

# 2010 Annual Report



Waterloo Institute for  
Sustainable Energy

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UNIVERSITY OF  
**WATERLOO**

2010 Annual Report

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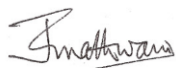
## Message from the Executive Director

Our vision is to be the premier institute for energy research in Canada, and recognized internationally as a centre of excellence. We develop innovative solutions to help bring about transformation of the energy system that meets the test of long term sustainability. Our focus on multi-disciplinary research teams as the vehicle that brings high quality expertise of our faculty members to bear on specific issues is proving to be effective.

We believe strongly in taking a comprehensive view of the complexity of energy issues and therefore continue to reach out to our faculty members and students to get engaged with business and industry, government agencies and civil society groups to help shape future paths and options for the energy sector. WISE provides advice and guidance to our external partners and we are actively engaged in working with energy sector leaders through participation in Advisory Boards and Committees, for example, the Ontario Smart Grid Forum, the Ontario Centres of Excellence, DFAIT Clean Tech Advisory Board and others. We have also been active participants in the media and continue to provide objective analysis and perspectives to help shape public agenda and policies for the future.

In this report we provide a capsule summary of the projects underway and some of our key activities that illustrates the range and depth of energy expertise available at uWaterloo. We are proud of the results and our successes but believe that the true value of our achievements can only be estimated by those whom we serve.

We will continue to expand our ties to national and international organizations and through such links help provide a stronger basis for enhancing the Canadian advantage.



Professor Jatin Nathwani, PhD, PEng  
Ontario Research Chair in Public Policy for Sustainable Energy  
Executive Director, Waterloo Institute for Sustainable Energy

[wise.uwaterloo.ca](http://wise.uwaterloo.ca)

## Expanding our Reach

The demand for sustainable energy solutions is increasing in the wake of serious global energy and environmental challenges. The University of Waterloo (uWaterloo) stands at the forefront of addressing these issues, with unique multi-disciplinary research expertise, world-class laboratory facilities (e.g. Energy Research Centre) and an extensive array of external partners. WISE members are increasingly recognized for their contributions in the sustainable energy field by industry, government and other external parties. We are committed to meeting the needs of our members while translating the fruits of their research efforts into meaningful impact across the energy sector.

This report provides a wide view of our institute, what we've accomplished in 2010 and paints the road ahead.

## Our Role

WISE advances sustainable energy research through strategic research direction, increased external partner – university researcher interactions and funding, and increasing the awareness of uWaterloo's sustainable energy research and education capacity. We focus on integrating energy research across multiple faculties, fostering industry interactions to gain insight into their technical challenges, and providing a compelling collaboration space that supports innovation. Our outputs are aligned with external partner goals to enhance national social, economic and environmental performance by creating options and alternatives to existing energy production and delivery systems.

## Our Unique Position

The Waterloo Institute for Sustainable Energy (WISE) is a recognized leader in sustainable energy research with more than 85 researchers across the faculties of Engineering, Environment, Science and Math developing advanced energy systems and policies. uWaterloo has embraced sustainable energy as a strategic research priority with significant commitments of infrastructure, curriculum and personnel to promote leadership in this field. This allows WISE to facilitate full spectrum energy R&D, education and partnerships.

WISE is unique in its research excellence across a diverse range of areas:

- Emissions Management
- Energy Asset Management
- Energy Management
- Energy Storage
- Information Science and Systems for Energy
- Power Systems
- Renewable Energy
- Sustainable Energy Policy
- Sustainable Mobility

World-class laboratory facilities at Waterloo support leading-edge energy research. These include, but are not limited to, the following: Energy Research Centre, High Voltage Engineering Laboratory, Applied Nanomaterials and Clean Energy, Emerging Energy Research, Giga-2-Nano Laboratory, and Power and Energy Systems (see Appendix A).

## Increasing Membership

Membership has grown from sixty to over eighty researchers since April 2008 when the Institute was first sanctioned by the uWaterloo Senate. The number of faculties represented now includes Engineering, Environment, Mathematics and Science. WISE continues to attract a wide variety of researchers who wish to apply their traditional expertise towards solving new and challenging issues faced by the energy sector. Table 1 lists those researchers who became members in 2010. For a complete WISE Membership List see Appendix B.

Table 1. New WISE Members (2010)

	Department	Areas of Interest	Current Research
<b>Sam Al-Kwifi</b>	Management Sciences	Management of Technology; Technology Transfer; Gov't Technology Policy; Innovation Strategy	Enhance companies' absorptive capacity to develop emerging technologies from university research
<b>Qing-Bin Lu</b>	Physics & Astronomy	Environmental chemistry & physics; Global climate change; Ozone depletion	Mechanism of global climate change; greenhouse gas effects & mechanism of the ozone hole formation; cancer research
<b>Robert Gracie</b>	Civil and Environmental Engineering	The simulation of carbon sequestration in multi-aquifer systems	CO <sub>2</sub> sequestration in multi-aquifer systems perforated by abandoned well using the Extended Finite Element Method
<b>Feridun Hamdullahpur</b>	Mechanical & Mechatronics Engineering	Energy Conversion Systems; Fluidized Beds: Hydrodynamics and Combustion; Hydrodynamics of Gas-solid Two-Phase Flow Systems; Fluidized Bed Drying; Fluidized Bed gasification of Bio-mass; Solid Oxide Fuel Cells	Thermal modeling of Solid Oxide Fuel Cells/Trigeneration Systems; Hydrogen Conversion
<b>Amer Obeidi</b>	Management Sciences	Sustainable Dev't; Strategic Policy Analysis; Social Network Analysis; Perceptual Decision Systems; Bayesian Networks; Systems Thinking	Perceptual graph model system; Systems of system in decision making; Bargaining and negotiation; Natural resource management
<b>Olaf Weber</b>	School of Environment, Enterprise and Development	Green energy investments, attitudes toward green energy, sustainability of green energy, financing green energy	Impact of the financial sector on sustainable development, integrating sustainability issues into financial decision making
<b>Hyung-Sool Lee</b>	Civil and Environmental Engineering	Microbial fuel cells for electricity generation from biomass; Microbial electrolysis cells for hydrogen production from biomass; Fermentative biohydrogen & methanogenesis; Production of bio-chemicals using principles of microbial fuel cells & fermentation; Carbon sequestration using photosynthetic bacteria	Electricity generation from biomass using microbial fuel cells; Improvement of biohydrogen production by combining fermentation & microbial electrolysis cells; Acetate synthesis from wastes & wastewaters in microbial fuel cells

<b>James R. Craig</b>	Civil and Environmental Engineering	Geothermal Energy; Carbon Sequestration	Computer simulation of heat transport in horizontal geothermal ground loops; Heat loop design using models; Modelling of post-sequestration carbon leakage from deep aquifer systems
<b>Susan Tighe</b>	Civil and Environmental Engineering	Solar Road Technologies; Usage of Solar Technologies in Civil Engineering Infrastructure; Development of materials & designs that can withstand environmental & traffic loadings	Sustainable Pavement & Infrastructure Management; Development of Solar Roads & Sustainable Pavements;
<b>Srinivasan Keshav</b>	School of Computer Science	The use of Information technology concepts & techniques to improve efficiency & reduce the carbon footprint of energy systems	Smart grid
<b>Chao Tan</b>	Mechanical & Mechatronics Engineering	Thermochemical conversion of biomass to biofuels; Syngas & biofuel purification by filtration & absorption; Post-combustion air pollution control; Aerosol technology; Indoor air quality	Thermochemical conversion of biomass to biofuels; Syngas & biofuel purification by filtration & absorption; Post-combustion air pollution control; Aerosol technology; Indoor air quality

## Establishing a Powerful Presence

We are gaining significant recognition in the energy sector. Our strong partnership with Hydro One has been followed by numerous other utilities, and sectors beyond electricity including information technology. We have effectively doubled external partnerships since April 2008 (e.g., industrial partnerships increased from 26 to more than 64, and government/other partners from 14 to over 26). Please refer to Appendix C for a list of WISE Partners.

Increasingly Ontario energy market participants are arriving at our door seeking help in addressing their fundamental technical issues. We encourage and welcome their arrival. Through membership and participation in industry groups and Boards, e.g. the Smart Grid Forum and OCE, WISE provides its members insights into financial opportunities, and regulatory and legal issues facing the industry. Most significantly, WISE has fostered many new industry-researcher interactions. Researchers have formed new connections with companies or groups such as IBM, RIM, the Utilities Standard Forum, Union Gas Lmt., and GMA Cover.

## Delivering Performance

We believe innovative multi-disciplinary research translates into outstanding performance.

In 2010, we succeeded in building the foundation to deliver on uWaterloo's Sixth Decade Plan by effectively integrating researcher's expertise across various disciplines; raising the profile of uWaterloo's sustainable energy research capacity; and promoting active engagement of external partners at all levels both nationally and internationally.

## Partnering for Success

Our goal is to facilitate seamless interactions between faculty and industry. One way we accomplish this is through Memorandum of Understandings (MOUs) with strategic partners. In addition to our MOU with Hydro One, in 2010 WISE entered into an MOU with Natural Resources Canada to enhance collaboration in support of clean technology initiatives. We are also working with Union Gas, IESO and others on similar collaborative platforms.

We set up faculty – industry meetings and prepare the agenda to match technical objectives and research expertise. As a result, faculty have broadened their network and in some cases have accessed increasing funding and/or in-kind resources. Certainly they have gained insight into the technical challenges facing companies where their research has an impact.

The success of these efforts can also be measured by the level of discussions that ensue: meaningful discussions reflect the right matching of faculty with industry i.e., "right people at the table". Different forms of interactions have also been encouraged. For example WISE has also set up speaking and networking opportunities for faculty, and has performed primary market research on behalf of faculty members to establish potential applications of their research.

## Collaborative Initiatives

Selected WISE member projects are described below.

### The Energy Hub Management System

The purpose of this project is to develop, implement and deploy an Energy Hub Management System (EHMS) that will allow static energy users of various sectors to effectively manage their energy requirements. This project will empower energy hubs so that they can contribute to the development of a sustainable society through the real-time management of their energy demand, production, storage and import or export of energy.

This project is valued at \$3,753,600, and partners include Hydro One, Energent, Milton Hydro, OPA and OCE. Within uWaterloo, the Faculties of Environment and Engineering are leading parts of the work. The Faculty of Environment is advancing our understanding of how people – in homes and workplaces – use energy

information to further their own priorities. This understanding is being used to guide the interface between the technology developed (the EHMS) and the user. The Department of Electrical and Computing Engineering is focused on the development, testing and validation of optimization models of the various energy users. These models are the “brains” of the EHMS so that energy loads, generation and storage can be properly dispatched and managed to minimize energy costs, energy usage and/or carbon footprint.

Program achievements to date include: the development of optimization models; the increased understanding of means to accentuate consumer engagement; and new knowledge regarding the ways to integrate smart grids systems. Up to 65 pilots are scheduled to be deployed during the first half of 2011 across the residential, commercial/institutional, agricultural and industrial sectors in south-western Ontario. The project is scheduled to be completed during the first half of 2012. This work has already generated substantive intellectual property (IP).

### Operation, Communications and Information Management for Smart Electricity Grids

This research proposal seeks to bring together, for the first time, a collaborative effort in finding solutions to the pertinent issues arising in Smart grids not only from power systems viewpoint, or from a communications engineering viewpoint, or merely as an information management problem- but the three aspects merged and inter-twined because of the necessity of the day. A smart home energy management device needs communication channels with the individual controllable appliances but it cannot stand alone- it needs "information" from the external "power system" in terms of real-time market prices. Every such activity in Smart Grids is therefore linked between the three important pillars- the power system, the communication system, and the information system. This 3-year project combines expertise in computer science, power systems engineering and smart grid policy to develop new and innovative solutions in five areas: Smart Grid Modeling, Analysis & Operation; Smart Loads in Smart Grids; DER, Storage & Integration; Communication & Security in Smart Grids; and Smart Grid Information and Data Management. Project partners include NSERC, IBM, ABB and Hydro One.

### Research into Solar-Assisted Heat Pumps, Thermal Storage and Natural Refrigerants

Researchers in Mechanical and Civil Engineering have partnered with a local heat pump developer, Ecologix, to assist in research and development of their technology. Previous research focused on ways to inexpensively adapt their existing heat pump technologies to the Canadian climate. The findings from this work led to a partnership with Emerson Climate Technologies to utilize their variable capacity digital scroll compressor matched with a EC3 refrigerant management system, and the integration of this technology, with the assistance of uWaterloo, into a demonstration project (Solar Decathlon) sponsored by the US DOE.

Current research continues to advance heat pump technologies for cold climates in three main areas:

- Solar panels to assist space heating in cold weather
- Use of CO<sub>2</sub> or hydrocarbon refrigerant system alone or in combination with other refrigerants
- Thermal storage to allow at least partial load shifting to take advantage of time of use electric rates.

uWaterloo accesses Ecologix's manufacturing and development expertise and their ability to build prototypes in order to assist in developing next generation products, including overcoming technical, safety and regulatory hurdles.

### Electric Vehicle Demonstration

The demonstration project is led by Burlington Hydro, with collaborative research conducted by Chemical and Mechanical Engineering at the University of Waterloo and funding from Transport Canada. It is designed to increase understanding of the operating characteristics of an all-electric fleet vehicle in practical, working applications, including its recharging patterns and requirements, how to optimize the usage and recharging cycle in a "real life" setting; overall performance, drive-cycle, battery state-of-health and electricity grid impacts. Rapid Electric Vehicle Technologies Inc. developed the motor and drive system technology specifically for the fleet vehicle. The University of Waterloo is data logging and modeling the electric vehicles, and also developing assessment and management tools to assist with the integration of Plug-in Hybrid Electric Vehicles (PHEV's) into the electricity grid. The findings will be useful to designers and prospective operators of electrified fleet vehicles.

### Wind-Diesel-Storage Micro Grid Project

In an effort to reduce diesel dependency in remote Northern Ontario communities, this partnership aims to develop a low-carbon community energy system that combines new kinds of rugged wind turbines, specifically designed for extreme Northern climates, community engagement and power systems and control. This off-grid hybrid power system provides a lower-cost, environmentally friendly solution to alleviate the significant financial burden of diesel power systems on remote communities. Kasabonika Lake is part of the Nishnawbe Aski's 26 communities that rely on diesel – currently they use about 20 million litres annually. The new wind plants will cut that consumption significantly and provide a renewable energy alternative for remote communities. This project is supported by OCE and Wenvor.

### Large-Scale Photovoltaic Solar Power Integration in Transmission and Distribution Networks

The Province awarded WISE researchers \$3M to help power grid operators incorporate large-scale solar photovoltaic (PV) farms into their transmission and distribution networks. The research team is designing prototypes of new equipment that will help solar plants operate at maximum efficiency: weather sensors, power quality monitors, develop commercial software to keep the new plants running smoothly, and study problems of grid control and operation. Sample activities with respect to the latter include the impact on reverse power flow through transformers, voltage regulation, reactive power compensation needs, power quality issues, and harmonic injection and line losses in distribution networks. The project also develops robust control strategies to consider other renewable power sources including wind and biomass. Collaborators include Hydro One, OPA, OCE, the University of Western, local distribution companies (LDCs) such as Bluewater Power and London Hydro, and Ontario's largest solar farm, OptiSolar Incorporated.

## CO2 Bioconversion

A new technology solution is under development that not only helps sequester carbon dioxide but reuses this harmful greenhouse gas as a resource to produce important products like renewable fuel and sustainable chemicals. Until now, the best way to convert CO<sub>2</sub> into valuable products is based on photosynthesis, with bioconversion of carbon dioxide into biomass, and the most promising candidates are unicell microalgae that can produce various chemicals, namely oil.

Research focuses on a type of closed photobioreactor for the cultivation of microalgae to address the industrial requirements of efficiency and control. This innovative technology increases the production efficiency of algal biomass compared to other systems as a result of its design, optimized use of light, and accurate control of the CO<sub>2</sub> monitoring, while providing industrial scalability due to its modular design. In 2009 a provisional patent (US 61/235,337) was filed on the system, followed by the formation of a company, ProDaLG Biofuels, Inc.

## Operation of Power Systems with High DG Penetration

The main objective here is to develop short-term operational analysis models and tools for LDCs operating in a competitive environment and with significant penetration of Distributed Generation (DG). The models will consider the effects of electricity market dynamics on the decision-making of LDC operators in day-ahead and real-time time-frames. Studies will be carried out on the effect of LDC operation and market decisions in power system operation and security.

This is an ABB-MITACS research project supporting two PhD students. The project involves development, testing and validation of power flow and dynamic models and tools for LDC grids with a variety of DG sources. These models and tools will allow studying operation, stability, control and regulation issues in distributions networks with DG.

## Grid Integration of Renewables

Researchers at uWaterloo have made significant advances to help integrate wind and PV based systems into the grid. The lack of ability to schedule DG units has been an impediment to wider adoption of DG resources because researchers have only applied traditional models. A detailed review of the incorporation of DG units into the operations of distribution systems was presented in IEEE GM09 Super Session - Panel, Regulator and Public Challenges to Utility Enhancements on July 28, 2009. The work based on stochastic approaches was also presented in CORS-INFORMS International Meeting, Toronto June 14-17, 2009. The research team is working closely with Waterloo North Hydro Inc. to assist them with the challenges of integrating DG into the distribution network.

## Hydrogen & Storage Potential for Grid Application

This ongoing project has concentrated on the development and study of hydrogen-based technologies for electrical and transportation systems in the context of a Hydrogen Economy, which basically comprises all economic and technical aspects of hydrogen production, storage, distribution, and utilization to address

environmental and resource depletion issues associated with energy supply and demand. The improvement and application of electrolysis and fuel cell technologies for the generation and utilization of hydrogen are an integral part of this project. On the electrical side, feasibility studies have been carried out on the use of hydrogen for electricity storage to facilitate the integration of wind-power as well as the use of the grid to generate hydrogen for transportation applications. This project has been funded and supported by Bruce Power, the Canadian Hydrogen and Fuel Cell Association (CHFCA), NSERC, MITACS and OCE.

### Reactive Power Ancillary Service Markets and Dispatch

This 5-year, successful project concentrated on the development of a market and management framework and methodology for reactive power ancillary services. Proper, practical and novel optimization models and tools were developed, tested and validated for the seasonal procurement and real-time dispatch of reactive power services. Ontario's market and network was used to demonstrate, in collaboration with the IESO, the usefulness and feasibility of the proposed methods and tools. This work resulted in the publication of seminal and well received papers on reactive power ancillary service markets and dispatch. Financial support was received by ABB, NSERC, MITACS, OCE and OPA.

### Electricity Market Price Forecasting

This multiyear and successful research effort concentrated on developing appropriate and practical methodologies for the forecasting of the hourly Ontario energy price (HOEP), based on publicly available electricity market information. Several forecasting models and techniques were developed and applied, each one resulting in better estimates of the HOEP. Ontario and its neighbouring electricity markets were first investigated and a set of explanatory variable candidates that are publicly-available before real-time were selected as input to a variety of forecasting methods. Univariate ARIMA and multivariate transfer function and dynamic regression models were initially proposed, followed by hybrid time-series and learning models (e.g. Neural Networks). A practical implementation of these methods has been successfully deployed by one of the industry partners. This work has been funded by Energent, NRGENT, MITACS, NSERC and OCE. This work has generated substantive IP.

### Distribution Systems Planning and Operation with DG

This research involves a hierarchical dynamic optimization model to address the design, planning and energy scheduling problem in power distribution systems. This model's usefulness also extends into predicting the impact of different energy policies on system operation and economics. This project develops a novel schematic approach for coordinating the selection of DG unit investment proposals submitted by multiple, competing, private investors to achieve maximum investor participation while complying with the technical operational limits of the local distribution company. The concept of domains and commons has been used to identify the largest transgressors to system function, and forms the basis for revisions to the investor proposals.

## Solar PV Generation in Power Systems

This project seeks to determine the role and contribution of new investments in solar power generation resources particularly to the Ontario power system, their penetration into the distribution grid, their impact on electricity market prices, and their possibility to participate in electricity market auctions.

## FACTS

The work on FACTS has focused on development of a STATCOM based on current-sourced inverter (CSI) topology and development of power flow control schemes for series-connected FACTS controllers. It was demonstrated through analysis, simulation and experiments using a lab prototype that all expected operational aspects of STATCOM could be realized by a CSI-based STATCOM, with improved dynamic response and power quality. The future plan is to build upon the existing knowledge and carry out theoretical and experimental study in collaboration with the utilities leading to integration of FACTS controllers in power systems as part of the smart grid initiative.

## Grid- and Microgrid-Integration of Alternative Energy

Research on Grid-Connected PV Systems includes, but is not limited to, the following: developing controls for power flow and power factor; maximum power point tracking; anti-islanding protection; novel high-efficiency connection configurations for PV panels and modules; development of methods and tools for investigation of impacts of large PV systems on the utility grid; and smoothing the output power of PV systems using power flow control and energy storage management. Another solar project has focused on comparative evaluation of different grid-connected PV system products manufactured by the top PV product suppliers for connection to Ontario's grid.

Research collaboration is expected to grow with the utility sector to facilitate the integration of alternative energy sources (solar, wind and fuel cell) into the grid. This may be accomplished by improving the interface from the converter topology and control scheme points of view; enhancing the efficiency of PV systems under partial shading conditions through innovative connection configurations and maximum power point tracking schemes; and optimization of size, site and power management of distributed generation units and micro-grids.

Future research also includes studying the impact of a high penetration of alternative energy sources on the grid and mitigating any associated adverse effects. Smart grids of the future will heavily depend on integration of renewable and non-renewable alternative energy sources in the grid and their smart control.

## Power Quality Control

Research on active filters and power quality has led to the development of CSI-based active power filters for per-phase treatment of line current harmonics in unbalanced distribution systems. This calls for further study into power quality impacts of integration of small and large inverter-based alternative energy sources on the grid at the points of common coupling and devising systems for identifying the sources of power quality problems and mitigating them.

## High Voltage Engineering and Insulation Diagnostics

In power systems, electrical insulation plays a major role in system reliability; as insulation failure leads to equipment failure and subsequent system outages. Research work has significantly contributed to the understanding of the performance of insulating materials and development of novel methods to detect the early degradation of materials. The partial discharge diagnostic method was developed to detect the loss of hydrophobicity, inception of dry band arcing, and hence degradation much earlier than other conventional methods that are being currently used. Complementary research has focused on using a novel approach, based on harmonic analysis of leakage current, to identify dangerous levels of arcing on insulation surfaces. As a result, an index that is defined based on the third harmonic component can be used to monitor the conditions on high voltage bushings and insulators.

In addition, a laser-based technique was developed to assess both qualitatively and quantitatively the erosion resistance for electrical arcing in composite materials. Considering the development of nanomaterials, the laser-based fast, simple and reproducible method will have a high impact on the choice of materials for means of evaluation. A US-Patent was awarded in 2009. UW's Intellectual Property & Management Group (IPMG) is actively seeking partners to license this technology. Funding is required to develop a complete test set-up for industry use and to generate data using the same for the purpose of including this new method as a Standard ASTM or IEC Erosion Test Method to evaluate insulating materials.

Research on rotating machine insulation under non-conventional sinusoidal voltage waveforms has underscored the importance of evaluating the performance of insulation using steep-front pulses. This knowledge can be extended to understand equipment insulation performance under fast transients that are developed by renewable generation (e.g., wind and solar) in the power system. Recent legislation in Ontario and beyond has precipitated the deployment of non-conventional generation sources. Thus, it becomes highly important to study the insulation performance under non-conventional sinusoidal voltage waveforms. Considering the importance of power system security and reliability that in fact relies on the insulation strength, there is a great need for training students in this field. The outcome of this research is expected to help power utilities prevent insulator failures and consequently power outages.

## REEP House for Sustainable Living

Kitchener's REEP House for Sustainable Living is a hands-on showroom offering "one-stop-shopping" for green living ideas, from the newest sunlight balanced LED lighting for your kitchen to money-making solar panels on the roof. Tours of the century brick home are available to view heritage style wood-framed arch-top stained glass windows that are R-7, 100 year old recycled flooring, and a \$138 a year heating bill. Modeling software can determine the cost, payback and energy savings of green options for a home. Contacts for suppliers, contractors, grants and financing are also available.

## Advanced Batteries and Storage Technologies

Research underway in Chemistry on the Li-S battery has been under intense scrutiny for over two decades, as it offers the possibility of high gravimetric capacities and theoretical energy densities ranging up to a factor of 5 beyond conventional Li-ion systems. Research involves highly ordered interwoven composites based on channel-structured mesoporous carbon whereby metallic lithium forms the negative electrode and sulfur

forms the cathode. A nanoporous conductive carbon channel framework is created into which molten sulfur is imbibed via capillary forces. On cooling, the intimate contact “wires” up the sulfur fibres contained within, but allows ingress of electrolyte into the structure. The framework, further modified by hydrophilic polymers, constrains the intermediate reaction products so that full reduction to Li<sub>2</sub>S is facilitated. Capacities up to 8 times that of conventional lithium-ion intercalation materials are achieved. This work has received widespread attention (e.g., CBC news (May 18/09), MIT Technology Review, Energy Efficiency News (USA), Royal Society of Chemistry, EurekAlert! (AAAS), and the Swedish Technology News).

Battery researchers at uWaterloo have also developed a new 2-dimensional electrode material A<sub>2</sub>FePO<sub>4</sub>F (Nature. Matter, 2008) that may redefine the scope for new polyanion framework materials. The material has been patented by uWaterloo, and is the subject of an NSERC I2I award for further development of its commercial potential. The most important aspect is the ability to utilize a sodium iron phosphate directly as a cathode in a Li-ion cell. This offers significant advantages with respect to cost and lithium availability, and the possibility of developing viable Na-ion cells.

## Solar Roads

uWaterloo researchers are collaborating to develop a solar technology that could be used in a solar roads. Experts in civil, electrical and mechanical engineering are developing a technically-advanced and cost-effective solar technology for usage in road applications, but also in other civil infrastructure such as sidewalks, curb and gutter, roadways, car pool lots, shoulders, barrier walls, glass areas, paver lights. This program has been identified by Ontario’s Ministry of Transportation as a strategic initiative and will likely also be of interest to other government agencies. The group will consider traditional technologies but will also explore opportunities for future new materials in order to create the world’s first true “electric highway”.

The research team will examine the traditional photovoltaic technologies and opportunities for future new materials. This will include carrying out an energy calculation associated with the various solar technologies and applications. The key considerations will include: evaluation of sustainability, development of an efficient energy conversion method, determinations of the amount of power that is generated by the various types of solar cells and the associated amount of energy that could be either tied into the grid or used to supply a local source, such as street lights, signs, etc. In addition, the application of light only, heat only and a combination of light and heating will be considered. The heating might be considered for usage in winter to melt snow or ice on the pavement surface.

The researchers are now working on developing a prototype. The pavement slabs will undergo freeze thaw testing in the full scale walk in freezer in the Centre for Pavement and Transportation Technology (CPATT) Laboratory. Based on preliminary discussion, the Ministry of Transportation of Ontario has been identified as a partner in the construction of a full scale test section. They have also expressed interest in evaluating this area. The researchers are seeking additional partners - both government and industry - for funding of graduate students, materials and testing associated with the laboratory and field research.

## Green Intelligent Transportation Systems

WISE members are contributing to the Green Intelligent Transportation Systems (Green ITS - a world class research program focused on developing leading-edge solutions to technological obstacles currently standing in the way of widespread adoption of intelligent electric vehicles (see illustration below). With significant support from the Ontario Research Fund (\$8M) and industry partners (\$8M), researchers from uWaterloo, University of Toronto, and various Canadian automotive companies are working closely to optimize the design and development of key electric vehicle enabling technologies.

The team is also investigating the feasibility of critical battery-charging infrastructure, electric highways with in-transit charging systems, as well as the impact of vehicle electrification on the electricity grid and power distribution. This wide-sweeping initiative includes 108 sub-projects, most of which are directly pertinent to smart grids. See [www.greenits.ca/about/milestones/](http://www.greenits.ca/about/milestones/)

## Plug-In Hybrid Electric Vehicles (PHEVS)

The report entitled “Towards an Ontario Action Plan for Plug-In-Electric Vehicles” identifies the key technical, regulatory and policy issues associated with meeting the electricity demands of PHEVs in the Ontario market, while maintaining system reliability, price stability, economic development, environmental sustainability and technological innovation. It includes a high level summary of the current state of development and deployment of PHEVs in relation to North America’s electricity infrastructure, and identifies Ontario’s role in supporting this emerging vehicle technology through its electricity system. The study also identifies what standards require further definition and technologies that will likely have to be developed to support the mass adoption of PHEVs in Ontario. This work was prepared for the Plug’n Drive Ontario Coalition and supported by Ontario Power Generation (OPG), Hydro One, NRCan, OPA and OCE.

Another sample PHEV project examines the effects of widespread adoption of PHEVs on emissions and electric generating capacity in partnership with Natural Resources Canada.

## Carbon Sequestration: Mathematical Simulation of Gaseous Injection in Saline Aquifers

Anthropogenic carbon dioxide (CO<sub>2</sub>) emissions have resulted in a considerable increase of atmospheric carbon dioxide concentration and mitigating action is considered by many to be an urgent need. Removal of CO<sub>2</sub> directly from anthropogenic sources (capture) and its disposal in geological formations can be for medium-term time periods (storage), or can be permanent (sequestration). The latter is being studied jointly with Terralog Technologies Inc., and includes researchers from Earth and Environmental Sciences, Civil and Environmental Engineering and Physics. The research focuses on a technology based on petroleum industry injection of CO<sub>2</sub> enriched gas.

## Plasma Enhanced Gasification for E-Waste

Rapid changes in technology, low initial cost, and planned obsolescence have resulted in a rapidly-growing surplus of electronic waste (e-waste) around the world. Processing of e-waste poses serious health and pollution risks. Research in Mechanical and Mechatronics Engineering in partnership with the University of

Toronto is focused on optimizing the plasma process using e-waste for maximum energy recovery and emission reductions. Aside from energy generation, benefits also include resource recovery and reduced landfill volume (relative to conventional treatment). Collaborating partners include MITACS and industry.

### Wind Noise & Health Impact Modeling

Wind power, as a source of green energy is growing at the rate of 30% annually. Residents claim that noise generated from wind turbines is extremely irritating when exposed to it for any length of time because of its rhythmic nature. It is believed that this rhythmic sound noise is caused by the aerodynamic or mechanical noise. Infrasound and low frequency noise is most controversial in terms of health.

Research focuses on the prediction of aerodynamic noise produced by wind turbines by combining Computational Fluid Dynamic (CFD) software and Computational AeroAcoustic (CAA) code in flow over wind turbines numerical simulation. The CFD software will give information about the flowfield and uses Ffowcs Williams and Hawkings equation which is based on Lighthill acoustic analogy to calculate the far field noise.

In addition, researchers in Applied Health Studies are studying the clinical and epidemiological studies of health effects of turbine noise. They are investigating the relationships of exposure to sound from wind turbines (low frequency as well as audible) with various health outcomes such as sleep disturbances and stress. The studies will be multidisciplinary (e.g., include inputs from the wind model) and involve both field studies, with collection of data on noise exposures, as well as health information from study subjects.

### Electric Vehicle Drive Cycle Analysis for Battery Management

The objective of this project is to collect drive cycle data from a Local Distribution Company's electric vehicle and to use this observed drive cycle to understand the expected impact of electric vehicles on their electricity grid and to collect battery degradation data to use in the development of a battery degradation model. This project provides experimental support to strongly complement the theoretical and computational drive cycle work proposed, as would the experimental results from others collecting in-situ drive cycle data. Researchers span Mechanical and Chemical Engineering, in partnership with Transport Canada and Burlington Hydro.

### Non-destructive Condition Assessment of Wood-pole Infrastructure

This project develops a new methodology for condition assessment of utility wood poles based on ultrasonic waves. The non-destructive method assists utilities in planning maintenance programs, maintaining staff and public safety, improving the reliability of the network by early detection, and achieving cost reductions through effective timing of utility pole replacement. The research team developed the methodology and prototype to perform the assessment. Project partners include Hydro One, OCE and NSERC.

### Sustainability and Environmental Risk Management in Canadian Banks and Financial Service Institutions – A Global Comparative Study

Researchers are investigating how Canadian banks report on, and incorporate, sustainability risks into corporate lending compared with their global peers. The analysis examines Canadian banks and financial institutions with respect to their sustainability performance. This research is supported by the UW Robert Harding Endowment Fund and through the EDC Chair in Environmental Finance.

### Novel Processes for Upgrading Bitumen Emulsions

A reaction process developed at uWaterloo involving research into in situ H<sub>2</sub>, supercritical fluids and nano catalysts has resulted in several patents. The process produces hydrogen, breaks/dewateres the emulsion and upgrades the bitumen in a single step using CO. The result includes numerous benefits as follows: higher pitch conversion and naphtha yield; higher percentage removal of S, metals and asphaltenes; lower viscosity, higher API gravity; and meets Canadian pipeline standards. In addition, in situ H<sub>2</sub> treatments produce a higher quality oil, provides a cost-effective alternative to molecular H<sub>2</sub> via syngas, and reduces the clean of oily water from oil sand tailings.

## Hydro One Supported Activities

Hydro One Networks Inc. (Hydro One) and the University of Waterloo have had a successful, long-standing and strong partnership. We continued to build upon this relationship in 2010 through research and graduate student activities under the Hydro One - WISE Memorandum of Understanding.

WISE has undertaken specific research projects, and supported graduate student work, developed in consultation with Hydro One. In 2010, eight projects were approved in the amount of \$307,600 (year 1 only), or \$557,600 (3 year funding commitment) – refer to Table 2. Two projects proceeded swiftly in 2010 and are now substantially complete, and minor expenses were incurred for the remaining projects. Undergraduate scholarships will also be granted later in 2011. Several reports were prepared for Hydro One including “Report on Investment in Education” (October 2010) and “2010 Status Report, MOU Hydro One - UW Projects”.

Table 2. 2010 Approved Hydro One Research (Hydro One - WISE MOU)

	Topic
<b>Keshav, S</b>	Peer-to-peer Communication for Distributed Energy Generation and Storage
<b>El Shatshat, R</b>	Line Drop Compensator Setting Calculation Considering the Stochastic Contribution of DG Production
<b>Cascanti, G</b>	Nondestructive condition assessment of wood poles using ultrasonic waves
<b>Salama, M</b>	Increasing Renewable Generation Connectivity in the Transmission System of Ontario through use of Innovative DG Controls
<b>Jayaram, S</b>	Voltage Waveforms Effects on Power System Insulation under High Frequency and Fast Transients
<b>Parker, Paul</b>	Energy Education in the North: Literature Review, Design Features and Unit Plans
<b>Salama, M</b>	Dynamic Interactions in Active Distribution Systems: Modeling, Analysis and Suppression via Control Design
<b>Cañizares, C</b>	Using Smart Grid Technologies to Reduce Production Costs and Increase Access to Renewable Energy In Power Systems

## Research Impact

Research impact can be measured in a variety of ways. These may include broad economic, commercial, social and/or environmental indicators. WISE is undertaking a review of performance metrics and measurement mechanisms to ensure impact is tracked effectively.

Appendix D includes a sample list of publications and other research outputs by WISE members.

## Outreach

A sampling of public activities follows. For a comprehensive view of WISE media, conferences and presentations see <http://www.wise.uwaterloo.ca>.

## Media

### **TVO The Agenda with Steve Paikin**

March 17, 2011

Jatin Nathwani panelist

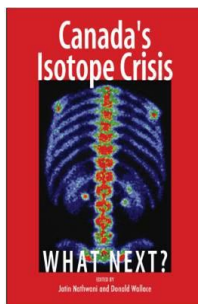
Ontario's Green Energy Blues: Part III in The Agenda's "Pressures of Progress" series: Ontario is trying to become a world leader in green technology. And while the McGuinty Liberals believe it's the future, citizens and industry aren't fully buying in. Do we all want to go green, until it happens?

### **Talk Local (Waterloo Region) - Rogers TV**

Is Green Energy Worth the Cost?

December 14, 2010

Jatin Nathwani



### **Canada's Isotope Crisis: What Next?**

J. Nathwani & D. Wallace (eds.)

Queen's Policy Study Series

McGill-Queen's University Press, May 2010

Should Canada get back into the radioactive isotope business?

### **Special to the Globe and Mail**

Jatin Nathwani

Monday, November 15, 2010

Does Ontario's Green Energy Act pass the 'net benefit' test?

No, says University of Waterloo's Jatin Nathwani - Ontario's race to implement green policies undermines the orderly path to a clean energy future.

## Presentations

**Ontario Centre for Engineering and Public Policy Engagement Series**

October 29, 2009

Shaping Ontario's Energy Future: Charting a path to sustainable prosperity

**The Consulate General of Canada, New York**

October 21-22, 2010

Partners in Sustainability:

Renewable Energy and the Canada/U.S. Relationship

**Council for Clean & Reliable Electricity**

October 25-26, 2009

Nuclear Power in Society: Finding the Balance



**Ministry of Energy**

October 7, 2010

Shaping Ontario's Energy Future:  
Charting a path to sustainable prosperity

## Conferences & Events

WISE plays a supporting role in connecting both faculty and students with the broader community to increase the profile and impact of their research. In 2010, WISE staff helped plan, host and/or organize a presence at numerous internal and external events.

### **Indo-Canada Workshop on Electricity Generation using Renewable Energy**

Indian Institute of Technology, Delhi

October 9-10, 2009

### **Governance and Regulation in the Electricity Sector**

June 4, 2010



### **International Green Energy Conference**

June 1- 3, 2010



### **OCE Discovery 2010 Exhibition and Conference - Plug'n Drive Ontario**

May 17-18, 2010



**Enercom 2010 – Conference and Exhibition**

March 29-31, 2010



**Colloquium co-hosted by Queen's University and WISE. M. Fowler, Chair.**

December 8-9, 2010

**FCRC-NRC Fourth Annual Colloquium on Fuel Cell and Hydrogen Technologies**

**WE Innovate 2010 Expo**

November 4, 2010



## University of Waterloo Energy Research Centre Official Opening

October 4, 2010



Ribbon cutting ceremony at ERC entrance. (L to R) Jatin Nathwani, Laura Formusa, Feridun Hamdullahpur, Manon Harvey, Peter Braid, Adel Sedra

## WISE Public Lectures

In 2010 WISE continued to attract numerous distinguished professionals to present on a wide range of sustainable energy related topics. The public lectures are free and open to the public. Many students attend these events and enjoy the collegial atmosphere and networking opportunities.



Smart Grid, Renewables, Electric Mobility: Challenges and Potential of an Integrative Approach

Prof. Dr. Hartmut Schmeck, Karlsruhe Institute of Technology



WIN-WISE Distinguished Lecture: Energy Technologies, Energy Security and Climate Change

Dr. R. Chidambaram



Sustainable Electric Power Systems in the 21st Century: Requirements, Challenges and the Role of New Technologies

Dr. Prabha Kundur



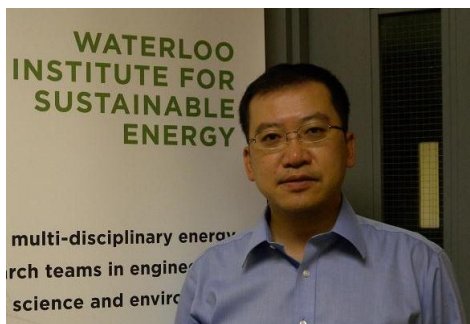
CO<sub>2</sub> Addiction: Difficult but Doable; Dither or Deploy

Mr. Alistair Miller

## International Collaboration



Dr. Prem Kalra, Indian Institute of Technology, Rajasthan, visited the University and met with selected Institute directors in June, 2010 to discuss research cooperation opportunities.



Dr. Artie Ng, Research Fellow (Public Policy for Sustainability and Accountability), Public Policy Research Institute, The Hong Kong Polytechnic University visited the University in July, 2009 and again in July 2010 as a Visiting Scholar to conduct research with J. Nathwani.



In October 2010, WISE hosted Parag Diwan, Vice Chancellor of the University of Petroleum and Energy Studies, Deradun, India (<http://www.upes.ac.in/>). The visit served to strengthen ties in research in sustainable energy under an existing MOU between the universities. Tours included research labs and the Accelerator Centre.



A training session was provided in November 2009 to the Guangxi Water and Electrical Power Group Ltd., China. The Guangxi group requested the visit to gain a better idea of Canadian policy in energy development, legal & management systems, and advanced management methods. WISE organized a tour of the IESO Clarkson Facility in Mississauga. Dr. David Woods hosted the group during the visit.

**University of Waterloo Visit to Indian Institute of Technology - Rajasthan**

**Energy Research Cluster – Energy and Information & Communication Technology Workshop**

November 18-24, 2010



Prem Kalra, Feridun Hamdullaphur, Adel Sedra



Magdy Salama, Prem Kalra, Sujeet Chaudhuri, John Wright, Pearl Sullivan, Balaraman Ravindran, Ibrahim Inayatoli, Peter Roe, Jatin Nathwani, Safieddin Safavi-Naeini, Roydon Fraser

## Development of Highly Qualified Professionals

### Building the Energy Leaders of Tomorrow

WISE provides an honorarium for a student coop position at Sustainable Waterloo. Students may be approved for Fall, Winter or Summer terms. Sustainable Waterloo guides corporations in Waterloo Region towards a more environmentally sustainable future by facilitating collaboration between industry, local government, academia, and non-governmental organizations. The goal is to ensure that Waterloo Region is more environmentally sustainable as a result of its efforts in environmental leadership. Jatin Nathwani is a member of the Advisory Board.

WISE also employs co-op students within its own offices on a regular basis to increase student's exposure to the sustainable energy field in practical and meaningful ways.

### Clean Energy Classrooms

WISE supports Clean Energy Classrooms, a one-stop resource portal for training and education options in the Canadian sustainable energy sector. Clean Energy Classrooms is also featured in the 2009 Canadian College Guide and Canadian University Guide.

## Recognition

WISE members are increasingly recognized for their achievements and awards as noted below.

### ECE professor receives new Canada Research Chair

Four Waterloo electrical and computer engineering faculty members were named as new Canada Research Chairs at the 10-year celebration of the CRC program. **Catherine Rosenberg** becomes the Canada Research Chair in the Future Internet.

### 2010 Waterloo Engineering awards for 2 WISE researchers

Awards were presented at the annual Faculty of Engineering dinner held September 30. The faculty's Teaching Excellence Award was presented to **Michael Fowler** of chemical engineering, Andrew Heunis of electrical and computer engineering and Hamid Jahed of mechanical and mechatronics engineering. The En-hui Yang Engineering Research Innovation Award was awarded to **Susan Tighe** of civil and environmental engineering.

### Geography & Environmental Management professor awarded ESA research contract

**Claude Duguay** has been awarded a new research contract from the European Space Agency (ESA). Worth 500 000 Euros over two years (2010-2012), the project designated under the name "North Hydrology" has been designated by ESA as a key component of its STSE (Support To Science Element) programme. Lead by Waterloo, the project will involve the participation of several international (academic, government and industrial) institutions. Partner institutions include: ENVEO (Austria), Environment Canada, the Finnish Environment Institute (SYKE), the Finnish Meteorological Institute (FMI), INRS Eau, Terre et Environnement (Canada), the Northern Research Institute (Norway), the Norwegian Computing Centre, and the Swedish Meteorological and Hydrological Institute (SMHI).

The overall goal of "North Hydrology" is to support the international efforts coordinated by the Climate and Cryosphere (CliC) project of the World Climate Research Programme (WCRP) to exploit the use of Earth-Observation technology, models and in situ data to improve the characterization of river and lake ice processes and their contribution to the Northern Hydrology system. To this end, North Hydrology aims at developing a portfolio of novel multi-mission geo-information products (maximizing the use of ESA data) to respond to the scientific requirements of the CliC community and the operational requirements of the weather and climate operational agencies (regional to global scale), and the requirements of the operational user community to better characterize river-ice (and glacier temporary lakes) dynamics in flood forecasting models at the basin scale. (See Interdisciplinary Centre on Climate Change: [www.ic3.uwaterloo.ca](http://www.ic3.uwaterloo.ca)).

### Professor wins water lifetime achievement award and PEO honours

**Keith Hipel** of systems design engineering was recently honoured with the Water 2010 Lifetime Achievement Award at the Water 2010: Hydrology, Hydraulics and Water Resources in an Uncertain Environment conference.

Keith Hipel was presented with the Engineering Medal for Research and Development from Professional Engineers Ontario at the PEO awards' gala on November 20 in Mississauga. His award citation says that he is "internationally recognized as an outstanding academic whose passion to develop systems thinking methods to ascertain how humans can live in harmony with one another and their environment has advanced the engineering profession."

### Government announces auto research funding

Tony Clement, the minister of industry, recently announced funding of \$115,000 over two years from the Natural Sciences and Engineering Research Council of Canada (NSERC) for a project that will focus on the development of a viable plastic heat exchanger. The project is led by **Pearl Sullivan**, chair of Waterloo's mechanical and mechatronics department, in partnership with Dana Canada Corporation. "Dr. Sullivan's research will be a major contribution to a sustainable automotive industry," said Suzanne Fortier, president of NSERC.

### Systems Design Engineering Prof wins sustainability design prize



February 2010: Professor **Ponnambalam** of Systems Design Engineering who is spending a sabbatical year in Technical University of Delft, Netherlands won second prize for his design of solar energy generation by using flexible solar cells on window blinds of this large building (see photo, building overlapped with him and the "cheque" ). The competition was open to students and employees. The prizes are awarded on the basis of what is practical to implement today. First prize of 1000Euros was won by two students suggesting a wind energy based solution.

### A fellowship and a chair for Culham

**Rick Culham**, Waterloo Engineering's associate dean of research and external partnerships, was recently honoured as a fellow of the American Society of Mechanical Engineers. Culham, a mechanical and mechatronics engineering professor, has also been appointed to a term as a University Research Chair, which recognizes "exceptional achievement and pre-eminence in a particular field of knowledge."

### Ontario Environmental Chair for E&CE Prof



February 2010: The Council of Ontario Universities announced that **Siva Sivoththaman** of UW's department of electrical and computer engineering, will hold the Ontario Research Chair in Renewable Energy Technologies and Health. Sivoththaman's research centres on silicon-based crystalline and thin-film photovoltaic devices, and he serves as director of the Centre for Photovoltaic Systems and Devices, which occupies much of the photovoltaic research building beside Matthews Hall. His interest extends to nanocrystalline semiconductors, and he was the first director of UW's nanotechnology engineering program when it was launched

in 2004.

Dr. Sivoththaman will bring focus to multi-disciplinary activities in renewable energy technologies and health, ensuring that health and safety are top priorities in the induction of new technologies. His research program will develop new technical approaches and will provide guidelines in setting standards to ensure health and safety in the manufacturing, use, and end-of-life phases of renewable energy technologies.”

### Optimization society elects vice-chair

Management sciences professor **Miguel Anjos** was recently elected vice-chair of linear programming and complementarity for the INFORMS Optimization Society. The goals of the society include promoting the development and application of optimization methods and software tools for the solution of problems in operations research/management science and encouraging the exchange of information.

### Engineering faculty honoured

Waterloo Engineering achievements were recognized October 1 at the annual faculty dinner. A Faculty Teaching Excellence Award was presented to **Rick Culham** of mechanical and mechatronics engineering. The En-Hui Yang Engineering Research Innovation Award was awarded to Flora Ng of chemical engineering and an Engineering Research Excellence Award was received by **Xianguo Li** of mechanical and mechatronics engineering.

### Waterloo engineer inducted as CAE fellow

**Mike Worswick**, a mechanical and mechatronics engineering professor was honoured as a Fellow of the Canadian Academy of Engineering.

### Simon honoured as a Top 40 Under 40

Chemical engineering associate professor **Leonardo Simon**'s name has been added to Canada's prestigious Top 40 Under 40 list for 2009. The annual contest celebrates exceptional Canadians under the age of 40 who are outstanding leaders in their chosen fields and are shaping the country's future. Prof. Simon is a lead investigator with Ontario's BioCar project which researches how to take agricultural products such as wheat straw to develop plastics used in car parts manufacturing.

### New university vice-president joins engineering

Engineer **Feridun Hamdullahpur** became University of Waterloo's vice-president, academic & provost for a five-year term starting September 1, 2009. He will also become a tenured faculty member of Waterloo's department of mechanical and mechatronics engineering. He is also a current member of WISE.

### UWAFT team receives honours in EcoCAR challenge

The University of Waterloo Alternative Fuels Team won the Best Mechanical Integration Award and the National Science Foundation Outstanding Long Term Faculty Advisor Award in the recent EcoCAR Challenge held in San Diego. The team is supervised by professors **Roydon Fraser** of mechanical and mechatronics engineering and **Mike Fowler** of chemical engineering.

### Cañizares appointed as inaugural Hydro One Chair

Official announcement of the appointment of Dr. **Claudio Cañizares**, electrical and computer engineering department, as the inaugural Hydro One Chair in Power Engineering took place on Monday, October 4, 2010. Laura Formosa, President of Hydro One Inc., made the presentation during an outdoor gala event that also included grand opening celebrations of the Energy Research Centre at the University of Waterloo.



Other noteworthy awards and honours for Dr. Cañizares: 33IEEE-PES Working Group Recognition Award for Outstanding Technical Report (WG Member) 2009, and Outstanding Performance Award, Faculty of Engineering, University of Waterloo, 2009.

### NSERC Industrial Postgraduate Scholarships awarded

Two Masters students (**James R. Craig** supervisor), Richard Simms and Simon Haslam, were awarded NSERC Industrial Postgraduate Scholarships to work with NextEnergy, Inc. on improved Geothermal heat loop systems.

### Melosh medal awarded to R. Gracie

Prof. **Robert Gracie** was awarded 1st Place in the 2009 Robert J. Melosh Medal Competition.

# Energy for the Future

## Emerging Research

New and existing WISE members have proposed novel research thrusts that show high potential for making significant contributions towards addressing our global energy and environmental challenges. These include, for example, Information Systems and Science for Energy and Carbon Capture and Storage, as detailed below.

### Information Systems and Science for Energy (ISS4E)

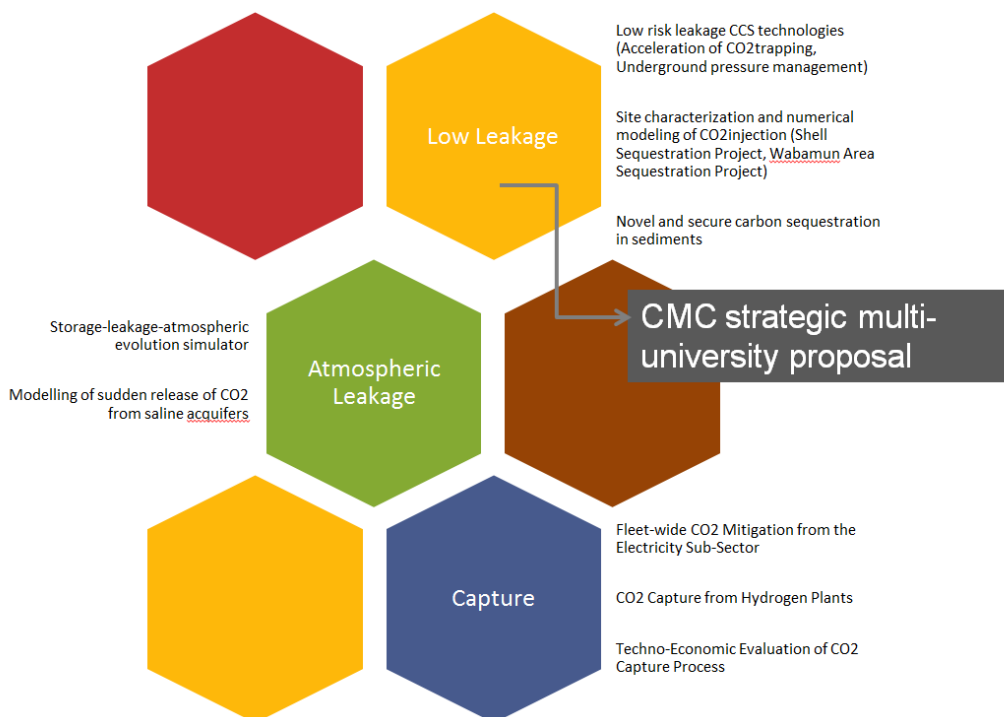
These projects apply information systems and science expertise from our Computer Science and Electrical Engineering faculty towards developing innovative solutions to smart grid issues:

1. Revisiting Demand Response (DR) to take into account much finer grained control, sophisticated communications infrastructure, elasticity of new loads (e.g., PHEVs), DG and storage
  - Overlays grid with control elements for demand shaping (exploit demand elasticity, protect network from overload, reduce peak demand)
  - DR to include PHEVs
  - Uses Internet principles of scheduling and proactive/reactive control for variable loads
2. Modeling and control of grid energy storage
  - Studies the effect of adding storage elements to the grid (reduce peak load, firm up variable-generation sources, deferring upgrade of installed base)
  - Uses principles of teletraffic analysis to model networks of storage elements
3. Smart Home (in collaboration with Infosys and Microsoft)
  - Fine-grained monitoring and control of appliances and renewable energy generation to improve energy efficiency (time-shift load, eliminate waste)
  - Builds on research prototypes from collaborators (home gateway (Microsoft Research), intelligent power strip (Infosys))
4. Data analytics of smart meter data
  - Smart meters will generate terabytes of data daily
  - Use data mining techniques to model and analyze smart meter data (find sources of waste, improve grid efficiency by better modeling, understand user behaviour)
5. Anomaly detection for renewable energy generators
  - Renewable energy systems exhibit deterioration over time
  - Use algorithms for Internet traffic anomaly detection to detect and predict failures and need for maintenance
6. Efficient and secure communication network for the grid

- Utility operators have licensed spectrum for private telecommunication networks (require real-time and robust control over unreliable links, tight guarantees)
  - Uses researcher's expertise in real-time wireless communication networks to allow real-time control of smart grids (rapid islanding for protection, user communication for demand-response)
7. Develop tools to allow the above: e.g., simulations and prototypes. Collect data.
  8. All these above projects are very context-dependent (e.g., developed or developing countries). Study the impact of the context on the appropriate solutions.

## Carbon Capture and Storage

A strong cluster of research expertise in carbon capture and storage is forming at uWaterloo. Funding proposals were submitted to Carbon Management Canada in 2010 representing various engineering faculties.



# WISE Leadership

## Structure

WISE is an institute with representation across uWaterloo faculties. We report under the Faculty of Engineering and hold member meetings throughout the year. WISE recognizes the role of good governance in a successful institute and provides full disclosure on its corporate governance practices.

## Executive Team



**Jatin Nathwani**

Executive Director



**Tracey Forrest**

Director



**Paul Parker**

Associate Director



**Claudio Canizares**

Associate Director



**Iris Strickler**

Administrative Assistant

## Advisory Council

An advisory council was formed in 2010 to provide a valued external perspective to our faculty members. The Council will help further our goals of developing innovative solutions to the challenges of the energy sector through multi-disciplinary research and to facilitate effective knowledge transfer to business, industry and government.

Members are formally invited to membership by the Executive Director of the Waterloo Institute for Sustainable Energy for a two-year, renewable term and are drawn from a mix of industry leaders in the energy sector. The Council is a bridge to the business community and government. The Council's primary role is to provide guidance and to serve as ambassadors for communicating the Institute's goals and achievements. The Board Advisory Council will meet twice a year.



**David McFadden**

Partner  
Gowling Lafleur Henderson LLP



**Ken Kozlik**

Chief Operating Officer & VP,  
Operations  
Independent Electricity System Operator (IESO)



**Mel Ydreos**

VP Marketing & Customer Care  
Union Gas Limited



**Carmine Marcello**

Executive Vice President, Strategy  
Hydro One Inc.



**Leo Piciacchia**

VP of Sustainable Development & HSE  
TOTAL E&P Canada



**George Greene**

Chair  
Stratos Inc.



**Steve Dorey**

Senior Consultant  
Charles River Associates



**Gordon Lambert**

Vice President, Sustainable Development  
Suncor Energy Inc.



**Andrew Teichman**

Executive Director of Investments  
OPG Ventures Inc.



**Richard Wunderlich**

Director, Smart Grid Initiatives  
SIEMENS Canada Limited



**Andrew Pride**

Vice-President, Conservation  
Ontario Power Authority



**Jatin Nathwani**

Executive Director, Waterloo Institute for Sustainable Energy  
University of Waterloo

## Board of Management



**Jatin Nathwani**

Executive Director, Waterloo Institute for Sustainable Energy  
University of Waterloo



**Claudio Cañizares**

Professor, Electrical & Computer Engineering  
Associate Director, Waterloo Institute for Sustainable Energy



**Ian Rowlands**

Professor, Environment & Resource Studies



**David Johnson**

Professor, Mechanical & Mechatronics Engineering



**David Fuller**

Professor, Management Sciences



**Linda Nazar**

Professor, Chemistry



**Mahesh Pandey**

Professor, Civil & Environmental Engineering



**Mike Fowler**

Associate Professor, Chemical Engineering



**Magdy Salama**

Professor, Electrical & Computer Engineering



**Peter Douglas**

Professor, Chemical Engineering



**Siva Sivoththaman**

Professor, Electrical & Computer Engineering



**Xianguo Li**

Professor, Mechanical & Mechatronics Engineering

## Contact us

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## 2010 Annual Report

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