Sustainable Energy

University of Waterloo

THE FULL SPECTRUM OF RESEARCH

Waterloo Institute for Sustainable Energy (WISE)

Dr. David Johnson with his wind turbine research team (bottom)

Dr. Siva Sivoththaman researches photovoltaic technologies (left)

Dr. Bill Epling and graduate student Karishma Irani with a diesel emissions catalyst reactor (right)

- Waterloo Institute for Sustainable Energy is a recognized leader in promoting innovation through research in the development and deployment of advanced sustainable energy systems.
- Energy researchers working as multi-disciplinary teams in the Faculties of Engineering, Science and Environmental Studies are undertaking leading-edge research with utilities, government agencies and private sector partners. This supports emerging energy technologies to enhance the reliability and efficiency of the power system.

INNOVATIVE WATERLOO

"Working with the wind energy group at Waterloo gives us access to some of the best expertise in the country, experts who understand Canadian design issues."

- **Richard Goodman, CEO MerGen Technologies Inc.**

"Having close proximity to the new Centre for Advanced Photovoltaic Devices and Systems was a key factor in our decision to locate on the North Campus (at the University of Waterloo)."

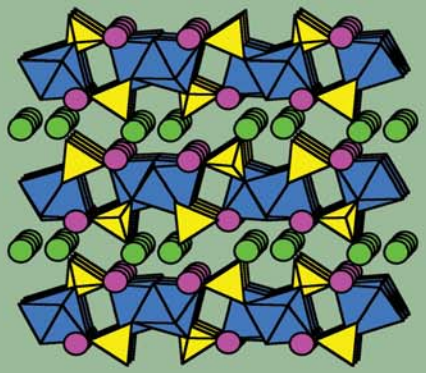
- **Ian MacLellan, CEO, ARISE Technologies**

"From our assessment of North American universities, we identified the University of Waterloo as having one of the top programs in power engineering. The high-quality research being conducted by the Power and Energy Systems Group is well aligned with a subset of ABB's internal power-technology research and development efforts."

- **Dr. Ernst Scholtz, Coordinator for North American University Relations, ABB U.S. Corporate Research Center**

"My goal is to stimulate high-impact, multi-disciplinary research on societal problems of energy use and development of policies and tools for environmental sustainability and economic growth. Alternative energies and better resource management - those will be UW's contribution to a balanced energy equation."

- **Dr. Jatin Nathwani, Ontario Research Chair in Public Policy and Sustainable Energy Management**



The goal of the Waterloo Institute for Sustainable Energy (WISE) is to develop energy systems and policies that enhance social, economic, and environmental performance for long term sustainability. The mission is to conduct original research and provide solutions for timely implementation by business, government and industry. A strong energy sector is essential for a vibrant and competitive economy. WISE is at the forefront of innovative research to generate options for the existing energy production and delivery system, and promote energy efficiency and environmental sustainability.

Waterloo is unique in its research excellence across a broad range of strategic areas critical to enhancing sustainable energy use. We advance solar and wind energy; bioenergy; fuel cells; battery technologies and storage; clean diesel for green auto power trains; greenhouse gas mitigation; integration of distributed generation systems; planning and reliability studies of the power system infrastructure; and policy research to support conservation, energy efficiency and demand management. More than 50 experts from the faculties of Engineering, Environmental Studies and Science are involved in multi-disciplinary studies to advance work in these areas. WISE is proud of the many accomplishments that have established it as a North American leader in sustainable energy research. Among the renowned initiatives are:

- World-class research facilities including the new Centre for Advanced Photovoltaic Devices and Systems (CAPDS), a solar thermal engineering centre, the advanced energy materials laboratory, several fuel cell engineering laboratories, state-of-the-art indoor, large-scale controlled wind turbine testing facilities and an advanced clean diesel engine research laboratory
- A new provincially-funded Ontario Research Chair in Public Policy and Sustainable Energy Management, cross-appointed with the Engineering and Environmental Studies faculties, to serve as a catalyst in bringing together multi-disciplinary research teams to provide practical solutions and to inform policy choices for Ontario
- A major provincial research award to the Faculty of Engineering to improve the safety, cost performance and reliability of the existing power infrastructure working under the UW Chair in Risk and Reliability of Energy Systems - the Chair was established and funded by the NSERC-UNENE Industrial Research Chair program
- Internationally renowned fuel cell and power systems research groups that are among the largest in North America
- Three leading-edge Master's level programs to train highly qualified professionals: Electrical and Computer Engineering offers an on-line MEng in Electric Power Engineering and an MEng program with a departmental certificate in Sustainable Energy; Mechanical and Mechatronics Engineering offers an MEng with a departmental certificate in Green Energy

With this foundation, WISE is positioned to provide innovative solutions to the complex challenges facing the energy sector and leadership in the development of a more sustainable energy future.

◀ Structure of a new material, A2FePO4F, prepared by the Nazar lab that functions as a low cost, high safety electrode in a Li-ion or Na-ion battery (Nature Materials, 2007, 6, 749).

Dr. Jennifer Lynes and student researchers study home energy use monitors and conservation behaviour.

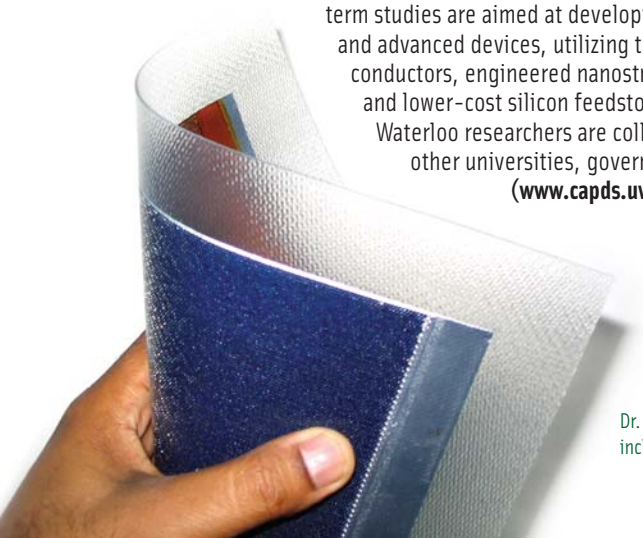
Research chair tackles energy efficiency and reliability options in Ontario

Jatin Nathwani, Chairholder

The Ontario Research Chair in Public Policy and Sustainable Energy Management has been established at the University of Waterloo to look at future options for energy use in the province. Dr. Jatin Nathwani leads a team that is researching ways to lessen impacts on the environment, lower the cost of energy and maintain reliability of supply. "We are focused on bringing the knowledge and expertise of our researchers to get engaged with members of the public, businesses and government. We want to help shape the economic future of energy use and how we manage the complexity of environmental policy issues," Dr. Nathwani said. Energy use is intricately linked to our economic well-being but it also contributes to adverse environmental impacts. "We will work on developing a comprehensive perspective and provide effective guidance to assist policy-makers. Alternative energy sources and better resource management - those will be UW's contribution to a balanced energy equation," he added. As well, the initiative is training a new generation of professionals to facilitate the rapid integration of renewable energy technologies within a diverse mix of energy options. The research includes partnerships with communities, policy-makers and the private sector to facilitate knowledge transfer.

Solar energy for electricity - Research at CAPDS

The University of Waterloo is leading research to advance photovoltaic technology - converting sunlight directly into electricity - with the new Centre for Advanced Photovoltaic Devices and Systems (CAPDS). This world-class research and development facility is dedicated to all aspects of photovoltaic energy conversion. This is "clean, very green, renewable energy that doesn't burn any fuel, feeds into the power grid, reduces fossil-fuel reliance, decentralizes power generation, has no moving parts, almost no wear-and-tear and requires minimal maintenance," said Dr. Siva Sivoththaman, CAPDS Director. The facility brings together researchers in semiconductor materials, microelectronics and electronics from Engineering and Science. They are working to make an impact in terms of affordable technology as photovoltaic energy is one of the most promising renewable energy technologies. Research focus is on reducing costs of the process while longer-term studies are aimed at developing new materials and advanced devices, utilizing thin film semi-conductors, engineered nanostructured materials and lower-cost silicon feedstock technologies. Waterloo researchers are collaborating with other universities, government and industry. **(www.capds.uwaterloo.ca)**



Dr. Sivoththaman's research includes flexible solar cells.

Waterloo professor helps *Reduce the Juice*

Dr. Jennifer Lynes, a Waterloo Environment and Resource Studies professor, assisted high school students encouraging homeowners in Shelburne to save energy. Students from Centre Dufferin District High School's Environment Club arranged to have PowerCost monitors installed in 30 homes. The monitors display real-time household electricity consumption and cost. Dr. Lynes guided the analysis of the results to see if providing households with immediate feedback helps to reduce their overall electricity consumption. Other research interests for Dr. Lynes are social marketing, conservation behaviour, youth engagement and green/social entrepreneurship.

Fuel cell R&D for automobiles

Dr. Xianguo Li, Mechanical and Mechatronics Engineering, is working with leading automobile manufacturers, fuel cell developers and government researchers to develop next generation PEM fuel cell technology as a viable solution for clean vehicles. Dr. Li's interest and research activities include seeking innovative fuel cell designs, improving functionality of fuel cell component materials and adopting novel methods for stack and system optimization. With the aid of predictive and simulation tools, his group has met with great success in modelling transport phenomena and electrochemical reactions at the nano-, micro-, and mesoscopic levels which are critical for optimal performance and durability. Additionally, he is involved in researching thermal and water management, the poisoning effect and chemical kinetics of contaminants in reactant gas streams, and life cycle assessment to maximize environmental and societal benefits.

Thin film flexible solar cell research in Giga-to-Nano Centre

Dr. Andrei Sazonov, Electrical and Computer Engineering, is the director of the state-of-the-art Giga-to-Nanoelectronics (G2N) Centre. He is currently researching thin film solar cells, examining thin film amorphous silicon, nanocrystalline silicon, silicon-germanium and silicon-carbon alloys, quantum dot/quantum well-based solar cells. The G2N Centre features unique equipment for fabrication of thin film flexible solar cells including a multichamber cluster roll-to-roll deposition system. **(http://ece.uwaterloo.ca/~a-sidic/)**

Power systems engineering

UW is home to Canada's largest power systems engineering research group whose members, Dr. K. Bhattacharya, Dr. C. Canizares, Dr. E. El-Sadaany, Dr. R. El-Shatshat, Dr. S. Jayaram, Dr. M. Kazerani, and Dr. M. Salama, have been recognized internationally for research excellence. The group pursues research in the following key areas: power systems, electricity markets, distribution system engineering, power quality, power electronics, and high voltage transmission engineering. The focus on sustainable energy systems includes development of solutions for a seamless integration of solar, wind, bioenergy, hydrogen and other distributed energy sources into the power grid, considering multiple energy carriers and sources in the context of competitive energy markets. Waterloo's state-of-the-art laboratories and training facilities are at the centre of development activities to incubate innovative products and software applications for electricity systems operators and utilities; the goal is to prevent system disruptions and to enhance system-wide reliability. Conservation and demand management initiatives coupled with research on improvements to power quality are intended to assist businesses maintain competitiveness.

Harnessing the wind leads to green energy future

Waterloo is an important player in the growing demand for Canadian research and development to advance wind turbine design and performance while producing highly skilled personnel in the wind energy field. Dr. David Johnson of the Wind Energy Laboratory, Mechanical and Mechatronics Engineering, is conducting research on critical areas for future wind turbine development. This includes studies of wind turbine aerodynamics involving laser-based measurement of turbine blade performance such as dynamic stall; turbine blade noise measurement and mitigation; undertaking large-scale wind turbine studies in controlled wind conditions; off-grid and remote wind systems; and developing wind resource measurement techniques. The research group has facilities both on and off campus for designing and evaluating turbines and components. Dr. Johnson is the lead UW collaborator in the development of a Wind Energy Research Park in partnership with the Municipality of Kincardine and wind farm operators in the Bruce region. He has developed strong research ties with wind energy researchers at 15 Canadian universities and internationally as well as collaborations with industry.

Hybrid and fuel cell vehicle power systems

A multi-disciplinary team of UW engineering researchers is working on the development of next generation hybrid vehicles. Dr. Mehrdad Kazerani and Dr. Magdy Salama of Electrical and Computer Engineering are bringing green auto technology to the forefront through the development of power conditioning and energy storage devices for hybrid vehicle systems. Power conditioning for fuel cell-based vehicle systems is also a key strength as researchers conduct high efficiency converter design and optimization studies at specialized test station facilities. Dr. Steve Lambert, Design Theme Leader for Auto21, helps direct a project on the potential of using ultracapacitors as energy storage devices for regenerative braking, which features the conversion of a Pacifica to hybrid electric status. Dr. Salama leads the design and development of the power electronics for this vehicle, particularly vector control of the induction motor, the development of an innovative charging system for ultracapacitors, and the development of the energy management system. The project also examines innovative strategies for vehicle stability control that take advantage of opportunities which arise with hybrid electric drives, as well as collaborative design processes for multi-disciplinary projects.

Studies promote conservation

Waterloo researchers are studying ways to promote conservation of electricity as well as working to advance residential energy efficiency. Dr. Ian Rowlands, of the Department of Environment and Resource Studies in the Faculty of Environmental Studies, is leading an Ontario Centre for Energy-supported project on conservation and demand management strategies in partnership with Milton Hydro. The research involves investigations into the attitudes and behaviours of both industrial and residential customers. Included in this is a thorough analysis of how 'feedback mechanisms' - that is, increased information about energy consumption through conventional and electronic means of delivery - can empower people to manage their energy needs more sustainably.

Thermoelectric materials and devices

Dr. Holger Kleinke, Professor of Chemistry and Canada Research Chair in Solid State Chemistry, is investigating new thermoelectric materials with support from the Ontario Centres of Excellence and the automotive industry. Thermoelectrics are able to convert heat into electricity as well as electricity into a temperature gradient, useful for cooling applications. Dr. Kleinke is designing advanced high temperature thermoelectrics that may be used to generate electricity from waste heat occurring in the combustion engines of automobiles. This technology offers enormous potential for fuel economy improvements as the thermoelectric generator installed around the exhaust pipe can supply energy towards automotive accessories. Dr. Richard Culham, professor of Mechanical and Mechatronics Engineering and director of the Microelectronics Heat Transfer Laboratory, in collaboration with an industry partner and the Ontario Centres of Excellence, has initiated a program to identify and evaluate potential breakthrough technologies in electronics cooling and power generation. Through this research, new electronic cooling technologies will be made available to a wide range of industries, including the telecom and networking equipment manufacturers, automotive and opto-electronics packaging.

UW in fuel cell R&D network

The Fuel Cell Research and Innovation Network is a collective effort in the field of fuel cell engineering funded by the Ontario Research Fund. The network is led by the Fuel Cell Research Centre in Kingston and includes 17 professors from eight Ontario universities and more than 12 industrial partners. Fuel cells are the key-enabling technology for the hydrogen economy in that they can be used to both power cars as well as produce electricity for homes. Dr. Michael Fowler, Chemical Engineering, is working with Hydrogenics Corporation in the study of membrane electrode assessable durability for fuel cells. In addition, with Dr. Claudio Canizares, he is involved in a project with Bruce Power to study the advancement of the hydrogen economy that holds the promise of addressing energy security, air quality and climate change issues within Ontario.

Fuel cell

Dr. Linda Nazar and student researcher investigate novel materials for energy storage.

Novel energy storage devices

A critical aspect of any system for sustainable energy relies on storage devices. These harness the peak energy from solar or wind generation and regenerative braking in hybrid electric vehicles or fuel cell powered vehicles to reduce emissions. Dr. Linda Nazar, Chemistry, is researching the development of new materials for energy storage, conversion and delivery. She focuses on lithium-ion batteries, fuel cells and nanostructured materials. Holder of the Canada Research Chair in Solid State Materials, Dr. Nazar's research explores the synthesis and properties of new solid state materials with particular attention to enhancing properties of the mixed ion/electron conductors that comprise energy storage devices.

Technology research aimed at cutting power plant pollutants

Dr. Eric Croiset and Dr. Peter Douglas, both of Chemical Engineering, are heading studies aimed at reducing pollution emitted by power plants. Coal-fired power plants are major emitters of carbon dioxide, the leading greenhouse gas responsible for global warming. They are researching ways of developing economically viable technologies to capture carbon dioxide from the flue gas in large-scale emitters. The research is in collaboration with the CANMET Energy Technology Centre, Canadian utility companies and the International Energy Agency Greenhouse Gas Research and Development Program.

New technologies for diesel engines

Dr. Bill Epling, Chemical Engineering, is exploring novel solutions to the problem of vehicle-based air pollution by developing new devices to reduce tailpipe emissions of nitrogen oxides (NOx) and soot from diesel engines. His research focuses on advanced catalysts for such aftertreatment control technologies. The NOX control technology also has potential for use in lean-burn gasoline engines resulting in significant fuel economy benefits. Dr. Epling's team develops and uses new techniques to understand these systems, including IR thermography and spatially resolved pilot- and micro-reactors, the first of their kind in Canada. The research will improve air quality and assist the automotive industry in meeting increasingly stringent vehicle emission regulations.

Biogas an alternative energy source

Dr. Wayne Parker, Civil and Environmental Engineering, and Dr. Ray Legge, Chemical Engineering are conducting research to enhance the application of anaerobic digestion of farm, agricultural and municipal waste to produce biogas for heat and electricity generation. Anaerobic digestion and biogas products offer several advantages in terms of use of a renewable resource and providing a sustainable energy carrier. Anaerobic digestion promotes pathogen reduction, increased nutrient recovery and carbon return to the soil. Biogas combustion reduces methane emissions that would have otherwise occurred resulting in a net reduction in greenhouse gas emissions. This research provides a basis for the development of advanced biogas systems that are effective and economically viable in an Ontario context with significant energy generation, ecological and environmental benefits.

Safer, reliable power systems

Engineering researchers in energy systems management are working to develop safer, less expensive strategies for improving the utilization of the existing power system. A project team led by Dr. Mahesh Pandey, Civil and Environmental Engineering, is developing innovative analysis and decision-making tools to guide engineers and policy-makers in cost-effective management of an aging infrastructure. This will help in deciding how to extend the life of the existing power system and prioritize investment decisions. The Ontario government awarded $1.4 million to the Faculty of Engineering to help manage the risks of the power infrastructure. Hydroelectric dams, generation plants and transmission lines are showing their age, raising concerns of blackouts, safety and pollution along with costly repairs or replacement. As well, Dr. Pandey holds the NSERC/UNENE Industrial Research Chair in Risk-Based Life Cycle Management of Engineering Systems. This initiative investigates the modernization of Canada's nuclear power plants, their reliability and life spans.

UW at forefront of solar thermal

Dr. Michael Collins, Mechanical and Mechatronics Engineering, is involved in research to develop innovative solar collectors. PV/thermal solar systems combine photovoltaic technologies and solar thermal technologies into one system with both electricity and thermal energy output. The typical systems are solar collectors with photovoltaic systems integrated in the collector surface or photovoltaic panels used directly as solar air collectors. Through combined production of electricity and heat, the overall efficiency can potentially be higher for a specific collector area than the efficiency of traditional "side-by-side" photovoltaic and solar thermal systems. The systems are typically integrated in the built environment. Current efforts are aimed at the design of building integrated air heating systems and the integration of solar electric and solar thermal aspects from the outset of the design process.

RESEARCH EXPERTISE

FACULTY MEMBER	DEPARTMENT	AREA OF EXPERTISE
RENEWABLE ENERGY SOURCES		
Michael Collins	Mechanical & Mechatronics Engineering	Active, passive solar-thermal applications; energy efficiency in buildings
Ehab El-Saadany	Electrical & Computer Engineering	Distributed power and generation
Roydon Fraser	Mechanical & Mechatronics Engineering	Solar radiation; fuel cell vehicle development
Terry Hollands	Mechanical & Mechatronics Engineering	Solar energy conversion; insulation materials; convection
David Johnson	Mechanical & Mechatronics Engineering	Wind turbine aerodynamics and design; turbine blade noise
Raymond Legge	Chemical Engineering	Green bioprocesses; biogas reactor engineering
Fue-Sang Lien	Mechanical & Mechatronics Engineering	Pollution modelling; wind energy
Linda Nazar	Chemistry	Materials for photovoltaics
Flora Ng	Chemical Engineering	Biodiesel
Wayne Parker	Civil & Environmental Engineering	Anaerobic digester optimization
Andrei Sazonov	Electrical & Computer Engineering	Thin film silicon solar cells
Siva Sivoththaman	Electrical & Computer Engineering	Solar energy; photovoltaic devices and systems; materials for photovoltaics
STORAGE AND TRANSPORT		
Chih-Hsiung Chou	Chemical Engineering	Biological production of hydrogen
Stephen Corbin	Mechanical & Mechatronics Engineering	Materials for solid oxide fuel cells
Eric Croiset	Chemical Engineering	Hydrogen production; solid oxide fuel cells
Rick Culham	Mechanical & Mechatronics Engineering	Thermoelectric devices
Peter Douglas	Chemical Engineering	Greenhouse gas mitigation; large-scale optimization
Bill Epling	Chemical Engineering	Emissions reduction; gas purification and hydrogen production
Michael Fowler	Chemical Engineering	Reliability of PEM fuel cells; conductive polymers; hydrogen distribution
Roydon Fraser	Mechanical & Mechatronics Engineering	Solar radiation; fuel cell vehicle development
Robert Hudgins	Chemical Engineering	Hydrogen production
Shesha Jayaram	Electrical & Computer Engineering	High-voltage and insulation engineering
Holger Kleinke	Chemistry	Materials chemistry; thermoelectric solid state energy conversion
Mehrdad Kazerani	Electrical & Computer Engineering	Power conditioning and energy storage
Steve Lambert	Mechanical & Mechatronics Engineering	Hybrid electric vehicles; Sustainable Energy Education Project
Xianguo Li	Mechanical & Mechatronics Engineering	Fuel cells; wind energy; energy systems
Linda Nazar	Chemistry	Li-ion batteries, energy storage materials, hydrogen storage
Mark Pritzker	Chemical Engineering	Fuel cell modelling; water electrolysis
Metin Renksizbulut	Mechanical & Mechatronics Engineering	Thermal engineering on combustion-related phenomena
Peter Silveston	Chemical Engineering	Hydrogen production
Leonardo Simon	Chemical Engineering	Fuel cell materials; polymers
Robert Varin	Mechanical & Mechatronics Engineering	Hydrogen storage; green batteries; fuel cells
Zbig Wronski	Mechanical & Mechatronics Engineering	Hydrogen storage; green batteries; fuel cells
CONVERSION TECHNOLOGIES		
Kankar Bhattacharya	Electrical & Computer Engineering	Power systems; electricity markets
Claudio Canizares	Electrical & Computer Engineering	Power system and integrated energy system analysis, optimization and operation
Stephen Corbin	Mechanical & Mechatronics Engineering	Materials for solid oxide fuel cells
Eric Croiset	Chemical Engineering	Hydrogen production; solid oxide fuel cells
Peter Douglas	Chemical Engineering	Greenhouse gas mitigation; large-scale optimization
Ramadan El-Shatshat	Electrical & Computer Engineering	Power systems; power conversions
Michael Fowler	Chemical Engineering	Reliability of PEM fuel cells; conductive polymers; hydrogen distribution
Roydon Fraser	Mechanical & Mechatronics Engineering	Solar radiation; fuel cell vehicle development
Mehrdad Kazerani	Electrical & Computer Engineering	Power conditioning and energy storage
Xianguo Li	Mechanical & Mechatronics Engineering	Fuel cells; wind energy; energy systems
Mark Pritzker	Chemical Engineering	Fuel cell modelling; water electrolysis
Magdy Salama	Electrical & Computer Engineering	Power quality; distribution systems
Siva Sivoththaman	Electrical & Computer Engineering	Solar energy; photovoltaic devices and systems; materials for photovoltaics

Other research projects:

- *Dr. David Fuller, Management Sciences, studies energy markets and policies with large-scale models, with a particular emphasis on electricity markets. He uses the models to assess alternative electricity market designs, market penetration of new technologies, and limits or taxes on emissions of pollutants.*

- *Drs. Eric Croiset, Robert Hudgins and Peter Silveston, Chemical Engineering, research catalytic cracking of methane and reforming of ethanol for producing hydrogen. Within a renewable energy future, hydrogen is considered a clean and efficient energy carrier and fuel for transportation applications.*

- *Drs. Robert Varin and Zbig Wronski, Mechanical Engineering, conduct nanotechnology research for climate change and hydrogen energy. Studies are concentrated on nanomaterials for hydrogen storage and for hydride green batteries and fuel cells.*

- *Drs. Terri Meyer Boake, Geoffrey Thün, John Straube, and Kathy Velikov, of the School of Architecture, work on energy efficient building design, including incorporation of solar technology into sustainable building prototypes, as well as sustainable urban design and planning strategies.*

- *Youth outreach is critical in accelerating knowledge transfer and uptake of energy conservation and demand management practices and use of renewable energy technologies. Dr. Christine Moresoli, Chemical Engineering, is promoting renewable energy and energy conservation in the curriculum of young people through her affiliation with Sherbrooke NSERC CRYSTAL (Centre for Research in Youth Science Teaching and Learning) and as VP Program Coordinator of the GoEngGirl program at the University of Waterloo.*

RESEARCH EXPERTISE

FACULTY MEMBER	DEPARTMENT	AREA OF EXPERTISE
EMISSION MANAGEMENT		
Eric Croiset	Chemical Engineering	Carbon dioxide abatement; solid oxide fuel cells
Cécile Devaud	Mechanical & Mechatronics Engineering	Computational modelling; turbulent combustion; emissions
Thomas Duever	Chemical Engineering	Chemical and environmental engineering
Peter Douglas	Chemical Engineering	Greenhouse gas mitigation; large-scale optimization
Maurice Dusseault	Earth Sciences	Carbon dioxide sequestration
Ali Elkamel	Chemical Engineering	Carbon dioxide; air-pollution control; large-scale optimization
Bill Epling	Chemical Engineering	Emissions reduction; gas purification; hydrogen production
Xianshe Feng	Chemical Engineering	Membranes; greenhouse gas emission control
David Fuller	Management Sciences	Energy economics and policies; large-scale optimization
Fue-Sang Lien	Mechanical & Mechatronics Engineering	Pollution modelling; wind energy
Flora Ng	Chemical Engineering	Catalysis; selective sorbents
Garry Rempel	Chemical Engineering	Catalysis; polymer science; environmental and pollution control
Leo Rothenburg	Civil & Environmental Engineering	Carbon dioxide sequestration in salt caverns
POWER SYSTEM OPTIMIZATION AND MANAGEMENT		
Miguel Anjos	Management Sciences	Large-scale optimization; electricity markets
Kankar Bhattacharya	Electrical & Computer Engineering	Power systems; electricity markets
Paul C. Calamai	Systems Design Engineering	Energy systems modelling and optimization
Claudio Canizares	Electrical & Computer Engineering	Power system and integrated energy system analysis, optimization and operation
Eric Croiset	Chemical Engineering	Hydrogen production; solid oxide fuel cells
Paul Doherty	Centre for Business, Entrepreneurship and Technology (CBET)	Nuclear energy materials and systems; failure analysis/life prediction
Peter Douglas	Chemical Engineering	Greenhouse gas mitigation; large-scale optimization
Ehab El-Saadany	Electrical & Computer Engineering	Distributed power and generation
Ramadan El-Shatshat	Electrical & Computer Engineering	Power quality, power conditioning, power conversion
Ali Elkamel	Chemical Engineering	Carbon dioxide; air pollution control; large-scale optimization
David Fuller	Management Sciences	Energy economics and policies; large-scale optimization
Keith Hipel	Systems Design Engineering	Energy systems modelling and decision support systems
Shesha Jayaram	Electrical & Computer Engineering	Insulation materials and failure analysis, high voltage engineering
Mehrdad Kazerani	Electrical & Computer Engineering	Power conditioning and energy storage
Mahesh Pandey	Civil & Environmental Engineering	Energy systems reliability; life cycle assessment of system integration
Kumaraswamy Ponnambalam	Systems Design Engineering	Design optimization under uncertainty; renewable energy planning
Magdy Salama	Electrical & Computer Engineering	Power quality; distribution systems
Gerald Schneider	Mechanical & Mechatronics Engineering	Mathematical/computational modelling; energy transfer; fluid flow
Eugene Yee	Mechanical & Mechatronics Engineering	Data assimilation and source inversion; hazard assessment
SUSTAINABLE ENERGY POLICY		
Paul Doherty	Centre for Business, Entrepreneurship and Technology (CBET)	Sustainable energy policy and planning
Xianguo Li	Mechanical & Mechatronics Engineering	Energy systems; life cycle analysis; energy forecasting
Jennifer Lynes	Environment & Resource Studies	Social marketing; conservation behaviour; youth engagement
Jatin Nathwani	Civil & Environmental Engineering/ Management Sciences/ Environmental Studies	Sustainable energy policy and planning
Paul Parker	Geography	Energy efficiency, policy; green electricity
Ian Rowlands	Environment & Resource Studies	Electricity policy; smart meters; market restructuring

Other research projects:

- *The Centre for Business, Entrepreneurship and Technology (CBET) has embarked on a major green technology initiative with a southern Ontario municipality and a power utility. CBET is providing business planning and technology commercialization support in this partnership, the objective of which is to deploy and showcase sustainable energy technologies.*

- *Dr. Fue-Sang Lien and Dr. Eugene Yee, both of Mechanical and Mechatronics Engineering, are conducting atmospheric modelling research in collaboration with Defence Research and Development Canada, part of the Department of National Defence, and Environment Canada. The studies seek to predict dispersion of pollutants produced by industrial and environmental sources, and infer the unknown locations and emission rates of the pollutant sources. Other research predicts wind patterns to improve the productivity of wind farms.*

- *Dr. Leonardo Simon, Chemical Engineering, is co-leading the "BioCar" Initiative in collaboration with the University of Guelph. The goal is to use farm and forest products in the auto sector to replace the use of fossil fuels to make plastics.*

- *Dr. Michael Worswick, Mechanical and Mechatronics Engineering, leads a Waterloo research team to work in conjunction with McMaster University to build lighter cars that use less fuel and are cost-competitive. The research is aimed at reducing the weight of automobiles by half through the use of lighter metals and alloys, plastics and composites without compromising safety or crashworthiness.*

RESEARCH EXPERTISE

FACULTY MEMBER	DEPARTMENT	AREA OF EXPERTISE
CONSERVATION, DEMAND MANAGEMENT, ENERGY EFFICIENCY		
Kankar Bhattacharya	Electrical & Computer Engineering	Power systems; electricity markets
Claudio Canizares	Electrical & Computer Engineering	Power system and integrated energy system analysis, optimization and operation
Michael Collins	Mechanical & Mechatronics Engineering	Active, passive solar-thermal applications; energy efficiency in buildings
Paul Doherty	Centre for Business, Entrepreneurship and Technology (CBET)	Energy efficiency and management
Jennifer Lynes	Environment & Resource Studies	Social marketing, conservation behaviour; youth engagement
Terri Meyer Boake	School of Architecture	Passive heating and cooling of buildings, sustainable design, energy efficiency
Flora Ng	Chemical Engineering	Catalytic distillation
Paul Parker	Geography	Energy efficiency, policy; green electricity
Ian Rowlands	Environment & Resource Studies	Electricity policy; smart meters; market restructuring
John Straube	Civil & Environmental Engineering/ School of Architecture	Energy efficiency of buildings
Geoffrey Thün	School of Architecture	Solar technology and sustainable building prototypes; sustainable urban design and planning strategies
Kathy Velikov	School of Architecture	Solar technology and sustainable building prototypes; closed-loop architectural systems
John Wright	Mechanical & Mechatronics Engineering	Energy efficiency in buildings
GREEN AUTO POWERTRAIN		
Stephen Corbin	Mechanical & Mechatronics Engineering	Materials for solid oxide fuel cells
Bill Epling	Chemical Engineering	Emissions reduction; gas purification; hydrogen production
Michael Fowler	Chemical Engineering	Reliability of PEM fuel cells; conductive polymers; hydrogen distribution
Roydon Fraser	Mechanical & Mechatronics Engineering	Solar radiation; fuel cell vehicle development
Mehrdad Kazerani	Electrical & Computer Engineering	Power conditioning; energy storage
Holger Kleinke	Chemistry	Materials chemistry; thermoelectric solid state energy conversion
Steve Lambert	Mechanical & Mechatronics Engineering	Hybrid electric vehicles; Sustainable Energy Education Project
Xianguo Li	Mechanical & Mechatronics Engineering	Fuel cells; wind energy; energy systems
Linda Nazar	Chemistry	Materials chemistry; solid state electrochemistry of metal oxides
Magdy Salama	Electrical & Computer Engineering	Power quality; distribution systems
Robert Varin	Mechanical & Mechatronics Engineering	Hydrogen storage; green batteries; fuel cells
Zbig Wronski	Mechanical & Mechatronics Engineering	Hydrogen storage; green batteries; fuel cells

Students helped install the Federation Hall photovoltaic solar array.

Student led initiatives:

SUSTAINABLE TECHNOLOGY EDUCATION PROJECT (www.step.uwaterloo.ca)

A student-led volunteer group, the Sustainable Technology Education Project (STEP), is establishing UW as a living laboratory of green energy. It involves faculty, staff, industry and community members in an effort to change society's reliance on fossil fuels. Projects include the installation of a photovoltaic (PV) solar array at Federation Hall; installing solar thermal panels at the Physical Activities Complex to help heat the pool and shower water; and plans for a meteorological tower and wind turbine.

CHALLENGE X (www.uwaft.uwaterloo.ca/challengex.htm)

Waterloo students placed first overall and continue to win awards in the Challenge X: Crossover to Sustainable Mobility competition sponsored by the U.S. DOE, GM and NRCan. The four-year North American competition is developing sustainable crossover vehicles. As the only Canadian university in the competition, UW was also the only one of 17 institutions with a primary hydrogen fuel cell power train.

MIDNIGHT SUN SOLAR CAR (www.midsun.uwaterloo.ca)

The Midnight Sun is Waterloo's solar-powered car, a top finisher in the bi-annual American Solar Challenge races. Driven by sun power, the student team set a world record for the longest journey - 15,079 kilometres - across Canada and 25 U.S. states. The team also takes part in the World Solar Challenge race in Australia, a 3,000-kilometre trek across the Outback.

CLEAN SNOWMOBILE TEAM (www.eng.uwaterloo.ca/~sled)

Student members of UW's Clean Snowmobile Team take part in an annual engineering design competition called the Clean Snowmobile Challenge. The event, held by the Society of Automotive Engineers, modifies a stock snowmobile. This demonstrates how to reduce exhaust emissions and noise while maintaining or improving performance, encouraging technical innovation in engine development, emission control and noise suppression techniques, all at minimal cost.

NEXT GENERATION CYCLING TOUR (www.next-generation.ca/index.aspx)

UW engineering students Benjamin Sanders and Eric Vieth cycled across Canada to inspire the next generation of scientists and engineers to build a greener world. They set out in the spring of 2007 and visited some 10,000 students at 29 high schools in their 8,776-kilometre trek from Victoria to St. John's. During the trip, they recharged their battery-operated devices using hydrogen fuel cells, portable power generators and solar panels mounted on two bike trailers.

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