WISE

WATERLOO INSTITUTE
FOR SUSTAINABLE ENERGY

2013/2014 ANNUAL REPORT

UNIVERSITY OF
WATERLOO

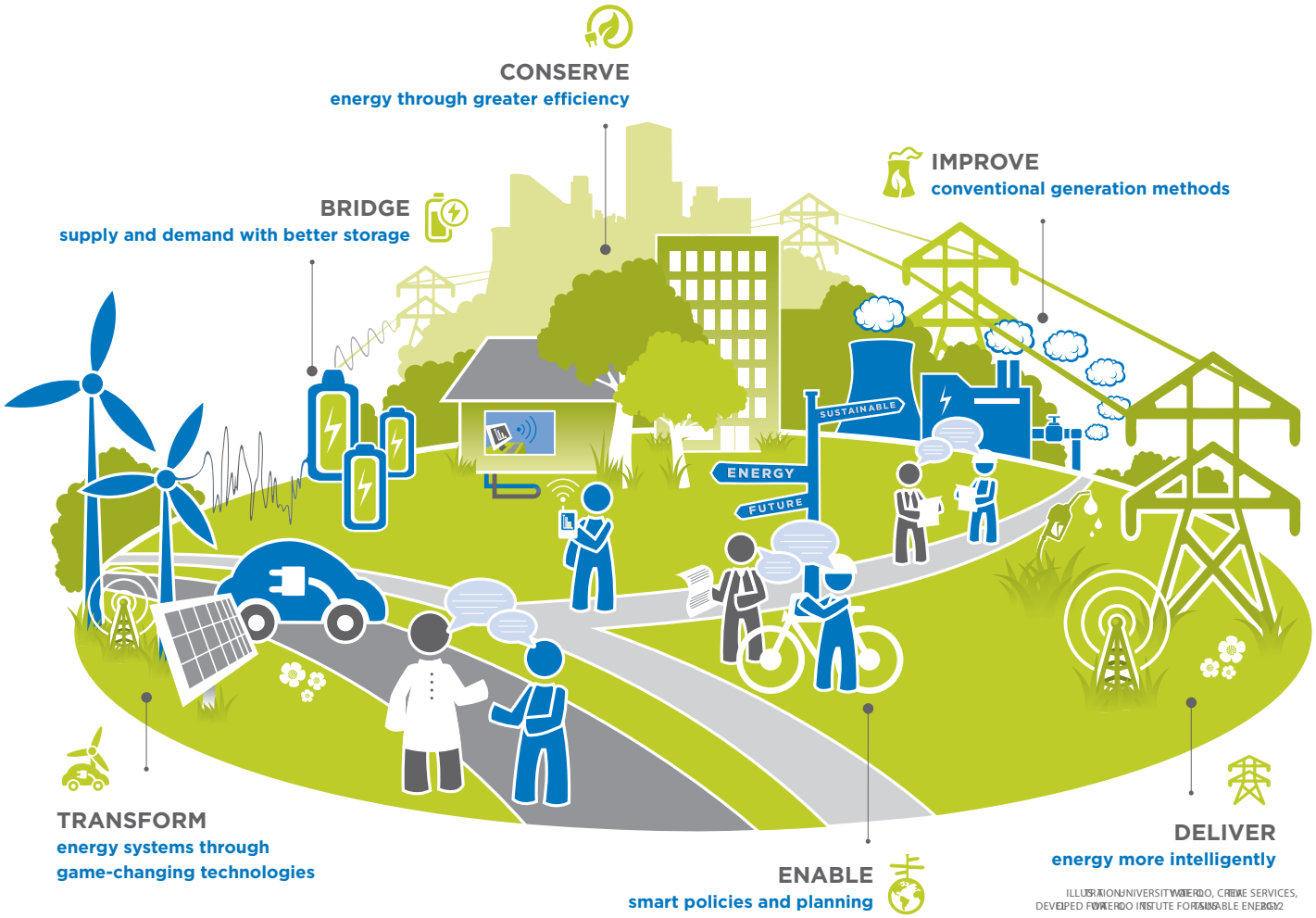

ILLUSTRATION: UNIVERSITY OF WATERLOO, CREATIVE SERVICES,
DEVELOPED FOR WATERLOO INSTITUTE FOR SUSTAINABLE ENERGY, 2012

Energy challenges command our world's attention. A healthy energy system requires balance amongst energy resources we know and those we have yet to bring to fruition.

Building a globally sustainable energy future requires us to rethink and then re-fashion the way we produce and use energy. In this critical endeavor, we wish to engage emerging science and technologies to unlock the previously unimagined pathways for the evolution of the energy system.

At WISE, we focus on integration of social, environmental and economic innovation that can enable rapid diffusion of transformative technologies.

Our vision: clean energy, accessible and affordable for all

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EXPLORE WISE

mission

CONDUCT ORIGINAL RESEARCH AND DEVELOP INNOVATIVE SOLUTIONS AND POLICIES TO HELP TRANSFORM THE ENERGY SYSTEM FOR LONG-TERM SUSTAINABILITY

strategic objectives

collaborate

EXPAND OPPORTUNITIES FOR MULTI-DISCIPLINARY ENERGY RESEARCH AT WATERLOO, IMPROVE RESEARCH PRODUCTIVITY - SHARE FACILITIES AND RESOURCES, AND DEVELOP HQP THROUGH RESEARCH AND EDUCATION

reach out

PROMOTE ENGAGMENT OF EXTERNAL PARTNERS AND ADVANCE ENERGY RESEARCH THROUGH PARTNERSHIPS AND GREATER ACCESS TO RESEARCH FUNDING

influence

ESTABLISH WISE AS THE AUTHORITATIVE SOURCE OF ENERGY INSIGHTS AND ANALYSIS, AND TRANSLATE IMPORTANT SCIENTIFIC DISCOVERIES FOR A WIDE AUDIENCE, INFORMING ENERGY POLICY BOTH HERE AND AROUND THE GLOBE

NOTE FROM THE EXECUTIVE DIRECTOR

It is a pleasure to introduce this year's WISE Annual Report. I hope you enjoy reviewing the material, exploring the interesting and important activities of the Institute and its members.

WISE continues to serve two critical functions with respect to energy research and education at the University of Waterloo. First, WISE catalyzes cross-Faculty consultations and collaborations. Many of our most significant energy challenges – and opportunities – require both multi-disciplinary and inter-disciplinary approaches. WISE brings together members from across the University in order to tackle these issues.

And second, WISE facilitates interactions between our members and our broader communities – be they businesspeople, government officials, civil society representatives, regulators, utility officials or others, and be they within Canada or abroad. WISE is an effective – and efficient – 'first stop' for those wanting to engage with energy researchers at the University of Waterloo. Similarly, WISE's members use the Institute's many external connections to advance their research and to offer opportunities to their students.

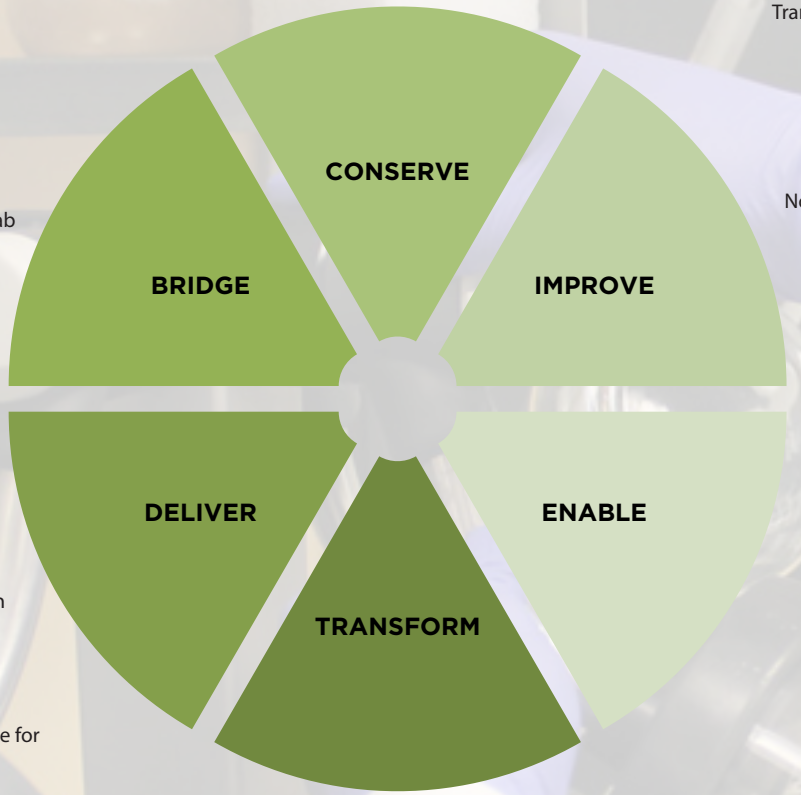
WISE builds upon the immense range and depth of energy research activities at the University of Waterloo: more than 100 faculty members, along with their graduate students and other collaborators, are making critical technological and scientific breakthroughs, working towards a sustainable energy future.

At WISE, we look forward to the future, to working with you within the University of Waterloo and beyond the campus's borders, in order to achieve our vision – namely, clean energy, accessible and affordable for all.

Ian Rowlands
Acting Executive Director, Waterloo Institute for Sustainable Energy (WISE)

RESEARCH LABORATORIES

28 RESEARCH LABORATORIES



Advanced Glazing System Lab

Applied Nanomaterials and Clean Energy Lab
▲
Carbon Nanomaterials Lab
▲
Fuel Cell and Green Energy Lab
▲
Giga to Nano Centre
▲
Nazar Group

Centre for Pavement and Transportation Technology Laboratory
▲
Centre for the Advancement of Trenchless Technology
▲
Mechatronics Vehicle Lab
▲
Non-Destructive Testing Laboratory
▲
Qing-Bin Lu's Laboratory
▲
Solar Thermal Research Centre

Electricity Market Simulation and Optimization Lab
▲
High Voltage Energy Lab
▲
Information Systems and Science for Energy Lab
▲
Real Time Simulation Lab

Sustainable Energy Policy Group

Air Pollution Research and Innovation Laboratory
▲
Center for Advanced Photovoltaic Devices and Systems
▲
Centre for Advanced Materials Joining
▲
Fluid Mechanics Research Lab
▲
Kleinke Research Centre

Lab for Biomanufacturing
▲
Laboratory for Emerging Energy Research Lab
▲
Printable Electronic Materials Lab
▲
Student Research Centre
▲
UW Live Fire Research Centre
▲
Wind Energy Laboratory

COLLABORATE

At WISE, we believe the biggest breakthroughs come from uniting leading researchers from dozens of disciplines. Our membership spans 21 departments and encompasses every faculty at the University of Waterloo.

19 Large-Scale Multi-Disciplinary Projects

- *Applied Health Sciences*
- *Arts*
- *Engineering*
- *Environment*
- *Mathematics*
- *Science*

ENERGY RESEARCH INITIATIVES

WISE's 2011/12 and 2012/13 annual reports included extensive lists of energy research initiatives underway at Waterloo. This year's report highlights a few new initiatives in which WISE provides a leadership role in attracting external partners and helps shape the development of the projects to approvals and execution.

Compressed Air Energy Storage in Salt Caverns in Canada


CLAUDIO CANIZARES


KANKAR BHATTACHARYA


DIPANJAN BASU


JATIN NATHWANI


MAURICE DUSSEAULT


ROYDON FRASER

Renewable energy sources offer great potential for producing energy on a large scale with low greenhouse gas emissions. The challenges are how to capture these dilute, low energy-density, intermittent, variable and geographically dispersed energy resources where they are needed and when they are needed, at a reasonable cost. The variable and intermittent nature of renewable sources such as solar power or wind means that they are currently only partially dispatchable – making it difficult to integrate them into electricity supply grids. Large-scale storage is therefore the critical technology required to enable solar and wind to 'mimic' the characteristics of baseload generation, and subsequently assume a greater role within the global energy supply mix.

As renewable resources such wind and solar are increasingly integrated into the Ontario and Alberta power grid, the intermittent and dispersed nature of these resources is having a significant impact on the reliability and resilience of the grid system. A storage medium can not only facilitate renewables integration, but can also help address the balancing of local and regional generation sources, and can reduce the level of base load need. Cost-effective energy storage on a large scale is necessary to improve overall performance and enhance reliability of the grid.

A group of WISE researchers, including Professors Maurice Dusseault, Dipanjan Basu, Roydon Fraser, Claudio Canizares, Kankar Bhattacharya and Jatin Nathwani is proposing Compressed Air Energy Storage (CAES) in Salt Caverns in Canada as a promising option to enable a large share of renewable energy generation into the power grid.

CAES leverages the geological advantage of salt caverns in both provinces to provide cost-effective energy storage on a large scale to facilitate renewables integration, improve grid stability and resiliency, reduce cost of new generation and transmission, deliver economic value to different types of industry stakeholders, and enable the provinces to meet and exceed sustainability targets, through integration with existing and next generation turbines and innovative grid management techniques.

In collaboration with leaders in the Canadian energy sector, such as Hydro One Networks Inc., Ontario Power Generation (OPG), Union Gas Limited, NRStor Inc., Compass Minerals and Rocky Mountain Power (RMP) as well as academics from University of Alberta and University of Calgary, the group is exploring the effective integration of renewables into the grid through a combined exploitation of a geological medium in close proximity to variable generation and innovative systems modelling of the turbine operating characteristics in support of the grid.

ENERGY RESEARCH INITIATIVES

Developing Smart Energy Networks in Ontario

In recent years, there has been significant pressure to reduce greenhouse gas emissions, to achieve higher efficiency systems and to integrate greater amounts of renewable energy resources.

A group of WISE researchers, including Professors John Wen, Jatin Nathwani, Ian Rowlands and Eric Croiset, in collaboration with Union Gas Ltd, have led the studies of Smart Energy Network (SEN) – a total energy network system consisting of an electricity grid, a natural gas infrastructure, a district heating network and advanced information and communications technology, as a means to provide energy services in an efficient manner, drawing upon multiple resources and advanced technology.

Distinct from the concept of Smart Grids, their initiatives, functionalities and demonstrations which have been focused on electricity and related components, SEN is a comprehensive concept an integrated energy system (or network) which covers all available energy resources such as natural gas, possible renewables, higher efficiency systems such as CHP (Combined Heat and Power), novel technologies for residential use such as fuel cell systems, and so on.

Off-Grid Energy Access

The International Energy Agency estimates that 1.5 billion people world-wide lack access to electricity and 85% of them live in rural areas where interconnecting them by extending the existing electric grid is not economically feasible. In Canada, approximately 200,000 people living in 280 northern and remote communities (N&RCs) are facing a similar challenge.

A group of WISE researchers including Professors Claudio Canizares, Ehab El-Saadany, Paul Parker, Mehrdad Kazerani, Kankar Bhattacharya and David Johnson, in collaboration with Natural Resources Canada, Hatch Ltd, Wenvor, and Hydro One, set out to further understand these communities' energy requirements and challenges, and to help them reduce diesel dependency and the financial burden of diesel power by introducing renewable resource-enabled microgrid systems to Kasabonika Lake First Nation community. The group focuses on microgrid controller development, energy management systems planning and community engagement studies.

Drive4Data – Accelerating progress toward a greener future

Launched by WISE in 2014, Drive4Data is the first initiative of its kind in Canada to advance innovative electric vehicle research and support local citizens in the optimum use of their electric vehicles.

The project involves collecting data from the owners of electric vehicles who agree to have a small wireless device about the size of a cell phone installed in their car. The Waterloo company CrossChasm, a technology partner in this initiative, created the device. It collects key statistics, such as mileage, battery charging and energy use, and then relays it to WISE. This real-world data could help advance research into everything from battery technology to smart grid management.

Drivers can access detailed reports on their vehicle's performance, including the distance they've travelled, charging schedule, fuel and electricity usage and performance against similar vehicles.

Drive4Data is generously supported by Kitchener-Wilmot Hydro, Cambridge and North Dumfries Hydro, Waterloo North Hydro and the Region of Waterloo.

RESEARCH SPOTLIGHTS

GOOD VIBRATIONS: HARVESTING ENERGY WHILE YOU DO THE CHORES

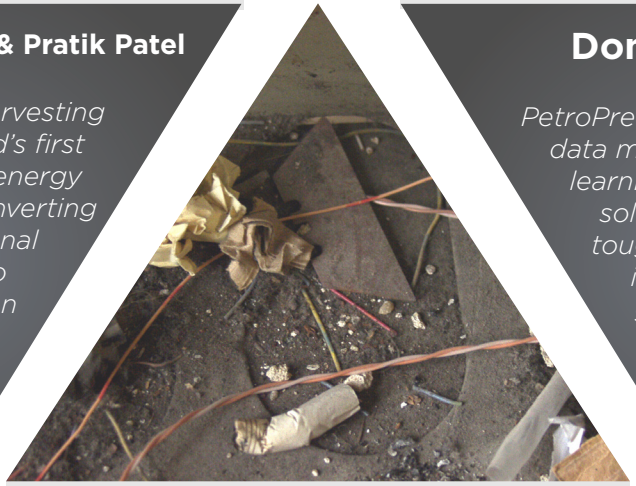
Mir Behrad Khamesee & Pratik Patel

A micro-energy harvesting system, the world's first patent-pending energy harvester with converting multi-directional motion into linear motion

MAKING SMARTER ENTERPRISE DECISIONS

Dominic Toselli

PetroPredict brings advanced data mining and machine learning techniques to solve some of the toughest problems in the oil and gas industry



TRANSFORMING SOLID WASTE INTO ENERGY

Bill Anderson

Methods of agricultural waste processing and resource recovery can be useful for transforming solid waste into energy - creating a viable, sustainable, and economic alternative

EDUCATION & TRAINING

ENERGY POLICY RESEARCH FELLOWSHIP

Energy Council of Canada Fellowship program supports original research to help develop innovative solutions and policies to help transform the energy system for long-term sustainability. Awards totalling $74,666 have been awarded from 2013 – 2015.

2014 MINIMISE CAPSTONE AWARD

Students were challenged to submit a research project to investigate energy management and efficiency and/or energy storage with applications in the built environment along with applicability in retrofit applications and commercial potential within a two year timeframe. The award valued at $2,000 was shared by a team of four graduate students. The system designed by the winning team aims to dramatically reduce wasted power caused by idled devices throughout the home by controlling the power to every circuit right at the source.

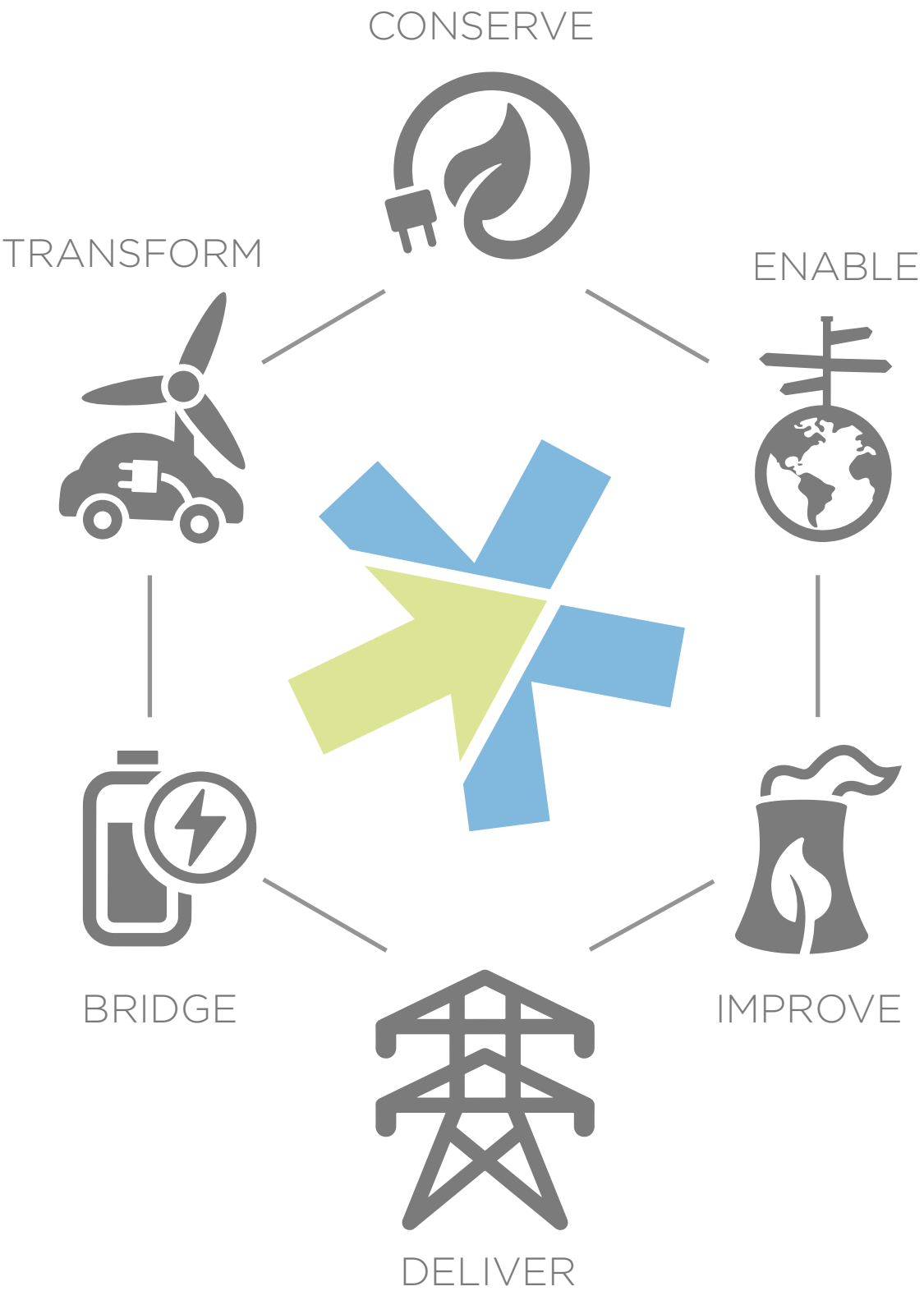
HYDRO ONE – UNDERGRADUATE SCHOLARSHIP

Fifty-one undergraduate scholarships were awarded over five years totaling $102,000

MASTERS IN ELECTRIC POWER ENGINEERING PROGRAM

Three hundred and seventy-one (371) graduates of the Masters in Electric Power Engineering Program, with 118 MEng Graduates from 2008-2014.

Training the energy leaders of tomorrow


CONSERVE
TRANSFORM
ENABLE
BRIDGE
IMPROVE
DELIVER

REACH OUT

At WISE, we work closely with utilities, private-sector partners, government and the non-profit sector to ground our work in real-world issues and to facilitate partnerships between the various stakeholders and WISE researchers. We offer our partners the full spectrum of energy R&D, education and training, networking, and commercialization activities.

In the past year, WISE has invited stakeholders from academia, industry, civil society, and government agencies to address topics such as smart energy networks, waste-to-energy management, energy-water-food nexus, energy entrepreneurship and so on, through our public forums. Our events create an environment in which leading energy experts can share their insight on key issues with the public. By hosting these events, WISE provides attendees with the necessary information to inspire innovative ideas, and opportunities to network with like-minded individuals.

DEVELOPING PARTNERSHIPS

HOSTING EVENTS

1 SOLID WASTE MANAGEMENT PARTNERSHIPS WORKSHOP JUNE 24, 2014

The *Solid Waste Management Partnerships Workshop* invited 40 stakeholders from academia, industry and government agencies to advance discussions regarding research, development and demonstrations for solid waste management in Canada.

The workshop explored opportunities for collaboration and integration of efforts on solid waste management research. Essentially, the workshop agenda focused on discussing three research themes including resource recovery, energy recovery, and analysis and policy. The workshop overall, aimed at contributing to a more coordinated activity for solid waste management research and development in Canada.

To view the resources, videos, and photos of this event, please visit:
https://wise.uwaterloo.ca/solidwastemanagement_partnerships_workshop

2 ENERGY PANEL ON BIOFUELS AND WASTE TREATMENT: NATIONAL BIOTECHNOLOGY WEEK SEPTEMBER 29, 2014

The *Energy Panel on Biofuels and Waste Treatment event* was co-hosted with the *Centre for Bioengineering and Biotechnology (CBB)* and highlighted work being conducted in biotechnology through a panel discussion, faculty and industry representative talks, and presentations showcasing graduate student work.

SUSTAINABLE DEVELOPMENT TECHNOLOGY CANADA: VIRTUAL INCUBATOR WORKSHOP SEPTEMBER 17, 2014

3

The *SDTC Virtual Incubator™ Workshops* targeted entrepreneurs with early-stage clean technologies who plan on applying to SDTC for funding and provide those entrepreneurs and prospective applicants with key information and practical guidance to prepare a quality SOI submission. The session enabled prospective applicants to assess the potential fit of their technology with SDTC's SD Tech Fund, and to help gain an understanding of the application process and key evaluation criteria.

ENERGY DAY 2014 OCTOBER 17, 2014

4

Energy Day 2014 invited over 100 stakeholders from academia, industry, the community, and government agencies to explore discussion addressing energy entrepreneurship and the future of energy service delivery. The event included energy research presentations, poster displays, panel discussions, and networking opportunities for researchers, graduate and undergraduate students, community organizations and industry professionals.

To view the resources, videos, and photos of this event, please visit:
https://wise.uwaterloo.ca/energyday2014

INFLUENCE

Informing public policy, by sitting on energy boards and engaging in industry forums, WISE brings evidence-based analysis to the governance and regulation of the energy sector. In the past year, we participated in the Council for Clean and Reliable Electrcity, the Ontario Smart Grid Forum and the Ontario Energy Board Chair's Advisory Roundtable for Industry. As a result, we helped to inform smart grid governance, the redesign of feed-in-tariffs, the global adjustment mechanism, technology choices for Ontario's next new nuclear plant, the Auditor General's report on Ontario's renewable energy program, governance models in the elctricity sector and biomass energy opportunities.

PUBLIC LECTURE SERIES

"Canadian Responsibility and the Energy Trilemma"
Dr. Brenda Kenny President & CEO, Canadian Energy Pipeline Association (CEPA)

"Microalgae for Energy Production: Between Dream and Reality"
Dr. Eric Prouzet Associate Professor, Chemistry at the University of Waterloo & Co-Founder of Prodal-G Inc.

"The Ecological Hoofprint: Meat, Energy, and Sustainability"
Tony Weis Associate Professor, Geography at the University of Western Ontario

"Transformations across the Energy Sector: Past, Present and Future"
Graham Campbell President, Energy Council of Canada

"Pandora's Promise"
A Robert Stone Film

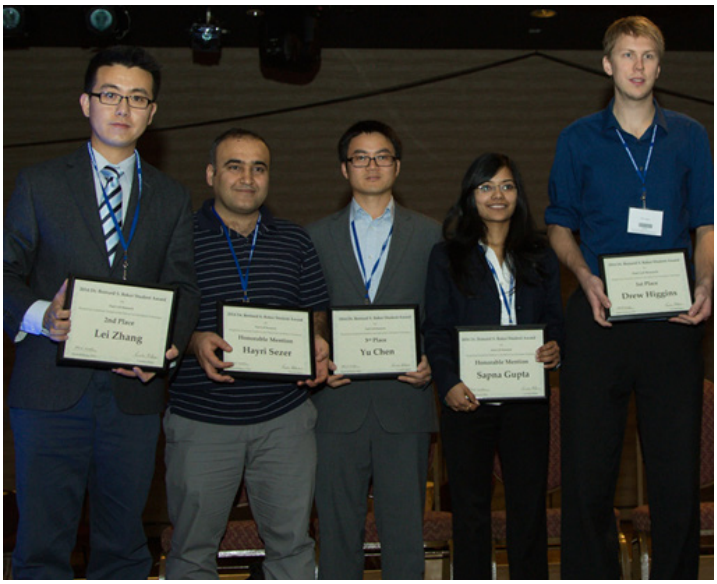
"Energy Perspectives for Germany and Europe: A Researcher's View"
Dr.-Ing. Joachim U. Knebel, Chief Science Officer, Karlsuhe Institute of Technology (KIT)

"Behaviour Change: An Untapped Resource in Coping with Climate Change"
Dr. Ron Dembo Founder and CEO, Zerofootprint

PAST LECTURES CAN BE VIEWED ON YOUTUBE BY SUBSCRIBING TO **WISEwaterloo**

SAMPLE MEMBER ACHIEVEMENTS

2014 DR. BERNARD BAKER FUEL CELL RESEARCH STUDENT AWARD



PhD candidate Drew Higgins on the far right receiving the 2014 Dr. Bernard Baker Fuel Cell Research Student Award, a top award given internationally to graduate students conducting research on topics related to fuel cells. Higgins works in **Professor Zhongwei Chen's** laboratory, carrying out research on the development of nanostructured catalysts for fuel cells.

> *"By designing new catalysts, we aim to reduce the cost, while increasing the performance and durability of these systems."*
>
> - Drew Higgins

ROYDON FRASER RECEIVES NSF AWARD FOR ENGINEERING FELLOWSHIP

Roydon Fraser, a mechanical and mechatronics professor, received the National Science Foundation (NSF) Outstanding Long Term Faculty Advisor Award presented to him at the EcoCAR2 competition finals held in Washington June 13. Fraser, whose research expertise includes fuel cells and stability control, is a long-term supervisor of the University of Waterloo's Alternative Fuels Team.

LINDA NAZAR AMONG WORLD'S MOST HIGHLY CITED RESEARCHERS

Waterloo Chemistry Professor Linda Nazar has been named a Thomson Reuters' 2014 Highly Cited Researcher, and is on their list of 2014 Most Influential Scientific Minds. Nazar ranks within the top one per cent of scientists worldwide for the number of academic citations received within their subject field. The research impact of Nazar's team can be traced to previous breakthroughs in Li-ion, Na-ion and Li-oxygen battery materials.

Heather Douglas, Philosophy

Institute for Science, Society and Policy Fellow, University of Ottawa

Srinivasan Keshav, David R. Cheriton School of Computer Science

Association for Computing Machinery Fellow

Linda Nazar, Chemistry

August Wilhelm von Hofmann Lecture Award, German Chemical Society

Flora Ng, Chemical Engineering

The Canadian Green Chemistry and Engineering Award (Individual) 2013

Garry Rempel, Chemical Engineering

Queen Elizabeth II Diamond Jubilee Medal

Catherine Rosenberg, Electrical and Computer Engineering

Canadian Academy of Engineering Fellow

Susan Tighe, Civil and Environmental Engineering

Bleeds Black Award, Ontario Hot Mix Producers Association

Sriram Narasimhan, Civil and Environmental Engineering

Humboldt Research Fellowship for Experienced Researchers,
Alexander von Humboldt Foundation, Bonn, Germany
Tier 2 Canada Research Chair in Smart Infrastructure

INFORMING PUBLIC DIALOGUE

ONTARIO'S LOW-CARBON ELECTRICITY SECTOR

Professor Jatin Nathwani featured in *IESO Annual Report 2013*

Jatin Nathwani, the Executive Director of WISE, commented on the significant change that has taken place in the Ontario electricity market over the last few years and some emerging challenges.

> "The enablement of a smart grid – another important Ontario achievement – has the promise and the potential to become a powerful tool in the hands of consumers to help mitigate the impacts of upward cost pressures"
>
> - Jatin Nathwani

BUILDING A BRIDGE FOR THE NEW "INTERNATIONAL SCIENTIST"

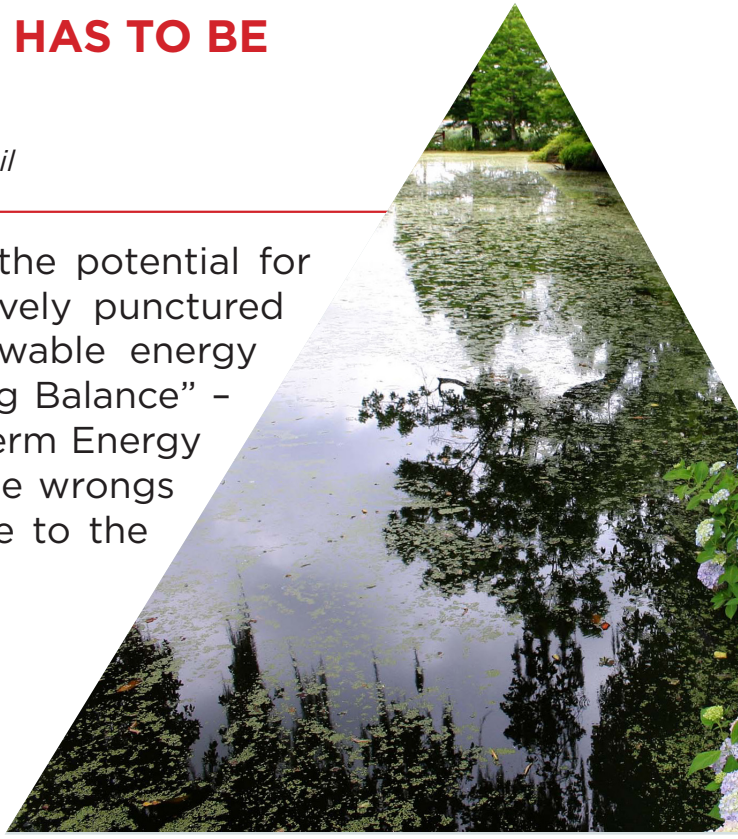
Professor Eric Prouzet & Professor Irene Goldthorpe featured in *WATERLOO STORIES*

A partnership between two international research leaders aims to create a new kind of scientist — one whose education and experience crosses disciplines and international boundaries.

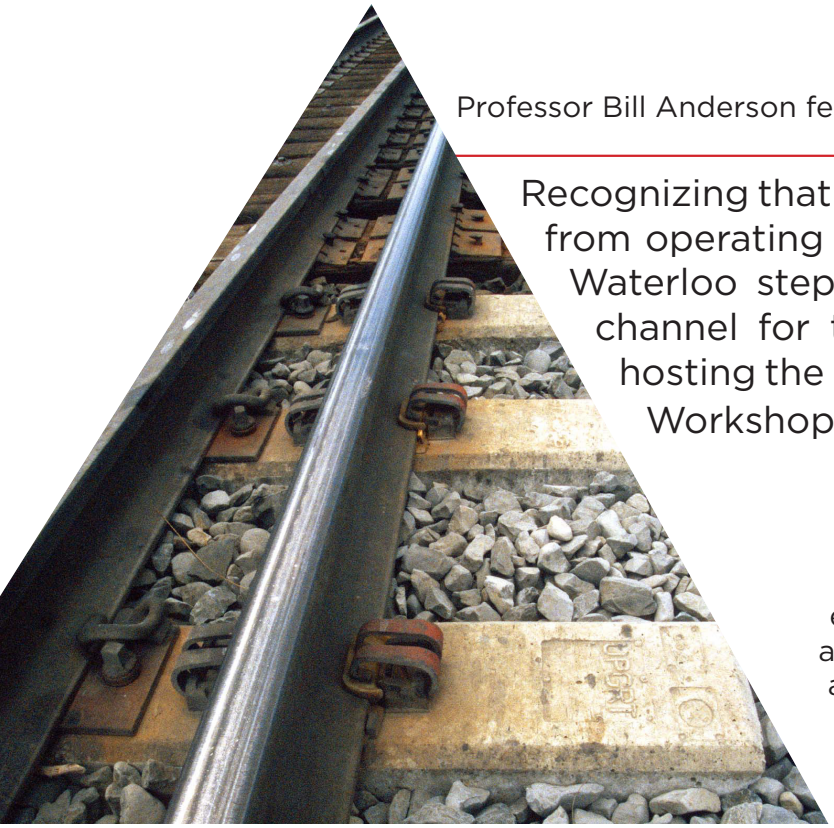
> "Bordeaux is a good fit because it has many of the areas of expertise and excellence that we find at Waterloo — chemistry, systems design, mathematics, aging, water management'
>
> - Eric Prouzet

IF NOTHING ELSE, GREEN POWER HAS TO BE GREEN

Professor Jatin Nathwani featured in *The Globe and Mail*



The sting of high electricity costs – and the potential for more pain in the near term – has decisively punctured Ontario's infatuation with high-cost renewable energy sources, such as wind and solar. "Achieving Balance" – the latest version of the province's Long-Term Energy Plan – is a courageous attempt to right the wrongs and administer the right dose of medicine to the patient at about the right time.



BRIDGING THE GAP

Professor Bill Anderson featured in *RENEWABLE ENERGY FROM WASTE*

Recognizing that this gap was holding back the industry from operating at the leading edge, the University of Waterloo stepped into the breach, opening a new channel for the study of waste-related issues by hosting the Solid Waste Management Partnerships Workshop.

> "Advancements through rigorous evidence-based science are critical if we are to realize the full potential of waste as a resource in a sustainable energy future"
>
> - Bill Anderson

EVENT PARTICIPATION

- **ONTARIO CENTRES OF EXCELLENCE (OCE) DISCOVERY**
  TORONTO, ONTARIO - MAY 12-13
- **WATERLOO-BORDEAUX WORKSHOP: PATH TO A PRIVILEGED PARTNERSHIP**
  WATERLOO, ONTARIO - MAY 19
- **SCIENCE-POLICY INTERFACE: INTERNATIONAL COMPARISONS WORKSHOP**
  WATERLOO, ONTARIO - MAY 21
- **MANAGEMENT SCIENCES SEMINAR SERIES: KORY W. HEDMAN**
  WATERLOO, ONTARIO - JUNE 9
- **2014 CANADIAN ENERGY SUMMIT & WEC NORTH AMERICA REGION ENERGY FORUM**
  CALGARY, ALBERTA - JUNE 25
- **27TH ANNUAL ENERGY & ENVIRONMENT FORUM**
  WATERLOO, ONTARIO - JUNE 25
- **SEMINAR: EVOLUTION FOR CONTROL FOR THE SMART TRANSMISSION GRID**
  WATERLOO, ONTARIO - JULY 25
- **SEMINAR: CURRENT AND FUTURE STATUS OF HYDRAULIC FRACTURING OF NATURAL GAS RESERVOIRS IN CANADA**
  WATERLOO, ONTARIO - OCTOBER 3
- **THE FUTURE FOR LDCS: COUNCIL FOR CLEAN & RELIABLE ELECTRICITY CONFERENCE**
  MARKHAM, ONTARIO - OCTOBER 15
- **EASTERN CANADA STUDENT ENERGY CONFERENCE**
  WATERLOO, ONTARIO - NOVEMBER 7
- **WE INNOVATE RESEARCH EXHIBITION**
  WATERLOO, ONTARIO - NOVEMBER 7
- **INTERNATIONAL EDUCATION WEEK RESEARCH SHOWCASE**
  WATERLOO, ONTARIO - NOVEMBER 7
- **PUBLIC TALK ON THE GERMAN ENERGY POLICY CHALLENGES**
  QUÉBEC, ONTARIO - DECEMBER 9
- **ENERGY PERSPECTIVES FOR GERMANY AND EUROPE**
  MONTREAL, ONTARIO - DECEMBER 10
- **ENERGY PERSPECTIVES FOR GERMANY AND EUROPE: A RESEARCHER'S VIEW**
  OTTAWA, ONTARIO - DECEMBER 11
- **THE GERMAN ENERGIEWENDE: A RESEARCHER'S VIEW**
  WATERLOO, ONTARIO - DECEMBER 12

WISE MEMBERS

WILLIAM ANDERSON
MIGUEL ANJOS
DIPANJAN BASU
PHILIP BEESLEY
KANKAR BHATTACHARYA
PHILIP BIGELOW
JASON BLACKSTOCK
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JOHN WILKINSON
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Executive Director

KANKAR BHATTACHARYA
Associate Director
Advanced Training

CLAUDIO CANIZARES
Associate Director
External Partnerships

ERIC PROUZET
Associate Director
Global Initiatives

IAN ROWLANDS
Associate Director
Research

STAFF

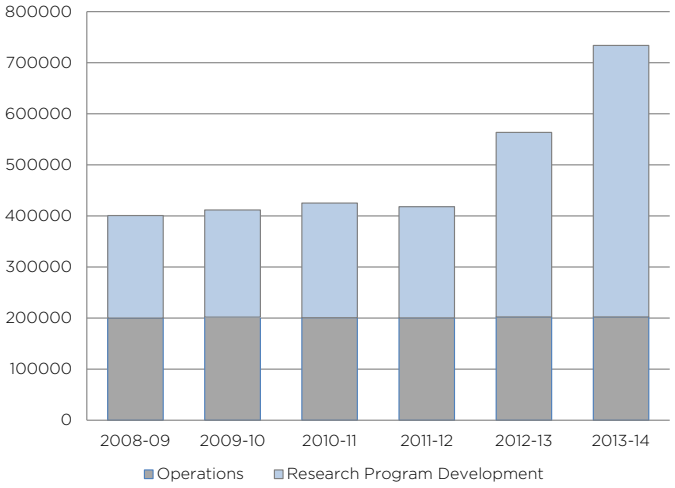
ZHEWEN CHEN
Manager
Program Development & Partnerships

IRIS STRICKLER
Administrative Assistant

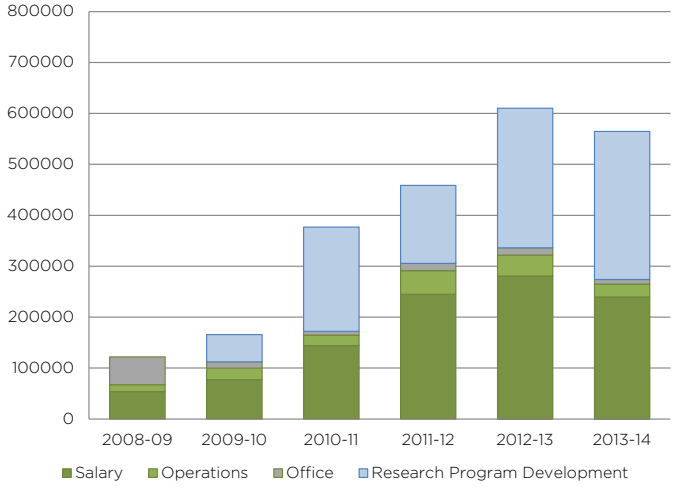
LILY QUYNH-THU THAI
Communications Specialist

WISE BY THE NUMBERS

SOURCE OF FUNDS



SUMMARY OF EXPENSES



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WISE
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WATERLOO

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