurley, Robert Jervis, Prabhat Jha, Charles Jia, Dylan Jones, Grazyna Kalabis, Pamela Kaufman, Nancy Kreiger, Nancy Lightfoot, Scott Mabury, Douglas MacDonald, Radhakrishnan Mahadevan, Andreas Mandelis, Loraine Marrett, Bruce McKague, David McKeown, Gail McKeown-Eyssen, John Ross McLaughlin, Murray McQuigge, James Mills, Carl Mitchell, Alex Mohajer, Anthony Muc, Ted Munn, Scott Munro, Michelle Murphy, Timothy Myles, Peter John O'Brien, Allan Okey, Steve Penfold, Blake Poland, James Purdham, Nancy Reid, David Riddick, Patricia Romans, Marie Roy, Stefan Salbach, Andrea Sass-Kortsak, James Scott, Jeremy Scott, Harvey Shear, Barbara Sherwood Lollar, Frances Silverman, Andre Simpson, Myrna Simpson, Lesbia Smith, Kimberly Strong, Susan Tarlo, Peter Telford, Murray Thomson, Shelly Ungar, Ross Upshur, R. Bruce Urch, Kaley Walker, Frank Wania, Peter Webster, Peter G. Wells, Mitchell Winnik, David Zingg, et al.

RESEARCH IN THIS AREA HAPPENS IN

Centre for Biocomposites and Biomaterials Processing
 Centre for Environment
 Centre for Geoinformatics
 Centre for Global Change Science
 Dalla Lana School of Public Health
 Dept. of Cell and Systems Biology
 Dept. of Chemical Engineering and Applied Chemistry
 Dept. of Chemistry

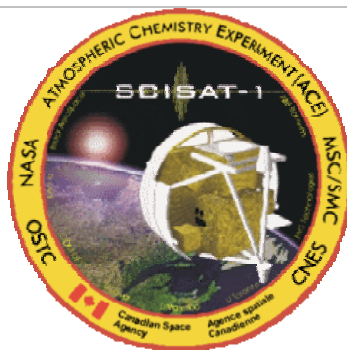
Dept. of Economics
 Dept. of Family and Community Medicine
 Dept. of Geography & Program in Planning
 Dept. of Geology
 Dept. of Health Policy, Management and Evaluation
 Dept. of History
 Dept. of Mechanical and Industrial Engineering
 Dept. of Medicine
 Dept. of Nutritional Sciences

Dept. of Paediatrics
Dept. of Pharmacology and Toxicology
Dept. of Physics
Dept. of Psychology
Dept. of Statistics
Faculty of Forestry
Faculty of Pharmacy
The Hospital for Sick Children
Institute for Aerospace Studies
Joint Centre for Bioethics

The Ontario Tobacco Research Unit
Program on Water Issues
Southern Ontario Centre for Atmospheric Aerosol Research
UTM: Dept. of Biology
UTM: Dept. of Geography
UTSC: Dept. of Physical and Environmental Sciences
UTSC: Dept. of Social Sciences

PROJECTS INCLUDE:

Atmospheric Chemistry Experiment Satellite Mission - The Atmospheric Chemistry Experiment (ACE) is a Canadian-led mission on the SCISAT-1 satellite to perform measurements of the gases in the Earth's atmosphere. Kaley Walker is the Deputy Mission Scientist for ACE and her group is responsible for evaluating and ensuring the quality of the ACE data. ACE's primary goal is to study depletion of the ozone layer. In addition, it is also monitoring greenhouse gas concentrations and tracking atmospheric pollutants.

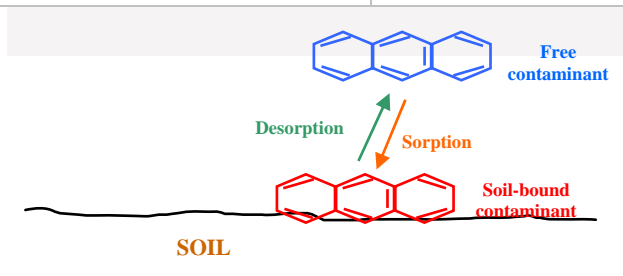


Aerodynamic Concepts to Reduce Greenhouse Gas Emissions of Aircraft - The research of [David Zingg's](#) group is based on two premises. The first is that we require a substantial reduction in greenhouse gas emissions per passenger-km from the next generation of aircraft. Although the current contribution of civil aviation to climate change is relatively modest, demand for air travel is projected to increase at 5-6% per year, while emissions per passenger-km have historically decreased at a rate of 1-2% per year. It should be clear that this situation is not sustainable, and we need aggressive R&D to obtain larger reductions in emissions. The second premise is that aerodynamic optimization can play an important role in achieving this goal through the design and evaluation of new concepts and configurations for ultra-low drag aircraft. Over the past 40 years, improvements in fuel consumption have been associated roughly 50% with engines and 50% with airframes. Future improvements are expected to be similarly split. Airframe improvements will be largely associated with weight and drag reduction. Drag reduction will come from new configurations and active flow control (primarily to maintain laminar flow). Thus the objective of the *computational aerodynamics* group is to apply aerodynamic optimization to the development of novel aircraft concepts and flow control techniques.

Better Tools for Organic Synthesis – The research mission of [Vy Maria Dong's](#) research group is to invent better tools for organic synthesis, including new reagents, catalysts, and strategies. More specific goals include finding ways to directly convert carbon-hydrogen bonds into other functional groups, use carbon dioxide as a raw material, and make biologically active heterocycles. Our approach to these diverse challenges shares a common theme—to harness the power of transition metal catalysis and transform simple reagents into valuable products. Their work is motivated by 1) a fundamental interest in new organometallic pathways and 2) a practical need for more efficient and environmentally friendly technologies. They plan to use these methods to make natural products, pharmaceutical agents, and unique materials.



Childhood Asthma and Traffic-Related Air Pollution – [Sharon Dell](#) and her colleagues at SickKids have been studying the relationship between asthma in Toronto elementary school children and traffic-related air pollution.



Contaminant Interactions with Soils & Sediments – Sorption of nonionic, hydrophobic, organic chemicals to soil and sedimentary organic matter increases contaminant persistence and hinders remediation attempts. Sorption mechanisms are complex, but [Myrna Simpson's](#) research group is using nuclear magnetic resonance to study how the structure and physical conformation or organic matter impacts the extent of contaminant sorption.

Environmental Applications of Sulphate-Reducing Bacteria - The fundamental study by [Charles Jia's](#) Green Technology Research Group on sulphate-reducing bacteria (SRB) is based on the technological significance of SRB in simultaneous metal recovery and sulphur-oxides removal from aqueous streams under extreme conditions.

Fluorinated Pollutants - [Scott Mabury's](#) research group is focusing their efforts on developing the use of ^{19}F NMR as a selective analytical technique for obtaining structural and quantitative information about fluorinated organic chemicals. They investigate environmental degradation pathways and products directly in an NMR tube without the onerous extraction, clean-up, concentration or chromatographic steps involved with traditional techniques. Future work will focus on utilizing these techniques to investigate the influence of fluorine on environmental degradation pathways.

Fundamental Models of Soot and Carbon Nano-Particle Formation - This research, performed by [Murray Thomson's](#) research group, seeks to improve our understanding of the fundamental physical and chemical processes involved in the formation of carbon particles especially soot. Recent work has combined sophisticated aerosol dynamics models with detailed chemistry models to provide a state-of-the-art model. This work provided a new model that accurately predicts the particle dynamics while maintaining fast convergence. This work also improved the soot modeling by including the addition of polycyclic aromatic hydrocarbon (PAH) species to the particle surface. Aromatic hydrocarbons play a central role in the formation of soot. Current work has developed new models of soot formation that is applicable to fuels containing aromatics. This calculates the soot inception rate from the polycyclic aromatic hydrocarbon (PAH) levels. The group has worked closely with aircraft engine designers to transfer this fundamental research into more practical engine models. Soot emissions are an important problem for engine designers.



The Global Fate of Persistent Contaminants - The presence of persistent, anthropogenic compounds in remote areas such as the Arctic has resulted in considerable interest in their global transport and accumulation behaviour. [Frank Wania's](#) work aims at an improved conceptual understanding and quantification of the processes involved in the global dispersion of these chemicals. In 1993, his group put forward the hypothesis of global fractionation and cold condensation for semi-volatile organic compounds, which states that certain characteristics make chemicals prone to preferential deposition and accumulation in cold areas. Chemicals become fractionated latitudinally based on their temperature-controlled atmosphere-surface partitioning characteristics. They are presently developing and testing a passive air sampling technique to probe this hypothesis by mapping the large scale dispersion behaviour of persistent contaminants across Canada. They are further developing and using zonally averaged global computer models to simulate the long term fate of persistent organic chemicals, such as organochlorine pesticides and the polychlorinated biphenyls.

Identifying and Managing Adverse Environmental Health Effects - [Alan Abelsohn](#) and colleagues have published a series of 6 papers in the [Canadian Medical Association Journal](#) on the medical management of various environmental exposures including outdoor air pollution, lead exposure, pesticides and persistent organic pollutants.

In Situ Environmental Impacts of Treated Wood Use - One of the main concerns with the use of wood preservatives is the fear that leached or dislodged preservative components could have adverse effects on human health and the environment. Paul Cooper's research focuses on understanding the loss and fate of preservatives from products in service and in developing ways of minimizing impacts of losses in service.

Investigation of the Influence of Long-range Transport of Pollution on Air Quality in the Arctic - The Arctic is a fragile ecosystem that is particularly sensitive to changes in the climate system and to the influence of anthropogenic pollution. [Dylan Jones'](#) research group is using the GEOS-Chem global three-dimensional chemical transport model and its adjoint to exploit the new satellite measurements, together with existing surface measurements, to quantify the impact of intercontinental transport of pollution on the chemistry of the Arctic troposphere. In particular, they seek to better constrain the budget of ozone (O_3) and nitrogen oxides (NO_x) in the Canadian Arctic to obtain an improved understanding of the factor controlling the seasonal dependence of the O_3 and NO_x budgets.



Investigations of Second Hand Smoke in Public, Private and Outdoor Spaces - [Roberta Ferrence's](#) group at the [Ontario Tobacco Research Unit](#) (OTRU) is involved in a continuing line of research on second hand tobacco smoke. Current projects include two studies, lead by **Pamela Kaufman**. The first, Reducing Smoking in Outdoor Public Places: An Environmental Design Approach, examines the physical and social factors of outdoor environments that affect when and where people smoke, how they react to smoking restrictions, and how smokers and non-smokers interact. The second is a study of tobacco smoke exposure at entrances to buildings, which includes both qualitative and quantitative data collection. Roberta Ferrence has also led several studies that have been conducted in hospitality venues: one assessed smoke leakage from designated smoking rooms to non-smoking areas in bars; the other examined outdoor second hand smoke exposure on bar patios and potential drifting of smoke indoors. Other work at OTRU examines attitudes toward restrictions on second hand smoke and estimates of exposure among various population groups. These studies provide critical information for government policy development and key evidence for those involved in health promotion and advocacy.



Latex Films: Film Formation from Polymer Nanoparticles - The main component of latex paints is a colloidal dispersion in water of soft polymer nanoparticles. When the water evaporates, these fuse into a clear continuous film that holds the pigment onto the surface being painted. Most latex paint contains substantial amounts of organic solvent (volatile organic compounds, VOC) as a plasticizer to aid in film formation. When these evaporate from the painted surface, they contribute to smog. Concern for the environment is forcing the paint industry to develop new technologies with lower VOC content, but this requires new knowledge about the complex processes that occur when the polymer nanoparticle (latex) dispersion dries and evolves to form a mechanically coherent film. Mitchell Winnik's research group is interested in all aspects of this process, but their greatest contribution has been in developing new tools to study the final stage, in which polymer molecules diffuse across the interfaces between cells in the void-free solid film. This is the step that builds mechanical strength into the coating. Over the past 15 years, we have worked with paint companies and latex manufacturers around the world to help build a deeper understanding of the latex film formation process.



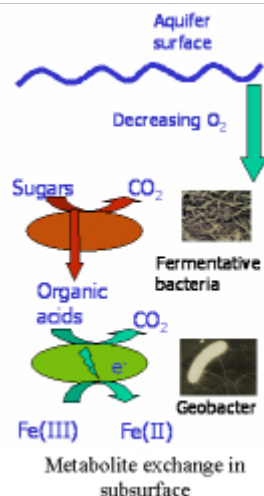
MAPLE – (Mobile Analysis of ParticuLate in the Environment) is a mobile sampling vehicle capable of measuring the spatial and temporal variations of ambient aerosol characteristics. MAPLE's mobile sampling platform is advantageous because it can provide a large pool of information about a designated geographical range, rather than stationary facilities, which only rely on a few locations. MAPLE can also be used to study atmospheric processes, map concentration distributions of aerosols, and determine the composition of emission sources and their influence on local and regional air quality. This being said, MAPLE can take a snapshot of a region's atmospheric chemistry, so that aerosol production and dispersion in Southern Ontario can be better understood. MAPLE is just one of many state-of-the-art facilities employed by researchers in the newly created Southern Ontario Centre for Atmospheric Aerosol Research (SOCAAR), directed by Greg Evans. www.socaar.utoronto.ca



The METAALICUS Project - [Brian Branfireun](#) has been involved in the Mercury Experiment to Assess Atmospheric Loading in Canada and the United States (METAALICUS) since 1999. The overall goal of the project being undertaken at the Experimental Lakes Area (ELA) is to study the relationship between changes in atmospheric loading of mercury to watersheds and mercury levels in fish.

Models of Microbial Communities for Improving Bioremediation - In the environment, microbes rarely exist in isolation and almost always function together as a part of an overall community. These microbes can also communicate within these environments by synthesizing and spreading small organic compounds, a phenomenon known as quorum sensing. Understanding of how these communications and the individual function of species have evolved together can be valuable for reverse engineering these aspects for improved practical applications. An example of these applications is in the area of bioremediation.

Bioremediation of toxic heavy metals and chlorinated compounds is catalyzed by anaerobic microbial communities such as *Geobacteraceae* and *Dehalococcoides* spp. These remediation processes result from the reduction of these toxic compounds due to electron transfer by the anaerobic organisms. The electron transfer rate is directly related to respiration and the metabolic processes in the cell and consequently, it is critical to understand metabolism in these organisms for the efficient design of strategies for bioremediation of heavy metals and chlorinated compounds. [Radhakrishnan Mahadevan](#)'s group, in collaboration with the Environmental Biotechnology Center at the University of Massachusetts, has pioneered the analysis of metabolism in such dissimilatory metal reducing bacteria and are actively working on analyzing the metabolism of *Dehalococcoides* spp in collaboration with Elizabeth Edwards.



Molecular Genetic Characterization of Microbes in Outdoor and Indoor Air and Dust -

This project, led by [James Scott](#), involves the examination of the biological constituents of fine and coarse particulate matter (PM) in outdoor air, and indoor fine settled dust by denaturing gradient gel electrophoresis (DGGE) and sequencing of ribosomal gene targets in prokaryotes and eukaryotes.

Occupational and Environmental Airborne Exposures - This program focuses on studies of cardiopulmonary responses to occupational and environmental airborne exposures, and is carried out by a multidisciplinary team of biomedical researchers, epidemiologists, toxicologists, occupational hygienists, chemists and atmospheric scientists, directed by [Frances Silverman](#). The environmental research arm features a unique (to Canada) human exposure facility that concentrates urban ambient particulate matter and adds gaseous outdoor pollutants. Studies are aimed at understanding biological processes that may explain the epidemiological associations between pollutant levels and cardiopulmonary morbidity/mortality. The occupational research is focused on epidemiologic studies of groups of workers exposed to respiratory sensitizers or irritants, with subsequent characterization of responses in representative subgroups to assess mechanisms of response.

Pollution and the Price of Power - Recent benefit-cost studies have shown that the marginal benefits from controlling conventional air emissions from coal-fired electric utility power plants in the US exceed marginal costs of pollution control. Moreover existing and proposed regulations ignore harm caused by the emission of greenhouse gases and harm caused in Canada. This means that electricity prices are too low wherever coal is the predominant fuel. However the same studies suggest that the mis-pricing of electricity is 4% or less. [Donald Dewees](#) argues that in some regions of the US the wholesale price of electricity should be increased by up to 50%, if all externalities are to be included in the price. Getting the environmental price right could reduce pollution levels, increase energy conservation, and lead to wiser choices of new generation technology.



Port Colborne, Ontario: Community health assessment project - Since its inception in 2000, [Paul Corey](#) and [Marie Roy](#) of the Dalla Lana School of Public Health, have been involved in this project. Funded by Vale Inco, these researchers are investigating the health of residents in and around the Port Colborne Refinery.

Research in Contaminant Hydrogeology - Contamination of groundwater resources with petroleum hydrocarbons and chlorinated solvents is widespread and represents one of the most urgent challenges facing environmental science. [Barbara Sherwood Lollar](#)'s research group is one of the first to have successfully developed and applied techniques for using compound specific stable carbon isotopes to investigate controls on the origin of these low level dissolved priority pollutants and on their transport and fate in the subsurface and provided an essential foundation for applying compound specific carbon isotope analysis (CSIA) in groundwater - characterizing the isotopic fractionation associated with dissolution, volatilization and adsorption of two groups of priority pollutants - chlorinated solvents and aromatic hydrocarbons.

Structure and Function of the Ah Receptor - The AH (aryl hydrocarbon) receptor mediates toxic effects of halogenated aromatic hydrocarbons such as 2,3,7,8-tetrachlorodibenzo-p-dioxin ("TCDD"). The overall goal of [Allan Okey's](#) laboratory is to thoroughly characterize the structure and function of the AH receptor. This involves pharmacologic, biochemical, and molecular analyses of the receptor from mammalian tissues, cells in culture and populations. In studies in humans, they are identifying genetically variable forms (polymorphisms) of the AHR in human populations and determining how these genetic variations affect an individual's sensitivity to toxic environmental chemicals.

The University of Toronto Atmospheric Observatory (TAO) - Located at 43.66 N, 79.40 W, and 174 m above sea level, is ideally located for long-term studies of the atmosphere at mid-latitudes. TAO was established in 2001, and is located on the 16th floor of the Burton Tower of the McLennan Physical Laboratories located on the St. George Campus in downtown Toronto. A high-resolution Fourier transform infrared spectrometer (FTS) is the primary instrument at TAO and has been operating since October 2001, with daily measurements since May 2002. It is used to record solar absorption spectra on a daily basis for long-term measurements of stratospheric and tropospheric trace gases, studies of urban pollution, and mid-latitude atmospheric chemistry and satellite data validation. TAO is run by [Kimberly Strong](#) and is certified as a station of the international Network for the Detection of Atmospheric Composition Change.

<http://www.atmosp.physics.utoronto.ca/TAO/>



Urban Air Chemistry – [Jonathan Abbatt's](#) research group is examining the chemical interactions between pollutants in urban environments, including particulates like soot, and polycyclic aromatic hydrocarbons (PAHs), byproducts of burning fuel, which are toxic and carcinogenic and have particular implications for human health.

Urban Entomology Program – Trap-Treat-Release (TTR) is a technique for suppressing or killing social insect colonies, particularly, subterranean termite colonies. TTR was developed by [Timothy Myles](#) and was licensed by the University of Toronto Innovations Foundation to FMC Corporation. TTR directly affects the termite colony, suppressing or even killing it, whereas traditional methods which employ a chemical barrier only deter termites. Advantages of TTR include: 1) TTR is environmentally friendly, since only a minute amount of pesticide is used. Compare this with chemical barriers, which use up to 5000 times more pesticide, and whose residues can last up to 20 years. 2) Adverse health effects to exposed people are greatly reduced because of the minute amounts of chemical used. 3) If the termite colony is eliminated, which is the goal of TTR, the danger of re-infestation is minimized, whereas re-infestation can occur if chemical barriers are disturbed or if termites find a gap in the barrier. 4) The little pesticide that is used is applied only to the target organisms, thus minimizing non-target environmental exposure.

VII. SUSTAINABILITY, RECYCLING AND CONSERVATION

SPOTLIGHT	FEATURED PROJECTS: 26
	RESEARCHERS IN THIS AREA: 126
	FUNDING CURRENTLY HELD BY THESE INVESTIGATORS: \$54M

RESEARCH KEYWORDS

Arctic, biocomposites, biodiversity, biomimicry, brownfields, conservation biology, ecosystem, energy consumption, fisheries sustainability, forest management, green development, habitat degradation, invasive species, lake ecology, landfill, life cycle analysis, lignocellulosic fibres, limnology, paper recycling, population dynamics, residential development, sustainable architecture, sustainable neighbourhoods

CANADA RESEARCH CHAIRS

Baher Abdulhai, CRC in Intelligent Transportation Systems
Herbert Kronzucker, CRC in Metabolic Bioengineering of Crop Plants
Joaquim Martins, CRC in Multi-disciplinary Optimization
Hani Naguib, CRC in Smart and Functional Polymers
Chul Park, CRC in Polymer Processing Technologies
Douglas Stephan, CRC in Catalysis and New Materials
Sean Thomas, CRC in Forests and Environmental Change
David Zingg, CRC in Computational Aerodynamics and Environmentally Friendly Aircraft Design

PRESTIGIOUS AWARD WINNERS

American Society of Chemical Engineers Fellow – Chul Park
American Society of Engineers Fellow – Shaker Meguid
Award of Merit, ASTM International – Douglas Hooton
Award of Merit, Canadian Standards Association– Douglas Hooton
Canadian Aeronautics and Space Institute Fellow – David Zingg
Canadian Association of Geographers Award for Service to Geography in Government and Business – Chuck Hostovsky
Canadian Institute of Forestry's Scientific Achievement Award – Shashi Kant
Canadian Society of Mechanical Engineers – Hani Naguib
Ciapetta Lectureship Award, North American Catalysis Society – Douglas Stephan
Engineering Institute of Canada Fellow – Chul Park
E.W.R. Steacie Fellowship, NSERC – Spencer Barrett
Fellows of the Royal Society – Spencer Barrett
Fellows of the Royal Society of Canada – Peter Abrams, Spencer Barrett, Dan Brooks, Larry Bourne, Stephen Clarkson, Richard Sandbrook, Douglas Stephan, R. Paul Young
F. W. Taylor Medal, College International pour l'Etude Scientifique des Techniques de Production Mecanique – Lily Shu
G.H. Duggan Medal, Canadian Society of Mechanical Engineers – Hani Naguib
Governor General's Literary Award – Stephen Clarkson
Guggenheim Fellowship – Peter Abrams, David Zingg
Humboldt Foundation Senior Research Award – Douglas Stephan

ISI Highly-Cited Researchers – Peter Abrams**John A. Franklin Award, Canadian Geotechnical Society – R. Paul Young****Killam Research Fellowship – Stephen Clarkson, Gary Sprules, Douglas Stephan****Leadership in Science and Sustained Development Award, Ontario Federal Council – Sandy Smith****LaSueur Memorial Medal, Society of Chemical Industry – Douglas Stephan****Massey Medal, Royal Canadian Geographical Society - Larry Bourne****Morand Lblala Award, Polymer Processing Society – Chul Park****NSERC Chair in Design Engineering - Paul Gauvreau****Premier's Discovery Award – Spencer Barrett****Premier's Research Excellence Award – Shashi Kant****Professional Prix de Rome in Architecture, Canada Council for the Arts – Pierre Belanger****Public Policy Scholar, Woodrow Wilson International Center for Scholars – Stephen Clarkson****Queen's Award for Forestry, Commonwealth Forestry Association – Shashi Kant****Scientific Achievement Award, International Union of Forest Research Organization – Shashi Kant****Sewall Wright Award, American Society of Naturalists – Spencer Barrett****Sherritt Hydrometallurgy Award, Canadian Institute of Mining, Metallurgy and Petroleum - Vladimiro Papangelakis****Society of Plastic Engineers Fellow – Chul Park****Synergy Award, NSERC – Mohini Sain, Douglas Stephan****ENDOWED CHAIRS****Keck Chair of Seismology and Rock Mechanics – R. Paul Young****UT RESEARCHERS INCLUDE**

Baher Abdulhai, Peter Abrams, Barry Adams, Paul Aird, David Balsillie, Spencer Barrett, Nathan Basiliko, Brad Bass, Pierre Belanger, Thomas Berleth, Larry Bourne, Donald Boyes, Daniel Brooks, Patrick Brown, Rorke Bryan, Ron Buliung, Michael Bunce, Carole Burnham, Philip Byer, Terence Carleton, Stephen Clarkson, Nick Collins, Tenley Conway, Paul Cooper, Don Cormack, Gary Crawford, Alexander Cruden, H el ene Cyr, Chris Darling, Anthony Davis, Vy Maria Dong, James Eckenwalder, Alis Ekmekci, Tamer El-Diraby, Mark Engstrom, Paul Gauvreau, Murray Grabinsky, Brian Greenwood, Lino Grima, Mart Gross, Clinton Groth, Omer Gulder, Jason Hackworth, John Hannigan, Danny Harvey, Bryan Henderson, Paul Hess, Douglas Hooton, Chuck Hostovsky, Reiner Jaakson, Greg Jamieson, Robert Jefferies, Tim Johnson, Shashi Kant, Bryan Karney, Christopher Kennedy, Andy Kenney, Ted Kesik, Mark Kortschot, Peter Kotanen, Sally Krigstin, Herbert Kronzucker, Eva Kuhn, Susanna Laaksonen-Craig, Philippe Lavoie, Shawn Lehman, Nigel Lester, Virginia Maclaren, Heather Maclean, Nick Mandrak, Lisa Manne, David Martell, Joaquim Martins, Shaker Meguid, Eric J. Miller, James Mills, Charles Minns, Monirul Mirza, Alex Mohajer, Barbara Murck, Robert Murphy, Timothy Myles, Hani Naguib, Vladimiro Papangelakis, Chul Park, Steve Penfold, K.D. Pressnail, Nicholas Provar, James Purdham, Mark Ridgway, Jim Rising, J.S. Rogers, D.N. Roy, Tammy Sage, Mohini Sain, Richard Sandbrook, Amer Shalaby, Shamim Sheikh, Lily Shu, Krystyna Sieciechowicz, Anthony Sinclair, C. Tattersall Smith, Lesbia Smith, Sandy Smith, Keith Somers, Gary Sprules, Craig Steeves, Douglas Stephan, Richard Stren, Stefan Salbach, Zeb Tate, Peter Telford, Sean Thomas, Paul Thompson, James Thomson, Victor Timmer, Matthew Turner, R. Bruce Urch, Bill Vanderburg, Graham White, Mason White, Ning Yan, Keiko Yoshioka, R. Paul Young, Ann Zimmerman, et al.

RESEARCH IN THIS AREA HAPPENS IN



Centre for Biocomposites and Biomaterials
Processing
Centre for Environment

Centre for Geoinformatics
Centre for Global Change Science
Centre for Technology and Social Development

Dalla Lana School of Public Health
 Dept. of Anthropology
 Dept. of Cell and Systems Biology
 Dept. of Chemical Engineering and Applied Chemistry
 Dept of Chemistry
 Dept. of Civil Engineering
 Dept. of Ecology and Evolutionary Biology
 Dept. of Electrical and Computer Engineering
 Dept. of Geography & Program in Planning
 Dept. of Geology
 Dept. of History
 Dept. of Mechanical and Industrial Engineering

Dept. of Philosophy
 Dept. Political Science
 Faculty of Architecture, Landscape and Design
 Faculty of Forestry
 Institute for Aerospace Studies
 Institute for the History and Philosophy of Science and Technology
 UTM: Dept. of Anthropology
 UTM: Dept. of Biology
 UTM: Dept. of Geography
 UTM: Dept. of Political Science
 UTSC: Dept. of Biological Sciences
 UTSC: Dept. of Physical and Environmental Sciences
 UTSC: Dept. of Social Sciences

PROJECTS INCLUDE:

	<p>Biomimetics for Innovation and Design Laboratory - In the past, biologically inspired design has mostly relied on personal or chance knowledge and observation of biology to inspire design. As many engineers may not know the most relevant biological phenomena for any given design problem, a systematic method of accessing biological knowledge is required. The approach taken by Lily Shu and her research group is to search the vast amount of biological knowledge already in natural-language format. Current research aims to optimize the process of identifying and using the most relevant biological phenomena for any given design problem.</p>
<p>Catalyzing Change - One portion of Douglas Stephan's research group is focused on new, greener technologies for the production of commodity polymers. The goals are to develop new catalyst technologies that provide cheaper, more energy efficient processes for the larger scale production of valuable materials such as plastics and rubbers. In addition, catalyst design initiatives target precise control of the nature of the polymers produced. Such technology will allow minimize waste and broaden the range of applications. A recent seminal discovery in the Stephan group has uncovered a green, metal-free approach to the most commonly used chemical transformation, namely hydrogenation. This finding has wide ranging implications for chemical, agrochemical and pharmaceutical production technologies. In addition, the work has also spawned new initiatives in hydrogen storage systems.</p>	
 <p>Centre for Technology and Social Development – Bill Vanderburg and colleagues in the Centre are focused on the study of technology, society, biosphere interactions and its application to the development of preventive approaches for the engineering, management and regulation of modern technology. Examples include: pollution prevention, industrial ecology, design of environment, energy demand management, healthy workplace design, and healthy sustainable city concepts. These methods take a proactive approach to dealing with social and environmental consequences of technology, which is typically more cost-effective while reducing burdens imposed on society and the environment.</p>	
<p>Classifying Brownfields to Aid Decision Making - Significant economic, legal and environmental concerns present obstacles to the redevelopment of thousands of brownfields in Canada, which have the potential to stimulate economic growth, community revitalization, and urban renewal. However, there are inadequate tools to assist site owners and developers, municipalities, and the local community understand the multiple and complex issues that must be addressed in order to make sound decisions on site redevelopment in any particular situation. In this current, joint project with Edwin Tam at the University of Windsor, Philip Byer's research group is developing a methodology for classifying brownfields on the basis of a broad set of factors including site characteristics, alternative remedial actions, existing and proposed site uses, potential liability, and community settings, in order to prioritize sites for redevelopment, identify obstacles to their redevelopment and serve as a communications tool among stakeholders.</p>	



Design of Sustainable Streets and Neighbourhoods - Designing streets and neighbourhoods to achieve low life-cycle environmental impacts while attaining socio-economic goals lies at the heart of developing sustainable cities. [Christopher Kennedy's](#) research blends together traditional areas of building science, municipal engineering and transportation planning, and applies methods of life cycle assessment, towards the design of sustainable streets and neighbourhoods. Projects include: design of green roofs; the impacts of urban form and microclimatology on building energy use; design of neighbourhoods to support sustainable transportation modes; and study of the influence of urban forestry on neighbourhood sustainability.

Economics of Sustainable Forest Management: Social Choice and Agent Based Approach - Led by [Shashi Kant](#), the main objectives of the research are: (i) to document the stated and revealed preferences of different groups for forest attributes; (ii) to develop a theory of revealed preferences in non-market context; (iii) to develop intra-group and inter-group preference aggregation rules; and (iv) to develop agent-based models incorporating heterogeneity and dynamics of preferences, of different groups, for forest attributes.



Geospatial Technology for the Analysis of Human Activities and Environmental Change in Canadian Cities and Metropolitan Regions - This research project, led by [Ron Buliung](#), involves both geographical information systems (GIS) software development and policy-based studies aimed at enhancing critical discourse on the effectiveness of widely publicized and accepted transportation and land use planning strategies developed to improve quality of life in Canadian cities and regions.

Getting to Carbon Neutral – The latest project of [Christopher Kennedy's Sustainable Infrastructure Group](#) aims to stretch the knowledge on sustainable urban design and package it in a way that can help Canadian municipalities become carbon neutral.



The Hudson Bay Project - [The Hudson Bay Project](#) is a collaborative research program designed to examine the interacting biotic and abiotic factors that lead to the initiation and spread of runaway trophic cascades in the coastal lowlands of this region. By understanding underlying processes and their impacts, we will be in a better position to develop strategies that may slow or halt the spread of the trophic cascades and perhaps lessen or even reverse their attendant degradation. The scope of the problem requires the integration of numerous areas of biological and physical sciences. [Robert Jefferies](#) is a PI on the project, which includes collaborators from government and the U of T ([Peter Kotanen](#)) and other academic institutions.

Human Factors in Sustainable Energy Consumption – [Greg Jamieson's](#) research team is looking at application of human factors engineering to the design of sustainability aides and systems for the home and workplace. Their aim is to support sustainable behaviour by creating an effective feedback control system around resource consumption.

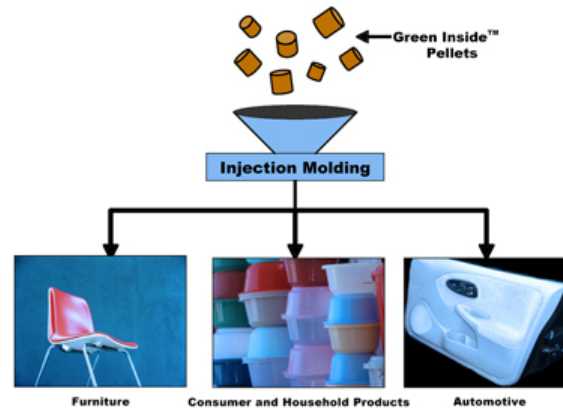




The [ITS Centre and Testbed](#) - The ITS Centre and Testbed provides an instrumented, multijurisdictional, multiagency transportation operations environment linked to university laboratories for real-world development, testing, and evaluation of ITS technologies and applications. It is also a meeting ground or melting pot for public, academic, and private practitioners and researchers to explore new approaches to transportation system management. It offers a site for private industry to demonstrate and evaluate its prototype technologies under live traffic conditions and an ongoing testing ground for Canadian ITS efforts. The director of the Centre is [Baher Abdulhai](#).

Life-Cycle Costs of Reinforced Concrete Structures - [Douglas Hooton](#) and colleagues are developing and applying models for predicting the service life and life-cycle costs of reinforced concrete structures. Their work further involves development of methods for evaluating the durability of high performance concretes, and evaluation of repair systems for deteriorated reinforced concrete structures.

Lignocellulosic Fibres - The new [Centre for Biocomposite and Biomaterials Processing](#) bridges the research activities of three faculties within the University and eight national universities. The research is led by [Mohini Sain](#) in collaboration with [Mark Kortschot](#), [Ning Yan](#), and [Chul Park](#) and focuses on the development of novel fibres and fibre-based materials that add value to wood and agro-residues. The recent focus has been nano-biocomposites manufacturing. The group worked with a team of international researchers and graduate students to mass-produce nano-fibres from wood, agro and root-based raw materials. In the nano-fibre isolation project, structurally strong nano-fibres were isolated from bleached kraft pulp and then characterized using a high pressure defibrillation process. Another ongoing project involves microfibre dispersion in biopackaging. Funded by Auto-21 Network of Centre of Excellence, the group has made significant progress in developing novel ways to incorporate wood and other natural fibres in liquid molding and injection molding processes to enhance fibre dispersion and resin impregnation in manufacturing high impact resistant structural parts. See page 46 for more details on GreenCore Composites.



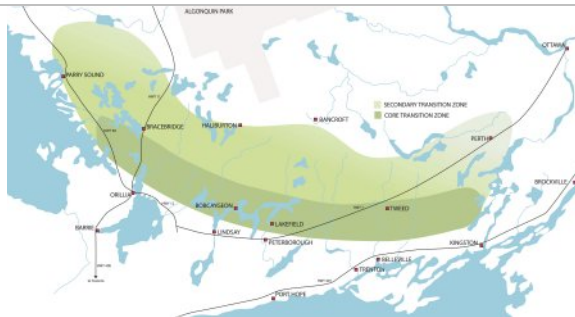
Making Better Use of Cement Kiln Dust - Cement production plants produce vast quantities of cement kiln dust (CKD) which is usually vacuum extracted from the manufacturing process, pelletized and stored in a surface heap. These surface facilities must now be engineered much like a landfill, adding cost to the production of cement. The trick is to turn the CKD waste product into a value-added engineering material. Examples of this already exist, but the existing applications don't consume nearly the volumes of CKD that are produced. [Murray Grabinsky's](#) research group has a project that is looking at using CKD as a Soil Stabilizing Agent (SSA) for highway construction. This was already attempted in the Highway 407 Express Toll Route (ETR) around Toronto with some success. Highway and similar Civil projects could potentially significantly reduce the amount of CKD that needs to be stored on surface, while reducing the projects' capital construction costs.



Minimum Habitat Size for Species Persistence - What is the threshold fragment size below which a particular species does not persist? Primarily using birds as their subjects, [Lisa Manne](#) and her research group are investigating this question, and have found that the answer varies from species to species, depending on their habitat, ability to travel and the size of fragment, among other factors.

Philosophy of Design Loads in Civil Engineering Practice - Incorporating sustainability into all areas of Civil Engineering design is an area of on-going interest within the Department of Civil Engineering. This work is primarily being undertaken by [Barry Adams](#) and [Bryan Karney](#).

Practical Studies in the Effectiveness of Endangered Species Policy – [Mart Gross](#) and his research team are investigating the risk status of fishes sold in Toronto, the largest fish market in Canada. Surprisingly, as much as 25% of species are mislabeled and thus cannot be identified without genetic tools. We are collaborating with a genetics laboratory to use DNA barcoding as a forensic tool, following which we will ascertain the risk status of the various species. We predict that a substantial proportion of the fish are recognized at risk under various government assessments and consumer awareness campaigns. Therefore, our work will examine both government and NGO effectiveness in conservation and consumer choice.



Residential Development Threats in The Land Between - The Land Between is a mosaic transition zone between two distinct biomes, the Mixed wood Forests in the South and the Boreal Forest in the North. It is within commuting distance of two major urban centers (Toronto to the South and Ottawa to the East), and is a popular cottage country area rich in natural amenities. [Tenley Conway's](#) research group is studying the ecological importance of the Land Between because ecotones act as zones of control that facilitate or impede flows of material and wildlife. In this area, increasing exurban development is threatening these processes through landscape fragmentation and increased barrier effects. www.thelandbetween.ca



Sustainability Elements in Feasibility Analysis of Urban Infrastructure: The case of Downtown Toronto Monorail - Infrastructure is being renovated all over Canada. Inclusion of sustainability elements in the renovation is important. Improved public transit has been identified as a priority for the overly congested Greater Toronto Area (GTA). [Tamer El-Diraby](#) and his students are investigating the technical and economical feasibility of replacing existing shared right-of-way streetcars with a monorail alternative, using the 504 King Streetcar route in downtown Toronto as a case study.

Sustainable Flight Initiative at the University of Toronto Institute for Aerospace Studies – [Alis Ekmekci](#), [Clinton Groth](#), [Omer Gulder](#), [Philippe Lavoie](#), [Joaquim Martins](#), [Craig Steeves](#) and [David Zingg](#) form a team of researchers conducting research with the goal of reducing the environmental impact of air transportation, especially the impact on climate change. They are investigating unconventional aircraft configurations, drag reduction techniques, novel materials to reduce weight, low emissions combustors, and alternative fuels.

Sustainable Forest Management Under Uncertainty - Forest management planners develop plans that describe how the land for which they are responsible is to be managed during the near and far distant future. Such plans may include access road construction plans, descriptions of when and where timber harvesting and other resource management activities are to take place, the designation of protected areas such as nesting sites and other important wildlife habitat areas that are not to be disturbed by human activities, and fire management strategies. In their efforts to achieve sustainability they must decide what should be done while considering what might happen over very long time periods, typically 150 years or more into the future. Fire, insects and disease, changes in technology, the prices of forest products and how society views its forests and how they should be managed can be expected to change over time as the future unfolds and plans are implemented. Forest managers must therefore deal with enormous uncertainty and develop robust flexible plans that can be modified as the future as it unfolds. [David Martell's](#) research group is investigating sustainable forest management under uncertainty with emphasis on dealing with fire as a source of uncertainty, including the long term structure and sustainability of flammable forests that are managed according to plans prescribed by mathematical planning models. One of their objectives is to determine the extent to which such models produce "good" sustainable forest management plans. He has developed a simulated planning environment that includes a flammable forest that is managed by an embedded planning model. He can modify the embedded planning model to investigate how its structure including the re-planning interval, the length of the planning horizon, and the accuracy of the fire loss estimates influence the sustainability of the simulated forest.



Sustainable Transportation Research Group – Sustainable transportation systems are those which, for example, aim to reduce emissions, fossil fuel consumption, the consumption of agricultural land, park land and wildlife habitat. Most fundamentally, this means an emphasis on reducing the role of the private automobile as the prime mode of transportation and shifting travel toward other sustainable modes such as public transit cycling and walking. Transportation infrastructure has a strong impact on urban land use patterns, and congestion, both of which result in profound environmental impacts. Hence, advances in the transportation planning process and in the efficiency of transportation systems through technologies such as Intelligent Transportation Systems are key components of the development of sustainable transportation infrastructure. This work is being done by researchers in the Dept. of Civil Engineering, including [Christopher Kennedy](#), [Heather MacLean](#), [Eric J. Miller](#) and [Amer Shalaby](#).

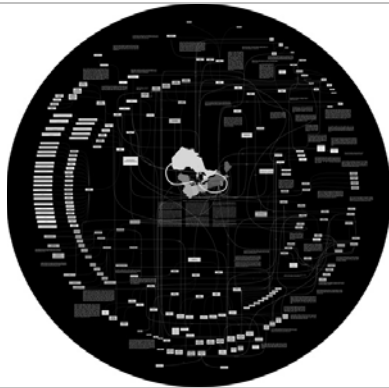
Toronto Green Development Standard (TGDS) - [TGDS](#) is among a number of instruments being fashioned by the City of Toronto to address the negative impacts associated with urban growth. The Standard contains performance targets and guidelines for site and building design to better promote environmentally sustainable development. A new study by [Ted Kesik](#) and colleagues explores the issues and trends in green development across Toronto and its neighbouring regions by identifying the key opportunities for the development or improvement of practices, products and services that enable cost effective green development, while enhancing the competitiveness of Ontario's building industry. The study also makes recommendations to all three levels of government, the development industry and consumers.



TREE (Tropical Research in Edge Effects) Project - Edges effects are characterized by dynamic, ecological changes that occur at habitat boundaries; these include changes in species composition, gradients of moisture, sunlight, soil and air temperature, wind speed, etc. Hypothetically, if edge effects penetrate 300 m into a 100 ha square-shaped forest fragment, then approximately only 16% of the total forest amount will be unaffected by edge effects. Moreover, shape can have a major influence on edge penetration in forest fragments. A long, narrow forest fragment may be completely dominated by edge effects. Forest habitats are becoming increasingly fragmented in most tropical regions of the world. One of the most significant consequences of forest fragmentation is an increase in the amount of habitat edge. [Shawn Lehman](#) and his research group are studying edge effects on forests and primates in Madagascar. Lemurs are one of the most threatened primate taxa in the world due to the loss of 80% - 90% of forest habitats in Madagascar. The remaining forest is highly fragmented and, therefore, may be prone to extreme edge effects.



Waste Econ – Led by U of T researchers [Virginia Maclaren](#) and [Barbara Murck](#), the Waste-Econ Program is a six-year collaborative program funded by the Canadian International Development Agency (CIDA). Partners include a number of government institutions, universities, and non-governmental institutions in Vietnam, Laos and Cambodia. The aim of the project is to explore methods for recycling, exchanging and reducing wastes in a way that will be beneficial to the economies of the partner countries, the people working in the waste sector and to the environment as a whole. A number of pilot projects and training courses have been implemented with the ultimate aim of using the knowledge gained to strengthen institutional capacity, improve university curricula, and create a vibrant and economically sustainable waste economy in each of the partner countries. <http://www.utoronto.ca/waste-econ/>



Wasteshed: The Landscape & Economies of Landfills in Michigan – This project, by [Pierre Belanger](#), involves cartographic visualization of the geological, environmental, political, logistical and operational characteristics of landfills in Michigan. The project was exhibited at the Toronto Free Gallery. Sites: Carleton Farms & Pine Tree Acres Landfills, Michigan Client/Agency: Republic Services Inc.

VIII. WATER

SPOTLIGHT	FEATURED PROJECTS: 13 RESEARCHERS IN THIS AREA: 55 FUNDING CURRENTLY HELD BY THESE INVESTIGATORS: \$34M
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RESEARCH KEYWORDS

Arctic, aquatic ecosystems, aquatic food webs, ballast water, biodegradation, biofiltration, biogeochemistry, bioremediation, contaminants, disinfection, drinking water, fisheries, freshwater ecosystems, Great Lakes, groundwater, governance, hydroelectricity, hydrologic cycle, invasive species, lake ecology, limnology, mercury, population dynamics, safe drinking water, stable isotope geochemistry, urban drainage, waste treatment, wastewater, water demand, water quality, water resource management, watershed, water-soil interactions,

CANADA RESEARCH CHAIRS

Barbara Sherwood Lollar, CRC in Isotope Geochemistry of the Earth and the Environment

PRESTIGIOUS AWARD WINNERS

American Association for the Advancement of Science (AAAS) Fellows – D. Grant Allen

American Geophysical Union Fellow - Richard Peltier

American Meteorological Society Fellow - Richard Peltier

Bancroft Award, Royal Society of Canada – Richard Peltier

Canadian Association of Physics Gold Medal for Achievement in Physics – Richard Peltier

Canadian Environmental Scientist of the Year, Canadian Geographic – Miriam Diamond

Canadian Geophysical Union Young Scientist Award – Brian Branfireun

Chemical Institute of Canada Fellow – D. Grant Allen

Conservation Council of Ontario's Lieutenant Governor's Conservation Award – Adèle Hurley

Bancroft Award, Royal Society of Canada – Richard Peltier

E.W.R. Steacie Fellowship, NSERC - Richard Peltier, Barbara Sherwood Lollar

Fellows of the IEEE – Francis Dawson

Fellows of the Royal Society of Canada – Peter Abrams, Ted Munn, Richard Peltier, Barbara Sherwood Lollar

Guggenheim Fellowship – Peter Abrams, Richard Peltier

Henry Darcy Distinguished Lecturer, Association of Ground Water Scientists & Engineers - Barbara Sherwood Lollar

ISI Highly-Cited Researchers – Peter Abrams, Richard Peltier

J. Tuzo Wilson Medal - Richard Peltier

Killam Research Fellowship – Elizabeth Edwards, Richard Peltier, Barbara Sherwood Lollar

Kirk Bryan Award of the Geological Society of America – Richard Peltier

Milankovic Medal, European Geosciences Union – Richard Peltier

Patterson Medal for Distinguished Service to Meteorology – Richard Peltier

Project of the Year, Strategic Environmental Research Development Program – Elizabeth Edwards

Sloan Research Fellowship – Richard Peltier

Vetlesan Award, Vetlesan Foundation – Richard Peltier

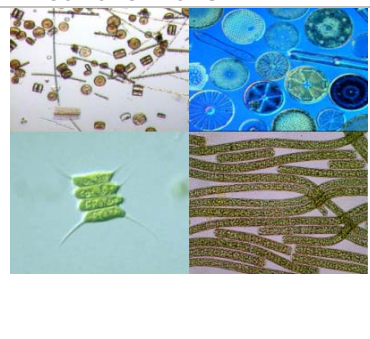

UT RESEARCHERS INCLUDE

Jonathan Abbatt, Peter Abrams, Barry Adams, D. Grant Allen, Robert Andrews, Susan Andrews, George Arhonditsis, Alana Boland, Brian Branfireun, Nick Collins, H el ene Cyr, Francis Dawson, Miriam Diamond, Elizabeth Edwards, Ramin Farnood, Grant Ferris, Roberta Fulthorpe, Lino Grima, Mart Gross, Jason Hackworth, Harold Harvey, Ad ele Hurley, Ronald Hofmann, Kenneth Howard, Robert Jefferies, Donald Jackson, Tim Johnson, Bryan Karney, Nigel Lester, Nate Lovejoy, Scott Mabury, Nick Mandrak, Murray McQuigge, Charles Minns, Monirul Mirza, Carl Mitchell, Paul Muldoon, Ted Munn, Richard Peltier, Anthony Price, Mark Ridgway, Stefan Salbach, Harvey Shear, Barbara Sherwood Lollar, Brian Shuter, Brent Sleep, Lesbia Smith, Keith Somers, Gary Sprules, Peter Telford, R. Bruce Urch, Frank Wania, Mathew Wells, Dudley Williams, Ann Zimmerman et al.

RESEARCH IN THIS AREA HAPPENS IN

Centre for Environment	Dept. of Geology
Centre for Global Change Science	Dept. of Physics
Dalla Lana School of Public Health	Faculty of Forestry
Dept. of Cell and Systems Biology	Program on Water Issues
Dept. of Chemical Engineering and Applied Chemistry	Pulp & Paper Centre
Dept. of Civil Engineering	UTM: Dept. of Biology
Dept. of Ecology and Evolutionary Biology	UTM: Dept. of Geography
Dept. of Electrical and Computer Engineering	UTSC: Dept. of Biological Sciences
Dept. of Geography & Program in Planning	UTSC: Dept. of Physical and Environmental Sciences

PROJECTS INCLUDE:

	<p>Aquatic Biogeochemical Modeling - George Arhonditsis and colleagues have recently developed a complex eutrophication model for Lake Washington that simulates multiple elemental cycles (org. C, N, P, Si, O) and multiple functional phytoplankton (diatoms, green algae and cyanobacteria) and zooplankton (copepods and cladocerans) groups (University of Washington, M.T. Brett). This model will be used for testing alternative watershed management schemes and assess their effects on the lake's dynamics. This research aims to provide a much needed analysis/demonstration of the benefits and the practical difficulties of several recently developed parameter estimation techniques in a way that can assist the common water quality modelling practice, and thus provide new methodological tools for natural resource management and sampling design for water quality monitoring programs.</p>
	<p>Biodegraders Research Group: Biological processes play major roles in many aspects of environmental science and engineering. We strive to attain a better fundamental understanding of environmentally relevant biological processes to inform the scientific and non-scientific communities and to facilitate environmental decision-making at all levels. A primary goal of Elizabeth Edwards' research group is to fundamentally understand how specific organic contaminants are biotransformed by microorganisms in subsurface environments. Over the past several years, we have discovered novel biodegradation pathways, characterized novel bacterial cultures and have demonstrated the efficacy of bioremediation in field trials.</p>
<p>Biogeochemical stability of bacteriogenic iron oxides for sustainable natural remediation of metal and radionuclide contaminants in groundwater-wetlands systems – This NSERC Strategic Grant project is led by Grant Ferris in collaboration with researchers at the University of Ottawa and AECL. It's part of the ongoing efforts by the Microbial Geochemistry Laboratory to investigate the ability of microorganisms to precipitate minerals and other materials from water sources.</p>	



University Of Toronto Pulp & Paper Centre

Biological Treatment of Wastewater from the Pulp and Paper Industry. While already applied in industry on a wide scale this area continues to show enormous further potential, largely because of increasingly stringent environmental controls and the remarkable ability of microorganisms (wild or genetically engineered) to degrade a wide range of pollutants. [D. Grant Allen](#) and his research team have been working to understand and optimize the biological treatment of chlorinated organic compounds from kraft pulp mills, and are also examining the potential for in-mill water re-use. This area has both engineering (e.g., kinetics, modelling, optimization) and microbiology (e.g., identification, monitoring, molecular biology) projects and has received significant funding from government and industry through the [Pulp and Paper Centre](#).

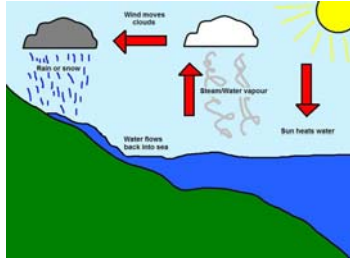
Ultraviolet Disinfection and Photocatalytic Treatment of Water and Wastewater - [Ramin Farnood](#) and his research team are specialized in the treatment of water and wastewater using ultraviolet light in the presence of oxidants and/or photocatalysts. A key focus of Farnood's group is the characterization of suspended particles and their effects on the ultraviolet disinfection of wastewater. In collaboration with Environment Canada and through the support from Ontario's Ministry of Environment, Farnood's team is looking into developing advanced treatment technologies for water reuse applications. Another current research project is focused on the use of sunlight for treating water contaminated with chemicals such as endocrine disrupting compounds.

Connecting Chemical Contaminant Sources, Emissions Fate and Exposure - [Miriam Diamond's](#) research group is exploring the dynamics of organic and inorganic contaminants in lakes, urban areas, aquatic food-webs, and indoor environments. Methods of analysis include field work, experimental investigation, and mass balance modeling. Research on lakes concentrates on the fate of chemicals through aquatic systems that include their food webs. The goal of the research is to connect contaminant emissions with prevailing concentrations in order to set emission limits, predict the time course of water quality improvements, etc.

Distribution and Dynamics of Foodwebs in the Littoral Zone of Lakes - The shallow littoral areas in lakes support the most productive and diverse biological communities, and because of their proximity to shore, they are potentially the most vulnerable to changes in the watershed (e.g. fire, logging, urban development), and in direct and indirect effects of climate changes (e.g., water levels, thermal structure and transparency of lakes). However, because these littoral communities are very patchy and dynamic, it is still extremely difficult to measure and predict their productivity, and to detect anything but the most dramatic impacts from natural or anthropogenic changes. It is well known that winds and lake morphometry are important determinants of the thermal stratification and of water movements in lakes, and that hydrological forces affect the pattern and timing of sediment movements. These forces set clear constraints on the characteristics of habitats that can be found in the littoral zone, which in turn should determine the distribution, composition and dynamics of biological communities. [Hélène Cyr's](#) research group is studying the links between physical constraints, chemical composition of the sediments (nutrients, organic matter) and biological communities (algae and invertebrates) in the littoral areas in lakes.



	<p>Drinking Water Research Group – The Drinking Water Research Group, formed in 1998, is a consortium of researchers from three North American universities: University of Toronto, Dalhousie University, and Indiana University at Kokomo. Our group approach to research recognizes of the benefits derived from regular collaboration of team members on joint projects. Unique resources and expertise are located at the three universities, allowing a broader range of issues to be examined than would normally be available for a project conducted at a single facility. The group is particularly interested in addressing issues of treatment, distribution, innovation to meet future water needs and compliance. The group is led by U of T researchers Robert Andrews and Ronald Hofmann.</p>
	<p>The Hydrodynamics of Discharged Ballast Water - In a collaborative project with DFO biologist Sarah Bailey, Mathew Wells' group is studying how ballast water disperses from Great Lakes freight ships. The idea is to determine how fast and how far a potential aquatic invasive species might spread after ballast water is discharged. Such information will allow them to better understand the likelihood of establishment success of a new potential invasive species.</p>
<p>Stable Isotope Laboratory - Cleaning up the dangerous contaminants -- dry-cleaning fluids, solvents and petroleum hydrocarbons -- found in underground water presents one of the most urgent challenges facing environmental science. A report issued Jan. 30 by the U.S. Environmental Protection Agency (EPA) sheds light on a new way to monitor and improve the success of cleanup efforts using a technique developed at the University of Toronto. "The most common method to clean up groundwater is biodegradation -- using microbes to consume the contaminants and break them down into more benign end products that are not harmful to the environment," said U of T geochemist Barbara Sherwood Lollar, the scientist who initiated the concept and goals for the EPA report and is one of its five international authors. The report outlines how cleanup can be done using a novel technique called compound specific isotope analysis, developed in U of T's Stable Isotope Laboratory. The elements of carbon that form the basis for the hydrocarbon contaminants actually come in two types called isotopes, explains Sherwood Lollar. "When microbes degrade contaminants, they prefer the lighter isotope carbon 12 over the heavier isotope carbon 13. The resulting change in the ratio of these isotopes in the contaminant itself is a dramatic and definitive indicator that the biodegradation is successfully taking place." Read the full story.</p>	
	<p>Water Privatization in China – Alana Boland has been examining the legal construction of water markets and the ideological foundations of water supply privatization in China.</p>
<p>Water Quality Group – Environmental Section, Dept. of Civil Engineering - Research in water quality in the Environmental Section (Robert Andrews, Susan Andrews, Ronald Hofmann and Brent Sleep) of the department focuses on the treatment of water for drinking and on the remediation of contaminated soils and groundwater. The research in drinking water treatment, which requires specialized understanding of the chemistry and biology of water, focuses on alternative disinfection techniques. Much of this research involves study of the formation and removal of disinfection by-products and identification of organic compounds in drinking water. Other projects include the use of physical/chemical methods to reduce <i>Giardia</i> and various viruses and the application of activated carbon adsorption in water treatment.</p> <p>Decades of industrial activity, with often environmentally insensitive disposal practices, have caused untold damage to groundwater aquifers throughout the World. The research into remedial groundwater technologies focuses primarily on light non-aqueous phase liquids (LNAPLs), such as fuel oils, and dense non-aqueous phase liquids (DNAPLs), such as chlorinated solvents. It involves both comprehensive numerical model for simulating the remediation of groundwater contaminated by LNAPLs and DNAPLs and the bioremediation of contaminated sites.</p>	



Water Resources Engineering Group – Led by [Barry Adams](#) and [Bryan Karney](#), research in this group is concerned with society's interaction with the Earth's water cycle. To meet our continual and growing water requirements, engineers need to understand the hydrologic cycle and be able to design suitable structures for controlling, transporting and utilizing water. A broad variety of topics is covered including urban drainage and flood control; flood frequency analysis; optimal multipurpose reservoir operation; stormwater management modelling; water resources systems analysis; the hydraulics and performance of water distribution systems; and transient analysis and design of pipeline systems. With problems of global climate change and a growing world population, water resources is a particularly challenging and exciting area of research.

COMMERCIALIZATION IN ENERGY AND THE ENVIRONMENT

Moving new technologies that produce cleaner energy and reduce pollution, and other products of research like alternative fuels and “greener” materials from the lab to the marketplace is the mandate of [The Innovations Group](#), U of T’s commercialization division. Below you’ll find some examples of our recent success stories, and current opportunities for industrial commercialization of U of T inventions related to Energy and the Environment.

Successful Technology Transfer Stories:

Biox: Biodiesel Fuel That Can Compete With Petroleum

Biodiesel fuel created from grease, waste animal fat, recycled vegetable oil and agricultural seed oils is better for the environment than petroleum fuels, but was not competitive because the production process was slow and expensive.

In 1999, **Dr. David Boocock** came to The Innovations Group (TIG), known then as the Innovations Foundation, with a new process that not only improved the speed and efficiency of the conversion, but could also be used in conjunction with an acid-catalyzed step to convert previously unusable fatty acids. Dr. Boocock’s project received first and second phase funding from the IPM Group (which has since been paid back in full), and then worked with TIG to develop a company that would continue research and develop a commercially viable product. In September 2000, BIOX Corporation was formed.

Achievements

- Successful operation of a one million litre per year capacity pilot plant since 2001
- Test facility has proven that BIOX process is approximately 40% cheaper in capital cost and over 50% cheaper in operational cost compared to other biodiesel processes
- BIOX process is only technology capable of converting high fatty acid feedstocks into biodiesel cost effectively with 1:1 yields
- Received a \$5 million contribution from Sustainable Development Technology Corporation
- Has raised over \$150 million in financing to date

In 2007, Biox opened a commercial scale facility capable of producing 67 million litres of biodiesel annually. Major energy companies have shown strong interest in buying the entire production, given the cost advantages and environmental benefits, and the alternative fuels sector continues to show explosive growth. For more information, see www.bioxcorp.com

GreenCore Composites Inc.: Environmentally Friendly and Affordable Materials for Manufacturing

Excerpted from the company’s website: www.greencorenc.com

GreenCore Composites is a spin-off created by the Innovations Group at the University of Toronto (TIG) in September 2005, to commercialize Natural Fibre Composites technology invented by **Professor Mohini Sain** of the Faculty of Forestry and Chemical Engineering.

Extensive trials with automotive industry partners have confirmed the commercial potential of GreenCore’s technology. GreenCore has also conducted prototyping trials in furniture, toys, and household products applications.

Since 2005, GreenCore has raised over \$2.2 Million in financing from the Ontario Centres of Excellence (OCE), the Ontario Ministry of Research and Innovation (MRI), the Ontario BioAuto Council, and Private Equity sources including First Leaside Visions LP. With this funding, GreenCore is currently operating a Pilot Plant in Toronto, Canada for product development, and to produce commercial quantities of composite material for testing and validation with potential customers.

Using Nanomaterials to Power Greener Homes and Automobiles

by Kate Brand, for Skulematters, Spring 2008

<http://www.research.utoronto.ca/stories/greener-electricity/>

Professor Steven Thorpe can create greener electricity. His research group, which spans from design to development, aims to provide small, economic solutions that could potentially supply clean hydrogen to power homes and vehicles using advances in nanomaterials.

Using hydrogen as a primary source of energy would reduce greenhouse gas emissions, according to the National Hydrogen Association. This is achieved by using renewable energy, such as solar and wind as well as nuclear power to separate hydrogen from water through electrolysis.

"This area requires such a multitude of complementary skill sets that success will only come through collaboration with others," says Professor Thorpe, who works collaboratively with Professors Don Kirk and John Graydon in Chemical Engineering and Applied Chemistry as well as Professor Francis Dawson in the Edward S. Rogers Sr. Department of Electrical and Computer Engineering.

To make Professor Thorpe's research a reality, a hydrogen-fuel firm based in Mississauga called Hydrogenics Corporation, who recently acquired Stuart Energy, purchased the rights to patents held by Professors Thorpe, Kirk and Graydon to develop new materials that reduce the cost of producing hydrogen through electrolysis.

"We are also working with other companies that have needs for novel nanomaterials/amorphous alloys that are also aligned with energy," says Professor Thorpe.

"The hope is that these companies will serve as vehicles for commercialization of these technologies," says Professor Thorpe.

Available Technology Transfer Opportunities:

From The Innovations Group

Recovery of Metal Values from Smelter Slags

Many mine sites, especially in Canada, contain thousands of tons of waste slag. This slag has been generally considered to be worthless in terms of metal content, and also inert so that it can be used, for example, in railway beds. Recent results at the University of Toronto have shown that some slags are neither inert nor valueless, and that valuable metal content can be economically extracted through the use of new techniques. The fact that the slags are in fact not inert, as has been generally assumed, also has profound environmental implications.

Researchers working with **Dr. Vladimiros Papangelakis** and **Dr. Walter Curlook** of the University of Toronto have developed a method for pressure-leaching of metals from waste slags. For many slags, this process can economically recover zinc, nickel, cobalt or copper. At the same time as recovering valuable metals, the new process would remove an environmental hazard from the slag leaching dangerous metals into groundwater as a result of exposure to acidic rainwater. The Innovations Group is looking to partner with a company that is interested in further developing the technology and using it to recover valuable metals from waste slag

Biological Solubilization of Metal Contaminated Sludge

Municipalities dispose of sewage sludge by incineration, land filling and land application. Concerns of unpleasant odours and heavy metal and pathogen contamination make the use of sewage sludge as a low-cost fertilizer or soil conditioner undesirable.

Glynn Henry Professor Emeritus in the Dept. of Civil Engineering has invented a continuous process for the biological solubilization of heavy metals from primary or other metal-laden sludges that utilizes indigenous sulphur oxidizing bacteria and elemental sulphur as the energy source, prevents nitrite formation, reduces pathogens, and minimizes the residual sulphur remaining in the processed biosolids.

The continuous Biosol process uses sulphur oxidizing bacteria indigenous to sewage sludge in an aerobic biological reactor to solubilize any metals present, reduce pathogens, and produce biosolids having minimal residual sulphur. The solubilized metal liquid fraction can be subsequently processed to recover valuable metals by precipitation or other recovery methods. The method allows for the conversion of sewage sludges to biosolids for beneficial land application or for producing compost.

The continuous or intermittent sludge feed process minimizes the sulphur required, eliminates nitrite formation, has effective gravity thickening, and accepts primary activated or digested sludges. The process removes heavy metals, minimizes pathogens and odour, and leaves chosen levels of residual sulphur in the treated biosolids. Competing processes do not minimize sulphur content, which could cause soil acidification. The Innovations Group University of Toronto is seeking partners interested in commercializing this technology.

High Organic Group Content Periodic Mesoporous Organosilicas as Films

All structures immersed in water suffer from fouling by algae and barnacles that settle and colonize those structures. Aquaculture cages, boat hulls, water intake and sewage pipes are all affected by these organisms. In the aquaculture industry, for example, fouling of cages and nets leads to an estimated 20% increase in production costs. Commercial fleets plying the seas of the world are penalized with an extra fuel consumption as high as 40% and corresponding increases in maintenance costs. Existing antifouling coatings are based on tin and copper biocides that are toxic to marine organisms and to maintenance operators. New regulatory policies have recently banned tributyltin paints and will require a reduction of copper content in hull coatings in the near future. New coating materials are required that combine durability in use, lack of toxicity, low VOC emissions and have fouling release properties or directly inhibit the settlement of marine organisms. Attempts to meet some of the preferred characteristics have been made by employing elastomers and silicon polymers based paints. These products exhibit low adhesion to marine organisms under hydrodynamic conditions and are non-toxic. However, bio-settlement still occurs and they are not strong enough for continuous use in marine environments.

U of T Researchers are working on developing fouling inhibitors based on nanostructured diblock copolymers that meet all the requirements for use in aquatic environments, and a provisional US application has been filed. The new coatings are especially useful for the protection of aquaculture cages and ship hulls due to their foul-release properties and low adhesion to marine organisms.

Marine paint formulators, twine or net manufacturers and aquaculture operators are being sought to participate in the further development of the technology, its application and field testing.

Light Harvesting Coatings for Organic Solar Cells

Interest in organic solar cells is growing due to the renewed thrust in alternative energy sources and new developments in technology. Organic solar cells are intrinsically low solar conversion efficiency devices because of their limited spectral bandwidth and are prone to photodegradation by continuous UV exposure. On the other hand, they are very cheap to manufacture in large areas by means of well established fabrication methods. Therefore, when thinking about the use of organic solar cells it is more relevant to consider the conversion efficiency-cost relationship than their absolute efficiency. Adding a component to the solar cell to enhance its spectral response and to protect the active layer from UV damage would go a long distance toward their commercial adoption.

Greg Scholes and his research team are developing advanced polymer coatings that enhance the efficiency of organic photovoltaic solar cells by broadening the spectrum of light the cell absorbs and converts to electricity. The strategy

consists of a light-harvesting arrangement with an antenna layer which absorbs light at a wavelength outside the spectral range of the active layer (typically in the UV) and transfers the energy to it. The antenna has the added benefit of protecting the active layer against UV damage which limits the usable life of these devices.

This invention extends the capability of organic solar cells to collect light in a wider wavelength range, increasing their conversion efficiency and improving performance especially under reduced interior lighting or low angle incident light conditions such as in northern latitudes. At the same time, photo-degradation of the organic active layer is reduced since its exposure to harmful UV is minimized. Canada and US patent applications have been filed.

Light harvesting antenna arrangements will find applications to organic solar cells where a reasonable efficiency/cost relationship is required, especially in large area installations. Both civilian and military markets are candidates for adoption of the technology since it can be used advantageously in portable and low light applications such as in northern latitudes and indoors. The University of Toronto seeks licensees with specific applications of the technology.

TEACHING IN ENERGY AND THE ENVIRONMENT

The University of Toronto continues to be the leading institution in Canada for graduate students pursuing research in fields related to Energy and the Environment. These students are enrolled in nearly 30 traditional disciplinary, as well as collaborative and multidisciplinary programs across campus. In the last 5 years, our Energy and the Environment faculty have supervised the completion of over 470 Doctoral degrees and over 770 Master's degrees.

Graduate Programs with Relevance to Energy and the Environment:

Aerospace Science and Engineering	Mechanical Engineering
Architecture	Physics
Astronomy and Astrophysics	Planning
Chemical Engineering and Applied Chemistry	Political Science
Chemistry	Public Policy
Civil Engineering	Urban Design
Economics	
Electrical and Computer Engineering	<u>Multidisciplinary Programs:</u>
Environmental Engineering	Dynamics of Global Change
Environmental Science (M.Env.Sc.)	Environment & Health
Forest Conservation	Environmental Engineering
Forestry	Environmental Studies
Geography	Geology & Physics
Geology	Global Health
Landscape Architecture	Institute for Environmental Studies
Materials Science Engineering	International Relations

Our faculty are also widely recognized for their dedication and innovation in teaching in these important and relevant fields. Faculty who have been honoured recently for their role as teachers are listed below.

Teaching Awards

- **Robert Andrews, Mark Kortschot** and colleagues– won the Allan Blizzard Award, Society for Teaching & Learning, 2007 for their collaborative teaching and implementation of a new first-year engineering course "Engineering Strategies and Practice"
- **Murray Grabinsky** - Engineering Society Teaching Award
- **Bryan Karney** - Faculty Teaching Award, University of Toronto - Engineering Alumni Association, 2002
- **Mark Kortschot** - Alan Blizzard Award, Society for Teaching and Learning in Higher Education (STLHE), 2007
- **Scott Mabury** - Leadership in Faculty Teaching (LIFT), Ministry of Training, Colleges and Universities, 2007
- **Andrew Miall** - Grover E. Murray Distinguished Educator Award of the American Association of Petroleum Geologists,
- **Baher Abdulhai, Hani Naguib** - Early Career Teaching Award, University of Toronto

Curricula across campus are constantly being updated to reflect the issues that matter most to society. Energy and The Environment are excellent examples of how U of T's approach to teaching and learning evolves with the issues. For example, in 2007, the Faculty of Applied Science and Engineering created a new [Division of Environmental Engineering and Energy Systems](#), with dedicated undergraduate and graduate programs in these areas. In the 2009-10 Academic Year, UT Mississauga is introducing two new undergraduate minors, Environmental Management and Environmental Science, allowing students focused in discipline-based studies to complement and broaden their education with minors in environmental areas.

In addition to undergraduate programs in all relevant academic departments, the following specialist undergraduate degrees in areas related to Energy and the Environment are offered:

Earth Systems: Physics and the Environment (BSc)
Environment & Human Society (BA)
Environment and Health (BSc)
Environment and Science (BSc)
Environment and Society (BA)
Environment and Toxicology (BSc)
Environmental Analysis & Monitoring (BSc)
Environmental Biology (BSc)
Environmental Chemistry (BSc)
Environmental Chemistry (BSc)
Environmental Economics (BA)
Environmental Ethics (B.A.)
Environmental Geoscience
Environmental Geosciences (BSc)
Environmental Geosciences (BSc) (Specialist and Major)

Environmental Management (BA)
Environmental Physics (BSc. UTSC)
Environmental Policy and Practice (BA)
Environmental Science (BSc) (Major or Minor)
Environmental Science and Technology (BSc) (Joint Specialist)
Forest Biomaterials Science (BSc)
Forest Conservation (BA)
Geographic Information Systems (BA)
Life and Environmental Physics (BSc)
Minor: Environmental Anthropology (BA)
Natural Sciences (BSc) (Specialist)
Past Environments (BSc)
Physical and Environmental Geography (BSc)
Environmental Engineering and Energy Systems (BASc) (Minor)

APPENDIX A: RESEARCHERS IN RELATED GOVERNMENT PRIORITY AREAS

Federal S&T Strategy

Environmental science and technologies:

ABBATT, JONATHAN	DAVIS, ANTHONY	JHA, PRABHAT
ABDULHAI, BAHER	DAWSON, FRANCIS	JIA, CHARLES
ABELSOHN, ALAN	DELL, SHARON	JOHNSON, TIM
ABRAMS, PETER	DESLOGES, JOSEPH	JONES, DYLAN
ACOSTA, EDGAR	DESVEAUX, DARRELL	KALABIS, GRAZYNA
ADAMS, BARRY	DIAMOND, MIRIAM	KARNEY, BRYAN
AIRD, PAUL	DIOSADY, LEVENTE	KAUFMAN, PAMELA
ANDREWS, ROBERT	DONALDSON, JAMES	KENNEDY, CHRISTOPHER
ANDREWS, SUSAN	DONG, VY MARIA	KENNEY, ANDY
ARHONDITSIS, GEORGE	ECKENWALDER, JAMES	KOTANEN, PETER
BAINES, CORNELIA	EL-DIRABY, TAMER	KREIGER, NANCY
BARRETT, SPENCER	ENGSTROM, MARK	KRIGSTIN, SALLY
BASILIKO, NATHAN	EVANS, GREGORY	KRONZUCKER, HERBERT
BASS, BRAD	EYLES, NICHOLAS	KUHN, EVA
BELANGER, PIERRE	FARNOOD, RAMIN	KUSHNER, PAUL
BERLETH, THOMAS	FERENCE, ROBERTA	LEHMAN, SHAWN
BLAKE, TERRY	FERRIS, GRANT	LESTER, NIGEL
BOLLMANN, JORG	FINKELSTEIN, MURRAY	LIGHTFOOT, NANCY
BONDY, SUSAN	FINKELSTEIN, SARAH	LOVEJOY, NATE
BOONSTRA, RUDY	FORTIN, MARIE-JOSEE	MABURY, SCOTT
BOURNE, LARRY	FRANK, JOHN	MACDONALD, DOUGLAS
BOYES, DONALD M.	FULTHORPE, ROBERTA	MACLAREN, VIRGINIA
BOZEK, PAUL	GAUVREAU, PAUL	MACLEAN, HEATHER
BRANFIREUN, BRIAN	GESKINK LAW, DIONNE	MANDELIS, ANDREAS
BROOK, JEFFREY	GONG, SUNLING	MANDRAK, NICK
BROOKS, DAN	GOUGH, WILLIAM	MANNE, LISA
BROWN, PATRICK	GRABINSKY, MURRAY	MARRETT, LORAIN
BRYAN, RORKE	GREEN, LOIS	MCKAGUE, BRUCE
BULIUNG, RON	GREENWOOD, BRIAN	MCKEOWN, DAVID
BUNCE, MICHAEL	GROSS, MART	MCKEOWN-EYSSEN, GAIL
BURNHAM, CAROLE	GROTH, CLINTON	MCLAUGHLIN, JOHN ROSS
BURTON, IAN E	GULDER, OMER	MCQUIGGE, MURRAY
BYER, PHILIP	HACKWORTH, JASON	MEGQUID, SHAKER
CAMPBELL, MALCOLM	HALFAR, JOCHEN	MELO, STELLA
CAMPBELL, MONICA	HARPER, PATRICIA	MILLER, ERIC J.
CARLETON, TERENCE	HARVEY, DANNY	MILLS, JAMES
CASPERSEN, JOHN	HELLER, JAMES	MINNS, CHARLES
CHEN, JING	HENDERSON, BRYAN	MIRZA, MONIRUL
CHIOTTI, QUENTIN	HENDRIKS, FRED	MITCHELL, CARL
CHIPMAN, MARY	HOFMANN, RONALD	MITROVICA, JERRY
CHOI, BERNARD	HOLNESS, D. LINN	MOHAJER, ALEX
COLE, DONALD	HOOTON, DOUGLAS	MUC, ANTHONY
COLEMAN, JOHN	HORGEN, PAUL	MULDOON, PAUL
COLLINS, NICK	HOSEIN, ROLAND	MUNRO, SCOTT
CONWAY, TENLEY	HOSTOVSKY, CHUCK	MURCK, BARBARA
COOPER, PAUL	HOWARD, KENNETH	MURPHY, JENNIFER
COREY, PAUL	HURLEY, ADÈLE	MURPHY, ROBERT
CORMACK, DON	JAAKSON, REINER	MYLES, TIMOTHY
COWLING, SHARON	JACKSON, DONALD	NAGUIB, HANI
CRUDEN, ALEXANDER	JAMIESON, GREG	OKEY, ALLAN
CYR, HELEN	JEFFERIES, ROBERT	PARK, CHUL
DARLING, CHRIS	JERVIS, ROBERT	PELTIER, RICHARD

POLAND, BLAKE
POLAVARAPU, SAROJA
PRESSNAIL, K. D.
PRICE, ANTHONY
PROVART, NICHOLAS
PURDHAM, JAMES
PYSKLYWEC, RUSS
REEVE, DOUGLAS
REID, NANCY
RIDDICK, DAVID
RIDGWAY, MARK
RISING, JIM
ROMANS, PATRICIA
ROY, MARIE
SAGE, ROWAN
SAGE, TAMMY
SAIN, MOHINI
SALBACH, STEFAN
SASS-KORTSAK, ANDREA
SAVAN, BETH
SCOTT, JAMES

SCOTT, JEREMY
SHALABY, AMER
SHEAR, HARVEY
SHEPHERD, TED
SHERWOOD LOLLAR, BARBARA
SHUTER, BRIAN
SIMPSON, ANDRE
SIMPSON, MYRNA
SMITH, C. TATTERSALL
SMITH, LESBIA
SOMERS, KEITH
SPRULES, GARY
STEEVES, CRAIG
STEPHAN, DOUGLAS
STRONG, KIMBERLY
TARLO, SUSAN
TELFORD, PETER
THOMPSON, PAUL
THOMSON, JAMES
TRASS, OLEV
UPSHUR, ROSS

URCH, R. BRUCE
VANDERBURG, BILL
WALKER, KALEY
WANIA, FRANK
WEBSTER, PETER
WEIS, ARTHUR
WELLS, MATHEW
WELLS, PETER G.
WHITE, RODNEY
WILLIAMS, DUDLEY
WILLIAMS, RON E
WINNIK, MITCHELL
WORTMANN, ULRICH
YAN, NING
YOSHIOKA, KEIKO
YOUNG, R. PAUL
ZEE, ROBERT
ZIMMERMAN, ANN
ZINGG, DAVID

Natural Resources and energy:

ABRAMS, PETER	HURLEY, ADÈLE	PEROVIC, DOUGLAS
ALLEN, D. GRANT	IRAVANI, REZA	PRICE, ANTHONY
AMARA, FOUED BEN	JACKSON, DONALD	RIDGWAY, MARK
AMON, CRISTINA	JOHN, SAJEEV	ROGERS, J.S.
ANDREWS, ROBERT	KANT, SHASHI	ROY, D.N.
ANDREWS, SUSAN	KARNEY, BRYAN	SAIN, MOHINI
ARHONDITSIS, GEORGE	KENNEY, ANDY	SALBACH, STEFAN
ASHGRIZ, NASSER	KESIK, TED	SARGENT, TED
BALSILLIE, DAVID	KESLER, OLIVERA	SAVAN, BETH
BARATI, MANSOOR	KHERANI, NAZIR	SAVILLE, BRADLEY
BAZYLAK, AIMY	KIRK, DONALD	SCHOLES, GREG
BENDER, TIMOTHY	KORTSCHOT, MARK	SECO, LUIS
BERLETH, THOMAS	KRIGSTIN, SALLY	SHEIKH, SHAMIM
BLAKE, TERRY	LAAKSONEN-CRAIG, SUSANNA	SHU, LILY
BOOCOCK, DAVID	LAVOIE, PHILIPPE	SHUTER, BRIAN J
BOONSTRA, RUDY	LEHN, PETER	SINCLAIR, ANTHONY
BOYES, DONALD M.	LESTER, NIGEL	SKOGSTAD, GRACE
BRANFIREUN, BRIAN	LIAN, KERYN	SLEEP, BRENT
CAMPBELL, MALCOLM	LOVEJOY, NATE	SMITH, LESBIA
CARLETON, TERENCE	LU, ZHENG HONG	SMITH, C. TATTERSALL
CASPERSEN, JOHN	MABURY, SCOTT	SMITH, SANDY
CHANDRA, SANJEEV	MACLEAN, HEATHER	SOMERS, KEITH
CHEH, CHRISTOPHER	MAHADEVAN, RADHAKRISHNAN	STANGEBY, PETER
CHEN, JING	MALCOLM, JAY	SULLIVAN, PIERRE
COOPER, PAUL	MANDELIS, ANDREAS	TATE, ZEB
CORMACK, DON	MANDRAK, NICK	TELFORD, PETER
COYLE, THOMAS	MARTELL, DAVID	THOMAS, SEAN
DAWSON, FRANCIS	MARTINS, JOAQUIM	THOMSON, MURRAY
DIOSADY, LEVENTE	MASTER, EMMA	THORPE, STEVEN
EDWARDS, ELIZABETH	MCGREGOR, DEBORAH	TIMMER, VICTOR
EDWARDS, R. NIGEL	MILKEREIT, BERND	TRAN, HONGHI
EKMEKCI, ALIS	MILLER, ERIC J.	TRASS, OLEV
ERB, UWE	MIMS, CHARLES	TURNER, MATTHEW
FARNOOD, RAMIN	MINNS, CHARLES	URCH, R. BRUCE
FERRIS, GRANT	MIRZA, MONIRUL	UTIGARD, TORSTEIN
FOULKES, FRANK	MITCHELL, CARL	WALLACE, JAMES
FRIEDMANN, HARRIET	MOHAJER, ALEX	WARD, CHARLES
GOH, CYNTHIA	MULDOON, PAUL	WINNIK, MITCHELL
GREENWOOD, BRIAN	NAGUIB, HANI	YAN, NING
GROTH, CLINTON	NEWMAN, ROGER	YATCHEW, ADONIS
GULDER, OMER	NOGAMI, JUN	ZIMMERMAN, ANN
HAASZ, ANTHONY	O'BRIEN, PETER JOHN	ZIMMERMAN, BARBARA
HENDERSON, BRYAN	OZIN, GEOFFREY	ZUKOTYNSKI, STEFAN
HORGEN, PAUL	PACKER, JEFFREY	
HOWARD, KENNETH	PAPANGELAKIS, VLADIMIRO	

Ontario's Innovation Agenda**Bio-economy and clean technologies:**

ABDULHAI, BAHER
ACOSTA, EDGAR
ALLEN, D. GRANT
AMARA, FOUED BEN
AMON, CRISTINA
ASHGRIZ, NASSER
BALSILLIE, DAVID
BARATI, MANSOOR
BENDER, TIMOTHY
BLAKE, TERRY
BOOCOCK, DAVID
BYER, PHILIP
CASPERSEN, JOHN
CHANDRA, SANJEEV
CHIOTTI, QUENTIN
COOPER, PAUL
COYLE, THOMAS
DIOSADY, LEVENTE
DONG, VY MARIA
EDWARDS, ELIZABETH
EDWARDS, R. NIGEL
EKMEKCI, ALIS
ERB, UWE
FORTIN, MARIE-JOSEE
FRIEDMANN, HARRIET
FULTHORPE, ROBERTA
GOH, CYNTHIA
GRABINSKY, MURRAY
GROTH, CLINTON
GULDER, OMER
HAASZ, ANTHONY
HOSTOVSKY, CHUCK
HURLEY, ADÈLE
IRAVANI, REZA
JIA, CHARLES
JOHN, SAJEEV

KANT, SHASHI
KENNEDY, CHRISTOPHER
KESIK, TED
KHERANI, NAZIR
KIRK, DONALD
KORTSCHOT, MARK
KRIGSTIN, SALLY
KUHN, EVA
LAAKSONEN-CRAIG, SUSANNA
LAVOIE, PHILIPPE
LEHN, PETER
LU, ZHENG HONG
MACLAREN, VIRGINIA
MACLEAN, HEATHER
MAHADEVAN, RADHAKRISHNAN
MALCOLM, JAY
MARTELL, DAVID
MARTINS, JOAQUIM
MASTER, EMMA
MCGREGOR, DEBORAH
MCKAGUE, BRUCE
MEGUID, SHAKER
MILLER, ERIC J.
MIMS, CHARLES
MYLES, TIMOTHY
NOGAMI, JUN
O'BRIEN, PETER JOHN
OZIN, GEOFFREY
PACKER, JEFFREY
PAPANGELAKIS, VLADIMIRO
PARK, CHUL
PEROVIC, DOUGLAS
PROVART, NICHOLAS
PURDHAM, JAMES
ROY, D.N.
SAGE, TAMMY

SAIN, MOHINI
SARGENT, TED
SAVAN, BETH
SAVILLE, BRADLEY
SCHOLES, GREG
SHALABY, AMER
SHEIKH, SHAMIM
SHU, LILY
SKOGSTAD, GRACE
SLEEP, BRENT
SMITH, C. TATTERSALL
SMITH, SANDY
STANGEBY, PETER
STEPHAN, DOUGLAS
SULLIVAN, PIERRE
TATE, ZEB
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THOMAS, SEAN
THOMSON, JAMES
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WALLACE, JAMES
WARD, CHARLES
YAN, NING
YOUNG, R. PAUL
ZEE, ROBERT
ZIMMERMAN, BARBARA
ZINGG, DAVID
ZUKOTYNSKI, STEFAN

Social Sciences and Humanities Related to Energy and the Environment

AMBACHTSHEER, JANE	HURLEY, ADÈLE	PRICE, ANTHONY
BAMFORD, SANDRA	JOHNSTON, JOSEE	PRICE, MATTHEW
BELANGER, PIERRE	KENNEY, ANDY	PRUDHAM, SCOTT
BERLETH, THOMAS	KINGSTON, PAUL	REEVE, DOUGLAS
BERNSTEIN, STEVEN	KIRTON, JOHN	RELPH, TED
BOLAND, ALANA	KNOWLES, GARY	RICHARDSON, GORDON
BOWMAN, KERRY	KRASS, DMITRY	ROBINSON, VINCENT
BOYES, DONALD	LESTER, NIGEL	SANDBROOK, RICHARD
BRUNNEE, JUTTA	LI, TANIA	SAVAN, BETH
CAMPBELL, MALCOLM	LI, YUE	SCHARPER, STEPHEN
CARLETON, TERENCE	MACDONALD, DOUGLAS	SECO, LUIS
CHEN, JING	MACDOWELL, LAUREL	SIECIECHOWICZ, KRYSZYNA
CLARKSON, STEPHEN	MACLAREN, VIRGINIA	SKOGSTAD, GRACE
CONWAY, TENLEY	MACLEAN, HEATHER	STABILE, MARK
CORMACK, DON	MANDELIS, ANDREAS	STEFANOVIC, INGRID
CRAWFORD, GARY	MCGEACHIE, SUE	STREN, RICHARD
CUNNINGHAM, FRANK	MCGREGOR, DEBORAH	SUMNER, WAYNE
CUNNINGHAM, HILARY	METCALFE, MURRAY	TELFORD, PETER
DANIERE, AMRITA	MIALL, ANDREW	THOMPSON, PAUL
DESROCHERS, PIERRE	MILLER, ERIC J.	THOMSON, JAMES
DEWEES, DONALD	MINNS, CHARLES	TIAN, HUILAN
DIFRANCESCO, RICHARD	MIRZA, MONIRUL	TURNER, MATTHEW
DOLDERMAN, DAN	MOHAJER, ALEX	UNGAR, SHELLY
DOOLEY, JAMES	MULDOON, PAUL	VAN BIESEBROECK, JOHANNES
DUFF, DAVID	MUNN, TED	WAKEFIELD, SARAH
EICHLER, MARGRIT	MUNRO, SCOTT	WHITE, RODNEY
FARNOOD, RAMIN	MURCK, BARBARA	WHITE, GRAHAM
FRIEDMANN, HARRIET	MURDOCK, JENNIFER	WHITE, MASON
GREEN, ANDREW	MURPHY, MICHELLE	WHITNEY, JOSEPH
GRIMA, LINO	MUZZIN, LINDA	WINNIK, MITCHELL
GROSS, MART	NAGUIB, HANI	YATCHEW, ADONIS
HANNIGAN, JOHN	O'HARA, DENNIS	ZIMMERMAN, BARBARA
HELLER, JAMES	O'SULLIVAN, EDMUND	
HESS, PAUL	PEDRETTI, ERMINIA	
HOFFMANN, MATTHEW	PENFOLD, STEVE	
HORGEN, PAUL	POND, DAVID	

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